THE PARADIGM OF REACTIVE METHODOLOGY-BASED HAZARD IDENTIFICATION IN AIRCRAFT MAINTENANCE INDUSTRY: AN EMPIRICAL EVALUATION IN THE SAFETY MANAGEMENT FRAMEWORK

A thesis is submitted to the
UPES

For the Award of
Doctor of Philosophy
in
Management (Aviation)

By

Alok Tyagi

May 2024

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DECLARATION

I declare that the thesis entitled **“The Paradigm of Reactive Methodology-Based Hazard Identification in Aircraft Maintenance Industry: An Empirical Evaluation in the Safety Management Framework”** has been prepared by me under the guidance of **Dr. Rajesh Tripathi,** Associate Professor, Department of General Management, School of Business, University of Petroleum and Energy Studies, Dehradun, Uttarakhand (Supervisor), and **Dr. Soufiane Bouarfa**, CEO & Founder of Novel Insights, Rotterdam, Netherlands (External Co-Supervisor).

No part of this thesis has previously formed the basis for awarding any degree or fellowship.

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THESIS COMPLETION CERTIFICATE (INTERNAL)

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ABSTRACT

The commercial aircraft maintenance sector, popularly known as the Maintenance, Repair, and Overhaul (MRO), is a critical service provider of the aviation business system. It is estimated that around 10% of the total operating cost of commercial airlines is credited to aircraft maintenance, and approximately 12% of aircraft accidents have resulted from some form of maintenance shortcomings. Although based on the aircraft accident rate per million departures, overall, commercial air transportation (CAT) is considered an ultra-safe mode of transportation, it is crucial to understand the societal perception of aviation safety. Global societies and passengers perceive aviation safety based on the number of accidents, not the accident rate. This aspect was experienced in the impact of two Boeing 737 Max accidents in late 2018 and early 2019. Another dimension of aviation safety is related to the growth of the aviation industry. Leading aircraft manufacturers predict cumulative growth of air transportation, particularly in India and the Asia Pacific region. This growth means more airlines and increased aircraft departures with more accidents and incidents in the future (if the present rate of 2.05 accidents /million departures is maintained). On the other hand, the cascading effect of this growth is expected to translate into more aging passenger aircraft queuing up for major maintenance, modifications, and/or freighter conversion with the aircraft maintenance industry. This increased aircraft maintenance demand, along with the prevailing competitive business environment, possesses the potential to stress the aircraft maintenance industry and make safety vulnerable.

Since CAT is already an ultra-safe industry, the real challenge for safety practitioners and industry stakeholders is improving the safety of an already ultra-safe industry. Perhaps the solution to further improve safety from the present level is embedded in the contemporary safety management framework, which is fundamentally a participative approach. One of the critical components of this regulatory framework is ‘hazard identification and risk mitigation’ (HIRM). This essentially means identifying hazards, assessing the associated risks, and mitigating them beforehand so that hazards do not translate into disasters. In the reactive

hazard identification (HI) framework (a data-driven decision-making process), stakeholders utilize 'safety data' and 'safety information' drawn from past accidents/incidents to identify hazards.

The sole purpose of investigating aircraft accidents, incidents, and near misses is to avoid recurrence. Today, aviation has an experience base of over a century, and the plethora of 'safety data' and 'safety information' derived from the accidents/incidents investigation reports supposedly available to stakeholders. However, numerous accidents have occurred in the commercial air transport industry because stakeholders have failed to learn lessons from the past. The critical aspect is why organizations are not learning or, in other words, what factors influence the learning process despite the necessary regulatory framework. All these aspects need to be investigated, including whether learning is hindered at individual and organizational levels or by inadequate regulatory interventions. Past studies have followed the qualitative approach wherein accurate weighing of factors influencing the different stages of learning is unavailable. Moreover, no study has been conducted in the aircraft maintenance industry where factors influencing the learning process were identified and measured.

To address this chronic problem, this study aims to (a) establish a learning process model for the aircraft maintenance industry, (b) identify the factors that influence learning, and (c) determine the effect of identified factors on learning from the past. A review of scholarly articles and regulatory publications enabled the development of learning from the past process model and a data collection tool, followed by Structure Equation Modelling (SEM) to quantify the relationship among influencing factors. The study was conducted in the Indian aircraft maintenance environment and is based on the perspective of the front-line maintenance staff. The study found that safety communication is the decisive stage for learning from the past. Contextualization of the safety information and evaluation of the lessons learned during safety communication strongly impact learning from the past, for which existing regulatory provisions are vulnerable. The findings of this study are meant to assist State regulators and management of the aircraft maintenance industry; nevertheless, safety managers and practitioners in other ultra-safe, high-risk sectors may also apply the results in compliance with the respective regulatory guidelines.

ACKNOWLEDGMENT

Firstly, I offer my sincere gratitude to my supervisors, Dr Rajesh Tripathi and Dr Soufiane Bouarfa, for trusting me and providing continuous guidance and support throughout my studies.

Mrs. Shalini Tyagi, my wife, has always been a consistent source of motivation throughout this Ph.D. program. Apart from me, she was the only one who knew it was tough for me. My daughters Shagun and Soumya regularly tolerated me for ignoring their communication as my mind remained deeply buried in resolving the complexities of the task at hand. Now, I look forward to spending time doing "normal" things and showing my children that I really can also behave normally and do something other than thinking and writing.

I dedicate this work to those who think of age as a barrier to learning.

TABLE OF CONTENT			
Chapters		**Description**	**Page No.**

List of Figures

List of Tables

List of Appendices

Table of Abbreviation

AAIB	Aircraft Accident Investigation Bureau
ADREP	Accident/Incident Data Reporting System
AM	Accountable Manager
AME	Aircraft Maintenance Engineer
AVE	Average Variance Extracted
ASN	Aviation Safety Network
ASRS	Aviation Safety Reporting System
BASIS	British Airways Safety Information System
CAT	Commercial Air Transportation
CPR	Complicated Reporting Procedure
CSIN	Contribution to Safety Investigations
CB-SEM	Covariance Based-Structural Equation Modeling
DGCA	Directorate General of Civil Aviation, India
EBM	Evidence-Based Management
EAMRO	Emerging Trends in Aviation MRO
HARP	Heightening your Awareness of Your Research Philosophy
HFACS	Human Factor Analysis and Classification System
HI	Hazard Identification
HIRM	Hazard Identification and Risk Management
HTMT	Heterotrait-Monotrait
ICAO	International Civil Aviation Organization
IATA	International Air Transport Association
LT	Lack of Trust
LFI	Learning From Incidents
LOSA	Line Operation Safety Audit
LPSI	Learning from Past Safety Investigations
LID	Learning Indicators
MLG	Main Landing Gear

MRO	Maintenance, Repair, and Overhaul
MOR	Mandatory Occurrence Reporting
OCSC	Organizational Commitment to Safety Communication
PLS-SEM	Partial Least Square-Structural Equation Modeling
PDSA	Plan Do Study Act
PRISMA	Preferred Reporting Items for Systematic Review and Meta-Analysis
QCM	Quality Control Manager
SC	Safety Communication
SMM	Safety Management Manual
SMS	Safety Management System
SARP	Standards and Recommended Practice
SHEL	Software, Hardware, Environment and Liveware
SLR	Systematic Literature Review
SRK	Skill, Rule, and Knowledge
SSP	State Safety Programme
TA	Thematic Analysis
UR	Utility of Reporting
VR	Voluntary Reporting
VIF	Variance Inflation Factor

CHAPTER 1: INTRODUCTION

Chapter Overview This thesis chapter provides an overview of the evolution of aviation safety and the existing safety paradigm applicable to aviation industry stakeholders (sections 1.1 to 1.3). The other sections (1.4 to 1.10) contain the factors that motivate the researcher to undertake this research, the criteria to identify research gaps, formulate research questions, research objectives, an overview of the research design, and its contribution to the aviation industry. In the last section (1.11), an outline of other thesis chapters is provided.

1.1 BACKGROUND: AVIATION SAFETY

Aviation safety has been managed and governed over the last hundred years by adopting different need-centered approaches. Based on the leading concept, it can broadly be described by the four approaches (ICAO, 2018b). Until the late 1960s, the approach to achieving aviation safety was focused on the design and technology used in aircraft production. Based on the investigation findings, aviation accidents were mainly attributed to technical and design deficiencies in aircraft systems. It could be determined that the aircraft itself was the primary factor in most aircraft accidents (S. A. Shappell & Wiegmann, 1997). Technological advancement with time, learning from the past, and more improved regulations enabled safer air transportation, and by the early 1970s, this resulted in an overall decline in accident rates because of aircraft systems design and technical deficiencies. After that (the mid-1970s), human error progressively became the primary causal factor in aviation accidents as the aircraft and its system became more reliable. To be more precise, in the initial phase of human factor studies, "Pilot Error" was the synonym of "Human Error," and aircrew themselves were considered more dangerous for aviation than aircraft (Murray, 1997). A study by (Hobbs, 2008) suggested that after a series of disastrous accidents, for instance, "Eastern Airlines Lockheed L-1011 in 1983, Japan

Airlines Boeing 747-100 in 1985, Aloha Airline Boeing 737-200 in 1988, British Airways BAC-111 in 1990, and Air Midwest Beech 1900D in 2003" attention of researchers, safety practitioners, and regulators was drawn to human factor aspects in the aircraft maintenance also. Gradually, the focus shifted to individual performance and the man-machine interface in other aviation industry activities. (Edwards, 1988) elucidated a conceptual SHEL model of the human factor to describe three interactive and interdependent dimensions between human beings (liveware) and other resources (hardware and software) in an aviation environment and underlined the importance of maintaining the state of equilibrium amongst all four components. (Edwards, 1988) "classified the human errors based on the human information processing system at which the fault occurs" (Rasmussen, 1982) and described the framework of "skill, rule, and knowledge (SRK) based human errors." Although it was not intended directly for the aviation industry (Hobbs et al., 2010) utilized the framework to evaluate the impact of circadian rhythm vis-à-vis human errors in aircraft maintenance and concluded that "skill-based errors were the most common form of error, followed by procedure violations, rule-based errors, and knowledge-based errors." During this era, human error was the focus rather than the various conditions that produced it (Korolija & Lundberg, 2010). This approach also contributed to reducing aircraft accidents and incidents; however, the number of factors contributing to human errors was not addressed.

To address the human error contributory factors issue (J. Reason, 1990a) proposed the genesis of human error, typically described as the "Swiss Cheese Model," which depicts four layers of human failure leading to an accident. Another approach to making aviation safer was suggested by Dupont (by identifying the 12 most common and frequent contributory factors for accident causation and, prevalently known as the "dirty dozen.") (Mellema et al., 2021) utilized the framework of Dupont's Dirty Dozen to study the maintenance incidents of European civil aviation organizations and observed presence of each dirty dozen element in the investigated data. At the beginning of the 21st century, the complex human factors perspective was extensively researched, and (S. A. Shappell & Wiegmann, 1997) synthesized the "Swiss Cheese Model" and described the characteristics and the dynamics of the holes "in the cheese" and developed "Human Factor Analysis and Classification System" (HFACS). Additionally, with continual growth in experience and knowledge, the SHEL model was modified to SHELL, followed by SHELLO to include inter and intra-team communication and coordination in an organizational setup (Chang & Wang, 2010). By this time, the concept of aviation safety had attained maturity, and maintenance safety started emerging. The aviation safety model was refined to include organizational factors besides technical and human characteristics. This approach was based on correlating the effect of organizational culture, processes, procedures, and policies on the efficacy of safety risk and was known as the organizational era. This approach shifted the focus from who blundered to how and why inbuilt organizational defenses failed (J. Reason, 2000). The beginning of the 21st century witnessed a mature aviation safety system and commensurate global safety results; however, numerous accidents have pointed toward the lack of coordination and communication between aviation organizations. This development led to the most recent approach to govern safety, i.e., the total system approach. This approach intends for global aviation to be regarded as an all-encompassing system with all aviation organizations as its several elements (Rozzi et al., 2016). All the critical actors in the civil aviation system, such as service providers, regulators, aircraft, engines, and component manufacturers, are elements of the global aviation system, and seamless coordination amongst these stakeholders is instrumental for aviation safety. Figure 1.1 depicts a pictorial representation of all four safety management approaches.

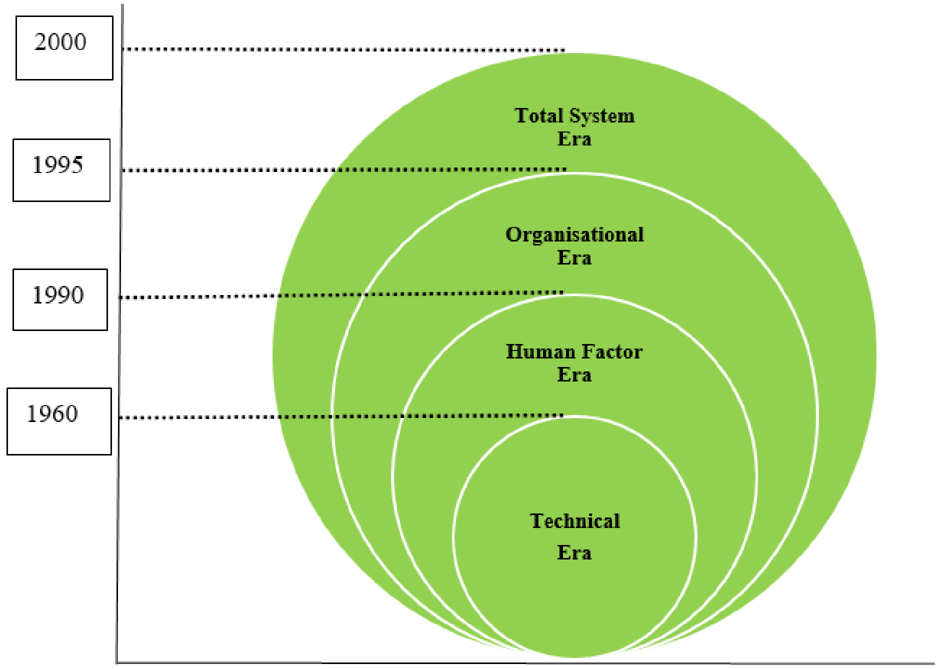

Figure 1.1 Evolution of Aviation Safety

(Source: Created by the scholar based on ICAO SMM document no. 9859)

1.2 CURRENT AVIATION SAFETY PARADIGM

The vital stakeholders of the aviation industry (Figure 1.2) can be classified into two broad categories: firstly, the designers and manufacturers of aircraft, engines, and components, whereas the second category is the service providers such as air operators (airlines), the MRO organizations, airports, air traffic management, and training establishments. Globally, the International Civil Aviation Organisation (ICAO), a United Nations agency, regulates the industry by developing "Standards and Recommended Practices" (SARPs) (Yadav & Nikraz, 2014). At the national level, the state regulatory authority ensures stakeholders' compliance with SARPs and other government regulations to achieve an acceptable safety level. The current safety paradigm of the commercial aviation industry is regulated by the ICAO Annex 19 'Safety Management.' This ICAO Annex was first published in 2013, and as the result of amendment 1, the second edition was published in 2016, with the applicability by November 2019 (ICAO, 2016). Essentially, this regulatory publication guides the stakeholders (Figure 1.2) to incorporate the standards and recommended practices into their business processes. Presently, SMS implementation amongst MROs is in varying degrees of maturity, and (Gerede, 2015c) argues that there are potential challenges to the successful implementation of the SMS because of a paradigm shift in the safety management approach.

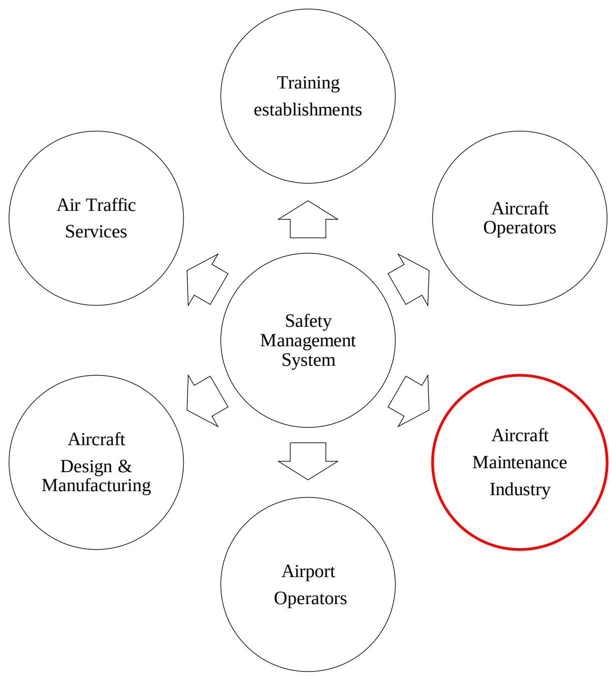

Figure 1.2 SMS Framework Applicability in Commercial Aviation
(Source: Produced by the scholar based on the ICAO Annex 19)

Safety is paramount in the commercial aviation transportation (Thomas et al., 2020). Today, the aviation industry has a knowledge base of over a century, and an overabundance of 'safety data' and 'safety information' derived from past accident investigation reports are available to industry stakeholders. However, worldwide aircraft safety occurrences (accidents and incidents) are constantly reported with more or less similar causal and contributory factors. The core purpose of civil air transportation is safely transporting passengers and cargo from one destination to another. The accomplishment of this task with perceived safety depends on the efficient and high degree of coordination amongst all the aviation industry stakeholders at every level. Aircraft flight operations, maintenance, ground handling, and air traffic management are vital entities of the civil aviation system that are interconnected and interdependent regarding technological, human, societal, and organizational interfaces for safe and efficient functioning. Annual safety reports of global agencies such as the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA) disseminate global commercial aviation safety status based on accident data. The data from the ICAO safety report (ICAO, 2022), as shown in Figure 1.3, demonstrate the aircraft accident numbers and accident rate per million departures from 2017 to 2022. However, while assimilating, one must keep in mind the effect of the pandemic; the years 2020 and 2021 do not reflect the realistic status of safety standards of the industry as, during this period, the air transportation sector was sternly hit, and the number of departures was considerably reduced. It is also to be comprehended that the ICAO safety reports only include accidents, and other safety data (serious incidents and incidents) are not included, which are significantly higher than the reflected figure and have the probability of causing accidents besides related social and financial implications. Therefore, it is reasonable to conclude from the ICAO safety report data that even though, over the years, the accident rate has been almost constant, the number of accidents is rising. However, the present accident rate in the commercial air transportation sector is sufficient to make it an ultra-safe mode of transportation. Given the above, it is challenging for industry stakeholders, safety practitioners, and global regulatory agencies to enhance the safety standards of an already safe industry. Another dimension of aviation safety is the perception of passengers and other stakeholders. (Gerede, 2015b) argues that the perception of safety amongst passengers and the general public is usually centered on the number of aircraft accidents, not the accident rate (accidents per million departures). (Martins, 2016), also suggests that an increase in the number of accidents and incidents will have an adverse effect on air transportation and, hence, might be unacceptable to the public and prospective passengers. Further, the impact global aviation and aerospace communities have undergone in the consequences of two Boeing 737 Max accidents in late 2018 and early 2019 is intriguing to realize in terms of the accident rate (Tyagi et al., 2023b).

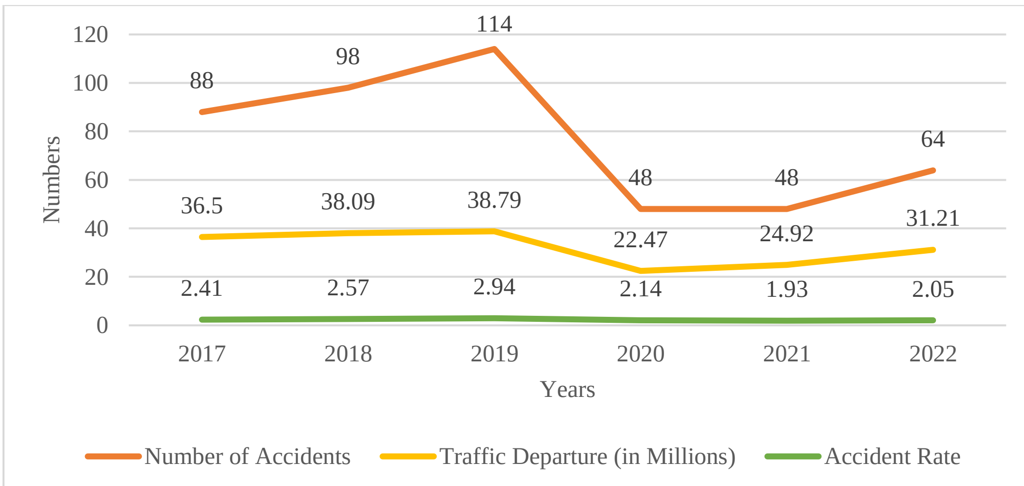

Figure 1.3 Accident Statistics of Scheduled Commercial Transport Operations
(Source: Created by the scholar based on the data of ICAO Safety Report 2023)

Although the current accident rate (2.05 accidents per million departures) is sufficient to assess CAT as an ultra-safe transportation industry, with the predicted growth rate (Boeing, 2022) (Airbus, 2022) of aircraft, airlines, and departures, the current accident rate is to be further lowered to maintain the current number of accidents and the passengers' confidence.

1.3 SAFETY IN THE AIRCRAFT MAINTENANCE INDUSTRY

The aircraft maintenance industry is a vital service provider of the aviation industry (Figure 1.2). Aircraft maintenance is a complex and costly process, and approximately 9.5% of the operational cost of an airline is attributed to maintenance (Lee & Mitici, 2020). (Hobbs, 2008) estimated that each flying hour needs twelve maintenance person-hours. This aspect can further be amplified by the necessity for the efficient and safe use of various tools, testers, and sophisticated equipment required to perform maintenance activities during maintenance person-hours in a complex organizational setup. (Gramopadhye & Drury, 2000) Illustrate that effective and efficient aircraft maintenance is a prerequisite to operational safety. A recently conducted study by (Illankoon et al., 2019) indicates that “roughly 12% of aircraft accidents result from maintenance faults, and one-third of all aircraft system malfunctions can be attributed to some kind of maintenance deficiency”. The aircraft maintenance industry is considered a high-risk industry, as several aircraft accidents and serious incidents are accredited to shortcomings in the activities conducted during maintenance (Insley & Turkoglu, 2020). Another aspect is related to the growth of the aviation industry, particularly in India and the Asia Pacific region, as predicted by leading global aircraft manufacturers (Airbus, 2022) and (Boeing, 2022). In the Indian context, the recent bulk aircraft orders by Airlines testify to the expected growth. This anticipated growth of CAT potentially will translate into additional departures and increased accidents and incidents (if the current rate of 2.05 accidents /million departures is maintained, Figure 1.3). Another aspect of this growth is related to the aircraft's age and optimum utilization for passenger transportation. The older and less efficient passenger aircraft are likely to queue up for major maintenance, modifications, and/or freighter conversion with the aircraft maintenance industry, which is also estimated to grow and be around 115 billion US Dollars by 2028 (Porter & Precourt, 2018). Therefore, it may be summarized that the expected growth of CAT poses a capacity challenge to the aircraft maintenance industry, potentially stressing the aircraft maintenance industry and making safety vulnerable in the prevailing competitive business environment. Given the above, safe aircraft maintenance activities are a prerequisite to enhancing safety performance, reducing accident rates, and keeping the number of accidents static (at present value). An understanding of the terms ‘aircraft maintenance,’ ‘safety in aviation,’ context with applicable regulatory framework wherein the study is conducted, and the scope of the study is described as follows:

1.3.1 CONCEPT OF 'AIRCRAFT MAINTENANCE'

ICAO Annex 8 (ICAO, 2018a) deals with "Airworthiness of Aircraft," defines maintenance as "the performance of tasks on an aircraft, engine, propeller or associated part required to ensure the continuing airworthiness of an aircraft, engine, propeller or associated part including any one or combination of overhaul, inspection, replacement, defect rectification, and the embodiment of modification or repair." The definition underlines the need to perform several tasks that are invariably performed and certified by the duly approved Aircraft Maintenance Engineers (AMEs) and technicians with the help of various tools, testers, and equipment in a maintenance environment, typically aprons, hangars, or workshops. (Ackert, 2010) suggests three principal reasons to justify the need for aircraft maintenance. The first one is operational, which keeps the aircraft and its systems serviceable for safe flying and revenue generation for an airline. The second is value retention, which maintains its value in the future by minimizing the deterioration likely to occur with usage and time. The third reason is to comply with the regulatory requirements. Aircraft maintenance is an intricate process differentiated from the line and the heavy maintenance based on the scope of maintenance tasks, resource requirements, and complexities involved (Albakkoush et al., 2021). Maintenance of aircraft and its various systems is imperative for an airline's efficient and safe operations.

1.3.2 CONCEPT OF 'SAFETY' IN AVIATION

In the aviation industry, 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 practical aspect of this definition emphasizes the countless operation-centric aviation activities performed in different stakeholders' business processes and identifying the hazards associated with them for timely controlling the risk. Hazards are dynamic and embedded in aviation activities in different forms. (ICAO, 2016) defines hazards as unsafe acts, unsafe conditions, and unsafe objects having the potential to contribute to or cause an aircraft accident or incident. The description of hazards in this context is very generic, which creates the necessity to monitor the operating environment very closely, as hazardous conditions, acts, and objects may be at any time and anywhere in the operating processes. On the other hand, an aircraft's airworthiness and safe flying depend on innumerable direct or indirect activities; for instance, air traffic management and airport operations, maintenance engineers' training, and aircraft maintenance processes directly influence aviation safety. Thus, by combining the aspects mentioned above, aviation safety management is essentially a three-step process: first, recognizing the ever-present hazards in various aviation-centric activities in the stakeholder's business processes, evaluating the related risk, and finally, mitigating or controlling the risk associated with the hazards. This study focuses on the safety aspects of one of the crucial service providers in the aviation ecosystem, i.e., the aircraft maintenance industry, also popularly known as the Maintenance, Repair, and Overhaul (MRO) sector of air transport operations.

1.3.3 INTER-ORGANIZATION OR INTRA-ORGANIZATION

(Batuwangala et al., 2018) draw attention to the safety data-sharing policies and the non-availability of safety data in the open domain. The impasse of the industry on the risk of losing reputation and the benefits of sharing safety data probably confine the learning at an intra-organizational level. Therefore, the scope of the study is limited to within an organization level.

1.3.4 CONTEXT OF THE STUDY

This study is conducted in the regulatory framework of SMS elaborated in ICAO Annex 19. The regulatory safety management system (SMS) framework complied by all aviation industry stakeholders is a comprehensive participatory approach to managing safety. This approach is a paradigm shift and asserts that employees' experience, knowledge, opinions, and suggestions must be drawn to improve safety performance (Jausan et al., 2017). In other words, all the stakeholders in an aircraft maintenance organization (different layers of management, maintenance staff, and regulators) must participate in managing safety within an acceptable limit. Under this framework, each aircraft maintenance organization must manage ‘safety’ within the acceptable limits set by the pertinent state regulator (usually, it is mutually agreed to, based on past safety performance). The SMS framework contains four ‘components’ and twelve ‘elements.’ The scholar has coded all four components and twelve elements by an abbreviated prefix followed by a corresponding number against each ‘component’ and ‘element’ sequentially (Table 1.1). The focal point of the SMS framework is hazard identification (HI) and managing the associated risk (C2E1 and C2E2) because each hazard can potentially cause safety occurrences of varying intensities under various conditions. The framework recommends two methods for hazard identification (C2E1), i.e., ‘reactive’ and ‘proactive’ methodologies. While the reactive method is for learning from past safety occurrences, the proactive is based on evaluating the present processes and preventing safety occurrences in the future. A mature SMS should consist of both methodologies aligned with the organizational scope of work and resources.

