BRIDGING MAINTENANCE ERROR TAXONOMIES AND SAFETY MANAGEMENT SYSTEMS: A STRUCTURED CRITICAL REVIEW OF AVIATION MAINTENANCE HUMAN FACTORS

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Abstract: Aircraft maintenance is a critical aviation safety function since any errors can remain latent and later interact with the flight operations or inspection failures. This paper critically reviews aircraft maintenance human factors by integrating accident evidences, maintenance-error taxonomies and also proactive safety-management researches. Following the PRISMA-aligned screening process, 24 sources were retained, which included peer-reviewed studies and foundational works on error classification and organizational accident theory. On the whole, the review shows that maintenance error is rarely caused by a single unsafe act. Instead, it typically results from interactions among fatigue, workload, procedures, documentation, training, communication, supervision and organizational pressures. Furthermore, this study highlights the limitations of retrospective tools such as MEDA and HFACS-ME, and proposes a practical framework linking error reports, structured coding, recurrent factors, SMS risk registers, safety performance indicators, preventive controls and continuous monitoring. It argues that future research should focus less on creating new taxonomies and more on connecting classification with prevention.

Keywords: aircraft maintenance, fatigue, human factors, maintenance error, safety management system

1. Introduction

Aircraft maintenance is one of the most safety-critical functions in the aviation industry because it directly affects airworthiness, dispatch reliability and also operational resilience. Unlike most flight-deck errors, maintenance errors may remain latent until their effects finally become evident in combination with subsequent operations, environmental conditions or later inspection failures. This latent character makes maintenance-related risk difficult to detect, quantify and also control using only outcome-based accident statistics [1]-[2]. Literatures on human factors have repeatedly shown that aviation maintenance cannot be simply understood as a matter of individual carelessness. In aviation, the maintenance work is performed in dynamic operational environments that are characterized by shift work, interruptions, incomplete feedback, time pressure, environmental discomfort, distributed teams and heavy reliance on manuals, technical orders, handovers, tooling and organizational procedures [1, 3]. In such settings, error is shaped by the interaction between the worker and the system rather than by the worker alone.

To date, several influential approaches have attempted to make the maintenance error more visible and actionable. Early works described the maintenance environment and its performance constraints [1, 4]. Decision-support and training approaches such as the Maintenance Error Decision Aid (MEDA) helped organizations investigate maintenance events and identify contributing factors [5]-[6]. Later, the

Human Factors Analysis and Classification System-Maintenance Extension (HFACS-ME) provided a structured way to classify unsafe acts and latent organizational conditions in maintenance events [7]-[9]. In parallel, studies on fatigue, documentation quality, safety climate, leadership, and also reporting showed that maintenance safety depends not only on the retrospective event investigation but also on the proactive management of organizational conditions [10]-[16]. However, despite this progress, the literature can be taken to remain essentially fragmented. One stream focuses on accidents, incidents, and occurrence evidence. In the meantime, the second stream focuses on taxonomies such as MEDA and HFACS-ME, while the third stream examines the safety management systems, reporting, fatigue management, safety leadership, and organizational learning. These streams are connected but they are often reviewed separately. Consequently, the field still lacks a clear explanation of how organizations can move from classifying past maintenance failures to designing forward-looking controls that reduce recurrence.

This paper addresses this identified gap through a structured critical review. The central argument is that the most important unresolved issue of human factors in the aviation maintenance is no longer whether the maintenance error matters since this has already been established. The unresolved issue is how retrospective error knowledge can be effectively operationalized within the proactive maintenance safety management. The review therefore examines three key questions: what human and organizational factors are most consistently associated with aircraft maintenance error, what do current maintenance-error taxonomies explain well and where are their limits, and how can the insights from accident and classification studies be translated into proactive SMS practice? On the whole, the contribution of this paper lies in integrating these questions into a single conceptual structure. Rather than treating HFACS-ME, fatigue, documentation quality, safety climate, and SMS as isolated topics, the review treats them as connected elements of one maintenance-safety problem.

