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Bridging Maintenance Error Taxonomies and Safety Management Systems: A Structured Critical Review of Aviation Maintenance Human Factors

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Systematic Review

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Abstract

Aircraft maintenance is a critical aviation safety function because errors can remain latent and later interact with flight operations or inspection failures. This paper critically reviews aircraft maintenance human factors by integrating accident evidence, maintenance-error taxonomies, and proactive safety-management research. Following a PRISMA-aligned screening process, 24 sources were retained, including peer-reviewed studies and foundational works on error classification and organizational accident theory. The review shows that maintenance error is rarely caused by a single unsafe act; rather, it results from interactions among fatigue, workload, procedures, documentation, training, communication, supervision, and organizational pressures. The paper 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.

1. Introduction

Aircraft maintenance is one of the most safety-critical functions in aviation because it directly affects airworthiness, dispatch reliability, and operational resilience. Unlike many flight-deck errors, maintenance errors may remain latent until they combine with subsequent operations, environmental conditions, or later inspection failures. This latent character makes maintenance-related risk difficult to detect, quantify, and control using only outcome-based accident statistics [1, 2].

The human factors literature has repeatedly shown that aviation maintenance cannot be understood simply as a matter of individual carelessness. Maintenance work is performed in dynamic operational environments 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.

Several influential approaches have attempted to make maintenance error more visible and actionable. Early work 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, 8, 13]. In parallel, studies on fatigue, documentation quality, safety climate, leadership, and reporting showed that maintenance safety depends not only on retrospective event investigation but also on proactive management of organizational conditions [9–14, 18].

Despite this progress, the literature remains fragmented. One stream focuses on accidents, incidents, and occurrence evidence. A second stream focuses on taxonomies such as MEDA and HFACS-ME. A

third stream examines 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 that gap through a structured critical review. The central argument is that the most important unresolved issue in aviation maintenance human factors is no longer whether maintenance error matters; that has already been established. The unresolved issue is how retrospective error knowledge can be operationalized within proactive maintenance safety management. The review therefore examines three questions: (1) What human and organizational factors are most consistently associated with aircraft maintenance error? (2) What do current maintenance-error taxonomies explain well, and where are their limits? (3) How can insights from accident and classification studies be translated into proactive SMS practice?

The novelty of the 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

2.1 Review design

This manuscript adopts a structured critical review design with PRISMA-aligned search and screening logic. The review was not framed as a statistical meta-analysis because aviation maintenance human factors literature is heterogeneous in research design, sample type, analytical unit, and outcome variable. 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 create a false impression of comparability. A structured critical review is more suitable because the goal is conceptual integration rather than numerical aggregation [15].

The term PRISMA-aligned is used deliberately. The review uses transparent search terms, eligibility rules, and screening logic, but it does not claim to be a full systematic review or meta-analysis. This distinction is important because the paper aims to synthesize mechanisms and practical implications rather than estimate pooled effect sizes.

2.2 Review question and scope

The review was guided by the following question: How do human factors contribute to 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 was limited to literature directly relevant to aircraft maintenance work, maintenance-induced events, maintenance-error classification, safety climate, fatigue, documentation quality, training, supervision, organizational influences, and SMS-oriented prevention. The review did not include general human factors literature unless it directly supported an aviation maintenance mechanism or a foundational safety-management concept.

2.3 Data sources and search strategy

The search strategy combined keyword searching, publisher-platform checking, and backward citation tracing. Searches were 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 were 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 covered literature from the late 1990s to 2026, which allowed inclusion of foundational maintenance human factors work and recent studies on fatigue, safety climate, and maintenance safety behavior.

2.4 Eligibility criteria and source consistency

To address source consistency, the revised review distinguishes between two types of retained sources. First, peer-reviewed journal articles formed the primary evidence base for the synthesis of fatigue, workload, documentation, safety climate, safety behavior, safety management, and maintenance-error mechanisms. Second, selected non-journal sources were 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 or documented historically important maintenance human factors concepts [1, 4, 5, 7, 8, 12, 17, 23, 24].

A source was included when it met at least one of the following criteria: (1) direct focus on aircraft or aviation maintenance; (2) analysis of maintenance-induced events, deviations, or contributing factors; (3) development or application of a maintenance-error taxonomy; (4) evidence on fatigue, documentation, communication, training, supervision, safety climate, or reporting in maintenance; or (5) foundational relevance to maintenance human factors or organizational safety theory. Sources were excluded when they were not aviation-related, not maintenance-focused, lacked a human factors or safety-management component, duplicated another source without adding conceptual value, or had unverifiable bibliographic information.

This clarification resolves the methodological inconsistency that can arise when a review claims a purely journal-only citation base while also relying on classical books, conference papers, and institutional documents. In the present synthesis, journal articles are treated as the primary empirical evidence base, while selected non-journal sources are used as foundational background.

