

Impact of QMS Practices on Human Factor Errors (Ground Crew) with the Mediation of Safety Compliance Behaviour and Moderation of Time Pressure in Aviation Maintenance Organizations of Pakistan

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Abstract

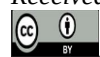
Background: Aviation maintenance is a safety-critical activity in which human-factor errors may arise from organizational, procedural, and operational conditions. Quality Management System practices may strengthen safety performance, but their relationship with human-factor errors and the roles of safety compliance and time pressure remain insufficiently understood in Pakistan. **Objective:** To examine the effect of QMS practices on Human Factor Errors among ground crew in Pakistani aviation maintenance organizations, and to assess the mediating role of Safety Compliance Behaviour and moderating role of Time Pressure. **Methods:** A quantitative, explanatory, cross-sectional study was conducted among 143 aviation maintenance personnel. Data were collected using a structured five-point Likert-scale questionnaire measuring QMS Practices, Safety Compliance Behaviour, Time Pressure, and Human Factor Errors. Data were analyzed using SPSS through descriptive statistics, correlation, regression, mediation, and moderation analyses. **Results:** QMS Practices significantly predicted Safety Compliance Behaviour ($\beta = .884$, $p < .001$; $R^2 = .781$). However, QMS Practices did not significantly predict Human Factor Errors ($\beta = -.124$, $p = .142$), and Safety Compliance Behaviour was not significantly associated with Human Factor Errors ($\beta = -.098$, $p = .244$). Mediation analysis was not significant. Time Pressure did not significantly moderate the proposed relationship ($\beta = -.612$, $p = .116$), but demonstrated a significant positive direct effect on Human Factor Errors ($\beta = .854$, $p = .003$). **Conclusion:** QMS practices strongly promote safety compliance but may not independently reduce human-factor errors. Effective error prevention should therefore combine QMS implementation with workload management, realistic scheduling, and broader human-factors interventions.

Keywords: Quality Management Systems; Human Factor Errors; Safety Compliance Behaviour; Time Pressure; Aviation Maintenance

Introduction

Aviation maintenance is a safety-critical activity in which human errors can have serious consequences for aircraft airworthiness, operational reliability, and aviation safety. Maintenance, Repair, and Overhaul (MRO) personnel perform complex technical tasks involving aircraft systems, maintenance documentation, inspections, repairs, and testing, often within demanding operational environments. Human-factor errors are influenced not only by individual performance but also

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by organizational conditions, including inadequate training, communication failures, fatigue, workload, supervision, and procedural weaknesses (Jiang et al., 2022; Zimmermann & Mendonca, 2021).

Quality Management Systems (QMS) provide an organizational framework for controlling and improving maintenance processes through process standardization, documentation control, training and competency development, internal auditing, corrective and preventive actions (CAPA), and continuous improvement. These practices are intended to reduce process variability, strengthen adherence to approved procedures, and support consistent maintenance performance. Research indicates that proactive quality auditing combined with human-factors assessment can help identify procedural non-compliance as well as underlying contributors to errors, including workload, fatigue, inadequate training, and ineffective documentation (Haruna & Taiwo, 2024). Similarly, deficiencies in aircraft maintenance documentation have been associated with increased risks of procedural mistakes, highlighting the importance of standardized procedures, effective training, and organizational controls (Güneş et al., 2021).

However, effective quality systems do not necessarily guarantee that safety requirements will consistently translate into employee behaviour. Safety Compliance Behaviour may represent an important mechanism through which QMS practices influence maintenance outcomes. Training, audits, documentation, and corrective actions can encourage employees to adhere to safety procedures and approved maintenance requirements. Nevertheless, compliance alone may not eliminate human errors arising from broader organizational and operational conditions. This is particularly relevant because maintenance errors frequently emerge from interactions between people, procedures, resources, and the working environment rather than from individual shortcomings alone (Jiang et al., 2022; Haruna & Taiwo, 2024).