2. Methodology

The work in this study adopts a structured critical review design with PRISMA-aligned search and screening logic. The review is not framed as a statistical meta-analysis because the aviation maintenance human factors literature is heterogeneous in research design, sample type, analytical unit and outcome variable. In general, the retained literature includes accident and occurrence analyses, taxonomy-driven classification studies, survey-based behavioral research, technical documentation studies, safety climate research and conceptual or institutional sources that introduced foundational methods. Under these conditions, statistical pooling would essentially create a false impression of comparability. A structured critical review is therefore more suitable because the goal is conceptual integration rather than numerical aggregation [15]. It should be noted that the term PRISMA-aligned is used deliberately here. The review uses transparent search terms, eligibility rules and also screening logic, but it does not claim to be a full systematic review or meta-analysis. This distinction is important because this paper aims to synthesize mechanisms and practical implications rather than estimate pooled effect sizes.

The review is guided by the following questions: how do human factors contribute to the aircraft maintenance error, how have these errors been classified in the literature, and how can classification knowledge be linked to proactive safety management in aviation maintenance organizations? The scope has been limited to literature directly relevant to the aircraft maintenance work, maintenance-induced events, maintenance-error classification, safety climate, fatigue, training, supervision, organizational influences, documentation quality and SMS-oriented prevention. Overall, this review does not include general human factors literature unless it directly supported an aviation maintenance mechanism or a foundational safety-management concept.

The search strategy used in this study combines keyword searching, publisher-platform checking, and backward citation tracing. Searches are conducted across broad academic and publisher platforms including Scopus, Web of Science, ScienceDirect, SpringerLink, Taylor & Francis Online, Wiley Online Library, and Google Scholar. Foundational sources are also checked through publisher, institutional or DOI records where available. The main Boolean search strings combined aviation maintenance terms with human factors and safety-management terms. Examples included: ("aircraft maintenance" OR "aviation maintenance") AND ("human factors" OR "maintenance error"); ("aircraft maintenance" AND "HFACS-ME"); ("aviation maintenance" AND "fatigue"); ("aircraft maintenance" AND "safety climate"); ("maintenance error" AND "safety management system"); and ("technical documentation" AND "maintenance reliability"). The search covers literature from the late 1990s to 2026, which allows inclusion of foundational maintenance human factors work and recent studies on fatigue, safety climate, and maintenance safety behavior.

Furthermore, to address source consistency, the revised review distinguishes between two types of retained sources. First, peer-reviewed journal articles form the primary evidence base for the synthesis of fatigue, workload, documentation, safety climate, safety behavior, safety management and also maintenance-error mechanisms. Second, selected non-journal sources are retained only when they were foundational to the field such as Reason's organizational accident model, Boeing MEDA, HFACS, and institutional or conference documents that introduced and/or documented any historically important maintenance human factors concepts [1, 4, 5, 7, 8, 13, 17]. In short, a source is included when it met at least one of the following criteria: direct focus on aircraft and/or aviation maintenance; analysis of maintenance-induced events, deviations and/or contributing factors; development or application of a maintenance-error taxonomy; evidence on fatigue, documentation, communication, supervision, safety climate, training and/or reporting in maintenance; or foundational relevance to maintenance human factors or organizational safety theory. Sources have been excluded when they are not aviation-related, not maintenance-focused, lacked human factors or safety-management component, duplicated another source without adding conceptual value, or had unverifiable bibliographic information. Effectively, this clarification helps to resolve methodological inconsistency that can arise when a review claims purely journal-only citation base while also relying on classical books, conference papers and institutional documents. In this present synthesis, journal articles are treated as the primary empirical evidence base, while selected non-journal sources are used as foundational background.