Table 1.1 SMS Components and Elements with the Simple Codification

SMS Component	**SMS Element**	**Codification by the scholar**
Safety policy and objectives	Management commitment Safety accountability and responsibilities Appointment of key safety personnel Coordination of emergency response planning SMS documentation	C1E1 C1E2 C1E3 C1E4 C1E5
Safety risk management	***Hazard identification*** ***Safety risk assessment and mitigation***	***C2E1*** ***C2E2***
Safety assurance	Safety performance monitoring and measurement The management of change Continuous improvement of the SMS	C3E1 C3E2 C3E3
Safety promotion	Training and Education Safety communication	C4E1 C4E2

Element one, ‘Hazard Identification’ (code C2E1), of component two, ‘Safety Risk Management’ (SRM), is the core of safety management. The guiding material for implementing the framework into organizational business processes is prescribed in the Safety Management Manual (SMM) document number 9859, fourth edition (ICAO, 2018b). The scholar formulated a ' hazard identification ' framework based on the guiding material and the SMS framework (ICAO, 2016) (Figure 1.4). Since “Hazard Identification” is a cornerstone of the study, it is essential to understand it in the context of aircraft maintenance safety. The regulatory publication also recommends various sources that can be used for hazard identification in an aircraft maintenance organization. In unison with this, (Necula & Zaharia, 2015) suggest four main areas for identifying hazards in aircraft maintenance organizations, i.e., hazards related to individual or personal characteristics, hazards associated with maintenance activities the third one is working conditions, and finally organizational hazards. Specific to the aircraft maintenance industry, safety can be seen from two different perspectives: firstly, the safety of maintenance staff while performing a wide variety of maintenance activities on aircraft systems, engines, and components. The second one is connected with the maintenance activities to produce an airworthy aircraft for continued safe flying operations. The study aims to include both attributes of maintenance safety, as hazardous working conditions can also negatively affect the performance of the maintenance staff. In aircraft maintenance processes, hazards are pervasive, and they become more complex owing to their association with the variability in technology and the human element, as well as other specified and unspecified variables. Typically, two methodologies are employed to identify hazards in aircraft maintenance organizations. While the reactive methods (also known as learning from the past) are based on past safety occurrences and their investigation reports recommendations, the proactive methods use safety data produced in the day-to-day process of aircraft maintenance, for instance, daily monitoring of maintenance activities, comparable to Line Operations Safety Audit (LOSA), voluntary reporting of unsafe acts/unsafe conditions by the maintenance staff, periodic audit reports (both internal as well as regulatory audits), audit reports at the time when major changes are introduced in the organizational functioning, training feedbacks, aircraft system data monitoring and safety information sharing. Although, in the SMS framework, ‘hazard identification’ is the responsibility of each stakeholder involved in the process, this study is grounded on the maintenance staff perception. The maintenance staff is considered critical for two reasons: firstly, they are the first to handle the technical faults/shortcomings in the aircraft system on the ground when an aircraft lands after flying, and secondly, the activities they perform are the final last before the aircraft is declared airworthy for the following flying commitment.

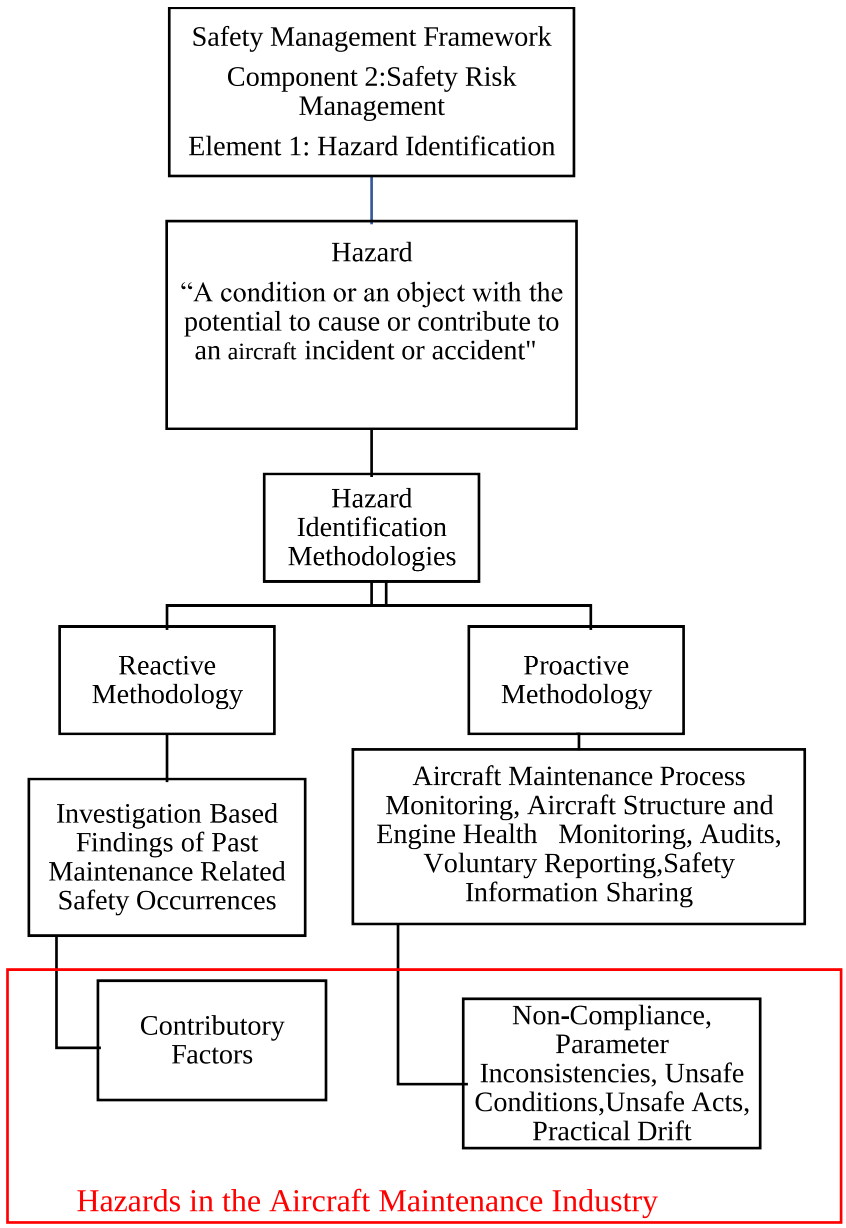

Figure. 1.4 HI Framework in the Aircraft Maintenance Industry

Source: (ICAO,2018)

Given above, the assumptions and context of the study are summarized as follows:

- The aircraft maintenance industry (Figure 1.2) is at the center stage of the study.
- As per ICAO SARPs and the local regulatory guidelines, the global aircraft maintenance industry's current safety management should comply with the SMS framework (ICAO,2016). However, the academic literature suggests significant challenges in this process as the current safety management framework is a paradigm shift compared to previous approaches.
- The study explores the reactive methodology-based ‘hazard identification’(C2E1) framework (Figure 1.4) within the broader SMS framework.
- The scope of aircraft maintenance is vast and complex. Therefore, this study follows the ICAO definition of ‘maintenance’ and limits the scope as described in para 1.3.1.
- Due to data-sharing policies and the sensitivity of safety data as described in para 1.3.3, the scope of the study is limited to intra-organizational.

1.4 RESEARCH MOTIVATION

Why do people embark on research? This question is of fundamental importance and can be answered with different perspectives. (Kothari, 2004) suggests a non-exhaustive list of probable motives and is taken as a reference to explain the scholar's motivation to undertake this research. The scholar believes that the “Desire to face the challenge in solving the unsolved problems, i.e., concern over practical problems” may be an appropriate reason to undertake this research. ‘Safety’ in aviation continues to be a problem area as it has posed a variety of challenges with time to industry stakeholders. In this context, (S. Shappell et al., 2007) illustrate that “all the low-hanging fruits have already been picked,” now, the real problem for service providers, safety practitioners, and state safety regulators is improving the safety of an already ultra-safe industry. This statement infers that all the metallurgical advancements, technological innovations, system automation, human factor interventions, and improved regulations are already in practice in managing safety in the aviation industry and, thus, means to underscore the necessity for a more detailed understanding of aviation business processes.

The solution to improving safety at the present level is possibly seen in the all-encompassing participative current safety management framework. In this framework, one of the fundamental aspects is learning from the past, which is essentially a reactive safety management method to prevent the recurrence of incidents and accidents. However, “numerous industrial accidents indicate that organizations have failed to learn lessons from the past.” (Drupsteen et al., 2013).

The abovementioned aspect of safety in the aviation sector motivates the scholar to study and contribute to the problem-solving process that benefits the industry's stakeholders. The agenda of the study is set by identifying gaps in the existing scholarly literature on ‘learning from the past’ and ‘hazard identification’ in the aircraft maintenance industry. Therefore, the research motivation for the scholar is aligned with the (Kothari, 2004) illustration of the “desire to face the challenge in solving practical problems.”

1.5 BUSINESS PROBLEM

The sole purpose of investigating aircraft accidents and incidents is to avoid their recurrence (ICAO, 2020). This purpose of investigating a safety occurrence is not only valid for the aviation industry; usually, regardless of the type of industry, the core purpose of investigating any catastrophe is to identify the causal and contributory factors and learn lessons for safer business practices. However, contrary to this, a study by (Drupsteen et al., 2013) based on various industries, including chemical, energy, construction, and transportation, discloses that “numerous accidents have occurred because organizations have failed to learn lessons from the past.” The commercial air transportation (CAT) industry also shows the same pattern as given in the following illustration: “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."

About 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." Given the above, it is sufficient to infer that globally and in the Indian context, the problem of the recurrence of aircraft accidents and incidents continues, and stakeholders still do not fully utilize the potential of past safety occurrences ('learning from the past') to manage safety.

"In the competitive aviation business environment, the recurrence of aircraft incidents and accidents is a serious problem and indicates the organizational inability to learn from past events. This adversely affects the performance and reputation of the aircraft maintenance industry, besides the loss of human lives and injuries to workers and passengers. The problem will likely get further compounded with the predicted growth of the sector." Therefore, the cited mishaps, scholarly literature, and the ASN database underscore the need to investigate this problem in the complex working environment of the commercial air transportation sector.

1.6 RESEARCH PROBLEM

(Kothari, 2004) describes a research problem in the context of either a practical or a theoretical situation wherein a researcher aims to contribute by changing processes (for a practical problem) or expanding the knowledge base (for a theoretical problem). The above-described business problem is a pragmatic problem that the global aviation industry is experiencing, and this research study aims to contribute to changes in processes. The research problem is defined following the four broad guidelines of (Kothari, 2004), as follows:

1.6.1 GENERIC STATEMENT

Problem formulation starts with an ambiguous and general problem statement, i.e., "different stakeholders (service providers) of the aviation industry are failing to learn the lessons from the past as manifested in the recurrence of aircraft accidents and incidents." This general problem statement is based on the study of (Drupsteen et al., 2013) on numerous industries, including energy, chemicals, construction, and transportation, illustrates the occurrence of numerous accidents attributed to organizational failure to learn lessons from the past. Besides this, the cited mishaps in para 1.5 above and the global ASN database substantiate the study's outcome and the general problem statement.

1.6.2 PROBLEM CONTEXT

The second aspect is related to understanding the nature and the context of the problem. Safety is paramount in commercial aviation transportation (Thomas et al., 2020). Although, based on the current accident rate (2.05 accidents per million departures), CAT is considered one of the safest means of transportation, it is essential to realize that the perception of the general public and passengers towards commercial air transportation safety is based on the number of accidents and not on the accident rate (Gerede, 2015b) and (Martins, 2016). Another aspect is related to the growth of the aviation industry, particularly in India and the Asia Pacific region, as predicted by leading global aircraft manufacturers (Airbus, 2022) and (Boeing, 2022). In the Indian context, the recent bulk aircraft orders by Airlines testify to the expected growth. This anticipated growth of CAT potentially will translate into additional departures and increased accidents and incidents (if the current rate of 2.05 accidents /million departures is maintained, Figure 1.3). Another aspect of this growth is related to the aircraft's age and optimum utilization for passenger transportation. The older and less efficient passenger aircraft are likely to queue up for major maintenance, modifications, and/or freighter conversion with the aircraft maintenance industry, which is also estimated to grow and be around 115 billion US Dollars by 2028 (Porter & Precourt, 2018). Therefore, it may be summarized that the expected growth of CAT poses a capacity challenge to the aircraft maintenance industry, potentially stressing the aircraft maintenance industry and making safety vulnerable in the prevailing competitive business environment. Therefore, the safety and its perception by the general public, the growth of aviation in the Indian subcontinent, and the effect of this growth on the aircraft maintenance industry guide to further improve the drafted research problem of "Aircraft maintenance industry (a critical service provider) of the aviation industry are failing to learn the lessons from the past as manifested in the recurrence of aircraft accidents and incidents attributed to maintenance shortcomings."

1.6.3 LITERATURE SURVEY

The third and vital aspect of the research problem formulation is the academic literature survey to get updated on relevant theories, records, reports, and other relevant data on the subject. To achieve this, two literature surveys (Tyagi et al., 2023a) and (Tyagi et al., 2023b) were undertaken to gain insight into the scholarly work and identify gaps in formulating the research problem. The DOI links and other specifics of the mentioned papers are given in Appendix A4, and relevant details of objectives, methodologies followed, and gaps identified in each literature survey are given in Chapter 2. In this chapter, the details of the literature survey are restricted to their utility in formulating the research problem.

1.6.4 PROBLEM STATEMENT

Based on the above considerations, the initially drafted research problem is rephrased, and specificities of the subject are included: "Although aircraft maintenance organizations have the 'reactive safety management' regulatory framework integrated into the business processes, the recurrence of aircraft accidents and incidents continues at global and domestic (Indian) levels, thus establishing the problem in the learning from the past process and indicating the organizational inability to learn from the past."

1.6.5 TERMS DEFINITION OF 'RESEARCH PROBLEM'

(Slife et al., 2016) highlight the importance of operational definition in the research to examine practical perspective. In the aviation sector, definitions of terms typically form part of the regulatory documents each stakeholder complies with globally. 'Reactive Safety Management' means a systematic approach to managing safety by identifying the hazards and managing associated risks based on the lessons learned from analyzing past accidents and incidents. '*Hazard*' means "a condition or an object with the potential to cause or contribute to an aircraft incident or accident." In the framework of this study, '*learning'* is explained as the development of front-line maintenance staff's hazard identification and risk management (HIRM) capabilities based on the safety information drawn from past safety occurrences. Understanding the term *'past'* is critical. The literature survey reveals that existing scholarly literature has viewed the term *'past'* predominantly based on the occurrences of disasters. This approach potentially limits the learning from the past as aviation is one of the safest means of transportation, and accidents or even incidents are rare. Therefore, this study has widened the scope of the *'past'* and includes the 'safety information' derived by investigating the hazards, errors, and near-misses reported by the front-line maintenance staff in day-to-day functioning. In this case, the past may be very recent, depending upon organizational agility. The frequently used terms, for instance, "accident," "serious incident," "incident', "safety data," "safety information," "causes," and "contributory factors" are used in the thesis as defined in ICAO Annex 13, twelfth edition (ICAO, 2020). To include the practical perspective, ICAO-defined definitions and terminology are used in this thesis unless specified. However, for convenience and to avoid repetition, the terms "maintenance staff" or "maintenance personnel" are employed for licensed aircraft maintenance engineers (AMEs), hangar floor supervisors, workshop supervisors, non-certifying staff working with AMEs, in tool and component (bonded or quarantine) stores, monitoring and updating components, engine, and aircraft performance and utilization data, etc., working in MRO sector. Similarly, "safety occurrence' is used for 'accident' and/or 'incident.'

1.7 RESEARCH QUESTIONS (WHAT SHOULD I START WITH?)

Scholarly literature suggests several methodologies that assist in identifying and developing the research questions. (Bell et al., 2022) illustrate that gaps in the existing literature, inconsistencies between the several studies, or unresolved issues in the literature lead to research questions. The authors further suggest that societal development sometimes provides a platform to formulate research questions. In contrast, (Alvesson, 2011) proposed the concept of problematization, i.e., identifying and challenging the assumptions in the existing literature and formulating research questions based on that. Arguably, this method is meant to develop more influential and exciting theories within management studies. Another critical aspect of research question development is related to relevance to practice. (Gummesson, 2000) argues that practitioners and researchers are involved in addressing organizational management problems but emphasize practice and theory differently. Based on the bits and pieces of theories, practitioners contribute to business processes, whereas researchers contribute to theories supported by fragmented practices. Essentially, both stakeholders are involved in addressing organizational management problems in their own way.

In aviation safety, the current safety management system (SMS) encourages 'Evidence-Based Management' (EBM), which requires making decisions based on data and analysis. This study aims to formulate research questions based on gaps identified in scholarly literature when reviewed through the regulatory framework's prism to include the practicalities of business processes.

To achieve this, two literature reviews were conducted (Tyagi et al., 2023c) and (Tyagi et al., 2023b), with clear object definitions aligned with the aim of this study. The detailed methodology followed for the literature reviews and the findings of each study are covered in Chapter 2; however, a brief overview of research problems, gaps, research questions, and research objectives on which this research is synthesized is given below:

1.7.1 RESEARCH GAP 1

In industrial safety, 'learning from the past' is "drawing information from the personnel involved in the safety occurrence and from the safety occurrence itself and converting it into knowledge for the entire organization, or at least for the stakeholders for whom it is critical" (Jacobsson et al., 2011). In the context of this study, 'learning from the past' is described as "enhanced hazard identification and risk management capabilities of front-line maintenance staff based on the safety information drawn from past investigations" (Tyagi et al., 2023b). Preferably, the development of capabilities to a level at least the hazards reported, caused, and contributed to accidents in the past are promptly identified and managed.

"The prerequisite for 'learning from the past' is the organization's formally structured learning system wherein safety information is drawn from the occurrences based on investigations and communicated to stakeholders for individual and organizational learning (Jacobsson et al., 2011). A model of accident investigation and prevention was developed by (Lindberg & Ove Hansson, 2006), also known as the CHAIN model or model of experience feedback. It consisted of five stages: reporting, selection, investigation, dissemination, and prevention, with all the stages contributing to the learning process to varying degrees. Another learning from the past model consisting of eleven steps under four stages was presented by (Drupsteen et al., 2013). The first stage included safety occurrence reporting and analysis; the second stage focused on formulating a practical action plan based on the analyzed results; the third was related to resource allocation for the action plan; the last stage evaluated the learning. This model can also be compared with the (Deming, 2018) Plan-Do-Study-Act (PDSA) cycle, which describes learning as an iterative process in which results are studied and causes of failure are investigated to formulate revised plans for action. A six-stage LFI process model was developed based on the energy sector studies (Littlejohn et al., 2017)". All the stated models are principally in unison and construct an envelope for learning with the starting point 'reporting' or, in other words, the origin of learning contents. Existing scholarly literature proposed a few 'learning from past' process models based on the energy, chemical, and construction sector processes, and a clear gap in the academic research is observed as none of the studies was conducted based on business processes of the aviation sector and considering the current safety management regulatory framework.

Therefore, in the current regulatory framework of SMS, the formally structured 'learning from the past' process model, wherein different semantically related activities (stages) are aggregated together to demonstrate the coarse-grained functioning of the business processes of the aircraft maintenance industry, has not been explored.

The study intends to fill the abovementioned research gap by following the literature review research method in conjunction with the current regulatory framework of safety management. The reason for selecting this research method is the fast production of knowledge in the fragmented and interdisciplinary business research domain, wherein literature review as a research method becomes more relevant than ever (Snyder, 2019). "An effective and well-conducted review as a research method creates a firm foundation for advancing knowledge and facilitating theory development" (Webster & Watson, 2002).

1.7.2 RESEARCH QUESTION 1

In the current safety management framework, what is the 'learning from the past' process model for the aircraft maintenance industry?

1.7.3 RESEARCH OBJECTIVE 1

To establish a formally structured 'reactive methodology-based hazard identification' process model for the aircraft maintenance industry, which complies with the current regulatory safety framework.

1.7.4 RESEARCH GAP 2

In other than aviation industrial settings, the ‘learning from the past’ process model broadly, all the stages are prone to barriers (impeding factors) that adversely affect the learning process (Drupsteen et al., 2013). Another comparable study conducted focus group discussions with seven companies (four chemicals, one manufacturing and service provider to chemical plants, and a construction company) and identified the causes and conditions that obstruct learning from the past (Drupsteen & Hasle, 2014). The study used the same model (Drupsteen et al., 2013) and highlighted the employees' reluctance to report safety occurrences. In aviation organizations consisting of typically all operational streams such as flying, air traffic controls, and maintenance, the barriers impacting the effectiveness of the ‘ voluntary reporting’ channel were classified as ‘organizational barriers, ‘work environment barriers,’ and ‘individual barriers’ (Jausan et al., 2017). Although the study identified the reporting system barriers based on a military aviation organization survey, most attributes are also consistent with commercial aviation.

Today, aviation has an experience base of over a century, and the plethora of ‘safety data’ and ‘safety information’ derived from the investigation reports supposedly available to stakeholders. However, numerous industrial accidents indicate that organizations have failed to learn lessons from the past (Drupsteen et al., 2013). Learning is hindered at an individual or organizational level or due to inadequate regulatory interventions; scholarly literature has not explored these aspects and hence must be investigated.

Therefore, the critical aspect is why organizations are not learning, or, in other words, what factors influence ‘learning from the past’ despite the necessary regulatory framework in the aircraft maintenance industry. Since researchers have not explored the ‘learning from the past’ process model in the aviation regulatory framework, impacting factors (catalyst and impeding) to each model stage are also unavailable. Although influencing factors of intermediate stages were studied fragmentedly, scholarly literature holistically evaluating the ‘learning from the past’ model and identifying stage-wise impacting factors is lagging. This gap is proposed to be filled by pursuing the literature review research method wherein existing studies identify the stagewise influencing factors and evaluate them in conjunction with the current regulatory framework of safety management.

1.7.5 RESEARCH QUESTION 2

What factors impact various stages of the 'learning from the past' process in the aircraft maintenance industry?

1.7.6 RESEARCH OBJECTIVE 2

To stage-wise identify the influencing factors to the 'reactive methodology-based hazard identification' process for the aircraft maintenance industry.

1.7.7 RESEARCH GAP 3

'Learning from the past' is not a novel concept. Researchers have explored this subject under the different names of 'learning from incidents (LFI),' 'learning from accidents and disasters,' and 'learning from experience or experience feedback,' etc. (Balasubramanian & Louvar, 2002) (Haunschild & Sullivan, 2002)) (Lindberg et al., 2010) (Jacobsson et al., 2011) (Akselsson et al., 2012) (Drupsteen et al., 2013) (Drupsteen & Hasle, 2014) (Drupsteen & Guldenmund, 2014) (Silva et al., 2017) (Littlejohn et al., 2017) (Margaryan et al., 2018) (Clare & Kourousis, 2021b) (Clare & Kourousis, 2021f). The abovementioned studies have predominantly viewed the 'past' based on the occurrences of accidents and incidents; this approach may have the possibility to confine learning from the past as aviation is one of the safest means of transportation, and accidents or even incidents are rare.

Studies mentioned in the previous paragraph have followed the qualitative approach wherein accurate weighing of factors influencing 'learning from the past' is unavailable. A clear gap exists in academic literature as no study has been conducted in the aircraft maintenance industry where factors influencing 'learning from the past' were identified and measured. Further, unlike previous research, this study views the 'past' from two different perspectives. Firstly, the 'safety information' produced from investigating historical accidents and incidents, and secondly, 'safety information' derived by investigating the hazards, errors, and near-misses reported by the front-line maintenance staff in day-to-day functioning; in this case, the past may be very recent, depending upon organizational agility.

This gap is proposed to be filled by measuring the perceptions of front-line maintenance staff using a qualitative data collection tool, 'survey.' A 42-item data collection tool was developed to reflect seven constructs on a 5-point Likert-type scale for data collection, having a neutral point to eliminate the forced response. To maintain unidimensionality, all the items of a construct are either positively or negatively worded (Nemoto & Beglar, 2014). Subsequently, partial least squares structural equation modeling (PLS-SEM) was used to evaluate the relationship between measurable (items) and unmeasurable (constructs) variables and between the constructs simultaneously.

1.7.8 RESEARCH QUESTION 3

Based on the findings of the above two objectives, the third objective of the study is to develop a framework for 'reactive methodology-based hazard identification' for India's aircraft maintenance organizations.

1.7.9 RESEARCH OBJECTIVE 3

To determine the impact of each factor on the stages of the 'learning from the past' process model on 'learning.'

1.8 RESEARCH FLOW PROCESS

A relational link between the Business problem, Research Problem, Research Gaps, Research Questions, and Research Objective is illustrated in Figure 1.5.

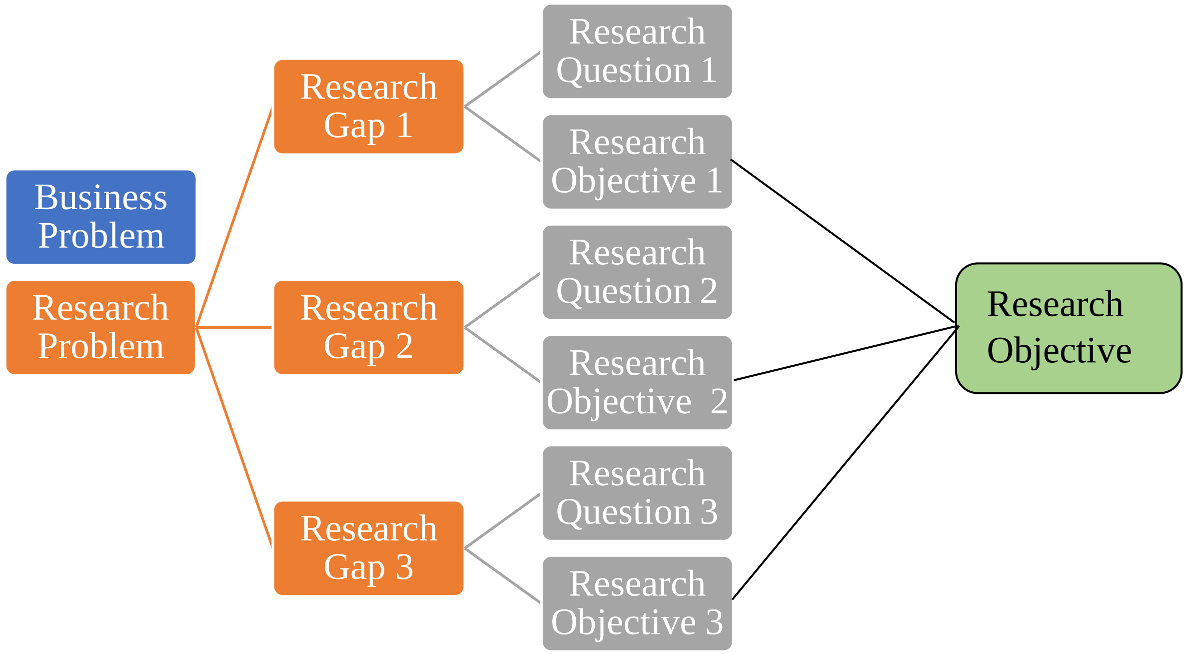

Figure 1.5 Research Flow Process

1.9 OVERVIEW OF RESEARCH METHODOLOGY & RESEARCH DESIGN

Individual beliefs and assumptions influence management and business research in deciding the methodology and methods (Saunders et al., 2019). This study's research model is derived from the ‘research onion,’ which is widely applicable to business and management research. The ‘research onion,’ suggested by Saunders et al. (2019), assists in organizing and developing a robust research design by following each layer of the research onion step by step. The ‘research onion’ is reproduced in Figure 1.6 with the due permission of copyright holders (Appendix A1).