2.5 Screening and analytical strategy

The screening process followed 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 initially produced **68 candidate records**. After removing **11 duplicate records**, **57 records** were screened by title and abstract. At this stage, **21 records** were excluded because they were not directly focused on aviation maintenance, did not address human factors or maintenance-error mechanisms, or were not relevant to safety-management practice. The remaining **36 reports** were sought for full-text assessment. Full text was available for all 36 reports.

During full-text eligibility assessment, **12 reports** were excluded. The main reasons for exclusion were: 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 consisted of **24 sources**. Of these, **14 peer-reviewed journal articles** formed the primary evidence base for the synthesis, while **10 foundational or contextual sources** were retained to explain 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 was 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
Review protocol and eligibility logic used in the revised manuscript

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.

In Fig. 1 The search and backward-citation process identified 68 candidate records. After duplicate removal, 57 records were screened, 36 reports were assessed for eligibility, and 24 sources were retained for final synthesis, consisting of 14 peer-reviewed journal articles and 10 foundational/contextual sources.

3. Human Factors Context of Aircraft Maintenance

The earliest core reviews in this field 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 the 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. That distance weakens error visibility and increases the importance of procedures, inspection, handover quality, and organizational memory [1, 3].

Studies of unsafe acts in maintenance reinforce 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 maintenance-related human error is often rooted in task design, coordination, equipment use, communication, and situational complexity rather than in individual negligence alone [3, 16].

This distinction is practically important because maintenance organizations may still respond to deviations by emphasizing individual discipline, retraining, or reminders. Such responses can be necessary in some cases, but they are rarely sufficient. If error pathways are created by 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 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 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. Although 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 checking behavior, poor documentation can increase memory reliance, and schedule pressure can suppress reporting or encourage workarounds.

4.1 Fatigue and workload

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 [9]. More recently, da Silva and colleagues reported significant relationships between fatigue, workload, sleepiness, and quality-of-life indicators among aircraft maintenance personnel [10]. 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 degrades checking behavior, 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 treated as a personal weakness. It is affected by rostering,

overtime, staffing, shift design, recovery opportunity, and organizational tolerance for degraded performance.

4.2 Documentation and technical information quality

Maintenance documentation is often treated as an administrative issue, but the literature shows 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 behavior. Poor readability, fragmented procedures, ambiguous wording, inconsistent revisions, and difficult access to 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.

4.3 Training and competence development

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 competency-based on-the-job training should be structured around real work performance and human-factors demands rather than checklist completion [11]. Task-support tools and assistance platforms can also improve adherence by making correct information available at the point of work [7].

Training should therefore be interpreted broadly. It includes initial qualification, recurrent learning, task-specific familiarization, cross-shift coordination skills, error management, and the ability to recognize degraded system states. 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.

4.4 Communication, reporting, and safety climate

Communication is central to maintenance because work is distributed across people, shifts, specializations, and locations. Failures in handover, reporting, and coordination can allow small deviations to persist until they become operationally significant. Safety climate research shows that safety leadership and organizational climate influence safety behavior among aircraft maintenance technicians [18]. This means that safety culture cannot be evaluated only from 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 often reflect deeper organizational properties such as hierarchy, blame, work pressure, insufficient staffing, or weak interdepartmental coordination. A

narrow corrective action that only instructs staff to 'communicate better' may fail unless the broader organizational conditions supporting poor communication are also addressed.

4.5 Supervision and organizational pressure

Supervisory and organizational influences are critical because they shape the conditions under which 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, 13].

Organizational pressure does not always appear as an explicit instruction to violate a procedure. More often, it appears through production targets, turnaround expectations, repeated overtime, insufficient staffing, poorly designed handovers, and implicit signals about what the organization rewards. In such environments, maintenance deviations may become locally rational even when they create system risk.

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.	[9, 10, 24]	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, 11]	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, 18, 20, 21]	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, 13, 16]	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,

classification does not automatically produce prevention. A taxonomy becomes useful only when its categories are linked to risk controls, safety performance indicators, and organizational learning.

5.1 MEDA

The Maintenance Error Decision Aid (MEDA) was 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 made the deviation possible. This supports a learning-oriented approach and helps reduce the tendency to treat maintenance error only as individual negligence.

The 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.

5.2 HFACS-ME

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, 8, 13]. This structure is especially useful in maintenance because many deviations originate in latent conditions such as inadequate task planning, poor documentation, fatigue-producing schedules, or weak supervisory controls.

HFACS-ME helps investigators 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.