The screening process in this study follows a PRISMA-aligned sequence of identification, duplicate removal, title-and-abstract screening, full-text eligibility assessment and final inclusion. The search and backward-citation process has initially produced 68 candidate records. After removing 11 duplicate records, 57 records are then screened by title and abstract. At this stage, 21 records are excluded because they were not directly focused on aviation maintenance, did not address human factors or maintenance-error mechanisms and/or were not relevant to safety-management practice. The remaining 36 reports are sought for full-text assessment. During full-text eligibility assessment, 12 reports are excluded. The main reasons for their exclusion are: non-maintenance focus, general aviation safety content without aircraft-maintenance relevance, insufficient discussion of human factors, lack of relevance to error classification or SMS practice, or unverifiable bibliographic details. The final retained corpus therefore is consisted of 24 sources. Of these, 14 peer-reviewed journal articles form the primary evidence base for the synthesis while 10 foundational or contextual sources are retained to explain the historically important concepts, taxonomies, institutional practices, or organizational accident theory. The analytical synthesis compared convergence and divergence across three clusters: Cluster A – accident and event evidence; Cluster B – taxonomies and explanatory frameworks; and Cluster C – proactive safety-management research. This approach is selected because the major opportunity in the field is not to repeat lists of contributing factors but to show how similar maintenance human-factor mechanisms recur across retrospective event analysis and prospective safety-management practice.

Table 1 summarizes the review protocol and eligibility logic used in this study while Figure 1 shows the search and backward-citation process. As previously stated, the process has identified 68 candidate records. After duplicate removal, 57 records are screened, 36 reports are assessed for eligibility, and 24 sources are retained for final synthesis, which is consisted of 14 peer-reviewed journal articles and 10 foundational/contextual sources.

Table 1: Review protocol and eligibility logic used

Protocol element	Revised specification
Review type	Structured critical review with PRISMA-aligned search and screening logic; not a statistical meta-analysis.
Search platforms	Scopus, Web of Science, ScienceDirect, SpringerLink, Taylor & Francis Online, Wiley Online Library, Google Scholar, and backward citation tracing.
Search period	Foundational literature from the late 1990s onward; recent studies considered up to 2026.
Core terms	aircraft maintenance; aviation maintenance; human factors; maintenance error; HFACS-ME; MEDA; fatigue; workload; safety climate; safety management system; reporting; documentation quality.
Primary inclusion criteria	Direct relevance to aviation maintenance, maintenance-induced events, human factors, error classification, organizational conditions, or proactive safety management.
Primary exclusion criteria	Non-aviation sources, non-maintenance studies, duplicate records, sources without human-factors relevance, inaccessible full text, or unverifiable bibliographic details.
Final corpus	24 retained sources: 14 peer-reviewed journal articles for evidence synthesis and 10 foundational/context sources for taxonomy, theory, or institutional background.