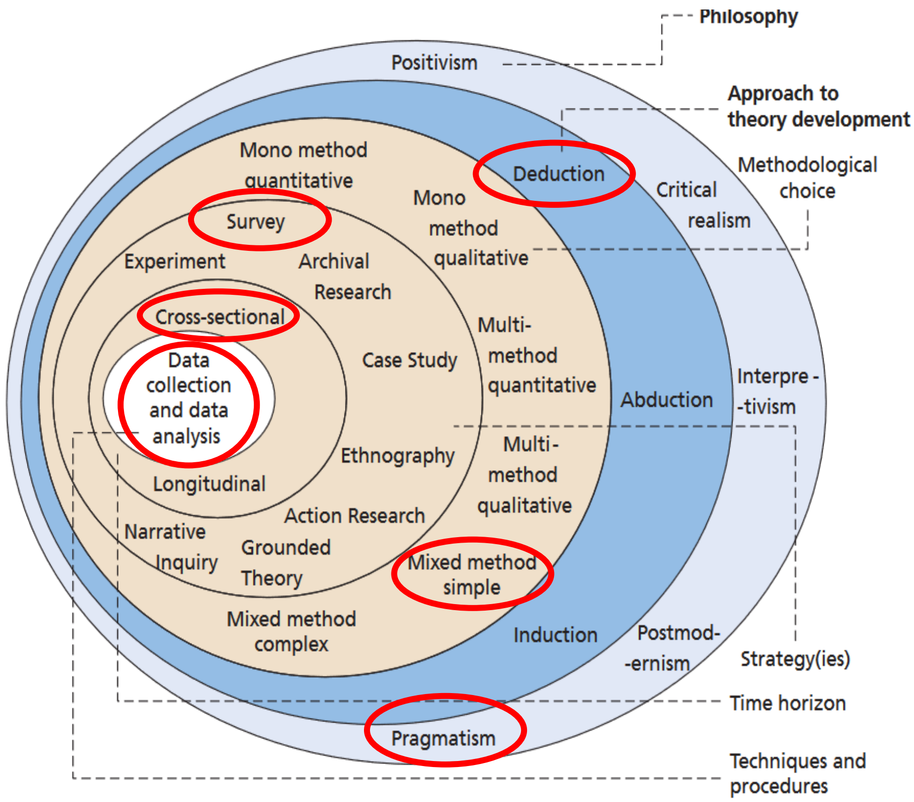

Figure 1.6 Research Onion

(©2018 Mark Saunders, Philip Lewis, and Adrian Thornhill)

In the six layers of the research onion, the outermost layer defines the main research philosophy, i.e., a basis of the research, by describing it as either ontological, epistemological, or axiological concepts. The next layer is a selection of research approaches, which usually include inductive, deductive, or abductive approaches. The third layer is a methodological choice, which determines the use of quantitative or qualitative methods or a mix of both. The fourth layer is the determination of strategy to collect data in one or more ways among survey, experiment, case study, ethnography, narrative inquiry, and action research. The next layer is related to the time horizons. It defines the data collection time frame, i.e., cross-sectional study, wherein data collection is at a specific time or longitudinal study in which data is repeatedly collected over a substantial period to enable comparative analysis. The core of the model onion is research data-centric, which essentially explains the data collection technique employed and its justification. This research is conducted with a 'pragmatism' paradigm as the researcher used a reflexive tool, 'Heightening your Awareness of your Research Philosophy' (HARP) questionnaire (Appendix A2), to arrive at this conclusion. Subsequent layers followed a 'deductive' method to theory development with a 'mixed' methodological approach. A survey questionnaire consisting of a total of 48 questions is used to collect demographic data (six questions) of the participants and their perceptions (forty-two questions) on different constructs related to research questions. The data was collected at a specific time (cross-sectional) using purposive and snowball sampling techniques. The minimum sample size was determined by the 'inverse root square method,' '10-time rule,' and 'A-priori online calculator,' and the highest value was considered. For analysis, smart PLS-SEM software was utilized as this method is acclaimed as one of the widely used multivariate analysis methods, which enables the researchers to simultaneously evaluate the relationship between measurable (items) and unmeasurable variables (constructs) and between the constructs (Hair Jr et al., 2021). To summarize the above, Table 1.2 may be referred to assimilate the overall research design of the study.

Table 1.2 Summary of Research Design

Research Philosophy	Pragmatism (Based on the HARP scores)
Theory Development approach	Deductive
Methodical Choice	Simple Mixed Methods
Research Strategy	Literature Review Research and Survey
Time Horizon	Cross-sectional
Techniques and Procedure	Scale development, Data collection, and Use of Smart SEM-PLS Version 4 software for modeling.

1.10 RESEARCH CONTRIBUTION

1.10.1 FOR INDUSTRY AND STATE REGULATORS

The measurement model and the structural model developed in this study provide a systematic and comprehensive understanding to decision-makers on the chronic issue of safety in the aircraft maintenance industry, i.e., learning from the past. The study's findings allow senior management to estimate the impact of various factors on different stages of learning from the past process model. The study highlights the shortcomings of the regulatory safety oversight, which is restricted to delivering 'safety communication' rather than verifying its effectiveness. If the organization and regulatory agency are not evaluating the learning outcomes of the 'safety communication' stage, learning from the past is negatively affected.

1.10.2 CONTRIBUTION TO THEORETICAL FRAMEWORK

The study establishes a relationship between the 'Aviation Risk Triangle,' the LPSI process model, and reactive methods of hazard identification and underscores its value in managing safety threats at the base of the 'Aviation Risk Triangle.'

1.11 OUTLINE OF THESIS CHAPTERS

This thesis is organized into nine chapters, and a brief introduction of each chapter is as follows:-

Chapter 2: Literature Survey: This thesis chapter describes the literature reviews conducted to identify gaps in the existing literature and formulate the research problem and the research questions.

Chapter 3: Research Methodology: This thesis chapter gives a detailed explanation of the methods used to explore each research question.

Chapter 4: RO1, RO2, Conceptual Model & Hypotheses: This thesis chapter describes the operationalization of the research methods explained for research questions one and two in Chapter 3. Subsequently, a conceptual model is developed based on the outcome of RQ1 and RQ2, and eventually, six hypotheses are stated for further testing.

Chapter 5: Research Objective 3: This chapter describes the data analysis and results derived to achieve the third research objective. Various sections and subsections illustrate the analysis of the respondents' demographic profiles, descriptive statistical analysis, analysis of measurement, and structure models.

Chapter 6: Summary of Key Findings: This chapter summarizes the results derived by exploring all three research questions.

Chapter 7: Theoretical Framework Underpinning: This chapter explains the theory of the 'Risk Triangle,' the evolution of the 'Aviation Risk Triangle,' and the concept of the 'leading' and 'lagging' indicators. To underline the importance of leading indicators, a relationship between the 'Aviation Risk Triangle' and the 'Learning from the Past Safety Investigations (LPSI) process model' is described.

Chapter 8: Research Contribution: This chapter first underlines the research novelty that forms the base for the research outcomes. Subsequently, the research contributions are described in two different dimensions: their contribution to the aircraft maintenance industry, including the state regulators, and their contribution to the theoretical framework.

Chapter 9: Limitations Of The Study, Scope For Future Research And Conclusion

CHAPTER 2: LITERATURE SURVEY

Chapter Overview This thesis chapter describes the foundation of recognizing the research problem and associated research questions. The scholar conducted two literature reviews (published papers) with specific aims. The methodology and findings of each literature review are explained in paras 2.2 and 2.3, respectively. A summary of both literature reviews, which includes the gaps in the current scholarly literature, is presented in para 2.4, while research questions are presented in para 2.5.

2.1 INTRODUCTION

A comprehensive, systematic, and transparent literature review process is mandatory to produce balanced research for a subject related to aviation safety, which is well developed, has a sufficiently large knowledge base, and simultaneously emerges with time. In the 21st century, complex aviation maintenance safety has matured into a systemic approach, and it continues to emerge in various dimensions because of changes in technologies and economic conditions. While understanding the current knowledge base of safety in the aircraft maintenance industry, it is prudent to take cognizance of the data from annual ICAO safety reports (ICAO, 2022) and the argument of (S. Shappell et al., 2007) "civil air transportation is one of the safest modes of transport, and now the real challenge for national safety regulators and service providers is to improve the safety of an industry that is already ultra-safe." Improved regulations, automation, technological advancement, and quality research from academia have made the civil aviation industry what it is today in terms of safety parameters. Research studies on the interaction amongst various elements within an organization popularly known as the "SHELL" model, "Dirty Dozen," the human factors related to hazards in aircraft maintenance, and numerous other studies and publications in aircraft maintenance safety are now part of various ICAO Standards and Recommended Procedures (SARPs) and Guiding Material (GM). Therefore, some research articles and publications are compiled (Table 2.1) that either form part of regulatory recommendations or are widely applied in the aircraft maintenance industry as best practices. The publications mentioned in Table 2.1 are not exhaustive, and the purpose of listing here is to segregate implemented and disseminated research work from the scope of the literature review.

Table.2.1 Details of Legendary Research in Aircraft Maintenance Safety

Author (s) references of the article	Key Themes	Scopus Citations (Sep 22)
(J. Reason, 1990b)	Described the active and latent human failures and aircraft accident causation dynamics.	484
(J. Reason, 1998)	Introduces the “Switch Cheese Model” of accident causation and the relationship between the safety culture and the causation of organizational accidents.	369
(Rankin, 2000)	Provides guidelines for the investigation of the safety occurrences attributed to maintenance processes.	56
(Hobbs & Williamson, 2002)	Established in aircraft maintenance, skill-based performance is safer than rule and knowledge-based interpretation.	51
(Hobbs & Williamson, 2003)	Explored the link between the specific errors and contributory factors in aircraft maintenance	108
(Snook, 2011)	The book explains the drifting of performance of any system in actual life operations from its original design	255

(Donthu et al., 2021) argue that a systematic literature review approach summarizes the findings of existing literature in a specific research domain. Therefore, two literature reviews (Tyagi et al., 2023b) and (Tyagi et al., 2023c) were conducted to identify the gaps and define the research problem and questions in the existing literature on safety in the aircraft maintenance industry in the SMS framework. In this chapter, the relevant portions, including the aim, methodology, results, and identified gaps of each review, are covered in the following paragraphs.

2.2 SYSTEMATIC LITERATURE REVIEW (SLR) 1

The first SLR, titled “Safety Management System and Hazards in the Aircraft Maintenance Industry,” was conducted following an updated version (2020) of

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommended by (Page et al., 2021).

2.2.1 AIM

Aligned with the safety management approach of the 21st century, i.e., SMS, this systematic literature review aims to comprehend hazards in the aircraft maintenance industry by reviewing research articles. Comprehension of hazards includes but is not limited to the assessment of unsafe acts, conditions, and objects in the aircraft maintenance industry that may have the potential to adversely affect the safety of aircraft operations and the various methodologies researchers have adopted to identify them.

2.2.2 METHODOLOGY

An updated version (2020) of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was followed with a clearly defined search strategy and inclusion/ exclusion criteria as follows:

2.2.3 RESULTS

The literature search based on the defined strategy yielded 396 studies (185 and 211 in the Scopus and Web of Science databases, respectively). A total of 113 records were identified as duplicates and removed, and the remaining 283 records were considered for further screening. The first author performed title/abstract screening based on the formulated criteria. To minimize the risk of bias, screened results were individually validated by SMEs, which reduced the number of studies to 66, eligible for the retrieval of the complete article. Only 61 studies could be retrieved entirely for further analysis to follow the next step. Additional screening of the full research article excluded 22 studies, as 16 were associated with the TECH code, four with the OPS code, and two with the HUT code, thus bringing the eligible study number to 39. Finally, following the PRISMA flow diagram (Figure 2.2), 39 studies were identified as eligible and included in the review.

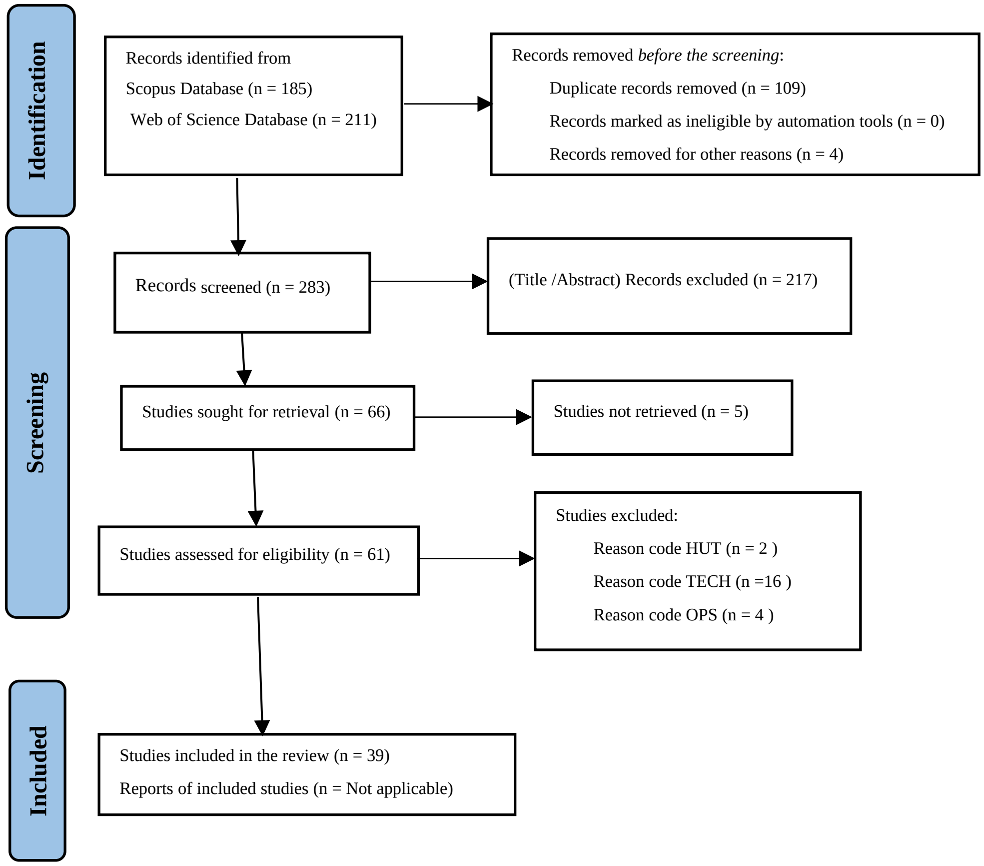

Figure. 2.1 PRISMA flow diagram SLR1

2.2.4 STUDY CHARACTERISTICS

Aligned with the review's objectives, each research study has been characterized to highlight the hazards-identifying methodology within the SMS framework and the methodology followed during the research. A summary is presented in Table 2.2.

Table: 2.2 Study Characteristics SLR1

Research Articles	Brief Description of the Study	Type of HI Methodology
(Clare & Kourousis, 2021b) and (Clare & Kourousis, 2021d)	Qualitative studies centered on learning from past safety occurrences underscore the factors that impede the learning process and adversely affect the organization's reactive and proactive hazard identification methodologies.	Reactive
(Quinlan et al., 2013) and (Quinlan et al., 2014)	Qualitative case-study-based research narrated various hazards and limitations of regulatory oversight in the outsourced aircraft maintenance process in the United States.	Reactive
(Machado et al., 2016)	Qualitative exploratory research identified several hazards associated with the outsourced maintenance of the Brazilian aircraft maintenance industry.	Proactive
(Bağan & Gerede, 2019)	Qualitative research used a nominal group technique and identified 55 safety hazards expected to ascend due to maintenance outsourcing in Turkey.	Proactive
(Le & Lappas, 2016)	The qualitative study highlighted the challenges and hazards in ensuring continued airworthiness with aging aircraft and the safety implications of converting old passenger aircraft to freighter ones.	Proactive
(MacLean et al., 2018)	Mixed research based on the Service Difficulty Report (SDR) database described the hazardous conditions in old aircraft.	Reactive
(Yazgan et al., 2022)	Mixed research aimed to assess various hazards that may cause musculoskeletal disorder (MSD) risks to maintenance staff.	Proactive
(Gharib et al., 2021)	A mixed study in the Middle East identified safety hazards to aircraft maintenance staff while performing maintenance tasks.	Proactive
(Insley & Turkoglu, 2020)	A qualitative study analyzed ASN's past accident database, identified numerous hazards, and established the primary maintenance causation factors.	Reactive
(Habib & Turkoglu, 2020)	A qualitative study investigated the database of past accidents and incidents in Nigeria and identified several hazards for maintenance safety.	Reactive

(Khan et al., 2020)	A qualitative study of the ICAO safety occurrence database described five broad categories of maintenance hazards.	Reactive
(Virovac et al., 2017)	A qualitative study evaluated 28 safety incidents in an aircraft maintenance organization and presented a range of hazards leading to adverse consequences.	Reactive
(Zimmermann & Mendonca, 2021)	A qualitative study analyzed 12 safety occurrences on the PEAR framework and illustrated a range of conditions that could cause maintenance-related safety occurrences.	Reactive
(Chang & Wang, 2010)	A mixed study investigated the human risk factors associated with AMEs in the airline industry. Nine risk factors were categorized, and the safety attitude of the AMEs was identified as the most critical hazard.	Proactive
(Trifonov-Bogdanov et al., 2013)	A qualitative study described a range of hazards that lead to safety incidents in various activities of the aircraft maintenance process.	Reactive
(Balcerzak, 2017)	A qualitative study underscores the impediments and hazards to safety reporting in aircraft maintenance organizations.	Proactive
(Atak & Kingma, 2011)	An ethnographic case study based on quantitative research identified hazards likely to be introduced in the maintenance organization during the change and transition phase.	Reactive
(Yazgan & Yilmaz, 2018)	A mixed study identified the 67 hazards contributing to maintainers' errors.	Proactive
(Santos & Melicio, 2019)	Research grounded on an online survey identified various conditions causing fatigue and symptoms commonly manifested by the maintenance staff under fatigue and stress.	Proactive
(Signal et al., 2019)	Questionnaire-based mixed research explored the personal and work-based hazards guiding fatigue-induced errors in aircraft maintenance setup.	Proactive
(P. H. Wang & Zimmermann, 2021)	A survey-based qualitative study examined various safety threats that may be confronted by the escalated use of composite materials in aircraft manufacturing.	

(Usanmaz, 2011)	A qualitative study investigated past safety occurrences, underscored the shortcomings of the existing training framework for maintenance personnel, and proposed more organized on-the-job Training (OJT) to minimize the hazards associated with human skills.	Reactive - Proactive
(Shukri et al., 2021)	A case study based on qualitative research reveals a relatively uncommon hazard related to language.	Proactive
(Under & Gerede, 2021)	A qualitative study identified four reasons maintenance staff remain silent or do not report hazardous conditions voluntarily.	Proactive
(Ulfvengren & Corrigan, 2015)	Action-based research underscores the need for trust and seamless communication among various organizational stakeholders.	Proactive
(Gerede, 2015a)	A qualitative study focused on the challenges encountered by aircraft maintenance organizations in Turkey while implementing the SMS constructs at the activity level.	Proactive
(Hobbs et al., 2010)	SRK framework-based qualitative study indicated that the maintenance activities performed in the early morning hours are prone to errors as maintenance staff is at maximum risk of being "absent-minded."	Proactive
(Tsagkas et al., 2014)	A qualitative ethnographic study in an MRO in Greece recognized hazards driving aircraft maintenance staff to deviate from the procedures.	Reactive
(Nathanael et al., 2016)	A qualitative study enumerated numerous instances where maintenance staff decision-making was compromised on at least one parameter, e.g., cost, out-of-schedule, and airworthiness while performing a maintenance activity.	Reactive
(T.-C. Wang & Chuang, 2014)	A questionnaire-based mixed research considered 19 psychological and 20 physiological conditions related to fatigue hazards and determined four major ones affecting maintenance safety.	Proactive
(Kourousis et al., 2018)	A qualitative case study based on research emphasized the importance of the systems' human-centric design by describing several error-	Reactive

	prone situations while carrying out maintenance activities.	
(Marretta & Bedson, 2015)	A qualitative case study based on research underlined the hazards due to inconsistencies in aircraft design and maintenance instructions.	Reactive
(Ward et al., 2010)	In participatory action research, the maintenance activities were recorded using an operational process model and blocker report. Blocker reports identified the potential hazards.	Proactive
(Chen, 2021)	A questionnaire survey based on mixed research identified several factors (hazards) affecting aircraft maintenance staff's passion for their job.	Proactive
(Ma et al., 2011)	Study on applicability of the Line Operation Safety Audit (LOSA) concept to the aircraft maintenance process as maintenance LOSA (m-LOSA).	Proactive
(Langer & Braithwaite, 2016)	The application of LOSA in the maintenance study examined the presence of hazards in all the maintenance process monitoring observations.	Proactive
(Elvira et al., 2020)	The study applied the operations research tool, and 88 different types of safety occurrences in Spain were classified into five levels of severity and eight consequences.	Proactive

Subsequently, the 39 research studies were grouped based on hazard-identifying themes (unsafe acts, conditions, and objects threatening aircraft safety) and themes contributing to safety. This resulted in recognizing six distinct hazard-prone areas and two contributory concepts of safety, i.e., implementation of SMS and 'learning from past safety occurrences' (LPSO) in the aircraft maintenance industry. The hazard-prone areas are aircraft maintenance outsourcing, aircraft age, working conditions at the aircraft maintenance site, maintenance processes, organizational influences, and aircraft design deficiencies. Therefore, by combining the above themes, a comprehensive categorization of 39 studies was made, with the number of studies under each category represented in Figure 2.2.

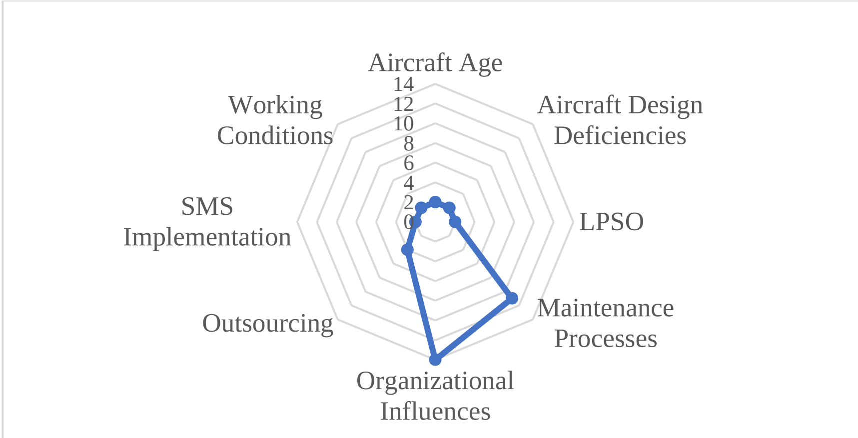

Figure. 2.2 Categorization of the included studies

The discussion on the data collection methodologies adopted in the selected studies resulted in the identification of four broad categories. Firstly, data collected through past accidents and serious incidents investigation reports is codified as MORs (Mandatory Occurrence Reports). One retrospective study used the Service Difficulty Report (SDR) data to synthesize findings; it was also categorized under the MORs code. Secondly, data collected through case studies, interviews, surveys, and questionnaires is codified as SCHO (Conventional scholarly methods of qualitative data collection). The third category is data collected through field observations at the work site, categorized as PRO MONI (Maintenance Process Monitoring). The last category is MISC (Miscellaneous), which includes data from regulatory publications, other research studies, and artifacts. The distribution of data collection methodologies against the included studies is presented in Figure 2.3.

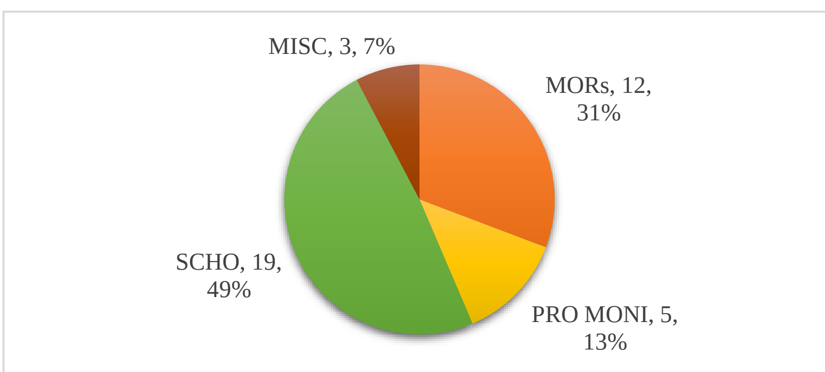

Figure. 2.3 Data collection methodologies

2.2.5 GAPS AND FUTURE RESEARCH

The review could align the findings of the selected studies with the hazard identification methodologies of the regulatory SMS framework. Also, it was established that no such literature review was conducted in the past using those criteria. Therefore, it is reasonable to presume that this review provides a fresh approach and introduces the possibilities of expansion in the existing knowledge base. The findings, along with trends and gaps in the scholarly literature exhibited in the literature review process, are listed below:

- The study identified six hazard-prone areas and two critical factors associated with the safety management of the commercial aircraft maintenance industry.
- Trend analysis illustrates that 41% of studies have identified the hazards based on the reactive methodology.
- A clear research gap is associated with the hazards identified from reactive methodology. To bridge this gap, researchers may identify the barriers to learning from past safety occurrences in an organizational setting for improved hazard identification.
- Most of the studies (64%, rounded off) were devoted to two categories of hazard-prone areas of the aircraft maintenance industry, i.e., “Organizational Influences” and “Maintenance Processes” out of eleven studies (28%, rounded off) have identified the hazards in the “Maintenance Processes.”
- Each safety occurrence attributed to maintenance shortcomings possibly indicates the need for a more rigorous mapping of hazards in the maintenance processes. Therefore, ‘Proactive (PRO MONI)’ method-based research studies could be one of the solutions. An opportunity for researchers wherein maintenance activities on an aircraft's critical systems and subsystems, such as aircraft structure, landing gears, flight controls, engines, brakes, hydraulics, and fuel systems, can be studied to identify deviations and non-compliances (hazards) and may be the standard procedure itself.

- Only two studies explored SMS implementation in aircraft maintenance organizations. Although both studies were conducted in the European region, the findings highlight challenges and problems during the SMS enactment. Thus, research gaps can be seen in the SMS implementation itself. These gaps are evident as the SMS approach is a paradigm shift compared to the conventional safety management approach. Therefore, more studies may be conducted, preferably geographic region-wise, to understand the complexities of the issues involved while implementing SMS in maintenance organizations. Similarly, the researchers engaged in aviation safety may also explore SMS implementation in the military aircraft maintenance industry.
- No study was found based on the aircraft maintenance organization's safety data (audit reports, voluntary safety reports, safety information, etc.).
- The limitation to conducting studies based on the safety data is acknowledged owing to the data sharing policies in vogue and the dilemma of the maintenance industry between the benefits of sharing safety data and the risk of losing reputation. This could be overcome by deidentifying the data source and including the academic community, which offers more domain competencies than the technical experts with maintenance organizations and regulators.

2.3 SYSTEMATIC LITERATURE REVIEW (SLR) 2

The second SLR, titled "Learning from the Past in the Commercial Air Transport Industry," was conducted following an updated version (2020) of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommended by (Page et al., 2021).

2.3.1 AIM

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" since 2000, and what is 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?

2.3.2 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 2.4), 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.

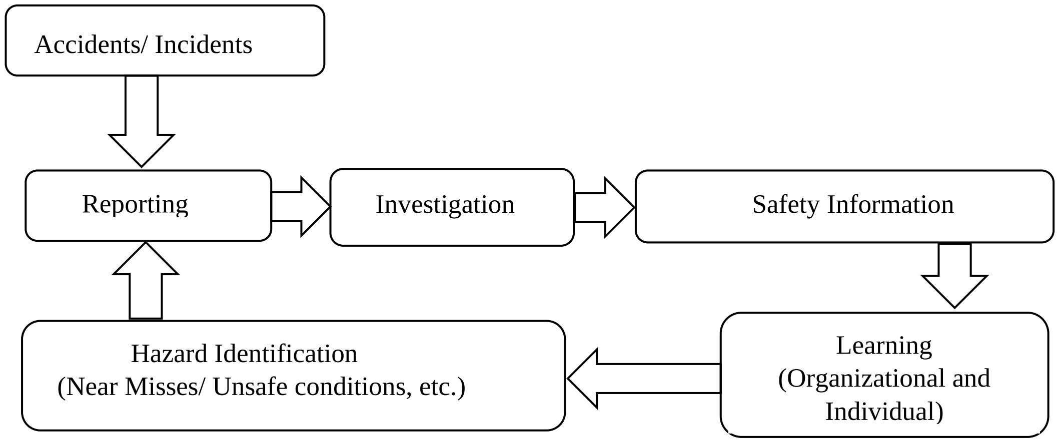

Figure 2.4 Learning from Past Framework in the Aviation Industry

Source: Scholar, based on ICAO Annex 19 (ICAO, 2016)

2.3.3 RESULTS

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 2.5) exhibits the details of the screening of the literature.