5.3 Critical limitations of current classification methods

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 important risks. Third, coding reliability can vary between investigators, especially when event information is incomplete or when categories overlap. Fourth, classification systems may identify repeated contributing factors without forcing the organization to assign 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 a 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. Recurrent codes should become safety performance indicators. Corrective actions should be tracked for effectiveness, not merely closure. In this sense, the 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, this paper proposes a simple framework for translating retrospective maintenance error classification into proactive SMS-based safety control. 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 a compatible local taxonomy. The organization then identifies recurrent contributing factors rather than treating events as isolated cases. Repeated codes related to fatigue, workload, documentation, supervision, training, or communication are transferred into the SMS risk register and converted into safety performance indicators. Preventive controls are then assigned, implemented, and monitored through audit and feedback.

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

6.1 How organizations can apply the framework

A maintenance organization can apply the 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 a 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 repeated events are coded under documentation quality, the control should include procedure usability review, revision control, and technician feedback on task-card clarity.

6.2 From descriptive review to practical contribution

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 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. Discussion

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 organizational conditions that shape performance. This is consistent with organizational accident theory and with maintenance-specific classification systems such as MEDA and HFACS-ME [1, 5, 7, 8, 13].

Second, the causal mechanisms identified in maintenance human factors are more stable than accident-severity estimates. 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 contributing factors 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 maintenance vulnerability.

Third, retrospective classification has limited value unless it is connected to 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.

8. Limitations and Future Research

This review has 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, 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 connect event reporting, taxonomy coding, risk registers, corrective actions, and effectiveness monitoring in one workflow.

9. Conclusion

Aircraft maintenance errors are not isolated individual failures; they are emergent outcomes of complex interactions among technician performance limits, task conditions, procedures, supervision, communication, fatigue, and organizational pressure. The reviewed literature shows 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 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 can use retrospective error knowledge to support forward-looking prevention, continuous monitoring, and more resilient maintenance safety systems.