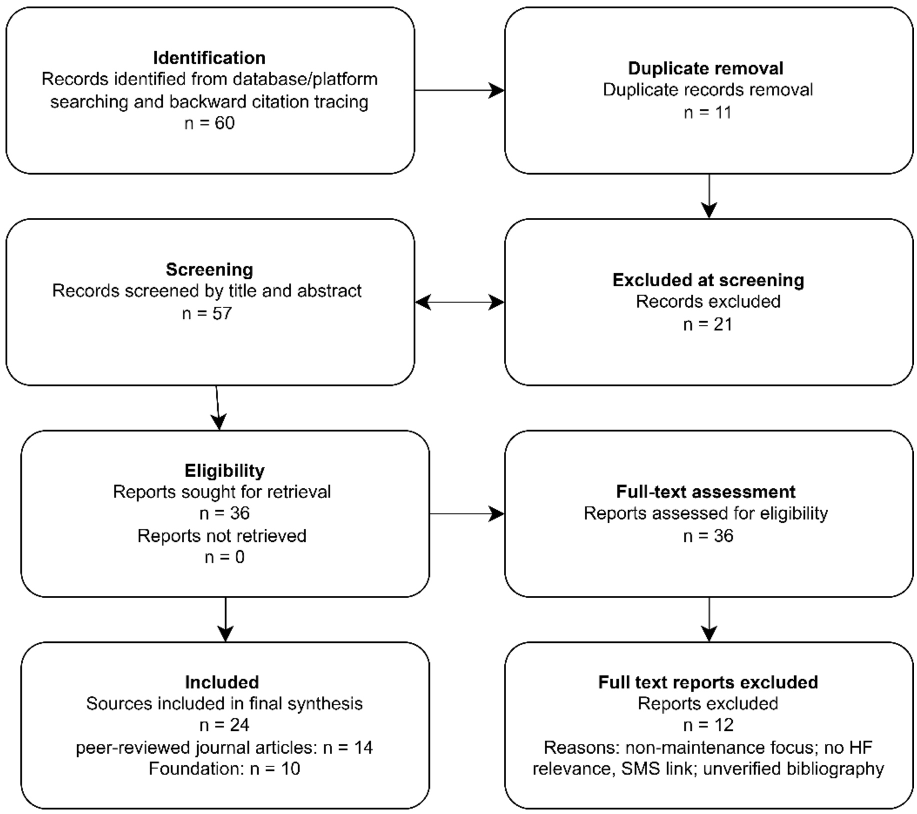

Figure 1: PRISMA-aligned screening logic and final retained corpus used for the structured critical review in this study

3. Human Factors Context of Aircraft Maintenance

Earliest core reviews in this field have established a point that remains valid: aviation maintenance is a context in which generic human performance limitations interact with domain-specific constraints [1, 4]. Maintenance technicians do not work in a stable, repetitive environment. They deal with system complexity, limited access to components, shift turnover, schedule pressure, environmental discomfort and uneven feedback about operational consequences of their work. Unlike flight crews, maintenance personnel are often physically and temporally distant from the eventual outcome of a subtle omission or deviation. Such distance has essentially weakened the error visibility and increases the importance of procedures, inspection, handover quality, and organizational memory [1, 3].

The studies of unsafe acts in maintenance have further reinforced this systems perspective. Hobbs and Williamson showed that maintenance outcomes cannot be reduced to simple rule-breaking because skill-based errors, mistakes and violations emerge within broader task and organizational conditions [2]. Ground-damage and occurrence evidence similarly suggests that the maintenance-related human error is often rooted in task design, coordination, equipment use, communication and situational complexity rather than individual negligence alone [3]. This distinction is practically vital because the maintenance organizations might still respond to any deviations by emphasizing individual discipline, retraining or reminders. Such responses are necessary in some cases but they are rarely sufficient. If error pathways are created by the staffing pressure, unclear procedures, poor tooling, fatigue, weak supervision or poor reporting climate, then a person-centered corrective action will not remove the underlying condition. A systems perspective therefore shifts the question from 'who failed?' to 'what conditions made this failure more likely and what control should be strengthened?'

The maintenance environment also differs from the cockpit operations in terms of feedback. A technician may complete a task successfully from a local procedural standpoint but never observe the later operational consequences of a minor omission. This weak feedback loop means that high-quality documentation, independent inspection, team communication and also the reporting systems are not administrative additions; they are direct safety controls.

4. Major Human-Factor Mechanisms Identified in the Literature

The reviewed literature identifies several recurring mechanisms. While accident-severity estimates vary depending on dataset, event definition and time period, the underlying mechanisms are relatively stable: fatigue and workload, documentation quality, training and competence, communication and reporting, supervision, safety climate and organizational pressure. These mechanisms do not operate separately. In practice, they often interact. For example, fatigue can reduce the checking behavior, poor documentation can increase the memory reliance and schedule pressure can also suppress reporting or encourage workarounds.