Time Pressure is another potentially important contextual factor. Tight aircraft turnaround schedules, urgent maintenance tasks, workload intensity, and operational deadlines may increase cognitive demands and encourage shortcuts or omission of procedural steps. Prasad and Raveendran (2024) identified time pressure and excessive workload as important contributors to maintenance-related errors, emphasizing the importance of standardized procedures, training, safety awareness, and organizational support.

Despite increasing research on aviation human factors, maintenance safety, and quality management, limited empirical evidence exists concerning the direct relationship between QMS practices and human-factor errors, particularly within developing aviation environments such as Pakistan. Furthermore, the mediating role of Safety Compliance Behaviour and moderating influence of Time Pressure remain insufficiently examined. Therefore, this study examines the impact of QMS practices on Human Factor Errors among ground crew in Pakistani aviation maintenance organizations, while investigating Safety Compliance Behaviour as a mediator and Time Pressure as a moderator.

Literature Review and Theoretical Basis

QMS are increasingly recognized as important organizational mechanisms for improving aviation maintenance quality and safety. QMS practices including process standardization, documentation control, employee training, internal auditing, corrective and preventive actions, and continuous improvement provide structured mechanisms for controlling maintenance processes and

reducing variability. Evidence suggests that human-factor errors in aviation maintenance are influenced by organizational conditions rather than individual performance alone. Jiang et al. (2022) identified fatigue, communication failures, inadequate training, workload, poor supervision, and procedural weaknesses as important contributors to maintenance errors. Similarly, Zimmermann and Mendonca (2021) demonstrated that maintenance documentation and organizational conditions can substantially influence human performance and safety outcomes.

Documentation and procedural standardization are particularly relevant to error prevention. Güneş et al. (2021) reported that unclear or incomplete maintenance documentation can negatively influence attention, perception, workload, and situational awareness, increasing the likelihood of procedural mistakes. Consequently, QMS mechanisms that ensure accurate documentation, standardized procedures, appropriate training, and effective supervision may create conditions that support safer maintenance performance. Haruna and Taiwo (2024) further emphasized the value of integrating proactive quality auditing with human-factors assessment, arguing that audit processes can identify both procedural non-compliance and underlying contributors such as workload, fatigue, inadequate training, and ineffective documentation.

An important behavioural pathway in this relationship is Safety Compliance Behaviour. QMS practices may strengthen employees' adherence to approved maintenance procedures, safety requirements, and organizational policies through training, auditing, documentation, and corrective actions. However, the literature also indicates that procedural compliance alone may not eliminate human-factor errors because maintenance performance is affected by multiple interacting organizational and environmental factors. The thesis framework therefore conceptualizes Safety Compliance Behaviour as a mediator between QMS Practices and Human Factor Errors.

Time Pressure represents an additional contextual factor affecting maintenance performance. Tight schedules, aircraft turnaround requirements, workload intensity, and urgent maintenance tasks can increase the likelihood of shortcuts and procedural deviations. Prasad and Raveendran (2024) identified excessive workload and time pressure as important contributors to maintenance-related errors and emphasized the importance of standardized procedures, training, safety awareness, and organizational support.

The study is theoretically grounded in Systems Theory, Safety Compliance Theory, and Human Factors Theory. Systems Theory views safety outcomes as products of interactions among organizational components rather than isolated individual actions. Safety Compliance Theory explains how organizational systems can influence employees' adherence to safety requirements, while Human Factors Theory emphasizes the interaction between individuals, tasks, equipment, procedures, and environmental conditions. Accordingly, the study proposes that QMS Practices influence Human Factor Errors partly through Safety Compliance Behaviour, while Time Pressure may alter the relationship between compliance and errors.

Methodology

Study Design and Setting

A quantitative, explanatory, cross-sectional study was conducted using a positivist research philosophy and deductive approach. The study examined the relationships among QMS Practices, Safety Compliance Behaviour, Time Pressure, and Human Factor Errors among personnel work-

ing in aviation MRO organizations in Pakistan. The design was selected to enable empirical testing of the direct, mediating, and moderating relationships proposed in the conceptual framework.