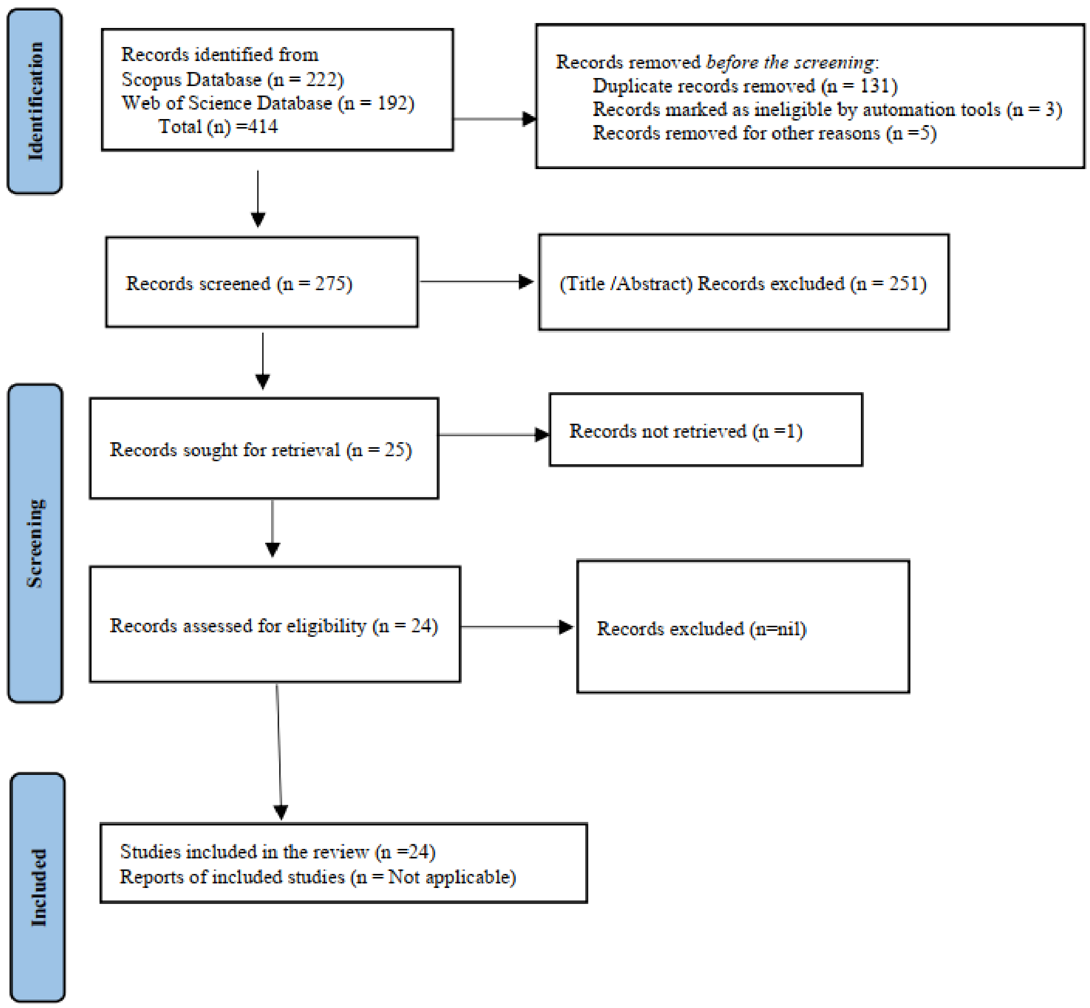

Figure. 2.5 PRISMA flow diagram SLR 2

2.3.4 STUDY CHARACTERISTICS

In this review, research articles are grouped into different stages based on their scope and leading theme; however, three studies are distinctly related to multiple stages and are therefore included in more than one group. Table 2.3 presents a stagewise summary of the included studies.

Table 2.3 Included Studies vis-à-vis Learning Stages

Stages of Learning Framework	Studies
Reporting	(Lofquist, 2010) (Madsen et al., 2016) (Lawrenson & Braithwaite, 2018) (H.-L. Wang, 2018) (Thoroman et al., 2019) (Patriarca et al., 2019) (Carrera Arce & Baumler, 2021) (Cross, 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, 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, 2015b) (Rawashdeh et al., 2021), (Kim & Rhee, 2021) (Clare & Kourousis, 2021a) (Clare & Kourousis, 2021c)

2.3.5 GAPS 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 twenty-two 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 the potential of these technological advancements.
- 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.

2.4 SUMMARY OF LITERATURE REVIEWS

The key findings and the gaps identified in both the literature reviews are summarized (Table 2.4) below.

Table 2.4 Summary of Literature Reviews

	Key Findings and Gaps
SLR 1	Identified a total of six hazard-prone areas and two critical factors associated with the safety management of the commercial aircraft maintenance industry.
	41% of studies have identified the hazards based on the reactive methodology.
	A clear research gap is associated with the hazards identified from reactive methodology. To bridge this gap, researchers may identify the barriers to learning from past safety occurrences in an organizational setting for improved hazard identification.
	Only two studies explored SMS implementation in aircraft maintenance organizations. Although both studies were conducted in the European region, the findings highlight challenges and problems during the SMS enactment. Thus, research gaps can be seen in the SMS implementation itself.
	No study was found based on the aircraft maintenance organization's safety data.
	'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.

SLR 2	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.
	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.
	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.

2.5 RESEARCH PROBLEM AND RESEARCH QUESTIONS

2.5.1 RESEARCH PROBLEM FORMULATION

The research problem is defined following the four broad guidelines of (Kothari, 2004), which include a generic statement related to the problem, understanding the problem context, a comprehensive literature review centered on the generic problem statement, and finally, the research problem statement.

Problem formulation starts with an ambiguous and general problem statement, i.e., "Different stakeholders (service providers) of the aviation industry are failing to learn the lessons from the past as manifested in the recurrence of aircraft accidents and incidents.” This general problem statement is based on the study of (Drupsteen et al., 2013) on various industries, including construction, chemical, energy, and transportation, which illustrates occurrences of numerous accidents attributed to the organizational failure to learn lessons from the past. Besides this, the cited mishaps in para 1.7 above and the global ASN database substantiate the general problem statement.

The second aspect is related to understanding the nature and the context of the problem, as described in para 1.3.1. Safety is paramount in commercial aviation transportation (Thomas et al., 2020). Although, based on the current accident rate (2.05 accidents per million departures), CAT is considered one of the safest means of transportation, it is essential to realize that the perception of the general public and passengers towards commercial air transportation safety is based on the number of accidents and not on the accident rate (Gerede, 2015a) and (Martins, 2016) and each accident is to be avoided. Another aspect is related to the growth of the aviation industry, particularly in India and the Asia Pacific region (Airbus, 2022) (Boeing, 2022). This growth means more airlines, increased aircraft in operations, and additional departures with more accidents and incidents in the future (even if the present rate of 2.05 accidents /million departures is maintained, Figure 1.3). On the other hand, the cascading effect of this growth is expected to translate into more aging passenger aircraft queuing up for major maintenance, modifications, and/or freighter conversion with the aircraft maintenance industry, which is also estimated to be around 115 billion US Dollars by 2028 (Porter & Precourt, 2018). This increased aircraft maintenance demand, along with the prevailing competitive business environment, possesses the potential to stress the aircraft maintenance industry and make safety vulnerable. Therefore, the safety and its perception by the general public, the growth of aviation in the Indian subcontinent, and the effect of this growth on the aircraft maintenance industry guide to further improve the drafted research problem of “Aircraft maintenance industry (a critical service provider) of the aviation industry are failing to learn the lessons from the past as manifested in the recurrence of aircraft accidents and incidents attributed to maintenance shortcomings."

The third and vital aspect of the research problem formulation is the academic literature survey to get updated on relevant theories, records, reports, and other relevant data on the subject. To achieve this, two literature surveys (Tyagi et al., 2023a) and (Tyagi et al., 2023b) were undertaken to gain insight into the scholarly work and identify gaps in formulating the research problem. The DOI links of the mentioned papers are placed in Appendix A4. Based on the above considerations, the initially drafted research problem is rephrased, and specificities of the subject are included: "Although aircraft maintenance organizations have the 'reactive safety management' regulatory framework integrated into the business processes, the recurrence of aircraft accidents and incidents continues at global and domestic (Indian) levels, thus establishing the problem in the learning from the past process and indicating the organizational inability to learn from the past."

To simplify the understanding of the research problem and induce clarity (Slife et al., 2016) highlight the importance of operational definition in the research to examine practical perspective. In the aviation sector, definitions of terms typically form part of the regulatory documents each stakeholder complies with globally. 'Reactive Safety Management' means a systematic approach to managing safety by identifying the hazards and managing associated risks based on the lessons learned from analyzing past accidents and incidents. 'Hazard' means "a condition or an object with the potential to cause or contribute to an aircraft incident or accident." In the context of this study, 'learning' is described as enhanced hazard identification and risk management capabilities of front-line maintenance staff based on the safety information drawn from past safety occurrences. Understanding the term 'past' is critical. The literature survey reveals that existing scholarly literature has viewed the term 'past' predominantly based on the occurrences of accidents and incidents. This approach potentially confines the learning from the past as aviation is one of the safest means of transportation, and accidents or even incidents are rare. Therefore, this study has widened the scope of the 'past' and includes the ‘safety information’ derived by investigating the hazards, errors, and near-misses reported by the front-line maintenance staff in day-to-day functioning. In this case, the past may be very recent, depending upon organizational agility. The frequently used terms, for instance, “accident,” “serious incident,” “incident’, “safety data,” “safety information,” “causes,” and “contributory factors” are used in the thesis as defined in ICAO Annex 13, twelfth edition (ICAO, 2020). To include the practical perspective, ICAO-defined definitions and terminology are used in this thesis unless specified. However, for convenience and to avoid repetition, the terms “maintenance staff” or “maintenance personnel” are employed for licensed aircraft maintenance engineers (AMEs), hangar floor supervisors, workshop supervisors, non-certifying staff working with AMEs, in tool and component (bonded or quarantine) stores, monitoring and updating components, engine, and aircraft performance and utilization data, etc., working in MRO sector. Similarly, “safety occurrence’ is used for ‘accident’ and/or ‘incident.’ Also, a list of acronyms and abbreviations used in the study is placed on page IV of the ‘abstract’ report.

2.5.2 RESEARCH QUESTIONS

Scholarly literature suggests several methodologies that assist in identifying and developing the research questions. (Bell et al., 2022) illustrate that gaps in the existing literature, inconsistencies between the several studies, or unresolved issues in the literature lead to research questions. The authors further suggest that societal development sometimes provides a platform to formulate research questions. In contrast, (Alvesson, 2011) proposed the concept of problematization, i.e., identifying and challenging the assumptions in the existing literature and formulating research questions based on that. Arguably, this method is meant to develop more influential and exciting theories within management studies. Another critical aspect of research question development is related to relevance to practice. (Gummesson, 2000) argues that practitioners and researchers are involved in addressing organizational management problems but emphasize practice and theory differently. Based on the bits and pieces of theories, practitioners contribute to business processes, whereas researchers contribute to theories supported by fragmented practices. Essentially, both stakeholders are involved in addressing organizational management problems in their own way. Therefore, based on gaps identified in the scholarly literature above when reviewed through the regulatory framework's prism to include the practicalities of business processes, three research questions are formulated as follows:

Research Question 1: In the current safety management framework, what is the 'learning from the past' process model for the aircraft maintenance industry?

Research Question 2: What factors impact various stages of the 'learning from the past' process in the aircraft maintenance industry?

Research Question 3: Based on the findings of the above two objectives, the third objective of the study is to develop a framework for 'reactive methodology-based hazard identification' for India's aircraft maintenance organizations.

CHAPTER 3: RESEARCH METHODOLOGY

Chapter Overview The research problem is addressed by exploring three research questions. This thesis chapter gives a detailed explanation of the methods used to study each research question. While research question one and research question two use the same techniques (para 3.2), research question three follows a simple mixed research method to achieve the overall research objective (para 3.3).

3.1 INTRODUCTION

Research methodology is a way to solve the research problem systematically and is considered a science of studying how research is done scientifically (Kothari, 2004). Research methodology has multiple dimensions, and research methods (techniques) constitute a part of the research methodology. Thus, while explaining the research methodology, it is essential to describe the research methods and also consider the logic behind the methods we use in the context of our research study, why using a particular method or technique, and why we are not using others so that research results are capable of being evaluated either by the researcher himself or by others (Kothari, 2004). This study addresses the research problem by dividing it into three research questions. While RQ 1 and RQ 2 use the same techniques (literature review research with thematic analysis), RQ 3 follows a simple mixed research method to achieve its research objectives.

3.2 RESEARCH METHOD FOR RESEARCH QUESTION 1 AND RESEARCH QUESTION 2

Knowledge production within the field of business research is accelerating at a tremendous speed while remaining fragmented and interdisciplinary at the same time. Because of this, the literature review as a research method is more relevant than ever (Snyder, 2019). In fact, an effective and well-conducted review as a research method creates a firm foundation for advancing knowledge and facilitating theory development. Both research questions are specific; therefore, a systematic literature review (SLR) method is recommended as a more suitable method (Snyder, 2019). However, semi-SLR and integrative literature review techniques are also used to achieve the objectives at the qualitative data-compiling stage (eligible studies compilation). Further, since the database was manageable enough, the contents of the eligible literature (qualitative data) were manually analyzed by applying the 'Thematic Analysis' (TA) framework (Braun & Clarke, 2006) (Castleberry & Nolen, 2018). The results obtained through the TA were interpreted and concluded in conjunction with the regulatory framework applicable to the aviation industry. The process of the TA framework followed to achieve RO1 and RO2 is described as follows:

3.2.1 COMPILING

Compiling the data into usable form is the first step to finding meaningful answers to research questions. An SLR with a suitable search strategy and inclusion/exclusion criteria is meant to identify a qualitative data set (eligible studies). The SLR is to be conducted in accordance with the updated version guidelines for the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021).

3.2.2 DISASSEMBLING

After compiling and organizing the data, it must be separated. Disassembling the data involves taking the data apart and creating meaningful groupings. This process is often done through coding. Coding involves researchers identifying similarities and differences in the data.

3.2.3 REASSEMBLING

The codes, or categories to which each concept is mapped, are then put into context with each other to create themes.(Braun & Clarke, 2006), use a house as an analogy to describe codes and themes-codes are the bricks that comprise the walls or themes.

3.2.4 INTERPRETING

This critical stage in the research process involves the researcher making analytical conclusions from the data presented as codes and then themes. In fact, interpretation by the researcher starts happening during the first three steps (compiling, disassembling, and reassembling). A regulatory framework applicable to the aviation industry is used for interpreting.

3.2.5 CONCLUDING

In the context of TA, raw data forms codes, and codes form themes and thematic maps. Identifying and defining these themes leads to interpretations. Conclusions are the response to the research questions or the purpose of the study.

3.3 RESEARCH METHODS FOR RO 3

3.3.1 MEASURING TOOL

This study views the factors that influence LPSIs based on the perspective of the front-line maintenance staff. To measure their perceptions, a qualitative data collection tool, ‘survey,’ was developed by the researchers. The survey questionnaire was drafted on the literature review outcomes, which yielded an item pool of 48 questions to reflect on seven constructs. Underpinned on the developed LPSI process model, while three constructs reflect the factors influencing the voluntary reporting stage, the other three represent the ‘safety investigation,’ ‘safety communication,’ and ‘safety audit’ stages. The last construct is an indicator of learning. The items under each construct of the survey questionnaire are adapted from previous research articles and /or regulatory publications. For instance, two studies associated with the aircraft maintenance industry (Under & Gerede, 2021) and (Jausan et al., 2017) have identified the factors that adversely influence voluntary reporting by the maintenance staff, whereas (J. T. Reason, 1997) underscores the essentials for a successful voluntary reporting system. Hence, in the questionnaire, three essential features of a successful voluntary reporting system, i.e., trust, ease of reporting, and usefulness, are defined as constructs, and the items are adapted based on (Under & Gerede, 2021) and (Jausan et al., 2017). The items of constructs ‘safety investigation,’ ‘safety communication,’ and ‘safety audit’ stages were adapted from (Littlejohn et al., 2017) and subsequently developed in the aviation context as the study was based on energy sector findings. Finally, a construct called a ‘learning indicator’ was developed to manifest the learning from the past. As mentioned earlier, the scope of this study is limited to viewing learning from the past as a continual demonstration of improved hazard identification and risk management capabilities of front-line maintenance staff based on the safety information drawn from past safety investigations. The items of this construct are based on the regulatory requirements of ICAO Annex 19 and SMM. In the validation process of the questionnaire, two academicians (one from organizational behavior and another one from a decision science background) and three aircraft maintenance experts were invited to validate the formulated item pool. Researchers designed a validation form for this purpose, and each expert's opinion was sought independently for each item. The validation form had 3 Rs (Retain, Remove, and Review) options against each item, and experts were requested to elaborate on the reason in case "Remove" is recommended. Finally, a 42-item data collection tool was developed to reflect seven constructs on a 5-point Likert-type scale for data collection, having a neutral point to eliminate the forced response. To maintain unidimensionality, all the items of a construct are either positively or negatively worded (Nemoto & Beglar, 2014). The formulated survey form was piloted with nine maintenance staff for face validation, and all 42 items were retained for subsequent data collection and quantitative analysis. Table 3.1 demonstrates the seven constructs' definitions and corresponding measurable items (42), and the survey questionnaire is placed in Appendix A3 of the thesis.

Table 3.1 Constructs and Items Definitions

Item Code	Items (Measurable Variables)	Constructs (Latent Variables)
LT1	Voluntary reporting of hazards may characterize me as a trouble-creator for management.	**Lack of Trust:** Implies measuring the trust deficit between the maintenance staff and the organizational management on various functional issues.
LT2	Voluntary reporting will adversely affect my career growth.	
LT3	If I disclose my errors, my organization has no "Waiver of Disciplinary Action" policy to protect my interest.	
LT4	The voluntary report-receiving agency is not independent of my employing and regulatory organizations.	
LT5	Management is production-centric, so I prefer to find my safe solution rather than report.	

CRP1	Voluntary reporting will invite an additional workload for me.	**Complicated Reporting Procedure:** Evaluates maintenance staff's perceptions about various difficulties encountered while voluntarily reporting unsafe acts and conditions.
CRP2	Voluntary Reporting procedure is very time-consuming.	
CRP3	Voluntary Reporting procedure is narrative.	
CRP4	I lost interest in voluntary reporting as the investigation is time-consuming.	
CRP5	I am not confident about what to report and not to report under voluntary reporting.	
UR1	I do not visualize any benefit to me for voluntary reporting.	**Lack of Usefulness of Reporting**: Infers weighing up maintenance staff's perceptions about the extent of voluntary reporting's utility.
UR2	I do not consider voluntary hazard reporting as critical safety information.	
UR3	I perceive the word 'reporting' as being against someone (colleagues/ seniors/organization).	
UR4	The voluntary reporting community is unaware of any organizational policy related to investigating voluntary reports.	
UR5	An organizational voluntary report investigating policy does not provide a clear time frame for investigating the reported issues.	
CSIN1	I consider a safety investigation aims to blame someone for the accident.	Lack of contribution in safety investigation: Measuring maintenance staff's perceptions about participating during various stages of safety
CSIN2	Investigation is time-consuming, with many legal implications, so I refrain from associating with it unless called for by the investigating team.	
CSIN3	I do not perceive the safety investigation as a means to improve safety.	
CSIN4	I avoid contributing to the investigation even if I have some relevant information because I perceive that I may be in trouble.	
CSIN5	The investigation is fault-finding rather than establishing the root causes for recurrences.	

		investigations and their outlook towards the investigation process.
SC1	I always receive contextualized safety communication in my organization. (Contextualized means related to my work practices, work environment, etc.)	Safety communication: The extent to which safety information drawn from safety investigations is organized in an organizational context for communicating to maintenance staff through emails, newsletters, safety circulars, bulletins, etc.
SC2	Written safety communication (bulletins, emails, circulars, newsletters, etc.) includes updated safety information drawn from past safety investigations of accidents/incidents in my organization.	
SC3	Written safety communication (bulletins, emails, circulars, newsletters, etc.) includes updated safety information drawn from the investigations of the voluntary reports of my organization.	
SC4	When applicable, written safety communication clearly guides me in incorporating changes in my work.	
SC5	Audiovisual safety communication (Safety training, human factor training, continuity training, etc.) includes updated safety information drawn from past safety investigations of accidents/incidents in my organization.	
SC6	Audiovisual safety communication (Safety training, human factor training, continuity training, etc.) includes updated safety information drawn from past safety investigations of the voluntary reports of my organization.	
SC7	In audiovisual safety communication, human factors are discussed in my organizational context.	
SC8	The contents of safety communication always remain in my memory; therefore, no repetition in any other form is needed.	
SC9	Safety communication provides an in-depth understanding of hazards at my workplace.	
SC10	Safety communication makes me more capable of identifying hazards in my work.	

OCSC1	All the managers, including the Accountable Manager, invariably attend the safety training.	Organizational Commitment: Measuring the extent of allocation of resources in terms of time, technology, and training aids for learning for HIRM By the organization.
OCSC2	My employing organization evaluates my learning in safety training.	
OCSC3	The regulatory agency evaluates my learning in safety training.	
OCSC4	The regulatory agency regularly evaluates the contents of safety training.	
OCSC5	Safety training is conducted creatively to enhance the interest of participants.	
OCSC6	If additional training is needed to incorporate changes in my work, the management promptly provides it.	
OCSC7	In safety training, the latest technological tools are applied to facilitate learning.	
LID1	I perceive learning when my awareness of the hazards at my workplace is consistently updated.	Learning Indicators: Perception of frontline maintenance staff when they perceive the learning from past investigations for HIRM.
LID2	I perceive the learning when my learning outcomes are evaluated each time I attend safety training.	
LID3	I perceive learning when safety information is integrated with my maintenance work procedures.	
LID4	I perceive the learning when safety information is consistently repeated in safety training.	
LID5	I perceive learning when I start applying it (safety communication content) at work.	

3.3.2 SAMPLE SIZE

PLS-SEM is characterized by obtaining solutions with small sample sizes of the models with multiple constructs and items (Hair et al., 2019). Contrary to this, (Sarstedt et al., 2018) suggest the possibility of questionable results if fundamental sampling theory guidelines are not complied with. An extensively used “10-times rule” suggests ten times the maximum number of arrows pointing to a particular latent variable to ascertain the minimum sample size in PLS-SEM (Kock & Hadaya, 2018). Although this sample size estimation is simple and userfriendly, it has been attributed to inaccurate estimation in the past (Goodhue et al., 2012). The "inverse root square method" for minimum sample size estimation is reasonably accurate and straightforward (Kock & Hadaya, 2018). Specific to this study, while the "10-time rule" suggests a minimum sample size of 50, as the latent variable 'safety communication' has five arrows pointing towards it, the maximum in the structure model. The "inverse root square" method with a minimum path coefficient between 0.11-0.20 at a 5% significance level and a power of 80% recommends a minimum sample size of 155 (Hair et al., 2021). A-priori online calculator with a medium (0.3) anticipated effect size, 0.8 statistical power level, and p-value of 0.05 suggests the minimum sample size of 170 to detect the effect and 200 for model structure (Soper, 2023). Therefore, it is reasonable to summarize that the minimum sample size of 200 is sufficient to achieve the study's objectives. The study was conducted with a valid sample size of 287.

3.3.3 DATA COLLECTION

To achieve the study's objectives, the target population is maintenance staff (defined in the introduction section) who have recently retired and/or are working in the Indian aircraft maintenance industry. A mix of purposive and snowball sampling was used for data collection. While the purposive sampling approach guides toward the object of the study and provides essential views of the participants (Campbell et al., 2020), the snowball sampling approach relies on networking and referrals for data collection (Parker et al., 2019). Mixing both sampling approaches will likely induce relevancy and efficiency in the data collection. The data was collected through a survey questionnaire. The first author was a delegate at an International Conference on Emerging Trends in Aviation MRO Industry [EAMRO 2023] organized on 22 April 2023 at the Indian Aviation Academy, India. Experienced maintenance staff from Indian MROs participated in the event. Following the networking and referrals approach, this opportunity was utilized for data collection, and eventually, 311 responses were received against the distribution of four hundred survey forms.

3.3.4 DATA ANALYSIS

This research objective is achieved by using partial least square–structural equation modeling (PLS-SEM) using the Smart-PLS version 4 software. PLS-SEM is a class of multivariate analysis techniques that includes factor analysis and regression, which enables the researchers to simultaneously evaluate the relationship between measurable (items) and unmeasurable variables (constructs) and between the constructs (Hair Jr et al., 2021). This method develops more accurate estimates and avoids the indeterminacy problem as its algorithm calculates the construct score as a precise linear combination of the observed variables. Additionally, analyzed results of measurement and structure models are reported following (Hair et al., 2019) recommendations.

CHAPTER 4: RO1, RO2, CONCEPTUAL MODEL AND HYPOTHESES

Chapter Overview This thesis chapter, para 4.3 and para 4.4, describes the operationalization of the research methods explained for research questions one and two in the previous Chapter 3. Subsequently, in para 4.5, a conceptual model is developed based on the outcome of RQ1 and RQ2, and in para 4.6, six hypotheses are stated for further testing.

4.1 INTRODUCTION

An effective and well-conducted review as a research method creates a firm foundation for advancing knowledge and facilitating theory development" (Webster & Watson, 2002). Two systematic literature reviews of (Tyagi et al., 2023c), (Tyagi et al., 2023b), are the bases for distinguishing the research articles, whereas updated regulatory publications of ICAO are referred to for regulations. This chapter examines aviation regulations that apply to the aircraft maintenance industry and scholarly research articles on learning from past concepts to achieve RO1 and RO2.

Learning from the past is not a novel concept. Researchers have explored this subject under the different names of "learning from incidents (LFI)," "learning from accidents and disasters," and "learning from experience or experience feedback" etc. (Balasubramanian & Louvar, 2002) (Haunschild & Sullivan, 2002)) (Lindberg et al., 2010) (Jacobsson et al., 2011) (Akselsson et al., 2012) (Drupsteen et al., 2013) (Drupsteen & Hasle, 2014) (Drupsteen & Guldenmund, 2014) (Silva et al., 2017) (Littlejohn et al., 2017) (Margaryan et al., 2018) (Clare & Kourousis, 2021b) (Clare & Kourousis, 2021f). The abovementioned studies have predominantly viewed the 'past' based on the occurrences of accidents and incidents; this approach may have the possibility to confine learning from the past as aviation is one of the safest means of transportation, and accidents or even incidents are rare. This concept's more significant operational dimension has surfaced in light of the current safety management regulatory framework, which underscores drawing safety data and information from day-to-day maintenance activities rather than relying only on rarely occurring events (ICAO, 2020). In the aircraft maintenance industry, while reporting accidents, serious incidents, and incidents falls under the mandatory occurrence reporting (MOR) category, the hazards and near misses that frontline maintenance staff observe in day-to-day work are reported under voluntary reporting (VR). *Contrary to the previously used term 'Learning from Incidents' (LFI), this study uses the term 'LPSIs' (Learning from Past Safety Investigations) for two main reasons*. Firstly, 'safety investigation' applies to both the rare accidents (reported under MOR) and the near misses or hazardous conditions observed during the daily maintenance activities (reported under VR). Both reporting, when investigated, generate safety data and information that can potentially prevent recurrences of accidents and enhance overall safety standards. Secondly, besides the informal and unrecorded experience sharing amongst the maintenance personnel, the 'safety information' drawn from these investigation reports is the solitary organizational learning repository.

4.2 REGULATORY FRAMEWORK AND LPSI

Hazard Identification and Risk Management (HIRM) is the cornerstone of the current SMS, wherein hazards are typically identified based on two methodologies, i.e., reactive and proactive (ICAO, 2018b). Safety information drawn from the safety investigation reports of accidents and incidents can avert the recurrences if appropriately utilized at individual and organizational levels. In contrast, voluntary reporting is directly from the front-line maintenance staff they encounter while performing aircraft maintenance activities on a day-to-day basis. When investigated, this anonymous or confidential reporting system provides safety information about the organization's latent unsafe conditions or acts without legal and administrative obligations (ICAO, 2018b) (Under & Gerede, 2021). If effectively and efficiently exercised, a voluntary reporting mechanism offers learning opportunities to maintenance staff and aircraft maintenance organizations without suffering severe consequences. In the regulatory framework, although voluntary reporting is considered a proactive hazard identification method, the safety information drawn from this methodology provides enhanced hazard identification capabilities for safety management, as today's reported hazard is a piece of safety information for tomorrow's safe work.