Fatigue is one of the most persistent themes in aviation maintenance research. Wang and Chuang found that psychological and physiological fatigue vary across line-maintenance work and are influenced by task demands and work conditions [10]. More recently, da Silva and colleagues reported significant relationships between fatigue, workload, sleepiness and also quality-of-life indicators among aircraft maintenance personnel [11]. These findings support the longstanding concern that maintenance fatigue has often been managed less systematically than flight-crew fatigue. Fatigue matters not only because it reduces alertness but also because it can degrade checking behaviour, memory, communication quality, judgment and willingness to challenge unsafe conditions under time pressure. It is therefore a bridge variable between individual performance and organizational design. In practical terms, fatigue should not be simply treated as a personal weakness. It is affected by rostering, overtime, staffing, shift design, recovery opportunity, and organizational tolerance for degraded performance.

Meanwhile, maintenance documentation is often treated as an administrative issue but the literature indicates that it is a direct human-factors variable. Hsia demonstrated that the readability of technical documentation can affect user performance [6]. In aviation maintenance, documentation is operational control: it shapes task interpretation, sequencing, inspection and sign-off behaviour. Poor readability, fragmented procedures, ambiguous wording, inconsistent revisions and difficult access to the current information can create error pathways even when technicians are experienced and motivated. This issue becomes more serious when organizations assume that procedural compliance alone is sufficient for safety. Compliance depends on whether the procedure is understandable, usable, current, available at the point of work and consistent with real maintenance conditions. A poorly designed procedure can increase reliance on memory, informal workarounds and undocumented local knowledge, all of which increase the probability of maintenance deviation.

Furthermore, training is another recurring mechanism but the evidence suggests that training is most effective when it is tied to actual task competence rather than regulatory completion alone. Walter emphasized that the competency-based on-the-job training should be structured around the real work performance and human-factors demands rather than checklist completion [12]. Task-support tools and assistance platforms can also improve adherence by making the correct information available at the point of work [7]. Training should therefore be interpreted broadly, which includes initial qualification, recurrent learning, task-specific familiarization, cross-shift coordination skills, error management and capability to recognize degraded system states. A poor training can amplify the effects of fatigue, poor documentation and time pressure because technicians have fewer cognitive and procedural resources available when the environment becomes demanding.

Moreover, communication is central to maintenance because the work is distributed across people, shifts, specializations and locations. Failures in handover, reporting and coordination will allow small deviations to persist until they become operationally significant. Safety climate research indicates that safety leadership and organizational climate influence safety behaviour among the aircraft maintenance technicians [16]. This means that safety culture cannot be evaluated only from the formal documents or stated policy. It must be judged by whether personnel actually speak up about unsafe conditions and whether leadership responses reinforce or suppress such reporting. Communication problems are rarely isolated events. They typically reflect deeper organizational properties such as hierarchy, blame, work pressure, insufficient staffing or weak interdepartmental coordination. A narrow corrective action that only instructs the staff to 'communicate better' might fail unless the broader organizational conditions supporting poor communication are also addressed.

In addition, supervisory and organizational influences are critical because they shape the conditions under which the technicians perform. Time pressure, resource shortages, unclear priorities, weak task planning and inconsistent supervision can normalize shortcuts. HFACS-ME is useful here because it explicitly directs attention beyond the technician-level act toward supervisory and organizational conditions [7]-[8]. Organizational pressure does not always appear as an explicit instruction to violate a procedure. More often, it appears through the production targets, turnaround expectations, repeated overtime, insufficient staffing, poorly designed handovers and also the implicit signals about what the organization rewards. In such environments, maintenance deviations may become locally rational even when they create system risk.

The summary of these identified recurrent maintenance human-factor mechanisms and also their safety-management relevance is presented in Table 2.