Population and Sampling

The target population comprised ground maintenance personnel working in aviation maintenance organizations across Pakistan, including military and commercial sectors. Eligible personnel included aircraft maintenance engineers, technicians, quality assurance and quality control personnel, inspectors, maintenance planners, supervisors, and other technical staff directly involved in aircraft maintenance activities. A total of 143 respondents were included in the final analysis. Purposive (judgmental) sampling was used to recruit participants with relevant aviation maintenance experience; because recruitment also occurred through professional contacts and online platforms, the sampling process incorporated an element of convenience-based access.

Data Collection and Instrument

Primary data were collected electronically using a structured questionnaire developed by adapting measurement items from previously validated instruments. The questionnaire comprised demographic information and measures of the four study constructs. All construct items were assessed using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The instrument contained 24 items: seven measuring QMS Practices, five measuring Safety Compliance Behaviour, six measuring Time Pressure, and six measuring Human Factor Errors. The questionnaire was administered through Google Forms and distributed electronically through professional networks and social media platforms. Participation was voluntary, and anonymity and confidentiality were maintained; no personally identifiable information was collected.

Validity and Reliability

Content validity was established through adaptation of previously validated measurement items and expert review by two experienced Pakistan Air Force engineering officers. A pilot study involving 41 respondents was conducted before the main survey to assess instrument clarity and internal consistency. Cronbach's alpha coefficients were 0.953 for QMS Practices, 0.945 for Safety Compliance Behaviour, 0.872 for Time Pressure, and 0.818 for Human Factor Errors, demonstrating satisfactory-to-excellent internal consistency. All items were therefore retained for the main survey.

Data Analysis and Ethics

Data were exported from Google Forms to Microsoft Excel and analyzed using SPSS V26.0. Descriptive statistics, Cronbach's alpha, Pearson correlation, linear regression, mediation, and moderation analyses were conducted to evaluate the hypothesized relationships. Participation was voluntary, informed consent was obtained, confidentiality was maintained, and respondents were informed that data would be used solely for academic purposes and that they could withdraw from participation.

Results

A total of 143 valid responses were included in the analysis. The sample was predominantly male (95.1%), with 44.1% holding an MS/MPhil/PhD, 35.0% a bachelor's degree, and 21.0% a diploma. Aircraft Maintenance Engineers constituted the largest occupational group (45.5%), followed by other technical personnel (23.8%) and Aircraft Technicians (15.4%). The sample was also highly experienced: 42.0% reported more than 20 years of aviation maintenance experience, while 18.9% each reported 11–15 and 16–20 years.

Table 1: Characteristics of study participants

Characteristic	Category	n (%)
Gender	Male	136 (95.1)
	Female	7 (4.9)
Education	MS/MPhil/PhD	63 (44.1)
	Bachelor's	50 (35.0)
	Diploma	30 (21.0)
Designation	Aircraft Maintenance Engineer	65 (45.5)
	Other technical position	34 (23.8)
	Aircraft Technician	22 (15.4)
	Supervisor	9 (6.3)
	Quality Inspector	8 (5.6)
	Quality Manager	5 (3.5)
Experience	<5 years	6 (4.2)
	5–10 years	23 (16.1)
	11–15 years	27 (18.9)
	16–20 years	27 (18.9)
	>20 years	60 (42.0)

The construct-level descriptive results showed generally high perceptions of QMS implementation and safety compliance. Safety Compliance Behaviour had the highest mean score ($M = 4.17$, $SD = 0.87$), followed by QMS Practices ($M = 4.07$, $SD = 0.89$). Time Pressure was moderate ($M = 3.47$, $SD = 0.85$), while Human Factor Errors had the lowest mean ($M = 3.00$, $SD = 0.86$).