4.3 RESEARCH OBJECTIVE 1

To establish a formally structured 'reactive methodology-based hazard identification' process model for the aircraft maintenance industry, which complies with the current regulatory safety framework.

4.3.1 LITERATURE REVIEW RESEARCH METHOD

A SLR was conducted in compliance with PRISMA's updated protocol with the objective of identifying studies related to "learning from the past" in the SMS framework. The search strategy and inclusion/exclusion criteria followed to reach the set of eligible studies are as follows:

4.3.1.1 Search Strategy The combination of keywords and Boolean operators used to search publications (Table 4.1).

Table 4.1 Data 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]

4.3.1.2 Inclusion/exclusion criteria The inclusion/exclusion criteria to identify eligible studies are given in Table 4.2 below.

Table 4.2 Inclusion/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.

4.3.2 FRAMEWORK OF THEMATIC ANALYSIS (TA)

Five steps: compiling, disassembling, reassembling, interpreting, and concluding the TA (Braun & Clarke, 2006) (Castleberry & Nolen, 2018), are briefly summarized below :

4.3.2.1 Compiling A total of 24 studies conformed to the eligibility criteria, and the 'Abstract' of each study was subsequently organized as qualitative data for TA.

4.3.2.2 Disassembly After compiling and organizing the data, it was separated to form meaningful groups aligned with the RO. Table 4.3 displays a group of studies under the different codes related to RO.

Table 4.3 Coding of Qualitative Data

Codes	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, 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, 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 study (Clare & Kourousis, 2021a) was further explored as this study conducted a TA of literature with 'learning from incidents' as one of the themes, as shown in Table 4.4. A total of nine studies were identified on the 'learning from incidents' theme conducted in varied industrial settings and carried forward to the next stage of TA.

Table 4.4 Studies with 'learning from incidents' theme

	Precursors 3	Just culture 4	Root cause 3	Reporting 9	Learning from incidents 10
Atak and Kingma [33]				X	
Drupsteen and Hasle [34]		X			X
Drupsteen and Wybo [35]	X				X
Drupsteen et al. [36]					X
Furniss et al. [37]					X
Gartmeier et al. [38]				X	
Gerede [39]		X			X
Gray and Williams [40]				X	
Bjerg Hall-Andersen and Broberg [41]				X	
Hobbs and Williamson [42]	X		X	X	
Jacobsson et al. [43]			X		X
Lukic [2]					X
Pickthall [44]			X	X	
Silva et al. [45]		X			X
Steiner [46]				X	
Storseth and Tinmannsvik [47]				X	
Ward et al. [48]	X	X			X
Zwetsloot et al. [49]				X	

4.3.2.3 Reassembling

Studies mentioned in Tables 4.3 and 4.4 were combined to achieve the RO. The ‘reactive methodology-based hazard identification’ process model essentially reflects different semantically related activities (stages) that are aggregated together to demonstrate the coarse-grained functioning of the business processes of the aircraft maintenance industry. A model of accident investigation and prevention was developed by (Lindberg & Ove Hansson, 2006), also known as the CHAIN model or model of experience feedback. It consisted of five stages: reporting, selection, investigation, dissemination, and prevention, with all the stages contributing to the learning process to varying degrees. Another learning from the past model consisting of eleven steps under four stages was presented by (Drupsteen et al., 2013). The first stage included safety occurrence reporting and analysis; the second stage focused on formulating a practical action plan based on the analyzed results; the third was related to resource allocation for the action plan; the last stage evaluated the learning. This model can also be compared with the (Deming, 2018) Plan-Do-Study-Act (PDSA) cycle, which describes learning as an iterative process in which results are studied, and causes of failure are investigated to formulate revised plans for action. A six-stage LFI process model was developed based on the energy sector studies (Littlejohn et al., 2017). All the mentioned models are predominantly in unison and create an envelope for learning with the starting point ‘reporting’ or, in other words, the origin of learning contents. The stages/activities of all three models can be viewed at a glance in Figure 4.1

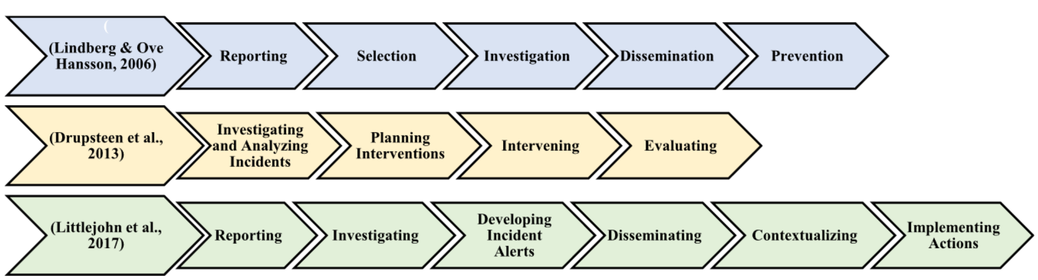

Figure 4.1 Learning from Incidents Process Models

4.3.2.4 Interpretation and Conclusion

There is no process model based on aircraft maintenance industry studies per se; therefore, to achieve the study's objective and underscore the difference in activities of the aircraft maintenance industry, the scholar has formulated the LPSI process model (Figure 4.2) based on the models described in the previous paragraph and the regulatory framework (ICAO, 2018b). The critical differences are in the 'reporting' and 'investigation' stages. Aircraft accidents, serious incidents, and incidents are compulsory to report (rather too big to hide, hence reported) and follow mandatory occurrence reporting (MOR) procedures. The state is responsible for investigating such reports by following the SSP based on the SARPs of ICAO Annex 13. In contrast, the frontline maintenance staff and other stakeholders are expected to voluntarily report hazards, unsafe conditions, unsafe acts, errors, and near misses. Voluntary reporting is investigated in-house by the concerned organization. Both safety investigations aim to generate safety information for dissemination to the relevant stakeholders at the 'safety communication' stage. Finally, the effectiveness of LPSI in an organization is evaluated at the ' Safety audit' stage by the organization itself and the regulatory agency. All the stages of the process model have the potential to offer learning value to the stakeholders; however, 'safety communication' is the formal learning zone for the maintenance staff and the organization in which safety data extracted from investigations are contextualized into safety information and is communicated in written (emails, safety circulars, bulletins, newsletters, etc.) and audiovisual (safety training, human factor training, continuity training, safety meetings, etc.) mode to organizational entities.

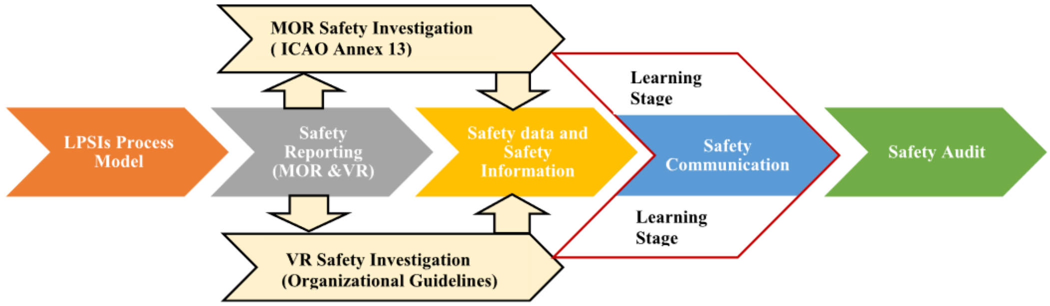

Figure 4.2 LPSI Process Model for Aircraft Maintenance Industry

(Developed by the scholar based on literature review and the regulatory framework).

4.3.2.5 SME Validation The process model shown in Figure 4.2 above and the description of stages were forwarded to three SMEs to ascertain the accuracy and compliance with the regulatory framework. All the three SMEs unanimously validated the process model.

4.4 RESEARCH OBJECTIVE 2

To stage-wise identify the influencing factors to the 'reactive methodology-based hazard identification' process for the aircraft maintenance industry.

4.4.1 Framework of Thematic Analysis (TA)

The outcomes of research objective 1 form the foundation for RO2. RO1 provides a formally structured 'learning from the past' process model, wherein different semantically related activities (stages) are aggregated to demonstrate the coarse-grained functioning of the aircraft maintenance industry's business processes. While exploring the process model further, RO2 is focused on each stage of the model and aims to evaluate stage-wise influencing factors. The data set (research articles) used to achieve the first research objective is taken as the baseline for RO2, and the 'main text body' of each study is subsequently organized as qualitative data for TA. Additionally, the legendary work (J. T. Reason, 1997) was also referred to in order to achieve the objective along with the regulatory publications. After compiling and organizing the data, the subsequent steps are explained as follows to achieve the RO2:

4.4.1.1 Factors Influencing 'Reporting' Stage

'Barriers' are the factors that impede learning in one or more learning stages/activities (Drupsteen & Hasle, 2014). All four stages of the model (Drupsteen et al., 2013) were identified with barriers that adversely affected the learning process. Another analogous study conducted focus group discussions with seven companies (four chemicals, one manufacturing and service provider to chemical plants, and a construction company) and identified the causes and conditions that impede learning from the past (Drupsteen & Hasle, 2014). The study used the same model (Drupsteen et al., 2013) and underscored the reluctance of the employees to report safety occurrences. Since the ongoing research is specific to the aircraft maintenance industry, which complies with ICAO Annex 13 regulations, safety occurrences reporting is essentially streamlined. In the case of accidents and incidents (MORs), the 'reporting' stage is not assessed as a barrier. Also, no scholarly literature substantiated the bottlenecks in safety reporting for accidents and incidents, or maybe owing to widespread media coverage and other social implications; these safety occurrences are impossible to conceal for organizations/individuals, hence reported. Nevertheless, reporting hazards, latent conditions, near misses, and events of low safety consequences dependent on the individual maintenance staff (Voluntary Reporting) remains a concern in the aviation sector. Voluntary reporting is critical for safety management, and (Reason, 1997) illustrates that minor incidents and near misses, not with severe consequences, are not reported. In aviation organizations consisting of typically all operational streams such as flying, air traffic controls, and maintenance, the barriers impacting the effectiveness of the ' voluntary reporting' channel were classified as 'organizational barriers, 'work environment barriers,' and 'individual barriers' (Jausan et al., 2017). Although the study identified the reporting system barriers based on a military aviation organization survey, most attributes are also consistent with commercial aviation. The motives for aircraft maintenance staff to remain silent and not report unsafe conditions and acts observed at work were investigated and categorized under four broad categories: prosocial, disengagement, fear, quiescence, and acquiescence (Under & Gerede, 2021). (J. T. Reason, 1997) highlighted the two most successful voluntary reporting programs, i.e., the Aviation Safety Reporting System (ASRS) and British Airways Safety Information System (BASIS). The identified three essentials for a thriving voluntary reporting culture are the trust between the reporters and management, the ease of reporting experienced by the reporters, and the usefulness of reporting as perceived by the reporters (J. T. Reason, 1997). Based on the abovementioned literature review, obtaining both facets, i.e., the barriers and facilitating factors of 'safety reporting' (voluntary reporting), was possible. Therefore, given the SMS framework's intent of an all-inclusive participatory ecosystem in the organization, this study views the 'voluntary reporting' system primarily as an organizational management function and explores the perception of maintenance staff towards it.

4.4.1.2 Factors Influencing 'Safety Investigation' Stage

The next stage after 'safety reporting' is 'safety investigation.' On 'safety reporting,' the investigation route is bifurcated into two streams based on the reporting category, whether MOR or VR (Figure: 4.2). Both streams generate critical 'safety data' and 'safety information' for an individual (maintenance staff) and the organization. In the case of MORs, numerous accident investigation methods are described in the scholarly literature; however, an aviation safety occurrence reported under the MOR category is investigated following ICAO Annex 13 and the associated safety manual (document 9756 part I to IV). To understand the vulnerability of these regulatory guidelines, the first edition of Annex 13 was adopted on 11 Apr 1951 and regularly amended and revised after that; probably one of the reasons behind these revisions was continued learning. On the analysis of this base document, it was observed that the Accident/Incident Data Reporting System (ADREP) was introduced in the ninth edition of Annex 13 in Feb 2001; the revised provision of 'causes' and 'contributory factors' included in tenth edition in Feb 2010 and so on. Currently, ICAO Annex 13, the twelfth edition (eighteen amendments), is the document that provides SARPs for investigating aircraft accidents and incidents. The purpose of mentioning the developmental background of this regulatory document is to underscore the inadequacy of 'safety data' and 'safety information' generated from past investigations. Based on the past investigation report analysis, it was observed that 'investigation' is an area that lacks objectivity and focus (Clare & Kourousis, 2021e), and the regulatory framework does not include the guidelines and quality standards norms of safety recommendations (Karanikas et al., 2019). The example of the Indian scheduled operator quoted in the 'Introduction' section can also be viewed with this reflection. However, the shortcomings of past investigations are beyond the scope of this study, although they are credible barriers to comprehensive learning from the past. This study takes safety data and information produced by past investigations as potential learning content. Since maintenance staff is the core of this study, for this stage, the scope of the study includes the contribution of maintenance staff in safety investigations and the outcomes they perceive from it. ICAO document 9756-part III (ICAO, 2011) deals with investigating a safety occurrence and provides guidelines to ascertain maintenance errors on different counts, such as human factors, skill, knowledge, equipment, etc. An honest and proactive contribution of the maintenance staff in the investigation process perhaps generates more credible safety information about the hazardous latent conditions in the organization. Thus, this study evaluates the contribution of maintenance staff to investigating processes to ascertain the causal and contributory factors of safety occurrences. This aspect will likely provide insight into maintenance staff's perception of the Reason's 'blame cycle' and the regulatory intent of 'investigation is to prevent a recurrence.'

In the case of investigation of the VRs, management's intent and actions on VR determine the quality and quantity of content for LPSI (Jacobsson et al., 2011). The generation of safety information through the investigation of voluntary reports is hindered as maintenance staff does not actively participate in voluntary reporting of unsafe conditions and acts because of several factors, including organizational culture, feedback, and trust in management (Under & Gerede, 2021). In other words, if VRs are not appropriately investigated, this eventually becomes the barrier to ‘safety reporting’ (included under the barriers to voluntary reporting) and, in turn, to LPSI.

4.4.1.3 Factors Influencing ‘Safety Communication’ Stage

In pursuit of identifying the other barriers to the LPSI process model, scholarly literature suggested that the investigation reports are generally voluminous, and technicalities, including the expression of contents and the taxonomy used, are unavailable in a sufficiently accessible format (Lindberg et al., 2010). This underscores the need to analyze and formulate the extracted ‘safety data’ and ‘safety information’ from the ‘safety investigations’ in the organizational context wherein maintenance staff comprehends the objective aspects of what happened and why the accident/ incident occurred (Statler & Maluf, 2003). Conceptually, this contextualized safety information indicates hazards in the working system that either have caused/contributed to past events (applicable for MOR) or have the potential to cause/contribute to future events (relevant to VR) (ICAO, 2018b). This is the essence of learning for HIRM and is closely associated with the organization’s communication strategies and the ‘safety communication’ stage of the LPSI process. ‘ Safety communication’ is a formally structured process, and in the aircraft maintenance industry, safety information drawn from safety investigations is communicated to stakeholders in written form through emails, newsletters, safety circulars, bulletins, etc., and audiovisual modes of safety training, human factor training, continuity training, safety meetings, etc., wherein each method of communication have barriers as argued by (Statler & Maluf, 2003), (Drupsteen et al., 2013),(ICAO, 2018b), (Clare & Kourousis, 2021b) and (Clare & Kourousis, 2021d).

4.4.1.4 Factors Influencing the ‘Safety Audit’ Stage

‘Safety audit’ in the aircraft maintenance industry can be viewed with two connotations: the internal audit, usually conducted by the organization itself (in some cases, may be outsourced to a third party), and the external audit conducted by the regulatory agency. A safety audit (internal or external) aims to verify compliance with the regulations and conformance with the procedures and good safety aviation practices (ICAO, 2006). However, safety oversight is restricted to only the delivery of training programs rather than verifying their effectiveness during the 'safety audit' stage (Clare & Kourousis, 2021f). Organizations focus more on remedial measures recommended in safety investigations rather than preventing recurrence or remedying quality (Drupsteen et al., 2013). The financial implication to the organization is seen as a significant factor when planning safety communication, such as training need analysis, continuity training programs, and human factor training (Clare & Kourousis, 2021b). In the competitive business environment, aircraft maintenance organizations are inclined to demonstrate minimum compliance rather than only consider it a baseline.

Finally, to ascertain the effectiveness of the learning of the maintenance staff, "A model for levels of learning from incidents" (Jacobsson et al., 2011) was taken as a reference along with the regulatory publication (ICAO, 2018b). The factors that influence various stages of the LPSI process model are summarized in Table 4.5. It can be assimilated that although the stages are named independently, they are interlinked, and the performance of one stage affects the other stages.

Table 4.5 Influencing factors to various stages of the LPSI process model

Stages	**Influencing Factors**	**Research and Regulatory publications**
Mandatory Occurrence Reporting	Nil	In aviation, accidents and serious incidents are invariably reported. Researchers have not found any study underscoring the barriers to mandatory occurrence reporting. As such, these occurrences are too big to conceal or go unreported.
Voluntary Reporting	Lack of Trust: Trust between the frontline maintenance staff and the management of aircraft maintenance facilities.	(J. T. Reason, 1997),(Jausan et al.,

	Complicated reporting procedure: The extent to which the frontline maintenance staff finds voluntary reporting difficult.	2017), and (Under & Gerede, 2021).
	Lack of Utility of Reporting: The degree of benefit (in terms of prompt action by management, recognition, organizational policy, etc.) perceived by the frontline maintenance staff for voluntary reporting.	
Safety Investigations	Lack of contribution: The extent to which frontline maintenance staff participates in a safety investigation.	(J. T. Reason, 1997) and (ICAO, 2011).
Safety Communication	Safety Communication: The extent to which safety information drawn from past safety investigations is organized in an organizational context for communicating to maintenance staff through emails, newsletters, safety circulars, bulletins, etc., and safety training, human factor training, continuity training, safety meetings, etc.	(Statler & Maluf, 2003), (Drupsteen et al., 2013), (ICAO, 2018b), (Clare & Kourousis, 2021b) and (Clare & Kourousis, 2021d)
Safety Audit	Organizational Commitment to Safety Communication: The extent to which resources regarding time, technology, and money are allocated to safety communication.	(Clare & Kourousis, 2021d) and (Clare & Kourousis, 2021f)
Learning	Indicators to LPSIs.	(Jacobsson et al., 2011) and (ICAO, 2018b)

4.5 CONCEPTUAL MODEL

The two primary outcomes of the preceding paragraphs of this chapter are, firstly, the LPSI model specific to the aircraft industry (Figure: 4.2) underpinned by the models of (Lindberg & Ove Hansson, 2006) (Drupsteen et al., 2013) (Littlejohn et al., 2017) and the regulatory framework (ICAO, 2018b) and secondly, the identification of the factors affecting LPSI based on Table 4.5. Combining the two, a conceptual model depicting the effect of variables on safety communication and, eventually, on learning from the past is developed by the scholar (Figure 4.3).

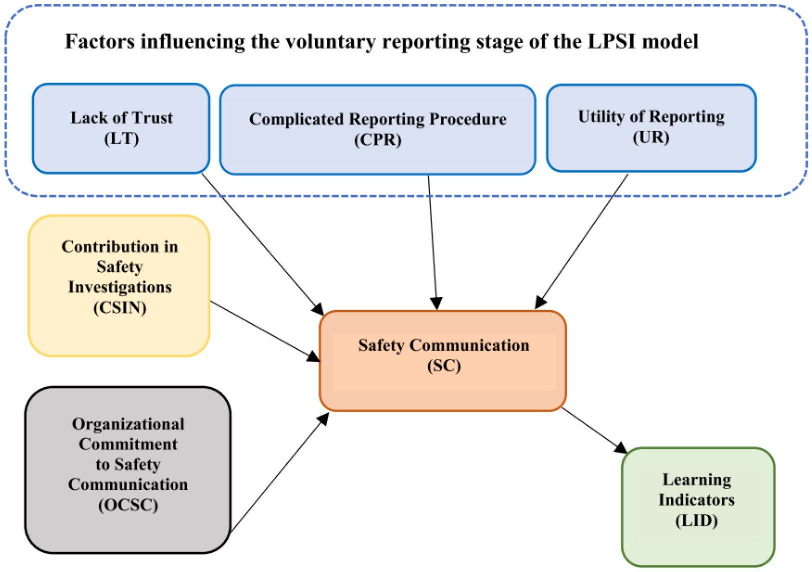

Figure 4.3 The conceptual model to assess the effect of factors on LPSI.

4.6 HYPOTHESES

Based on the above literature review and the conceptual model, the following hypotheses are formulated:

H1: In the voluntary reporting stage, a 'lack of trust' between the maintenance staff and management is negatively related to the safety communication stage of the LPSI process model.

H2: In the voluntary reporting stage, the 'complicated voluntary reporting procedure' is negatively related to the safety communication stage of the LPSI process model.

H3: In the voluntary reporting stage, the perception of the 'lack of usefulness of voluntary reporting' in maintenance staff is negatively related to the safety communication stage of the LPSI process model.

H4: The maintenance staff's 'Lack of contribution' in the safety investigations is negatively related to the safety communication stage of the LPSI process model.

H5: The safety communication stage of the LPSI process model is positively related to learning from past safety investigations.

H6: Organizational commitment is positively related to the safety communication stage of the LPSI process model.

CHAPTER 5: RESEARCH OBJECTIVE 3

Overview: This chapter describes the data analysis and results derived to achieve the third research objective. This research objective is achieved by using partial least square–structural equation modeling (PLS-SEM) using the Smart-PLS version 4 software. Various sections and subsections of this chapter illustrate the analysis of the demographic profiles of the respondents, descriptive statistical analysis, analysis of measurement, and structure models (para 5.2 and its sub-paras).

5.1 INTRODUCTION

This chapter discusses the framework for ‘reactive methodology-based hazard identification’ for Indian aircraft maintenance organizations. This chapter explains the impact of each factor on the stages of the ‘learning from the past’ process model on ‘learning.’ The objective is achieved with the help of the PLS-SEM methodology. PLS-SEM is a class of multivariate analysis techniques that includes factor analysis and regression, which enables the researchers to simultaneously evaluate the relationship between measurable (items) and unmeasurable variables (constructs) and between the constructs (Hair Jr et al., 2021). This method develops more accurate estimates and avoids the indeterminacy problem as its algorithm calculates the construct score as a precise linear combination of the observed variables. The chapter explains the results of different assumption testing, namely reliability analysis, validity analysis, item multicollinearity, common method bias, and descriptive analysis. PLS-SEM is done with the help of Smart-PLS version 4 software.

5.2 DATA ANALYSIS AND RESULTS

5.2.1 DEMOGRAPHIC PROFILE

In the survey form, the licensed AMEs are classified into two broad categories, category A1 and category (B1, B2, and/or C), primarily to differentiate the maintenance expertise of the maintenance staff directly working in aircraft line maintenance, hangar floor, component workshops, and engine shops. Non-licensed maintenance staff, personnel working in tool stores, spare warehouses, and/or having limited maintenance approvals are placed under the 'others' category. Further, only those forms were included in the study wherein the respondent has completed formal SMS training organized by the employing organization or with the regulatory agency-approved establishment. This filtering criterion aims to include responses aligned with the current regulatory framework, resulting in 287 valid participants out of 311 received responses. The demographic and professional details of the valid respondents are depicted in Table 5.1.

Table:5.1 Demographic and Professional Profile of the Respondents

Age	**n**	**Academic Qualifications**	**n**
Less than 30 years	58	High School	22
30 to 40 years	97	Intermediate (10+2)	46
41 to 50 Years	85	Bachelor's	176
More than 50 years	47	Postgraduate and above	43
Gender		**Aircraft Maintenance Experience**	
Male	278	Ten years or less	56
Female	09	11 to 20 years	105
Others	00	21 to 30 years	97
		More than 30 years	29
License Details			
Category A1	76		
Category (B1, B2, and/or C)	113		
Others	98		

5.2.2 DESCRIPTIVE ANALYSIS

The study uses descriptive analysis to estimate the mean score, standard deviation, skewness, and kurtosis of the collected responses. The mean score indicates the level of agreement of the maintenance staff who participated in the survey. The standard deviation indicates the level of dispersion in the responses, whereas the skewness and kurtosis indicate the distribution of the responses.