Table 2: Recurrent maintenance human-factor mechanisms and their safety-management relevance

Mechanism	Typical error pathway	Representative sources	SMS implication
Fatigue and workload	Reduced attention, memory, checking, and communication under high demand	[10, 11]	Monitor duty time, overtime, sleepiness, task loading and recovery opportunity
Documentation quality	Ambiguous or unusable procedures increase memory reliance and local workarounds	[6]	Audit readability, revision control, availability and procedural usability
Training and competence	Formal qualification may not guarantee task-specific competence under real conditions	[7, 12]	Link training to recurrent defects, task risk, competence evidence and observed performance
Communication and reporting	Weak handovers and poor reporting allow small deviations to persist	[14, 16, 18]	Track reporting rate, handover quality, near-miss themes and corrective-action closure
Supervision and organization	Schedule pressure, staffing limits, and weak oversight normalize shortcuts	[7, 8, 9]	Connect recurrent HFACS-ME/MEDA codes to risk registers, audits and management controls

5. Maintenance-Error Classification Systems

Maintenance-error classification systems provide a structured language for moving beyond blame. They help investigators organize contributing factors, compare events and identify latent conditions. However, the classification does not automatically produce prevention. A taxonomy becomes useful only when its categories are linked to the risk controls, safety performance indicators and organizational learning.

The Maintenance Error Decision Aid (MEDA) is developed to support investigation and learning from maintenance events [5]. Its central value is that it directs attention to contributing factors rather than only the final error. MEDA encourages organizations to ask why a technician's action made sense in context and what surrounding conditions that make the deviation possible. This supports a learning-oriented approach and helps reduce tendency to treat maintenance error only as individual negligence. The main practical strength of MEDA is its accessibility for organizational investigation. It can support internal reporting and corrective action because it is designed around real maintenance event analysis. Its limitation is that it remains dependent on the quality of the investigation, the openness of reporting culture and the organization's willingness to act on systemic contributors. Without these conditions, MEDA can become a documentation exercise rather than a prevention tool.

On the other hand, HFACS-ME extends the broader Human Factors Analysis and Classification System to the maintenance context. Its value lies in its multilevel structure, which distinguishes unsafe acts from preconditions, supervisory influences, and organizational factors [7]-[9]. This structure is especially useful in maintenance because many of the deviations originate in latent conditions including inadequate task planning, poor documentation, fatigue-producing schedules and/or weak supervisory controls. HFACS-ME helps investigators to see how technician-level actions are embedded within a broader system. For example, an incorrect installation may be associated with attention failure at the technician level but the deeper contributing factors may include poor lighting, time pressure, unclear manuals, insufficient independent inspection and normalized deviation from procedures. By making these layers visible, HFACS-ME supports stronger causal explanation than a simple unsafe-act label.

Although MEDA and HFACS-ME are useful, their limitations must be recognized. First, they are primarily retrospective. They organize what has already happened but they do not automatically predict where the next risk will occur. Second, they depend on reporting quality. If personnel fear blame or if near misses are not reported, the classification database will underrepresent the important risks. Third, coding reliability can vary between the investigators, especially when event information is incomplete or when categories overlap. Fourth, classification systems may identify the repeated contributing factors without forcing the organization to assign any preventive controls, owners, deadlines and effectiveness measures. These limitations do not make taxonomies unimportant. Rather, they define the conditions under which taxonomies become useful. Classification should be treated as the first step of the safety-management cycle, not the final product. A coded event should trigger trend analysis, comparison with audit findings and translation into the SMS risk register. The recurrent codes should become safety performance indicators. Corrective actions should be tracked for effectiveness, not merely closure. In this sense, value of HFACS-ME or MEDA depends on whether the organization converts retrospective knowledge into proactive control.

6. Proposed Framework for Connecting Classification with Proactive SMS

To make the review more practically applicable, a simple framework for translating retrospective maintenance error classification into proactive SMS-based safety control is proposed. The framework is not intended to replace MEDA, HFACS-ME, or organizational SMS processes. Instead, it connects them. Its purpose is to show how maintenance organizations can move from event coding to prevention design in a repeatable way. The framework begins with retrospective maintenance event data, including maintenance occurrence reports, inspection findings, quality escapes, audit findings, deferred defects and near-miss reports. These data are coded using MEDA, HFACS-ME or compatible local taxonomy. The organization then identifies the recurrent contributing factors rather than treating events as isolated cases. Furthermore, repeated codes related to fatigue, workload, documentation, supervision, training or communication are transferred into the SMS risk register and converted into safety performance indicators. The preventive controls are then assigned, implemented and monitored through audit and feedback.