Table 2: Descriptive statistics and correlations among study variables

Variable	M (SD)	QMS	SCB	TP	HFE
QMS Practices	4.07 (0.89)	1	.884***	.256**	-.124
Safety Compliance Behaviour	4.17 (0.87)		1	.233**	-.098
Time Pressure	3.47 (0.85)			1	.360***
Human Factor Errors	3.00 (0.86)				1

*Note: ** $p < .01$; *** $p < .001$.

QMS Practices demonstrated a very strong positive correlation with Safety Compliance Behaviour ($r = .884$, $p < .001$). Time Pressure was positively correlated with both QMS Practices ($r = .256$, $p = .002$) and Safety Compliance Behaviour ($r = .233$, $p = .005$), and showed a moderate positive correlation with Human Factor Errors ($r = .360$, $p < .001$). In contrast, neither QMS

Practices ($r = -.124$, $p = .142$) nor Safety Compliance Behaviour ($r = -.098$, $p = .244$) was significantly correlated with Human Factor Errors.

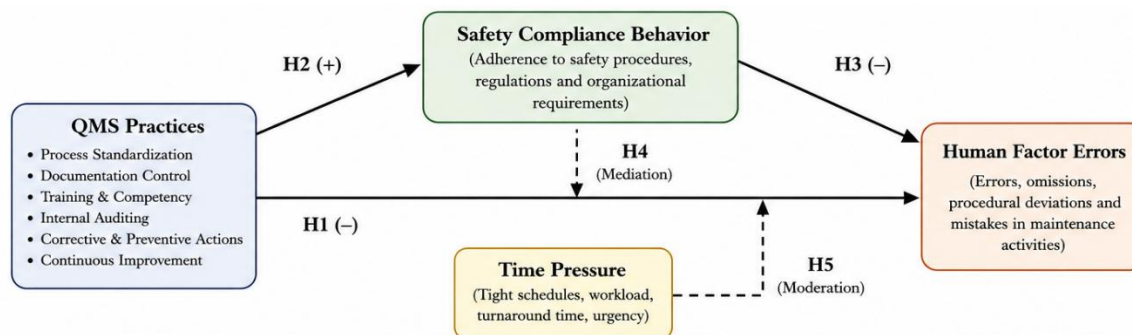


Figure 1. Conceptual model of the hypothesized relationships among QMS Practices, Safety Compliance Behaviour, Time Pressure, and Human Factor Errors.

Regression analysis demonstrated a significant positive effect of QMS Practices on Safety Compliance Behaviour, explaining 78.1% of its variance ($R^2 = .781$; $F(1,141) = 502.20$, $p < .001$; $\beta = .884$, $p < .001$). Conversely, QMS Practices did not significantly predict Human Factor Errors ($R^2 = .015$; $\beta = -.124$, $p = .142$). Safety Compliance Behaviour also failed to significantly predict Human Factor Errors ($R^2 = .010$; $\beta = -.098$, $p = .244$).

For the proposed mediation, the model including QMS Practices and Safety Compliance Behaviour explained only 1.6% of the variance in Human Factor Errors and was not statistically significant, $F(2,140) = 1.125$, $p = .328$. Neither QMS Practices ($\beta = -.168$, $p = .349$) nor Safety Compliance Behaviour ($\beta = .051$, $p = .778$) significantly predicted Human Factor Errors; consequently, the proposed mediation was not supported.

For moderation, hierarchical regression showed that the interaction term was not statistically significant ($\beta = -.612$, $p = .116$). Thus, Time Pressure did not significantly moderate the hypothesized relationship. However, Time Pressure demonstrated a significant positive direct association with Human Factor Errors ($\beta = .854$, $p = .003$), indicating that greater operational pressure was associated with increased human-factor errors.