5.2.2.1 Construct: Lack of Trust

Lack of trust indicates the trust deficit between the maintenance staff and the organizational management on various functional issues. It includes several aspects related to the construct, for instance, the existence and implementation of the ‘waiver of the disciplinary action policy’ in the business processes, the outlook of the management towards voluntarily reporting the mistakes/ shortcomings by the maintenance staff, and the perception of maintenance staff whether management is production-centric or safety-centric or striving to balance the two. The lack of trust is measured with the help of five statements included in the measurement model. The result of descriptive analysis of the responses received from the maintenance staff is reported below:

Table 5.2 Descriptive Analysis: Lack of Trust

Name	Mean	SD	Kurtosis	Skewness
LT1: Trouble-creator for management.	3.613	1.026	-0.427	0.558
LT2: Adverse effect on career growth.	3.627	1.048	-0.608	0.427
LT3: No “Waiver of Disciplinary Action” policy	3.686	1.049	-0.428	0.528
LT4: Report receiving agency is not independent	3.645	1.001	-0.347	0.529
LT5: Management is production-centric	3.648	1.011	-0.435	0.547

The result of the descriptive analysis indicates the presence of high agreement among the maintenance staff for the statements representing a lack of trust. The maintenance staff agreed on the Lack of a “Waiver of Disciplinary Action” policy in the organization if the staff discloses their errors (mean =3.686). The results also found that the management is production-centric, leading the staff to prefer a safe solution (according to themselves) rather than reporting the error (mean =3.648). The maintenance staff also agreed that the voluntary report-receiving agency is not independent of their employment and regulatory organizations (mean =3.645). The staff also perceived that voluntary reporting would have an adverse effect on their career growth (mean = 3.627), and voluntary reporting of hazards may characterize them as a trouble-creator for management. (mean = 3.613). The standard deviation of the responses indicates the presence of dispersion in the responses. The skewness and kurtosis of the responses are found to be less than 1, indicating the presence of normal distribution in the responses. The mean score of the different statements measuring lack of trust is shown below:

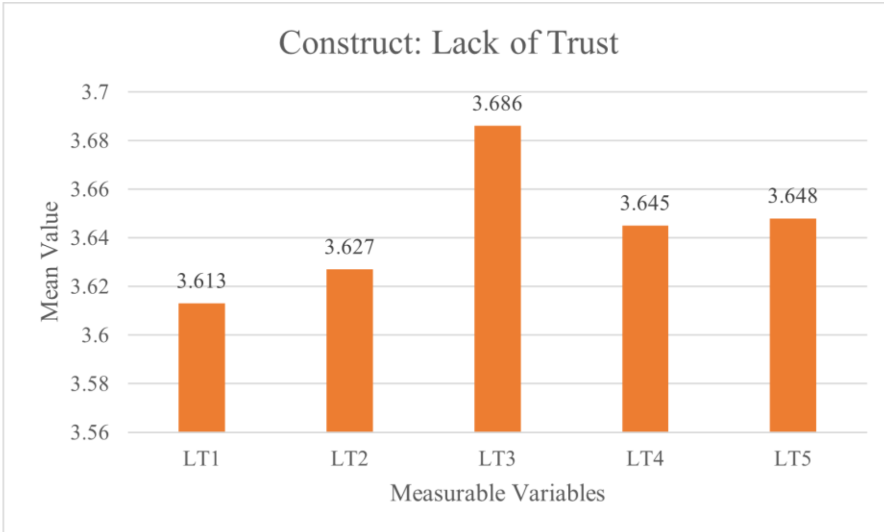

Figure 5.1 Descriptive Analysis: Lack of Trust

5.2.2.2 Construct: Complicated Reporting Procedure

This latent variable, "Complicated Reporting Procedure," intends to evaluate maintenance staff's perceptions about various difficulties encountered while voluntarily reporting unsafe acts and conditions. It incorporates several procedural aspects, such as the time consumed in reporting, the follow-up by management, and the awareness of the importance of the reporting itself. In the 'measurement model,' this construct is measured with the help of five items. The result of descriptive analysis of the responses received from the maintenance staff is reported below:

Table 5.3 Descriptive Analysis: Complicated Reporting Procedure

Name	Mean	Standard deviation	Kurtosis	Skewness
CRP1: Additional workload	3.78	1.257	-0.938	0.283
CRP2: Reporting is Time-consuming	3.948	1.154	-0.747	0.239
CRP3: Narrative format of reporting	3.861	1.202	-0.89	0.174
CRP4: Investigation is time-consuming	3.958	1.132	-0.675	0.082
CRP5: Lack of clarity on reporting	3.882	1.221	-0.889	0.193

The result of the descriptive analysis indicates the existence of a high level of agreement among the maintenance staff for the items representing a 'complicated reporting procedure.' The items CRP 2, which represents the excessive time consumption in the voluntary reporting, and CRP 4, the disproportionately lengthy investigating period, have the maximum mean values at 3.948 and 3.958, respectively, highly agreed to by the maintenance staff. The standard deviation of the responses indicates the presence of dispersion in the responses. The skewness and kurtosis of the responses are less than 1, indicating the presence of normal distribution in the responses. The mean score of the different statements measuring complicated reporting procedures is shown below:

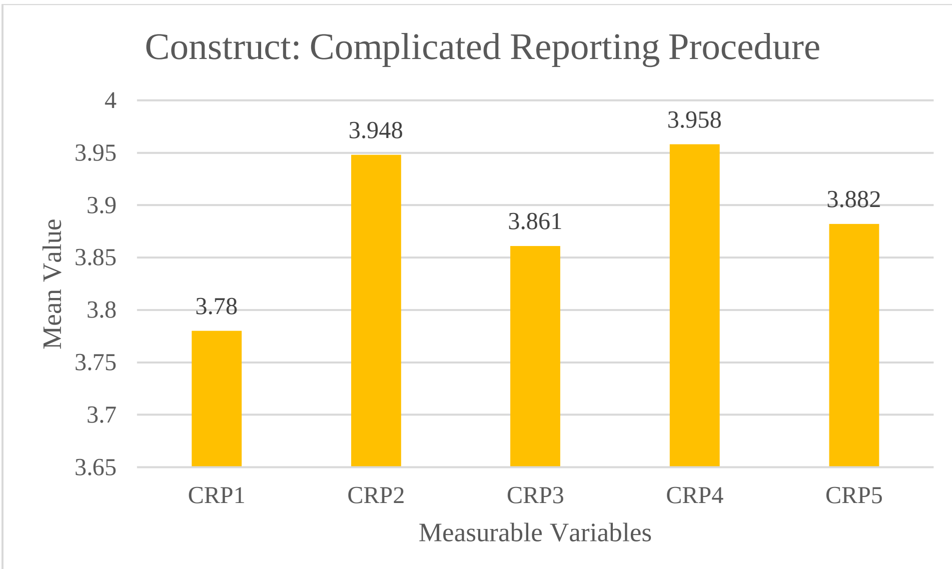

Figure 5.2 Descriptive Analysis Complicated reporting procedure

5.2.2.3 Construct: Usefulness of Voluntary Reporting

The construct aims to weigh maintenance staff's perceptions about the extent of voluntary reporting's utility in the organizational setting. It comprises the benefit sought by voluntary reporting and overall comprehension of this activity concerning safety. In the 'measurement model,' this construct is measured with the help of five statements and coded with UR1 to UR5 in a conventional sequence. The result of descriptive analysis of the responses received from the maintenance staff is reported below:

Table 5.4 Construct: Usefulness of Voluntary Reporting

Name	Mean	Standard deviation	Kurtosis	Skewness
UR1: Benefit for reporting	3.466	1.433	-1.394	-0.031
UR2: Reporting as safety information	3.452	1.439	-1.376	-0.134
UR3: ‘Reporting’ as being against someone	3.662	1.302	-1.054	0.342
UR4: Lack of policy on investigating	3.749	1.486	-1.449	0.194
UR5: Time frame to investigate reporting	3.746	1.318	-1.082	0.349

The descriptive analysis results indicate that the maintenance staff highly approves of the statements representing the construct ‘Usefulness of voluntary reporting.’ Items UR4 and UR5 have maximum mean values of 3.749 and 3.746, respectively, which is highly agreed upon by the maintenance staff. The standard deviation of the responses indicates the presence of dispersion in the responses. The mean score of the different statements measuring the Usefulness of Voluntary Reporting is shown below:

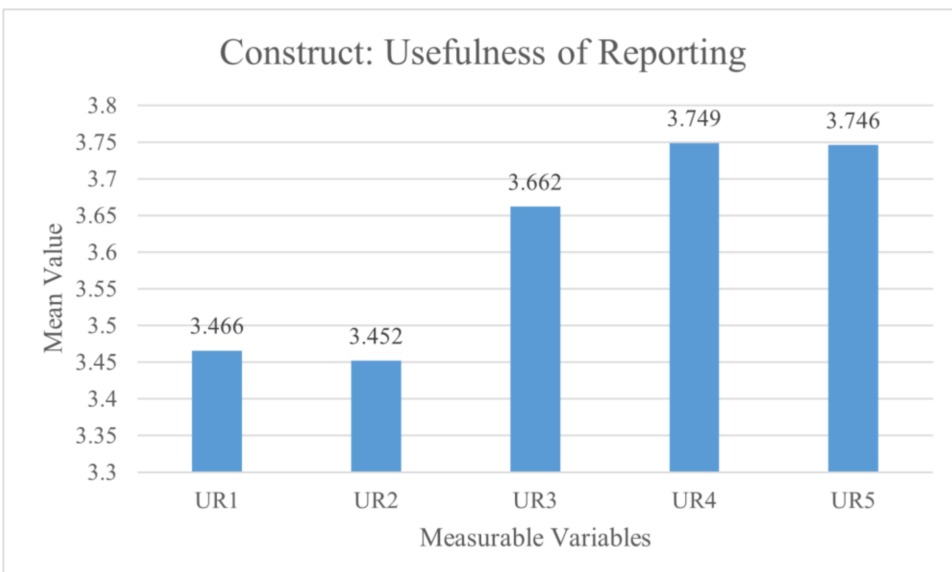

Figure 5.3 Descriptive Analysis: Usefulness of Voluntary Reporting

5.2.2.4 Construct: Contribution to Safety Investigation

This latent variable aims to determine the contribution of maintenance staff to the safety investigating processes in ascertaining the causal and contributory factors of safety occurrences. This includes measuring maintenance staff's perceptions about participating during various stages of safety investigations and their outlook towards the investigation process. An honest and positive involvement of the maintenance staff in the investigation process perhaps produces more realistic safety information about the threatening latent conditions in the organization. In the 'measurement model,' this construct is measured with the help of five statements and coded with CSIN1 to CSIN5 in a conventional sequence. The result of descriptive analysis of the responses received from the maintenance staff is reported below:

Table 5.5 Construct: Contribution to Safety Investigation

Item code and Description	Mean	Standard deviation	kurtosis	Skewness
CSIN1: The aim of safety investigation	3.822	1.082	-0.888	0.309
CSIN2: Investigation is time-consuming	3.829	1.096	-0.917	0.247
CSIN3: Investigation for improving safety	3.882	1.088	-0.842	0.27
CSIN4: Contributing may invite trouble	3.23	1.143	-0.454	-0.362
CSIN5: The investigation is fault-finding	3.962	1.164	-0.819	0.208

The descriptive analysis results indicate that the maintenance staff highly agreed with the statements representing the construct 'Contribution in safety Investigation.' Item CSIN5 has a maximum mean value of 3.962. The standard deviation of the responses indicates the presence of dispersion in the responses. The skewness and kurtosis of the responses are less than 1, indicating the presence of normal distribution in the responses. The mean score of the different statements measuring Contribution to Safety Investigation is shown below:

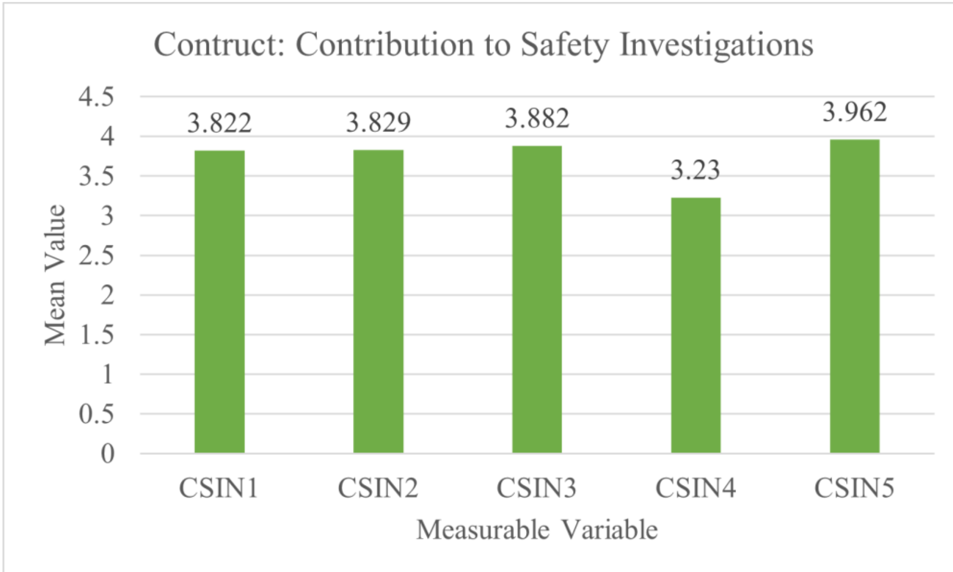

Figure 5.4 Descriptive Analysis: Contribution to Safety Investigation

5.2.2.4 Construct: Organizational Commitment to Safety Communication

This construct aims to measure the extent of allocation of resources in terms of time, technology, and training aids for safety communication. To measure the mentioned latent variable, indicators related to practical aspects such as participation of the middle and top management in the safety training programs, continuous evaluation of the learning during training, use of modern-day technologies in communication, and elements of creativity and innovativeness are referred to. A total of seven such indications are used to measure the construct and coded with OCSC1 to OCSC7. The result (Table 5.6) of the descriptive analysis indicates the existence of high agreement among the maintenance staff for the statements representing a construct 'Organizational Commitment to Safety Communication.'

Table 5.6 Construct: Organizational Commitment to Safety Communication

Item code and Description	Mean	Standard deviation	kurtosis	Skewness
OCSC1: Participation in safety training.	3.662	1.247	-1.058	-0.433
OCSC2: Evaluation of Learning	3.551	1.278	-1.132	-0.34
OCSC3: Evaluation by regulatory agency	3.645	1.343	-1.013	-0.606
OCSC4: Evaluation of safety training contents	3.425	1.351	-1.271	-0.262
OCSC5: Creativity in safety training	3.49	1.293	-1.01	-0.277
OCSC6: Response to training needs	3.516	1.271	-0.671	-0.567
OCSC7: Latest technological tools in training	3.742	1.199	-0.654	-0.649

The descriptive analysis indicates a high level of agreement among the respondents to the statements measuring Organizational Commitment to Safety Communication. The standard deviation of the responses indicates the presence of dispersion in the responses. The skewness and kurtosis of the responses are less than 1, indicating the presence of normal distribution in the responses. The mean score of the different statements measuring Organizational Commitment to Safety Communication is shown below:

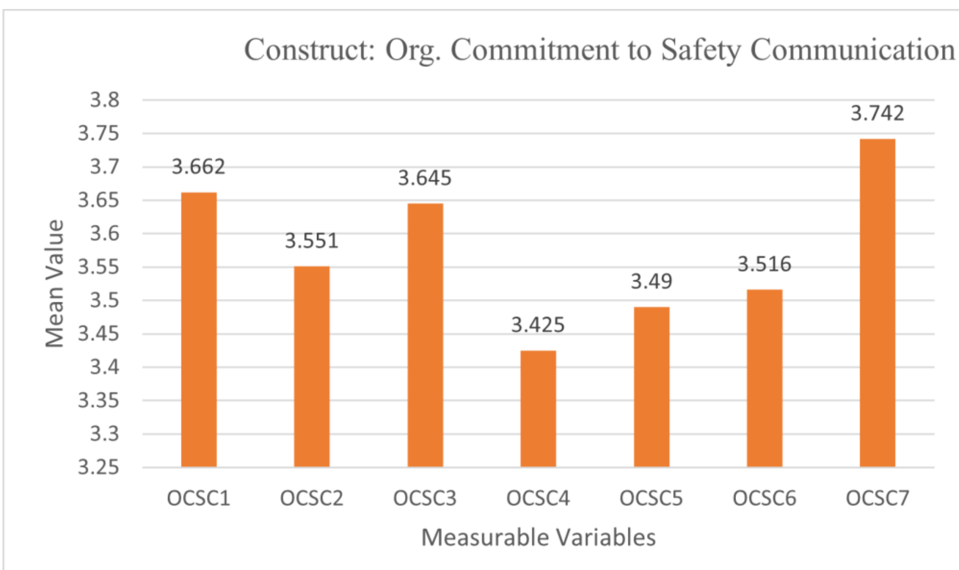

Figure 5.5 Descriptive Analysis Org. Commitment to Safety Communication

5.2.2.5 Safety Communication

This construct is intended to measure the extent to which safety information drawn from safety investigations is organized in an organizational context to communicate with maintenance staff through written and audio/video means. Safety communication' is a formally structured process, and in the aircraft maintenance industry, safety information drawn from safety investigations is communicated to stakeholders in written form through emails, newsletters, safety circulars, bulletins, etc., and audiovisual modes of safety training, human factor training, continuity training, safety meetings, etc. A total of ten statements are used to measure the construct and coded with SC1 to SC10. The descriptive analysis result (Table 5.7) indicates high agreement among the maintenance staff for the statements representing a construct 'Safety Communication.'

Table 5.7 Construct: Safety Communication

Item code and Description	Mean	Standard deviation	Kurtosis	Skewness
SC1: Contextualized safety communication	3.387	0.61	0.465	1.34
SC2: Accident written communication	3.484	0.364	0.944	4.531
SC3: Voluntary report communication	3.913	1.237	-0.951	0.078
SC4: Communication guides to change work	3.525	1.194	-0.848	-0.108
SC5: Accident AV communication	3.955	1.095	-0.84	-0.214
SC6: Voluntary report AV communication	3.51	1.143	-0.93	-0.063
SC7: HF aspects in AV communication	3.955	1.136	-0.816	-0.126
SC8: Need for repetition	3.552	1.181	-0.947	-0.051
SC9: In-depth understanding of hazards	3.531	1.19	-0.803	-0.098
SC10: Capable of hazard identification	3.542	1.18	-0.852	-0.196

The standard deviation of the responses indicates the presence of dispersion in the responses. The skewness and kurtosis of the responses are less than 1, indicating the presence of normal distribution in the responses. The mean score of the different statements measuring safety communications is shown below:

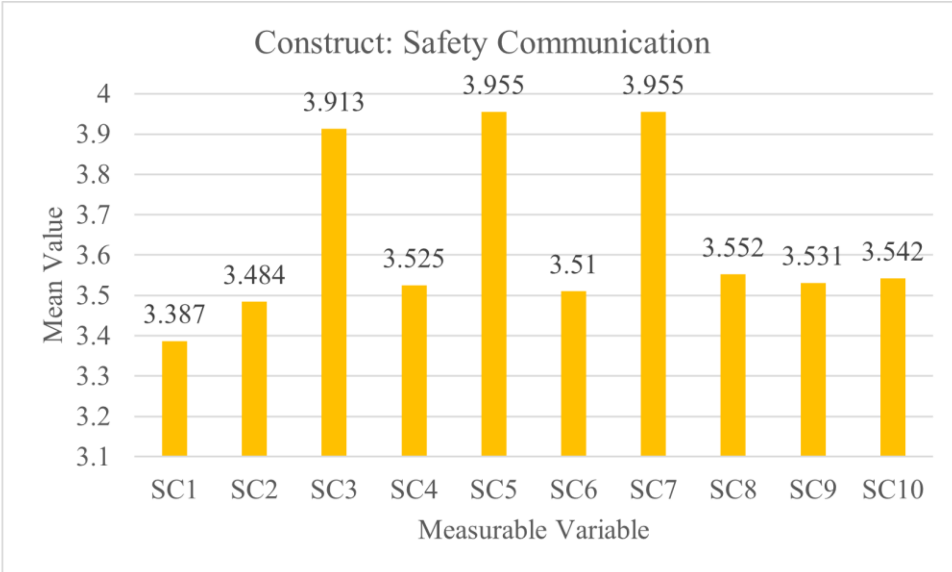

Figure 5.6 Descriptive Analysis Safety Communications

5.2.2.6 Learning Indicator

The objective of this construct is to measure the perception of frontline maintenance staff regarding what they perceive as learning from past investigations, or in other words, the learning for hazard identification purposes during safety communication. In the 'measurement model,' five items are used to measure the construct and are coded from LID1 to LID5. The result (Table 5.8) of the descriptive analysis indicates the existence of high agreement among the maintenance staff for the statements representing a construct 'Learning Indicator.'

Table 5.8 Construct: Learning Indicators

Item code and Description	Mean	Standard deviation	kurtosis	Skewness
LID1: Awareness of the hazards	3.422	1.114	-0.585	-0.342
LID2: Evaluation of learning outcomes	3.383	1.101	-0.747	-0.174
LID3: Integration of safety information	3.439	1.105	-0.62	-0.327
LID4: Repeated communication	3.421	1.022	-0.273	0.076
LID5: Application at work	3.515	0.993	-0.03	-0.061

The result of the descriptive analysis indicates the presence of moderate agreement among the maintenance staff for the statements representing leading indicators. The maintenance staff agreed on the Application at work in the organization (mean =3.515). The results also found moderate agreement among the respondents regarding the integration of safety information with procedures (mean =3.439). The maintenance staff also moderately agreed with the awareness of the hazards at their workplace (mean = 3.422) and about the repeated communication (mean=3.421). The staff was also found to moderately agree with the evaluation of learning outcomes (mean = 3.383), and voluntary reporting of hazards may characterize them as a trouble-creator for management. (mean = 3.613). The standard deviation of the responses indicates the presence of dispersion in the responses. The skewness and kurtosis of the responses are found to be less than 1, indicating the presence of normal distribution in the responses.

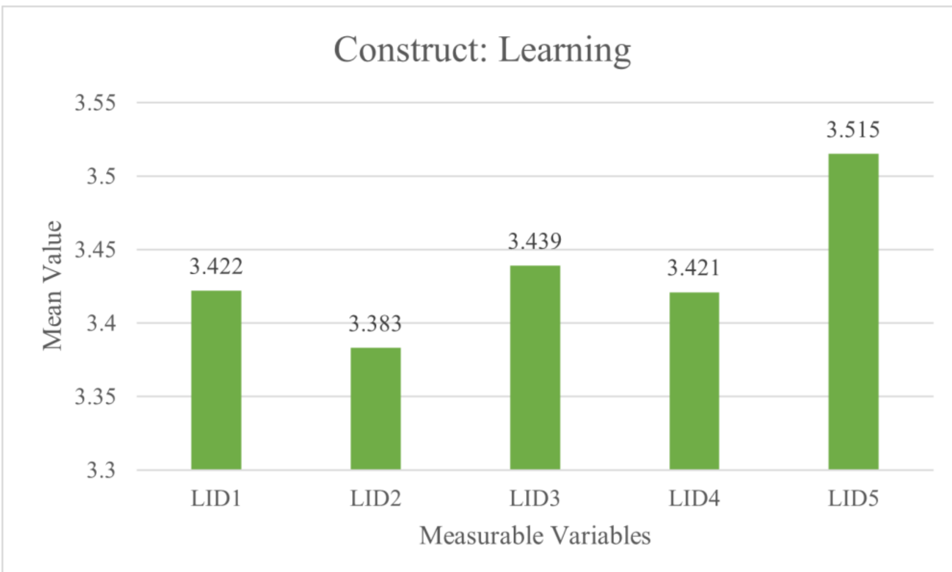

Figure 5.7 Descriptive Analysis Learning Indicators

5.2.3 MEASUREMENT MODEL

This study follows a reflective measurement model as a particular latent variable's independent measurable variables (indicators) are substantially correlated, and removing any indicator does not change the nature of the latent construct. The reporting sequence of results largely complies with the recommendations of Hair et al. (2019). Analysis of the measurement model is carried out in three steps: first, the reflective indicator loading assessment; second, the reliability and convergent validity check; and lastly, the constructs' discriminant validity assessment.

5.2.3.1 Indicator Loading

The latent variables, a brief description of associated items with the codes, and the psychometric analysis of the measurement model are demonstrated (Table 4.2). Three items, SC1, SC2, and SC5 of the 'Safety Communication (SC)' and CSIN5 of the 'Contribution to Safety Investigations (CSIN)' constructs are below the acceptable reflective indicator loading limits of ≥ 0.708. The SC construct's Average Variance Extracted (AVE) (.480) is also below the minimum acceptable level (0.500). While items SC1 and SC2 are far below the threshold value of loading SC5 at 0.646 and CSIN at 0.658, loadings are at the margin. Therefore, only two indicators (SC1 and SC2) are discarded from the analysis as they appear to reflect some other constructs. Discarding these two items from the study, the revised AVE (0.593) of the construct also falls within acceptable limits (see Table 5.9).

Table 5.9 Indicators Loading

Latent Variables (Constructs) with Codes	Brief Description of Observable Variables (Items) with Codes	Indicator Loading	AVE
CRP (Complicated Reporting Procedure)	CRP1: Additional workload	0.776	0.677
	CRP2: Reporting is Time-consuming	0.823	
	CRP3: Narrative format of reporting	0.770	
	CRP4: Investigation is time-consuming.	0.864	
	CRP5: Lack of clarity on what to report and not to report	0.876	
CSIN (Contribution in Safety Investigations)	CSIN1: Blame someone	0.884	0.685
	CSIN2: Legal implications	0.928	
	CSIN3: Not to improve safety	0.897	
	CSIN4: Possibility of getting into trouble	0.737	
	CSIN5: Fault-finding rather than establishing the root causes	0.658	

LID (Learning from Past Indicators)	LID1: Awareness of the hazards at my workplace LID2: Evaluation of learning outcomes LID3: Integration of safety information with procedures LID4: Repeated communication LID5: Application at work	0.836 0.827 0.844 0.811 0.787	0.674
LT (Lack of Trust)	LT1: Trouble-creator for management LT2: Adverse effect on career growth LT3: Lack of "Waiver of Disciplinary Action" policy LT4: No independent report-receiving agency LT5: Management is production centric	0.813 0.770 0.865 0.841 0.900	0.704
OCSC (Organizational Commitment to Safety Communication)	OCSC1: Management participation in the safety training OCSC2: Learning evaluation by employing organization OCSC3: Learning evaluation by the regulatory agency OCSC4: Evaluation of safety contents by the regulatory agency OCSC5: Creativity in safety training OCSC6: Training needs analysis OCSC7: Integration of technological tools in safety training	0.783 0.784 0.832 0.817 0.777 0.766 0.732	0.616
SC (Safety Communication)	SC1: Contextualized written safety communication SC2: Written safety communication on safety occurrences SC3: Written safety communication on hazards SC4: Quality of written safety communication SC5: Audiovisual safety communication on safety occurrences	-0.101 -0.304 0.758 0.819 0.646 0.752 0.732 0.759 0.819	0.480

	SC6: Audiovisual safety communication on hazards. SC7: Audiovisual safety communication on human factors SC8: Retention of safety communication SC9: Safety communication and hazards of the workplace SC10: Safety communication and hazard identification	0.827	
UR (Lack of utility of Reporting)	UR1: Benefit for reporting. UR2: Reporting is not a piece of safety information. UR3: Word 'reporting' as being against someone. UR4: Lack of policy related to investigating reports UR5: Time frame to investigate voluntary reporting	0.838 0.871 0.822 0.774 0.869	0.698

5.2.3.2 Reliability and Convergent Validity

The second step of assessing data reliability is measuring "composite reliability" and " Cronbach's alpha." While the measurement of the former is too liberal, the latter is considered too conservative, and the actual reliability of the construct lies within these two extreme values (Hair et al., 2019). To address this issue, (Dijkstra & Henseler, 2015) suggested a more accurate measure of construct reliability in the form of "rho-a," which varies between 0.881 and 0.915 for the data set (see Table 5.10). The convergent validity of each construct measures the variance of its items, and the metric used for this is the average variance extracted (AVE), with 0.50 as the minimum acceptable AVE. The AVE values of constructs lie between 0.593 lowest to 0.704 maximum.

Table 5.10 Reliability and Convergent Validity

Constructs	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average Variance Extracted (AVE)
OCSC	0.896	0.897	0.918	0.616
CPR	0.882	0.915	0.913	0.677
CSIN	0.882	0.910	0.914	0.684
LID	0.879	0.881	0.912	0.674
SC	0.901	0.903	0.921	0.593
LT	0.894	0.896	0.922	0.704
UR	0.893	0.905	0.920	0.698

5.2.3.3 Discriminant Validity

The next step is to assess the discriminant validity of the data set to understand the extent to which each construct is statistically distinct from others. Various methods are recommended to determine the discriminant validity. One way associated with variance and AVE suggests that all model constructs 'shared variance' should not be more significant than their AVEs (Fornell & Larcker, 1981). In contrast, (Henseler et al., 2015) argue that the Fornell-Larcker measure does not hold well, especially when the indicator loadings are too close and differ only slightly, and proposed the "Heterotrait-Monotrait" ratio (HTMT) to assess the empirical distinction among constructs. HTMT value above 0.90 indicates the nonexistence of discriminant validity; however, when the constructs are conceptually more distinct, a more conservative value such as 0.85 is suggested. The data set displays the maximum HTMT ratio of 0.607 (see Table 5.11) and thus establishes the discriminant validity.

Table 5.11 HTMT values of constructs for discriminant validity

	OCSC	CPR	CSIN	LID	SC	LT	UR
OCSC							
CPR	0.077						
CSIN	0.222	0.055					
LID	0.356	0.157	0.275				
SC	0.607	0.150	0.452	0.590			
LT	0.400	0.100	0.590	0.358	0.605		
UR	0.166	0.038	0.174	0.129	0.330	0.113	

5.2.4 STRUCTURAL MODEL

5.2.4.1 Collinearity Assessment

The first step is evaluating the collinearity of the model's predictor constructs and separating the potential collinearity sets for further evaluation. Collinearity describes the linearly related predictor variables in the statistical model, which may lead to unstable parameters and biased inference statistics (Dormann et al., 2013). The Variance Inflation Factor (VIF) estimates the degree of collinearity. Its recommended value ranges between 0.20 and 5; in the case of exceedance, the model will be reviewed, and constructs will be merged or eliminated (Hair et al., 2016). This study's data set demonstrates the VIF values for the pair of constructs between 1.000 and 1.546, which is well within the acceptable limits (see Table 5.12)

Table 5.12 Collinearity test for the pair of different constructs

Item code	VIF	Item code	VIF
CSIN1	3.287	UR1	2.136
CSIN2	4.478	UR2	2.699
CSIN3	3.245	UR3	2.054
CSIN4	1.587	UR4	1.952
CSIN5	1.538	UR5	2.64
LID1	2.127	OCSC1	2.208
LID2	2.273	OCSC2	2.047
LID3	2.433	OCSC3	2.479
LID4	2.003	OCSC4	2.244
LID5	1.872	OCSC5	1.948
SC1	1.3	OCSC6	1.847
SC10	2.73	OCSC7	1.66
SC2	1.376	LT1	2.126
SC3	1.962	LT2	1.688
SC4	2.525	LT3	2.784

SC5	1.476	LT4	2.368
SC6	2.164	LT5	3.436
SC7	1.75	CRP1	2.055
SC8	1.93	CRP2	2.067
SC9	2.6	CRP3	1.738
		CRP4	2.155
		CRP5	2.798

5.2.4.2 Common Method Bias

A single measuring scale (Likert scale 1 to 5, used in this study) for all survey questions can introduce measurement errors, usually known as common method bias. (Kock, 2015) argues that if all VIFs are within the threshold (3.3), the model may be treated free from common method bias. In this study, the maximum value of VIF is 1.546, which is well within the defined limits. However, for this study, the common method bias was also tested using the most widely used method, 'Harman's single factor test,' which resulted in the average variance against a single item being 26% (within the limits of 50%). Therefore, it is concluded that the data received in this study is free from common method bias.