Figure 2 depicts this proposed framework while Table 3 highlights the practical translation from the classification findings to the proactive SMS controls through this proposed framework.

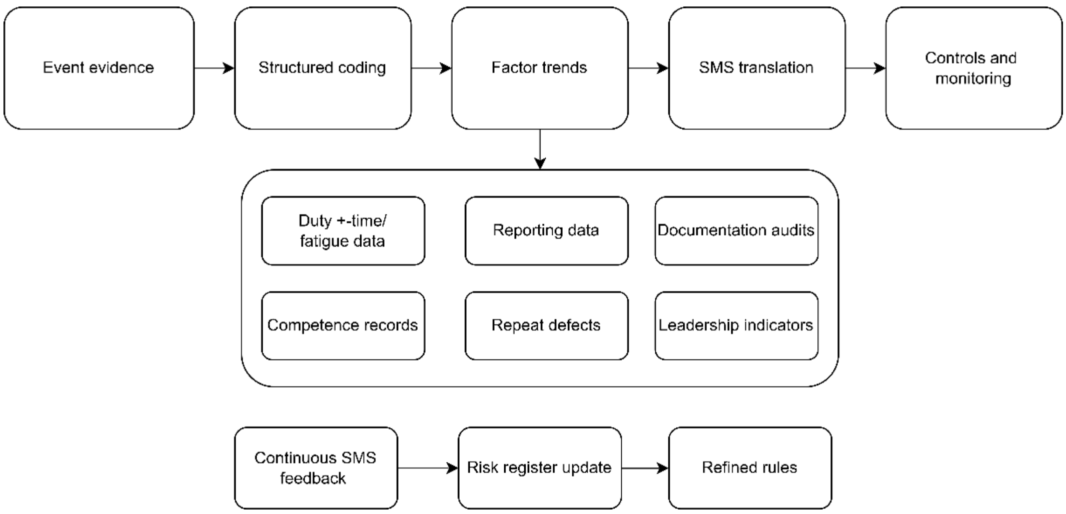

Figure 2: Proposed framework for translating maintenance-error classification into proactive SMS-based safety control

Table 3: Practical translation from classification findings to proactive SMS controls

Recurring Classification Pattern	Possible SMS Indicator	Preventive Control	Effectiveness Check
Fatigue or attention-related maintenance deviations	Overtime hours, shift length, self-reported sleepiness, repeated night-shift defects	Rostering redesign, fatigue reporting, high-risk task scheduling, mandatory rest windows	Reduction in fatigue-coded events and repeat defects after roster change
Documentation-related deviation or workaround	Procedure clarification requests, revision errors, manual-access problems	Readability review, simplified task cards, point-of-work access, revision-control audit	Lower rate of documentation-coded deviations and fewer task clarification requests
Training or competence-related errors	Repeat defects by task type, new-technician error trend, certification gap	Task-specific competency assessment, supervised practice, recurrent human factors training	Improved task pass rate and reduced repeat defects
Handover or communication breakdown	Shift-handover discrepancies, incomplete sign-off, deferred defect ambiguity	Structured handover checklist, cross-shift briefing, supervisor review	Fewer handover-related findings and clearer defect history
Supervision or production-pressure influence	High-risk tasks under time pressure, deferred corrective action, repeated shortcut reports	Supervisor workload review, stop-work authority, risk-based task planning	Increase in hazard reporting and reduction in pressure-related deviations

A maintenance organization can apply the proposed framework through a five-step cycle. First, collect maintenance event data from occurrence reports, audits, quality escapes, deferred defects, and near misses. Second, code each event using the structured taxonomy such as MEDA or HFACS-ME. Third, conduct trend analysis to identify recurring contributing factors. Fourth, transfer repeated high-risk patterns into the SMS risk register and assign preventive controls. Fifth, evaluate whether those controls reduce recurrence. This cycle converts classification from a static investigation output into an active safety-management process. The framework also supports practical governance. Each recurrent factor should have an owner, a control measure, a deadline and an effectiveness check. For example, if repeated events are coded under fatigue and workload, the corrective action should not be limited to refresher training. The organization should review overtime, night-shift patterns, staffing levels, high-risk task scheduling and recovery time. Similarly, if the repeated events are coded under documentation quality, the control should include procedure usability review, revision control, and technician feedback on task-card clarity.