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Figures

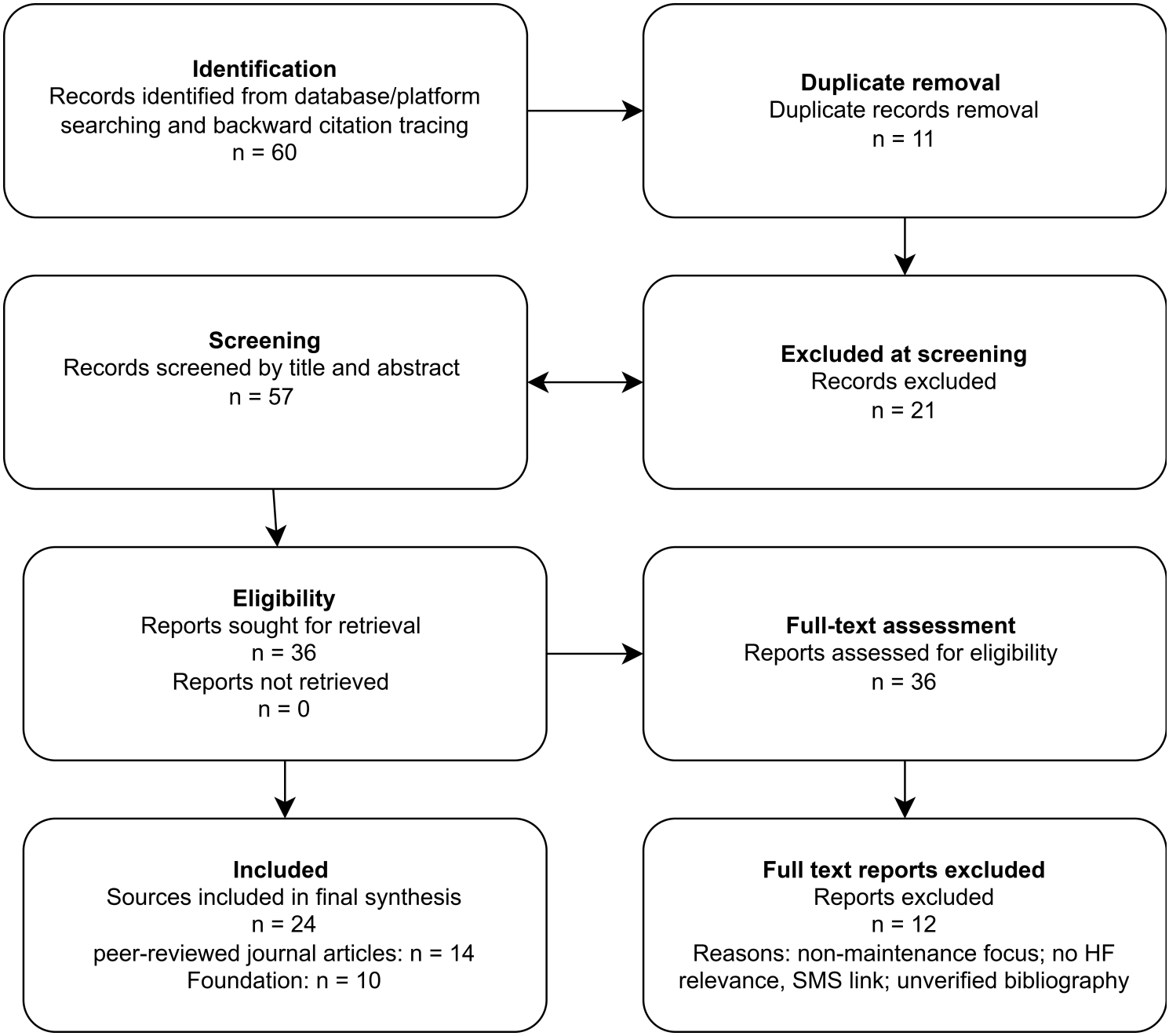


Figure 1

PRISMA-aligned screening logic and final retained corpus used for the structured critical review.

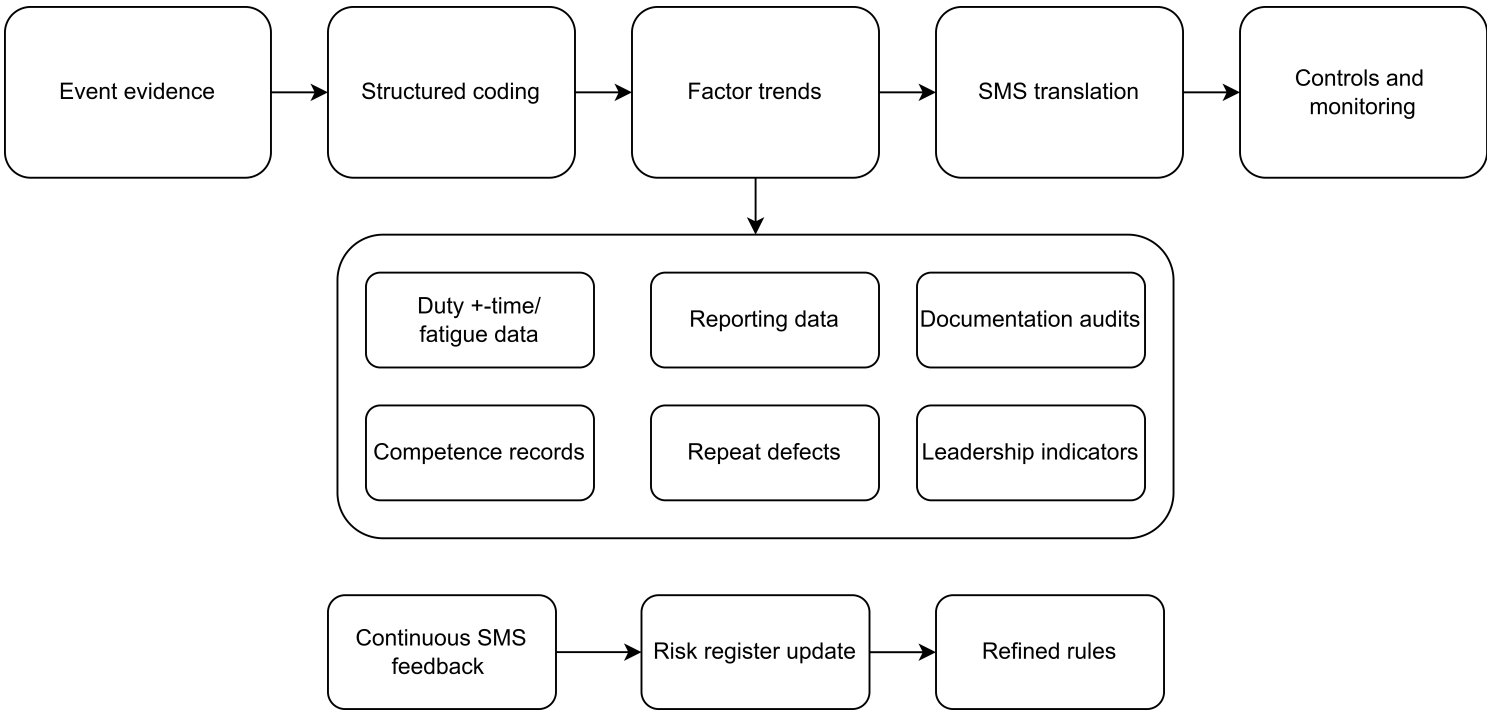


Figure 2

Proposed framework for translating maintenance-error classification into proactive SMS-based safety control.