Table 5.13 Harman single factor method for common method bias

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.922	26.005	26.005	10.922	26.005	26.005
2	3.652	8.696	34.700			
3	3.502	8.338	43.038			
4	3.238	7.710	50.748			
5	2.608	6.210	56.958			
6	1.688	4.019	60.977			
7	1.579	3.758	64.736			

8	1.194	2.843	67.579			
9	.783	1.865	69.444			
10	.722	1.720	71.163			
11	.698	1.662	72.825			
12	.651	1.550	74.375			
13	.613	1.460	75.835			
14	.596	1.418	77.254			
15	.588	1.400	78.653			
16	.559	1.330	79.983			
17	.531	1.264	81.248			
18	.514	1.223	82.471			
19	.493	1.175	83.646			
20	.464	1.105	84.751			
21	.455	1.083	85.833			
22	.438	1.044	86.877			
23	.425	1.011	87.889			
24	.413	.984	88.872			
25	.404	.962	89.835			
26	.372	.885	90.719			
27	.348	.830	91.549			
28	.326	.777	92.327			
29	.320	.763	93.089			
30	.306	.728	93.817			
31	.295	.703	94.520			
32	.289	.688	95.208			
33	.259	.617	95.826			
34	.246	.585	96.411			
35	.235	.559	96.969			
36	.223	.532	97.501			
37	.219	.521	98.022			
38	.200	.475	98.498			
39	.182	.434	98.932			

40	.174	.414	99.346			
41	.153	.365	99.711			
42	.122	.289	100.000			
Extraction Method: Principal Component Analysis.						

5.2.4.3 Significance and relevance of the model relationship

In the study, the relationship between "lack of trust," "Complicated reporting procedure," "Lack of utility of reporting," "Contribution in safety investigations," "organization commitment to safety communications," "Safety Communication," and "Learning Indicator" is examined with the help of SEM analysis. The structural model is developed with the help of included constructs. The "lack of trust," "Complicated reporting procedure," "Lack of utility of reporting," and "Contribution in safety investigations are assumed as the lower order exogenous constructs, the safety communications as mediating constructs, and leading indicators as endogenous constructs. All the constructs in the structural model are reflective in nature and measured with the help of statements included in the questionnaire. The following hypotheses are examined with the help of Smart PLS software:

Hypothesis: "Lack of Trust" significantly influences the "safety communication."

Hypothesis: "Complicated reporting procedure" significantly influences the "safety communication."

Hypothesis: "Lack of utility of reporting" significantly influences the "safety communication."

Hypothesis: "Contribution in safety investigations" significantly influences "safety communication."

Hypothesis: "Organisation commitment to safety communications" significantly influences "safety communication."

Hypothesis: "Safety communication" significantly influences the "learning."

The result of the hypothesis testing is reported and discussed below:

Table 5.14 Hypothesis Testing

Hypothesis	Beta Coefficient	Standard Deviation	T statistics	P values	Remark
Lack of Trust -> Safety Communication	-0.308	0.061	5.085	0.000	Supported
Complicated reporting procedure -> Safety Communication	-0.097	0.042	2.231	0.026	Supported
Lack of utility of reporting -> Safety Communication	-0.201	0.047	4.224	0.000	Supported
Contribution to safety investigations -> Safety Communication	-0.144	0.056	2.539	0.011	Supported
Safety Communication -> Learning	0.526	0.043	12.134	0.000	Supported
Organization commitment to safety communications -> Safety Communication	0.370	0.050	7.448	0.000	Supported

Conclusion (H_1): The result of the SEM analysis supported the hypothesis that "*Lack of Trust significantly influences the safety communication"* (path coefficient = -0.308, t stats= 5.085). The negative and significant path coefficient of lack of trust indicates a significant inverse impact on safety communications. The higher level of 'lack of trust' reduces the 'safety communications.'

Conclusion (H_2): The SEM analysis result supported the hypothesis that "Complicated reporting procedure significantly influencing the safety communication" (path coefficient = -0.097, t stats= 2.231). The negative and significant path coefficient of the 'complicated reporting procedure' indicates a significant inverse impact on 'safety communications.' The higher the level of 'complicated reporting procedure,' the less 'safety communications.'

Conclusion (H_3): The SEM analysis result supported the hypothesis that "Lack of utility of reporting significantly influences the safety communication" (path coefficient = -0.201, t stats= 4.224). The negative and significant path coefficient of Lack of utility of reporting indicates a significant inverse impact on safety communications. The higher level of Lack of utility of reporting reduces safety communications.

Conclusion (H_4): The result of the SEM analysis supported the hypothesis that "Contribution in safety investigations significantly influencing the safety communication" (path coefficient = -0.144, t stats= 2.539). The negative and significant path coefficient of Contribution in safety investigations indicates a significant inverse impact on safety communications. The higher level of Lack of Contribution in safety investigations reduces the safety communications.

Conclusion (H_5): The result of the SEM analysis supported the hypothesis that "Organisation commitment to safety communications significantly influences the safety communication" (path coefficient = 0.370, t stats= 7.448). The positive and significant path coefficient of the organization's commitment to safety communications indicates a significant positive impact on safety communications. The higher the level of organizational commitment to safety communications, the higher the level of safety communications.

Conclusion (H_6): The SEM analysis result supported the hypothesis that "Safety communications significantly influence the 'learning' (path coefficient = 0.526, t stats= 12.134). The positive and significant path coefficient of safety communications indicates a significant positive impact on learning. The higher the level of safety communications, the higher the learning from the past. All the hypotheses are endowed with significant p values. The results are presented in Table 5.14, and the structure model is shown in Figure 5.8.

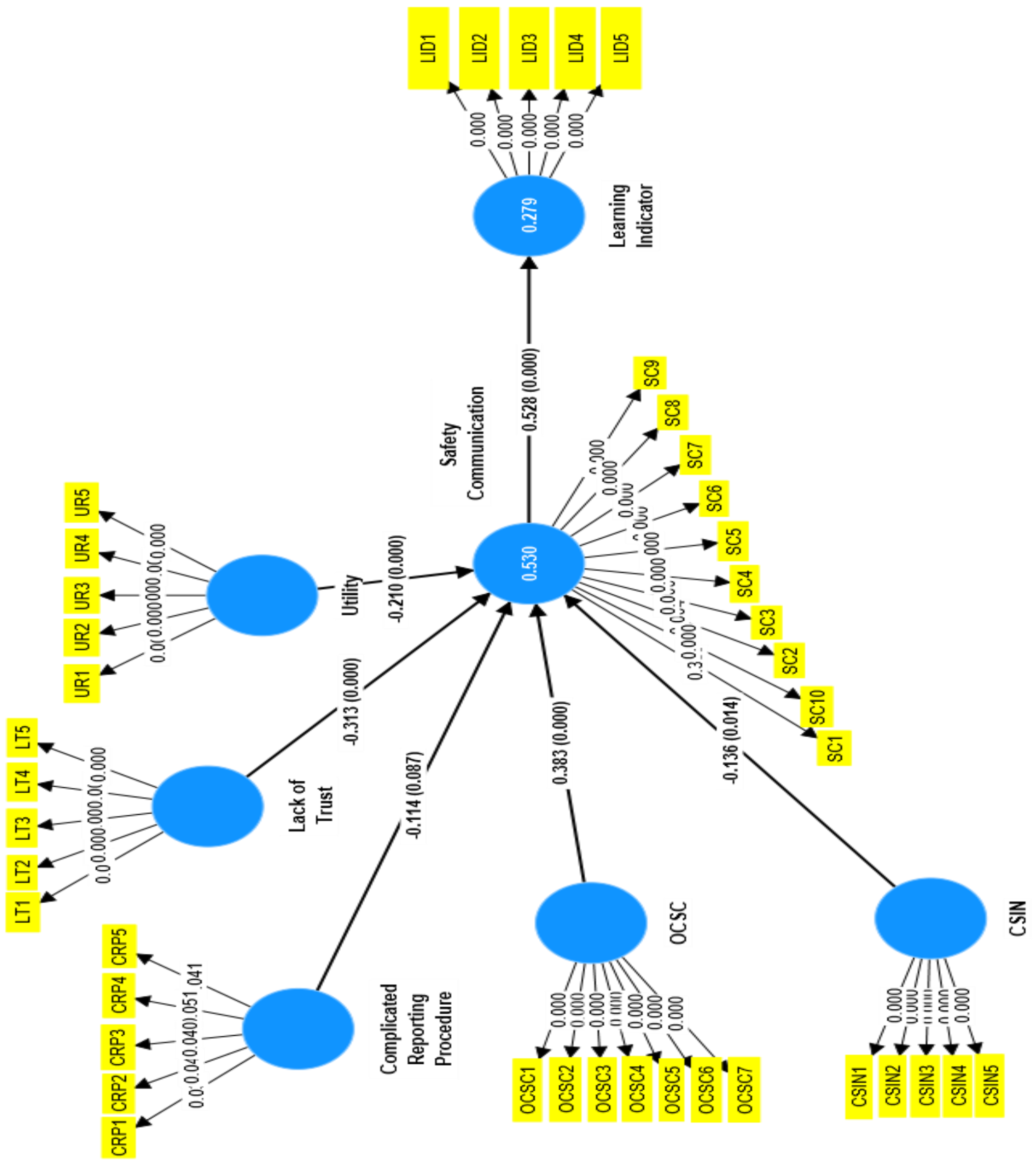

Figure 5.8 Path coefficient and t-values for the structural model

5.2.4.4 Coefficient of Determination (R^2) of Endogenous Constructs

After ascertaining the non-existence of collinearity, common method bias, and significance of model relationship in the structural model, the third step is evaluating the R^2 values of endogenous constructs, also implied as in-sample predictive power (Rigdon, 2012). R^2 value describes the variance in the endogenous variables by the exogenous variables and is also considered to measure the explanatory power of the model (Shmueli & Koppius, 2011). The range of R^2 varies from 0 to 1, and as a guideline, the values of 0.25,0.50 and 0.75 are treated as weak, moderate, and substantial (Hair et al., 2019). In this study's structural model, the R^2 of learning indicators (LID) and safety communication (SC) are .279 and .530, respectively.

5.2.4.5 Effect Size (F^2 Value)

F^2 value indicates the change in R^2 when an exogenous variable is deleted from the model and varying effect size is defined by the (Jacob, 1988) rule of thumb as ≥ 0.02 is small, ≥ 0.15 is medium, and ≥ 0.35 is large. The effect size results on this study's endogenous variable are given in Table 5.15.

Table 5.15 Effect Size

Exogeneous-Endogenous Relations	F^2	SE	T Stats	P values	Effect Size
Commitment -> Safety Communication	0.237	0.025	1.156	0.248	Medium
Complicacy -> Safety Communication	0.017	0.017	1.032	0.302	Very small
Contribution -> Safety Communication	0.029	0.052	2.353	0.019	Small
Safety Communication -> Learning Indicator	0.382	0.073	3.233	0.001	Large
Trust -> Safety Communication	0.123	0.088	4.32	0	Small
Utility -> Safety Communication	0.076	0.04	1.897	0.058	Small

5.2.4.6 Predictive Relevance (Q^2 Value)

The Q^2 of the PLS path indicates the model's predictive accuracy, and a model is considered to have predictive relevance if the Q^2 value is more than zero. In the case of this study, the Q^2 values for both the endogenous constructs (LID and SC) are 0.152 and 0.478, respectively, indicating that the model has predictive relevance, and these values conform to small and moderately large predictive relevance (Hair et al., 2019).

CHAPTER 6: SUMMARY OF KEY FINDINGS

Chapter Overview This chapter summarizes the results obtained by achieving research objectives one, two, and three in Chapters four and five.

6.1 Research Objective 1

The scholar has formulated the LPSI process model (Figure 4.2) based on the models described in paragraph 4.3 and the regulatory framework (ICAO, 2018b). The critical differences are in the ‘reporting’ and ‘investigation’ stages. Aircraft accidents, serious incidents, and incidents are compulsory to report (rather too big to hide, hence reported) and follow mandatory occurrence reporting (MOR) procedures. The state is responsible for investigating such reports by following the SSP based on the SARPs of ICAO Annex 13. In contrast, the frontline maintenance staff and other stakeholders are expected to voluntarily report hazards, unsafe conditions, unsafe acts, errors, and near misses. Voluntary reporting is investigated in-house by the concerned organization. Both safety investigations aim to generate safety information for dissemination to the relevant stakeholders at the ‘safety communication’ stage. Finally, the effectiveness of LPSI in an organization is evaluated at the ‘ Safety audit’ stage by the organization itself and the regulatory agency. All the stages of the process model have the potential to offer learning value to the stakeholders; however, ‘safety communication’ is the formal learning zone for the maintenance staff and the organization in which safety data extracted from investigations are contextualized into safety information and is communicated in written (emails, safety circulars, bulletins, newsletters, etc.) and audiovisual (safety training, human factor training, continuity training, safety meetings, etc.) mode to organizational entities. As the conceptual model depicts (Figure 4.3), ‘safety communication’ is the heart of learning from past safety investigations.

6.2 Research Objective 2

The factors that influence various stages of the LPSI process model are described in para 3.4 and summarized in Table 3.1. All the stages of the LPSI process model were identified with factors that have the potential to impact the learning process from past safety investigations.

6.3 Research Objective 3

Based on the conceptual model, the structural model was developed, where the predictive relevance of the 'safety communication' construct is observed as moderately large, which supports the conceptual model and the relations of safety communication with other constructs. Also, the results derived based on the (Hair et al., 2019) recommendations indicate the model's validity with values of different parameters within acceptable limits. This study was conducted with maintenance staff at the center stage, with the participation of 287 maintenance staff with varying experience in the aircraft maintenance domain (Table 2). However, the opinions of other stakeholders, such as safety managers, quality control managers (QCM), accident/ incident investigators, and accountable managers (AM), may add more value to understanding this reactive methodology. Thus, an opportunity exists for future research to explore organizational management and investigators' perspectives on learning from the past.

In the SEM, the three constructs (LT, CPR, and UR) relate to the factors that influence the 'voluntary reporting' stage of the LPSI process model. In other words, the first three hypotheses (H1, H2, and H3) establish the relationship between the 'voluntary reporting' stage and 'safety communication' stage of the LPSI process model (Figure 4.2). The results indicate that among the factors that influence voluntary reporting, 'lack of trust' (LT) between the maintenance staff and the management is the most muscular construct for safety communication (-0.308), followed by the 'Usefulness of reporting' (UR) at (-0.199). In contrast, the construct of a 'complicated reporting procedure' (CPR) is evaluated to have the least impact (-0.093) on voluntary reporting, as perceived by the maintenance staff.

As measured in the model, the lack of trust between the maintenance staff and the organization's management is the prime reason that prevents maintenance staff from reporting hazards and near misses they observe in the aircraft maintenance facilities. This condition weakens the all-inclusive and participatory pillar of contemporary SMS. Safety information about these hidden threats is not communicated at the 'safety communication' stage as it does not exist in the organizational repository. This adversely affects learning from the past because organizations fail to collect safety data and information. Moreover, non-reporting by the maintenance staff keeps the safety threats hidden until combined with other conditions to get converted into incidents and accidents. When viewed from the maintenance staff's perspective, the other interpretation of these three latent variables is the importance of the 'trust' and 'usefulness' components in voluntary reporting. This implies that when maintenance staff are convinced of the usefulness of voluntary reporting and have high trust in the organizational management, procedural complicacy and inconvenience in voluntary reporting are likely to be diminished. This aspect may be explored by conducting further research on this subject. The structural model is useful in prioritizing the problems; for example, the various indicators that reflect the 'lack of trust' indicator LT5 (management is production-centric, so I prefer to find my safe solution rather than reporting) have a maximum impact (0.901) as perceived by the maintenance staff. The management has to be cautious about this aspect as it may lead to 'disengaged silence' of maintenance staff (Under & Gerede, 2021) and defy the fundamental tenet of the participative and all-inclusive approach of the current safety management system. The accountable manager and the senior management of the aircraft maintenance organization may utilize the indicators impact factor to address and prioritize the problem areas.

Maintenance staff's 'lack of contribution' to the safety investigation negatively affects safety communication (-0.142). Lack of contribution invariably results in a shortfall of safety information generated by the investigations. Thus, safety information about some causal or contributory factors or latent unsafe conditions will likely be excluded from safety communication. The critical indicator reflecting this barrier, as seen by the maintenance staff, is CSIN2 (investigation is time-consuming, with many legal implications, so I refrain from associating with it unless called for by the investigating team), with an impact factor of 0.928. This indicates that the maintenance staff generally view the investigation process differently than the purpose it is meant for. The role of management and the investigating team is crucial to address this point. Honest communication with the organization's maintenance personnel highlighting the investigation's intent before commencing the investigation may encourage maintenance staff to participate without their self-imposed fear. The factors influencing the learning from past old investigation reports are not included in the scope of this study as firstly, it is not aligned with the target population (maintenance staff) of this study, and secondly, contextualization of the safety information of old investigation reports in the current context may be a separate area of research.

'Safety communication' has a positive and significant impact (0.528) on learning (Figure 5.8). This stage of the LPSI process model is also the formal learning zone where the learning product is delivered to maintenance staff. The learning product's delivery is typically accomplished by first contextualizing the safety information drawn from the investigation reports, followed by communicating it in written and audiovisual modes. The latent variable 'safety communication' was defined by eight indicators. The indicators measure all aspects of safety communication, i.e., contextualized safety information followed by delivery in written and audiovisual methods. SC9 and SC10 are the most significant indicators, with load factors of (0.819) and (0.827), respectively. These two indicators relate to maintenance staff awareness about the hazards at the workplace and their ability to identify them based on learning at the safety communication stage. This aspect makes contextualizing safety information one of the critical activities for safety communication. Safety managers must ensure that the safety information drawn from investigation reports is contextualized in the organizational working processes and environment before communicating it in written and audiovisual modes. The learning indicators of construct ‘LID,’ which explores the perception of maintenance staff on learning from the past, also support that safety information is to be integrated with their work procedures (LID3) with the maximum load factor (0.844), which eventually establishes that maintenance staff perceives learning when safety communication is in their working context.

Organizational commitment to safety communication (OCSC) is the most influential variable that affects safety communication (0.372). The construct ‘OCSC’ relates to the ‘safety audit’ stage of the LPSI process model. The measurement model indicator OCSC 3 (The regulatory agency evaluates my learning in safety training) with the maximum load factor (0.832) underscores the importance of assessing the knowledge acquired by the maintenance staff in the safety communication stage. As stated in the previous study (Clare & Kourousis, 2021f), regulatory safety oversight is restricted to delivering safety communication rather than verifying its effectiveness. If the organization and regulatory agency are not evaluating the learning outcomes of the safety communication stage, learning from the past is negatively affected. The measurement model provides each indicator's impact while measuring the organizational commitment to safety communication in the Indian context. This may vary, and some more indicators (not considered in this study) will be surfaced. Therefore, management must holistically assess their organizational working culture and consider the indicators applied in this study as a baseline.

CHAPTER 7: THEORETICAL FRAMEWORK UNDERPINNING

Chapter Overview This chapter describes the theory of the 'Risk Triangle,' the evolution of the 'Aviation Risk Triangle,' and the concept of the 'leading' and 'lagging' indicators (para 7.1). A relationship between the 'Aviation Risk Triangle,' and the 'Learning from the Past Safety Investigations (LPSI) process model is described to underline the importance of leading indicators (Para 7.2).

7.1 RISK TRIANGLE AND THE CONCEPT OF 'LEADING' AND/OR 'LAGGING' INDICATORS

The original Heinrich risk triangle was evolved based on data from actual accidents in the 1930s. Focused on risk exposure to an individual worker, it represented the risks to a worker performing a similar type of task in an unchanged environment. The original form of the 'Risk Triangle' (Heinrich, 1941) proposed that 300 recordable no-injury accidents would give rise to 29 minor injury accidents and subsequently to a major injury accident. Thus establishing a ratio or, in other words, a relationship between the accidents of varying magnitudes. Obviously, in the ensuing eighty years, the context in which accidents occur has dramatically changed, and accordingly, the proportions of the risk triangle. The triangle was updated, and underpinning analysis was performed within the insurance industry to express population-level risks. Based on 1.75 million accidents reported by 297 contributing companies across multiple sectors, the revised triangle saw the base broaden to 600 and a 20/1 ratio between near-miss incidents and injury accidents. It represents the safety situation in the 1970s. More recent research (Prem et al., 2010) illustrates over 30,000 no-injury accidents compared to 961 major injuries: a ratio of 170/1 (compared to Heinrich's original ratio of 10/1). In the UK aviation industry study, the base of the risk triangle can be seen even broader, with 49,000 ‘safety occurrences’ yet only 179 ‘serious incidents’ (a ratio of 274/1).

The terms ‘leading’ and ‘lagging’ have been borrowed from finance and economics. In economics, ‘leading’ indicators imply some indications or changes before significant economic changes (Lingard et al., 2017). Leading indicators of safety are defined in different ways. Leading safety indicators have been described as ‘‘precursors to harm that provide early warning signs of potential failure” (Shea et al., 2016). This reflects that leading indicators can be positive or negative. Still, the underlying logic is that measuring leading indicators allows for the detection and resolution of safety issues before accidents/incidents or injuries. Contrary to this, any kind of failure, irrespective of whether it produces harm, should be considered a lagging indicator. As the risk pyramids become broader, it amplifies the fact that focusing only on major accidents/injuries (i.e., lagging indicators) is likely to ignore valuable data (leading indicators at the triangle's base). Therefore, the purpose of these triangles (figure 7.1) is not to demonstrate a universal set of ratios between the different levels but to highlight the critical concept that there are many more precursor events (leading indicators) before every major incident (lagging indicator). Given the above, for the ‘Aviation Risk Triangle,’ it can be seen that safety management strategies should utilize the 49000 leading indicators to prevent lagging indicators of the triangle.

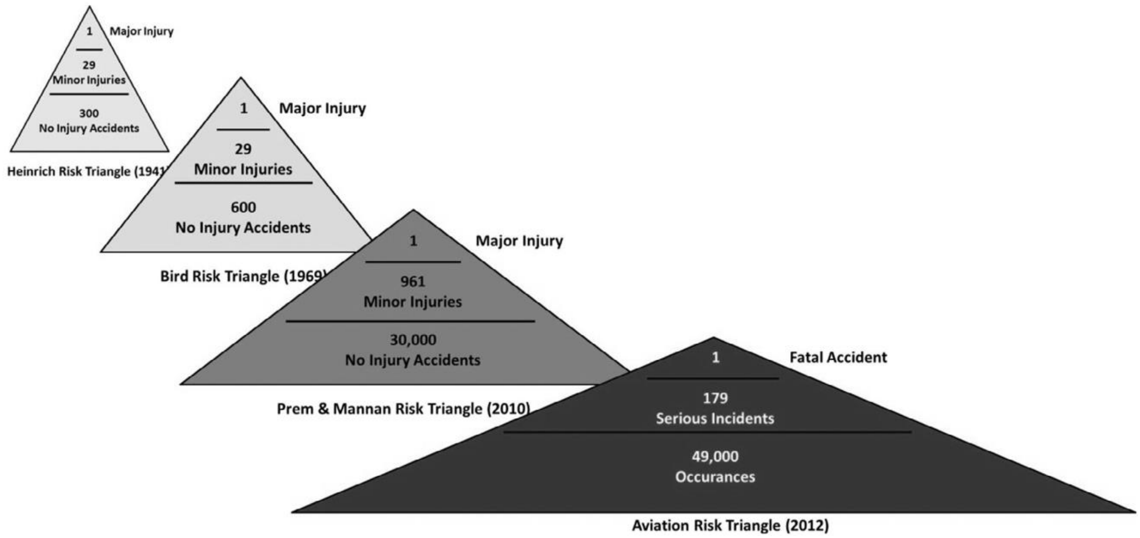

Figure 7.1 Risk Triangles (Walker, 2017)

7.2 LPSI PROCESS MODEL AND THE RISK TRIANGLE

Learning from past incidents via leading and/or lagging indicators is a fundamental safety science concept worth revisiting in this study. In the SMS framework, hazards identified from past safety occurrences (safety investigations) must be integrated with safety management strategies to enable a safer aircraft maintenance industry. That is where the organizational learning abilities from the past become critical and are considered one of the limitations in applying past safety data in continuing safety management. A relationship between the ‘Risk Triangle’ components, the LPSI process model, and reactive methods of hazard identification is shown in Figure 7.2. All three stages of ‘Aviation Risk Triangle’ are connected to the ‘reporting’ stage of the LPSI process model. ‘Accidents’ and ‘Serious Incidents’ are linked with the mandatory occurrence reporting stage, while the base of the triangle is with the voluntary reporting stage. Since aviation is considered an ultra-safe industry, inputs from the top side of the triangle (mandatory occurrence reporting) are minimal, as accidents and incidents are rare. The real opportunity exists at the triangle's base regarding leading indicators reported voluntarily by the workers in their day-to-day functioning.

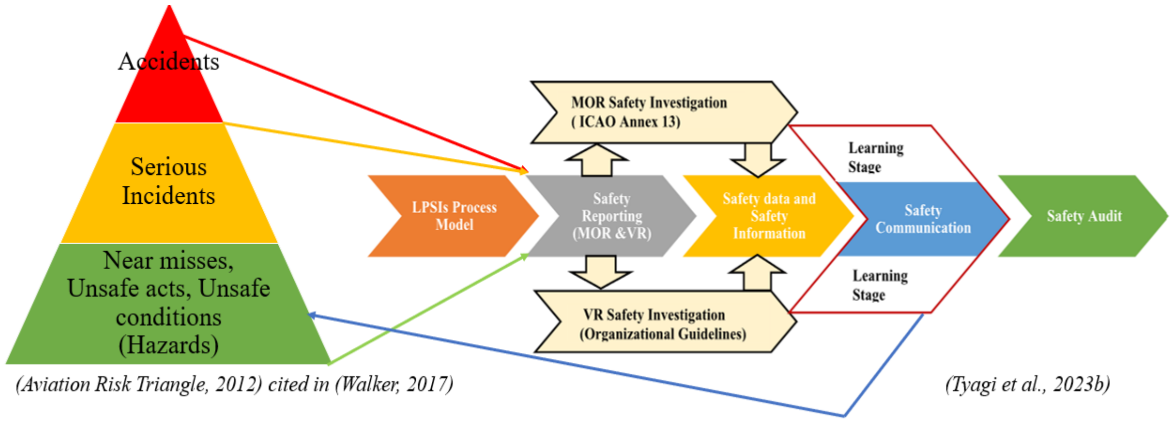

Figure 7.2 Risk Triangle Relation with the LPSI Process Model

This study is synthesized on the fact that organizations are not learning from past safety occurrences and fail to avoid recurrences. This implies that leading indicators (hazards) at the base of the triangle are either not identified or their associated risk is not mitigated timely. In this study, first, the 'learning from the past' process model was developed, which was followed by the identification of the stagewise barriers, and finally, the impact of various factors was measured besides identifying the critical stage for learning from the past. This study establishes that in the current SMS, 'learning from the past' is potentially related to the improved hazard identification capabilities of the maintenance staff. The maintenance organizations need to harness this information for improved hazard identification and risk management capabilities so that safety threats are limited to the base of the 'Aviation Risk Triangle' and occurrences of serious magnitudes are further minimized. While picture-perfect learning from past safety occurrences is a fallacy, maximizing and applying it in continuing safety management practices is a reality and has the potential to enhance the safety of the aircraft maintenance industry.

CHAPTER 8: RESEARCH CONTRIBUTION

Chapter Overview This chapter first underlines the research novelty (para 8.1 and its sub-paras) wherein research outcomes are synthesized. The contribution of the research findings is described in two different dimensions: its contribution to the aircraft maintenance industry, including the state regulators (para 8.2 and its sub-paras), and its contribution to the theoretical framework (para 8.3).

8.1 RESEARCH NOVELTY

8.1.1 RESEARCH ASSUMPTIONS

The novelty of this research can be described on multiple counts despite the researchers' past exploration of the subject. Firstly, the assumption of the term 'past.' Unlike previous research, this study views the 'past' from two different perspectives: the 'safety information' produced by investigating historical accidents and incidents and the 'safety information' derived by examining the hazards, errors, and near-misses reported by the front-line maintenance staff in day-to-day functioning. In the aviation sector, where accidents/ incidents are rare, this assumption provides ample opportunities for 'safety information' generation and learning from the past, as the 'past' may be very recent, depending upon organizational agility**.** Secondly, this study uses the term 'LPSIs' (Learning from Past Safety Investigations). This term applies to both the rare accidents (reported under MOR) and the near misses or hazardous conditions observed during the daily maintenance activities (reported under VR). Both reporting, when investigated, generate safety data and information that can potentially prevent recurrences of accidents and enhance overall safety standards. Another aspect of this assumption, besides the informal and unrecorded experience sharing amongst the maintenance personnel, is that the 'safety information' drawn from these investigation reports is the solitary organizational learning repository.