The main practical contribution of this review is therefore the proposed link between retrospective classification and SMS control. The literature already provides many lists of contributing factors. What is less developed is a simple operational pathway by which those factors can become measurable safety controls. The proposed framework addresses this gap by showing how classification categories can feed risk registers, safety performance indicators, targeted interventions, and continuous monitoring. This approach also helps avoid a common limitation of maintenance investigations: the tendency to close an event after identifying a human error label. In the proposed framework, a human-error label is not the conclusion. It is an entry point into a deeper analysis of fatigue, workload, documentation, competence, supervision, communication, and organizational pressure.

7. Conclusion and Future Work

Aircraft maintenance errors are not isolated individual failures; they are emergent outcomes of the complex interactions among technician performance limits, task conditions, procedures, supervision, communication, fatigue and organizational pressure. The reviewed literature has shown that classical taxonomies such as MEDA and HFACS-ME remain valuable because they help organizations move beyond blame and identify latent conditions. However, these systems are primarily retrospective and depend on investigation quality, reporting culture, and organizational willingness to act.

The review supports three main conclusions. First, aircraft maintenance error is best understood as a systems phenomenon. Individual actions matter but they occur within task, supervisory and also organizational conditions that shape performance. This is consistent with organizational accident theory and maintenance-specific classification systems such as MEDA and HFACS-ME [1, 5, 7, 8, 9]. Second, the causal mechanisms identified in maintenance human factors are more stable than accident-severity estimates. The statistics about the percentage of accidents involving maintenance or human error vary because they depend on the dataset, classification rule and time period. However, the same types of the contributing factors are found to recur across the literature: fatigue, workload, documentation quality, training, supervision, communication, reporting, safety climate, and organizational pressure. This means that preventive safety management should focus less on debating a single severity statistic and more on controlling the recurring mechanisms that create the maintenance vulnerability. Third, the retrospective classification has limited value unless it is connected to a proactive control. MEDA and HFACS-ME help explain past events but organizations need a further step: conversion of classification results into SMS risk registers, safety performance indicators, preventive actions and effectiveness monitoring. Without this step, classification can become a record-keeping exercise rather than a learning system.

On the whole, the main argument of this paper is that aviation maintenance human factors research must now move beyond classification alone. The next step is to connect classification knowledge with proactive SMS practice. The proposed framework shows how maintenance event data can be coded, aggregated into recurrent contributing factors, translated into SMS risk registers and safety performance indicators, and converted into preventive controls. In this way, maintenance organizations are able to use retrospective error knowledge to support forward-looking prevention, continuous monitoring and more resilient maintenance safety systems.

This review has several limitations. It is a structured critical review rather than a meta-analysis, and the literature is heterogeneous in design, sample, setting and outcome variable. The review also retains selected foundational non-journal sources because several core concepts in aircraft maintenance human factors originated in books, conference papers, institutional guidance and/or technical reports. These sources are valuable for conceptual grounding, but they were not treated as equivalent to peer-reviewed empirical evidence. This distinction should be maintained in future reviews.

Future research should strengthen the empirical bridge between retrospective classification and predictive safety management. Useful directions include inter-rater reliability studies for HFACS-ME coding, longitudinal studies linking coded maintenance events to SMS indicators, audit-based prediction models, fatigue and workload monitoring in maintenance organizations, and intervention studies that test whether specific controls reduce recurrence. Maintenance organizations would also benefit from digital tools that can connect event reporting, taxonomy coding, risk registers, corrective actions and effectiveness monitoring in one workflow.

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