8.1.2 EMPIRICAL APPROACH

The critical aspect of the study is why aircraft maintenance organizations are not learning despite the necessary regulatory framework embedded in the business processes. Whether learning is hindered at individual and organizational levels or inadequate regulatory interventions. Unlike previous studies that followed the qualitative approach, this study is based on an empirical evaluation wherein first, the ’learning from the past’ process was developed, followed by influencing factor identification and measuring their impact.

8.2 CONTRIBUTION TO AIRCRAFT MAINTENANCE INDUSTRY AND STATE REGULATORS

8.2.1 PROCESS MODEL

Based on the learning from the past process models applicable to other industries and the aviation regulatory framework, this research has developed an LPSI process model for the aircraft maintenance industry. The process model demonstrates different semantically related activities (stages) aggregated together to describe the coarse-grained functioning of the business processes of the aircraft maintenance industry. All the stages of the LPSI process model have the potential to offer learning value to the stakeholders; however, ‘safety communication’ is the formal learning zone for the maintenance staff and the organization in which safety data extracted from investigations are contextualized into safety information and is communicated in written (emails, safety circulars, bulletins, newsletters, etc.) and audiovisual (safety training, human factor training, continuity training, safety meetings, etc.) mode to organizational entities.

8.2.2 INFLUENCING FACTORS

The study identified three essentials for a thriving ‘voluntary reporting’ stage: trust between the reporters and management, the ease of reporting experienced by the reporters, and the usefulness of reporting as perceived by the maintenance staff. Related to the ‘safety investigation’ stage, this study evaluates the contribution of maintenance staff to investigating processes in ascertaining the causal and contributory factors of safety occurrences. This aspect provides insight into the maintenance staff's perception of the 'blame cycle' and the regulatory intent of 'the investigation to prevent a recurrence. 'Safety communication' is a formally structured process, and in the aircraft maintenance industry, safety information drawn from safety investigations is communicated to stakeholders in written form through emails, newsletters, safety circulars, bulletins, etc., and audiovisual modes of safety training, human factor training, continuity training, safety meetings, etc., wherein each method of communication have barriers. The financial implications to the organization are seen as significant factors when planning safety communication, such as training needs analysis, continuity training programs, and human factor training. In the competitive business environment, aircraft maintenance organizations are inclined to demonstrate minimum compliance rather than only consider it a baseline. The LPSI process model and the structural model developed in this study provide a systematic and comprehensive understanding to the decision-makers on the chronic issue of the aviation maintenance industry, i.e., learning from the past. Applying these models allows the senior management to estimate the impact of various factors on learning from the past.

8.2.3 IMPACT MEASUREMENT

The structural model helps prioritize the problems; for example, the various indicators that reflect the 'lack of trust' indicator LT5 (management is production-centric, so I prefer to find my safe solution rather than reporting) have a maximum impact (0.901) as perceived by the maintenance staff. Management has to be cautious about this aspect as it may lead to 'disengaged silence' among maintenance staff and defy the fundamental tenet of the participative and all-inclusive approach of the current safety management system.

Lack of contribution by maintenance staff in safety investigations invariably results in a shortfall of safety information. Thus, safety information about some causal or contributory factors or latent unsafe conditions will likely be excluded from safety communication. The critical indicator reflecting this barrier, as seen by the maintenance staff, is CSIN2 (investigation is time-consuming, with many legal implications, so I refrain from associating with it unless called for by the investigating team), with an impact factor of 0.928. This indicates that the maintenance staff generally view the investigation process differently than the purpose it is meant for. The role of management and the investigating team is crucial to address this point. Honest communication with the organization's maintenance personnel highlighting the investigation's intent before commencing the investigation may encourage maintenance staff to participate without their self-imposed fear.

Contextualizing safety information is one critical activity for safety communication. Safety managers must ensure that the safety information drawn from investigation reports is contextualized in the organizational working processes and environment before communicating it in written and audiovisual modes.

The measurement model indicator OCSC 3 (The regulatory agency evaluates my learning in safety training) with the maximum load factor (0.832) underscores the importance of assessing the knowledge acquired by the maintenance staff in the safety communication stage. In the current framework, regulatory safety oversight is restricted to delivering safety communication rather than verifying its effectiveness. If the organization and regulatory agency are not evaluating the learning outcomes of the safety communication stage, learning from the past is negatively affected.

8.3 CONTRIBUTION TO THEORETICAL FRAMEWORK

A relationship between the 'Risk Triangle' components, the LPSI process model, and reactive methods of hazard identification was established (Figure 7.2). The three-stage 'Aviation Risk Triangle' is not to be seen simply as a ratio between the level of occurrences but underscores that every accident and serious incident has a large number of pre-cursor low-intensity events (accumulated at the base of a triangle). If these low-intensity precursor events are identified and their associated risk is managed on time, major events (accidents and serious incidents) can possibly be prevented. All three stages of ‘Aviation Risk Triangle’ are connected to the ‘reporting’ stage of the LPSI process model. ‘Accidents’ and ‘Serious Incidents’ are linked with the mandatory occurrence reporting stage, while the base of the triangle is with the voluntary reporting stage. Since aviation is considered an ultra-safe industry, inputs from the top side of the triangle (mandatory occurrence reporting) are minimal, as accidents and incidents are rare. The real opportunity exists at the triangle's base regarding leading indicators reported voluntarily by the workers in their day-to-day functioning. This study is synthesized on the fact that organizations are not learning from past safety occurrences and fail to avoid recurrences. This implies that leading indicators (hazards) at the base of the triangle are either not identified or their associated risk is not mitigated timely. This study establishes that in the current SMS, ‘learning from the past’ is potentially related to the improved hazard identification capabilities of the maintenance staff. The maintenance organizations need to harness this information for improved hazard identification and risk management capabilities so that safety threats are managed at the base of the ‘Aviation Risk Triangle’ and occurrences of serious magnitudes are further minimized. While picture-perfect learning from past safety occurrences is a fallacy, maximizing and applying it in continuing safety management practices is a reality and has the potential to enhance the safety of the aircraft maintenance industry.

CHAPTER 9: LIMITATIONS OF THE STUDY, SCOPE FOR FUTURE RESEARCH AND CONCLUSION

The assumptions and the defined context of the study impose several limitations while applying the outcomes universally in the global aircraft maintenance industry. The study is based on the perception of maintenance staff about ‘learning from the past.’ While maintenance staff is a critical asset in an aircraft maintenance organization, the other stakeholders, for instance, middle and senior management, associated regulators, and accident investigators, also play significant roles in safety management. Therefore, their experiences related to the subject (learning from the past) can be instrumental in understanding the subject comprehensively. Another aspect, the organizational commitment towards safety, was limited to their roles in ‘safety communication.’ The other dimensions of organizational commitments to learning from the past, such as financial support, human resource allocation, and technological interventions, can also be considered while developing more detailed models. The measurement model provides each indicator's impact while measuring the key constructs in the Indian context. This may vary, and some more indicators (not considered in this study) are likely to surface while applying in some other contexts. Therefore, management must holistically assess their organizational working culture and consider the indicators applied in this study as a baseline. This study can be the foundation for further building up the concept of learning from the past.

The LPSI process model and the structural model developed in this study provide a comprehensive and systematic understanding to the decision-makers on the chronic issue of the aviation maintenance industry, i.e., learning from the past. The application of these models allows the state regulators and senior management to estimate the impact of various factors on different stages of learning from the past. In this study, scholarly research articles were viewed through the prism of regulatory framework primarily to include the practicalities of hangar floor level. Firstly, the word ‘past’ was evaluated with two different considerations; one is based on accidents and incidents occurrences (rare), while another is associated with hazards and near-misses encountered by the maintenance staff at the workplace (frequent). This approach considerably enhances the availability of safety data and aligns with the contemporary systemic safety management strategy. Secondly, based on the academic research articles and regulatory publications, an aircraft maintenance industry-specific learning process model was developed, which can also be applied to other high-risk ultra-safe industries by combining with the applicable regulatory guidelines to study the learning from past issues. Finally, the structural equation model establishes the relationship between learning from the past and its influencing factors. The primary outcome of this study is as follows:

- When maintenance staff are convinced of the usefulness of voluntary reporting and trust management, they intend to voluntarily report hazards and near-misses to the organizational system, even if the reporting procedure is complicated and inconvenient to them.
- Generally, maintenance staff avoid contributing to safety investigations because they perceive it as time-consuming with legal implications. This eventually leads to the loss of safety information and adversely impacts learning from the past. It is necessary for State regulators and the management to create an atmosphere where frontline aircraft maintainers are proactively involved in the safety investigation process.
- Safety communication has a substantially strong impact on learning from past safety investigations. Presently, no regulatory framework exists to assess the effectiveness of safety communication and associated learning from the past. This may lead to organizations conducting safety communication as an activity without paying much attention to its intent. Demonstrating ‘minimum compliance’ (of safety communication) to regulators eventually wastes resources if the objectives of safety communication are not achieved.

- Contextualizing safety information is critical for effective safety communication, as maintenance staff perceive learning from the past when safety communication is related to their work processes and environment.
- Maintenance staff perceive learning from the past as manifested in enhancing their capabilities to identify workplace hazards.

This study underscores the criticality of the ‘safety communication’ stage in learning from the past process; as such, it is the only established and policy-driven mechanism in aircraft maintenance organizations to share learning content with maintenance staff. State regulators and organizational management can easily adapt the models developed in this study to assess the weak areas in their context in the various stages of the LPSI process model for more efficient safety management.

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Appendix A1

BIRMINGHAM
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7 July 2023

Dear Alok Tyagi

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Yours sincerely

Appendix A2

HARP Questionnaire

HARP Statements							
Please indicate your agreement or disagreement with the statements below. There are no wrong answers.		Strongly Agree	Agree	Slightly Agree	Slightly Disagree	Disagree	Strongly Disagree
Your views on the nature of reality (ontology)							
1	Organisations are real, just like physical objects.	❑	❑	❑	❑	❑	❑
2	Events in organisations are caused by deeper, underlying mechanisms.	❑	❑	❑	❑	❑	❑
3	The social world we inhabit is a world of multiple meanings, interpretations and realities.	❑	❑	❑	❑	❑	❑
4	'Organisation' is not a solid and static thing but a flux of collective processes and practices.	❑	❑	❑	❑	❑	❑
5	'Real' aspects of organisations are those that impact on organisational practices.	❑	❑	❑	❑	❑	❑

HARP Statements							
Please indicate your agreement or disagreement with the statements below. There are no wrong answers.		Strongly Agree	Agree	Slightly Agree	Slightly Disagree	Disagree	Strongly Disagree
Your views on knowledge and what constitutes acceptable knowledge (epistemology)							
6	Organisational research should provide scientific, objective, accurate and valid explanations of how the organisational world really works.	❑	❑	❑	❑	❑	❑
7	Theories and concepts never offer completely certain knowledge, but researchers can use rational thought to decide which theories and concepts are better than others.	❑	❑	❑	❑	❑	❑
8	Concepts and theories are too simplistic to capture the full richness of the world.	❑	❑	❑	❑	❑	❑
9	What generally counts as 'real', 'true' and 'valid' is determined by politically dominant points of view.	❑	❑	❑	❑	❑	❑
10	Acceptable knowledge is that which enables things to be done successfully.	❑	❑	❑	❑	❑	❑
Your views on the role of values in research (axiology)							
11	Researchers' values and beliefs must be excluded from the research.	❑	❑	❑	❑	❑	❑
12	Researchers must try to be as objective and realistic as they can.	❑	❑	❑	❑	❑	❑
13	Researchers' values and beliefs are key to their interpretations of the social world.	❑	❑	❑	❑	❑	❑
14	Researchers should openly and critically discuss their own values and beliefs.	❑	❑	❑	❑	❑	❑
15	Research shapes and is shaped by what the researcher believes and doubts.	❑	❑	❑	❑	❑	❑
Your views on the purpose of research							
16	The purpose of research is to discover facts and regularities, and predict future events.	❑	❑	❑	❑	❑	❑
17	The purpose of organisational research is to offer an explanation of how and why organisations and societies are structured.	❑	❑	❑	❑	❑	❑
18	The purpose of research is to create new understandings that allow people to see the world in new ways.	❑	❑	❑	❑	❑	❑
19	The purpose of research is to examine and question the power relations that sustain conventional thinking and practices.	❑	❑	❑	❑	❑	❑
20	The purpose of research is to solve problems and improve future practice.	❑	❑	❑	❑	❑	❑

HARP Statements							
Please indicate your agreement or disagreement with the statements below. There are no wrong answers.		Strongly Agree	Agree	Slightly Agree	Slightly Disagree	Disagree	Strongly Disagree
Your views on what constitutes meaningful data							
21	Things that cannot be measured have no meaning for the purposes of research.	❑	❑	❑	❑	❑	❑
22	Organisational theories and findings should be evaluated in terms of their explanatory power of the causes of organisational behaviour.	❑	❑	❑	❑	❑	❑
23	To be meaningful, research must include participants' own interpretations of their experiences, as well as researchers' interpretations.	❑	❑	❑	❑	❑	❑
24	Absences and silences in the world around us are at least as important as what is prominent and obvious.	❑	❑	❑	❑	❑	❑
25	Meaning emerges out of our practical, experimental and critical engagement with the world.	❑	❑	❑	❑	❑	❑
Your views on the nature of structure and agency							
26	Human behaviour is determined by natural forces.	❑	❑	❑	❑	❑	❑
27	People's choices and actions are always limited by the social norms, rules and traditions in which they are located.	❑	❑	❑	❑	❑	❑
28	Individuals' meaning-making is always specific to their experiences, culture and history.	❑	❑	❑	❑	❑	❑
29	Structure, order and form are human constructions.	❑	❑	❑	❑	❑	❑
30	People can use routines and customs creatively to instigate innovation and change.	❑	❑	❑	❑	❑	❑

Your answer scores

Give yourself the points as indicated below for each answer within each philosophical tradition. The different philosophies are represented by specific questions in the HARP as indicated below. Fill each philosophy table with your answer scores, then total up the numbers for each philosophy. (For your reference, in the tables below, the letters in brackets indicate whether the question tests your agreement with the ontological, epistemological, axiological, purpose of research, meaningfulness of data and structure and agency aspects of research philosophy.)

Each answer you gave is given a number of points as shown in the table below:

Strongly agree	Agree	Slightly agree	Slightly disagree	Disagree	Strongly disagree
3	2	1	–1	–2	–3

Heightening your Awareness of your Research Philosophy (HARP)

Positivism: Questions 1, 6, 11, 16, 21, 26

Question	1 (ontology)	6 (epistemology)	11 (axiology)	16 (purpose)	21 (data)	26 (structure/ agency)	Total
Answer score							

Critical Realism: Questions 2, 7, 12, 17, 22, 27

Question	2 (ontology)	7 (epistemology)	12 (axiology)	17 (purpose)	22 (data)	27 (structure/agency)	Total
Answer score							

Interpretivism: Questions 3, 8, 13, 18, 23, 28

Question	3 (ontology)	8 (epistemology)	13 (axiology)	18 (purpose)	23 (data)	28 (structure/agency)	Total
Answer score							

Postmodernism: Questions 4, 9, 14, 19, 24, 29

Question	4 (ontology)	9 (epistemology)	14 (axiology)	19 (purpose)	24 (data)	29 (structure/agency)	Total
Answer score							

Pragmatism: Questions 5, 10, 15, 20, 25, 30

Question	5 (ontology)	10 (epistemology)	15 (axiology)	20 (purpose)	25 (data)	30 (structure/agency)	Total
Answer score							

Reflection

Now, for the first of what will almost certainly be many philosophical reflections, consider the following questions regarding how you scored yourself.

1. Do you have an outright philosophical winner? Or do you have a close contention between two or more philosophies?
2. Why do you think this is?
3. Which philosophy do you disagree with the most?
4. Why do you think this is?

Appendix A3

Survey Questionnaire: Primary Data Collection Tool

Dear Participant

We appreciate your participation in this survey. The information you provide will solely be utilized for this research and will not be shared with anyone else. This survey form is part of our research work**.** Our study's topic is " **The Paradigm of Reactive Methodology-Based Hazard Identification in the Aircraft Maintenance Industry: An Empirical Evaluation in the Safety Management Framework.**"

The following points are to brief you on the context of the questionnaire :

1. The questionnaire is designed to **know the perspective of front-line maintenance staff** working in line and/or major aircraft maintenance facilities, including the components and engine shops. *So, even if you are not deployed in any of the above maintenance areas but have previously worked, we request you utilize your experience while responding to the questionnaire.*

2. The questionnaire has a total of 6 **Sections.**

3. **Section 1** is to collect the participants' demographic profiles, while sections 2 to **6** are the survey questions. A brief outline of the questions' context is described at the beginning of each section.

Note:

Maintenance Staff: The term "maintenance staff" includes but is not limited to licensed aircraft maintenance engineers (AMEs), hangar floor supervisors, workshop supervisors, non-certifying staff working with AMEs in tool and component stores, monitoring and updating components, engine, and aircraft performance and utilization data, etc., in EASA Part 145 and/or Continuing Airworthiness Management Organizations (CAMO) approved facilities.

Terms for instance, "safety data," "safety information," "causes," and "contributory factors" are used as defined in ICA0 Annex 13, twelfth edition (ICA0, 2020), and "safety occurrences" implies accidents, serious incidents, and incidents.

Section:1

1. **Age**

   (a) Less than 30 years

   (b) 31 years to 40 years

(c) 41 years to 50 years

(d) More than 50 years

2. **Gender**

(a) Male

(b) Female

(c) Others

3. **Highest Academic Qualifications**

(a) High School

(b) Intermediate (10+2)

(c) Bachelor's

(d) Postgraduate or higher

4. **Total Aircraft Maintenance experience**

(a) Ten years or less

(b) 11 years to 20 years

(c) 21 years to 30 years

(d) More than 30 years

5. **Have you undergone any Safety Management System (SMS) training in-house by your employing organization or in a regulatory-approved training establishment?**

(a) Yes

(b) No

6. **Your license or authorization details (currently held or held in the past)**

(a) Category A1

(b) Category B1 or B2 or C

(c) Others (Aircraft Maintenance Approvals)

Section:2

Section 2 evaluates the attitude of the maintenance staff on voluntarily reporting hazards or near misses at their workplace. As a maintenance staff, I prefer not to report voluntarily the hazards and near misses observed in day-to-day maintenance activities to management because:

Sl. No.	Statement	Strongly Agree	Agree	Neither Agree nor Disagree (Neutral)	Disagree	Strongly Disagree
		1	2	3	4	5
1.	Voluntary reporting of hazards may characterize me as a trouble-creator for management.					
2.	Voluntary reporting will adversely affect my career growth.					
3.	If I disclose my errors, my organization has no "Waiver of Disciplinary Action" policy to protect my interest.					
4.	The voluntary report-receiving agency is not independent of my employing and regulatory organizations.					
5.	Management is production-centric, so I prefer to find my safe solution rather than report.					
6.	Voluntary reporting will invite an additional workload for me. (Additional workload: Producing evidence, more detailed information, and multiple explanations to different people in the hierarchy, etc.)					
7.	The voluntary Reporting procedure is very time-consuming.					
8.	The voluntary Reporting procedure is narrative.					
9.	I lost interest in voluntary reporting as the investigation is time-consuming.					
10.	I am not confident about what to report and not to report under voluntary reporting.					
11.	I do not visualize any benefit if I report the hazards voluntarily.					
12.	I do not consider voluntary hazard reporting as critical safety information.					

13.	I perceive the word ‘reporting’ as being against someone (colleagues/ seniors/organization).					
14.	Generally, maintenance staff is unaware of organizational policy related to investigating voluntary reports.					
15.	My organizational 'voluntary report investigating policy' does not provide a clear time frame for investigating the reported issues.					

Section:3

Section 3 evaluates the attitude of maintenance staff to contribute to maintenance-related investigations. While investigating a maintenance-related accident at my workplace, my attitude towards contribution to the investigation :

Sl. No.	Statement	Strongly Agree	Agree	Neither Agree nor Disagree (Neutral)	Disagree	Strongly Disagree
		1	2	3	4	5
16.	I consider a safety investigation aims to blame someone for the accident.					
17.	An investigation with many legal implications is time-consuming, so I refrain from associating with it unless called for by the investigating team.					
18.	I do not perceive the safety investigation as a means to improve safety.					
19.	I avoid contributing to the investigation even if I have some relevant information because I perceive that I may be in trouble.					
20.	The investigation is fault-finding rather than establishing the root causes for recurrences.					

Section:4

Section 4 evaluates the Contextualization of safety information. Written communication means safety circulars, bulletins, newsletters, emails, etc. Maintenance staff experienced based views on the safety investigation reports (MORs and VRs) and safety information drawn from investigation reports. Information. Audio-visual communication means various training programs, such as safety training, human factor training, continuity training, safety meetings, focus groups, etc. Maintenance staff's experience receiving and learning safety information from the investigations (MORs and VRs):

Sl. No.	Statement	Strongly Agree	Agree	Neither Agree nor Disagree (Neutral)	Disagree	Strongly Disagree
		5	4	3	2	1
21.	I always receive contextualized safety communication in my organization. (Contextualized means related to my work practices, work environment, etc.)					
22.	Written safety communication (bulletins, emails, circulars, newsletters, etc.) includes updated safety information from past safety investigations of accidents/incidents in my organization.					
23.	Written safety communication (bulletins, emails, circulars, newsletters, etc.) includes updated safety information drawn from the investigations of my organization's voluntary reports.					
24.	Written safety communication guides me in incorporating changes in my work when applicable.					
25.	Audiovisual safety communication (Safety training, human factor training, continuity training, etc.) includes updated safety information drawn from past safety investigations of					

	accidents/incidents in my organization.					
26.	Audiovisual safety communication (Safety training, human factor training, continuity training, etc.) includes updated safety information from past safety investigations of my organization's voluntary reports.					
27.	In audiovisual safety communication, human factors are discussed in my organizational context.					
28.	The contents of safety communication always remain in my memory; therefore, no repetition in any other form is needed.					
29.	Safety communication provides an in-depth understanding of hazards at my workplace.					
30.	Safety communication makes me more capable of identifying hazards in my work.					

Section:5

Section 5 evaluates the organizational importance of Safety Training. Maintenance staff's perception of the importance given by the organization to various safety trainings:

Sl. No.	Statement	Strongly Agree	Agree	Neither Agree nor Disagree (Neutral)	Disagree	Strongly Disagree
		5	4	3	2	1
31.	All the managers, including the Accountable Manager, invariably attend the safety training.					
32.	My employing organization evaluates my learning in safety training.					
33.	The regulatory agency evaluates my learning in safety training.					

34.	The regulatory agency regularly evaluates the contents of safety training.					
35.	Safety training is conducted creatively to enhance the interest of participants.					
36.	If additional training is needed to incorporate changes in my work to comply with safety information, the management promptly provides it.					
37.	In safety training, the latest technological tools are applied to facilitate learning.					

Section:6

Section 6 evaluates the learning indicators applicable to maintenance staff. As a maintenance staff, I perceive the learning from past investigations for hazard identification and risk assessment context:

Sl. No.	Statement	Strongly Agree	Agree	Neither Agree nor Disagree (Neutral)	Disagree	Strongly Disagree
		5	4	3	2	1
38.	I perceive learning when my awareness of the hazards at my workplace is consistently updated.					
39.	I perceive the learning when my learning outcomes are evaluated each time I attend safety training.					
40.	I perceive learning when safety information is integrated with my maintenance work procedures.					
41.	I perceive the learning when safety information is consistently repeated in safety training.					
42.	I perceive learning when I start applying it at work.					

Appendix A4

SCHOLAR'S CURRICULUM VITAE AND LIST OF PUBLICATION

Current Status:

- Ph.D. Scholar, School of Business, University of Petroleum and Energy Studies (UPES), Dehradun, India
- Empaneled Subject Matter Expert (Engg.) for three years w.e.f. Sep 21 with the Aircraft Accident Investigation Bureau (AAIB), Ministry of Civil Aviation (MoCA), India
- Visiting Faculty: UPES and Chitkara University, India

Executive Summary

- Over 24 years of Aviation industry experience in different roles and responsibilities: qualified aircraft maintenance engineer, safety compliance officer, incident/accident investigator, aircraft spares supply contract expert, instructor, and examiner.
- An academician for the last six years with three years of teaching experience to aircraft maintenance management students at Abu Dhabi Polytechnic, Al Ain, UAE, and around two years of experience with BBA and MBA (Management) students at Indian universities.
- Five years experience as Head of the Aircraft Component Overhaul Division at a military MRO in Kanpur, India.
- Four years' experience as Head of Maintenance and Training on Boeing 737 (used for the Prime Minister and President of India).
- Deft at drafting, negotiating, and executing aircraft spare procurement and long-term service support contracts and conducted a study to draft performance-based logistics (PBL) contracts in a defense environment.
- European Aviation Safety Agency (EASA) approved aviation instructor and examiner.
- International Air Transportation Association (IATA) approved instructor.
- An alumnus of the Toulouse Business School (TBS), Toulouse, France, and the Indian Institute of Management (IIM), Bangalore, India.

Academic Credentials

Pursuing Ph.D. Management (Aviation)	Enrolled in Jul 2018
MBA (Aerospace Management) from TBS, Toulouse, France	Sep 2017
General Management Programme, IIM, Bangalore, India	Apr 2015
B. Tech (Mech.), KNIT, Sultanpur (U.P.), India	May 1993

Certifications

Post Holder, CAR147,& CAR 66 Training, IACT, Dubai, UAE	2021
Train the Trainer course, Global Aerospace Logistics, Abu Dhabi, UAE	2019

Certified by IAF to carry out and supervise the ROH of aircraft Components	2005
Certified by DGCA for idle power engine run-up of Boeing 737	2005
Certified by DGCA to carry out and supervise Line Maintenance on Boeing 737	2002
Airframe and Engine type rated (B737) course (DGCA approved), India	2001
Aeronautical Engineers and flight safety course from AFTC, Bangalore, India	1996

Career Profile

Conducted IATA-approved 'Cargo Introductory Course' at Chitkara University, India	Jan'24-Mar' 24
Visiting Faculty in the School of Business, U.P.E.S., Dehradun, India	Jan'22- Aug'23
Aviation Instructor, Abu Dhabi Polytechnic, Al Ain, UAE	Jan'19 – Dec' 21
Opted for premature separation from IAF as Wing Commander	Jul'2017
Strategy Development Officer, DRDO Bangalore, India	Dec'14 – Jul' 17
Joint Director (Contracts), IAF HQs, New Delhi, India	Apr'10 – Dec'14
Head of Component OH Division at military MRO, Kanpur, India	Apr'05 – Mar'10
Head of Maintenance & Training of VVIP ac, New Delhi, India	Apr'01 – Mar'05
Line maintenance in charge of Transport aircraft, Agra, India	Sep'97 – Apr'01
Commissioned in Engineering branch in the IAF & Training, Bangalore, India	Nov'94 – Sep'97

Publications

Tyagi, A., Tripathi, R., & Bouarfa, S. (2023). Learning from Past in the Commercial Air Transport Industry: A Bibliometric Analysis and Systematic Literature Review in the Safety Management Framework. *International Journal of Aviation, Aeronautics, and Aerospace, 10*(3). DOI: https://doi.org/10.58940/2374-6793.1838

Tyagi, A., Tripathi, R., & Bouarfa, S. (2023). Learning from past in the aircraft maintenance industry: An empirical evaluation in the safety management framework. *Heliyon*. https://doi.org/10.1016/j.heliyon.2023.e21620

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THE PARADIGM OF REACTIVE METHODOLOGY-BASED HAZARD IDENTIFICATION IN AIRCRAFT MAINTENANCE INDUSTRY: AN EMPIRICAL EVALUATION IN THE SAFETY MANAGEMENT FRAMEWORK

by Alok Tyagi

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