Table 3: Regression, mediation, and moderation findings

Analysis	Key statistic	p-value	Interpretation
QMS → SCB	$\beta = .884$; $R^2 = .781$	$<.001$	Significant
QMS → HFE	$\beta = -.124$; $R^2 = .015$	.142	Not significant
SCB → HFE	$\beta = -.098$; $R^2 = .010$	.244	Not significant
QMS + SCB → HFE	$R^2 = .016$; $F = 1.125$	.328	Mediation not supported
Interaction effect	$\beta = -.612$	.116	Moderation not supported
Time Pressure → HFE	$\beta = .854$	.003	Significant positive effect

Overall, only H2 was supported. H1, H3, H4, and H5 were not supported.

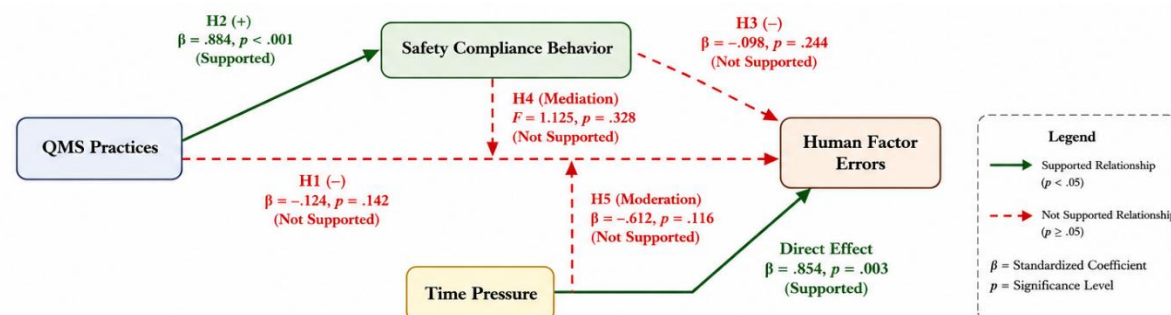


Figure 2: Summary of statistically significant and non-significant hypothesized relationships

Discussion

This study examined the relationship between QMS Practices and Human Factor Errors among ground crew in Pakistani aviation maintenance organizations, with Safety Compliance Behaviour examined as a mediator and Time Pressure as a moderator. The principal finding was that QMS Practices strongly predicted Safety Compliance Behaviour, but neither QMS Practices nor Safety Compliance Behaviour significantly predicted Human Factor Errors. Furthermore, Safety Compliance Behaviour did not mediate the QMS–Human Factor Errors relationship, and Time Pressure did not significantly moderate the proposed relationship. However, Time Pressure demonstrated a significant positive direct association with Human Factor Errors.

The strongest finding was the substantial positive effect of QMS Practices on Safety Compliance Behaviour ($\beta = .884$, $p < .001$; $R^2 = .781$). This suggests that standardized procedures, documentation, training, auditing, corrective actions, and continuous improvement are highly relevant to employees' adherence to safety requirements. This finding is consistent with previous literature emphasizing that quality-oriented systems, structured procedures, training, and organizational oversight strengthen compliance and safety performance. Tauseef and Asadullah (2023), for example, identified safety training, safe work procedures, and monitoring as important components of aviation safety systems. Similarly, Haruna and Taiwo (2024) emphasized the value of integrating quality auditing with human-factors management to identify procedural non-compliance and underlying organizational weaknesses.

Contrary to the expected relationship, QMS Practices did not significantly reduce Human Factor Errors. This finding differs from studies suggesting that effective documentation, training, standardization, and quality controls can reduce maintenance errors. Güneş et al. (2021) reported that poor maintenance documentation can increase procedural mistakes, while Jiang et al. (2022) identified inadequate training, workload, communication failures, supervision, and procedural weaknesses as important contributors to maintenance errors. One possible interpretation is that QMS primarily establishes the organizational conditions for compliance but may not independently address the broader human and operational factors that generate errors. This interpretation is consistent with the study's theoretical framework, which recognizes human performance as the product of interacting organizational, task, and environmental factors.

Similarly, Safety Compliance Behaviour did not significantly predict Human Factor Errors and consequently failed to mediate the QMS–error relationship. Although compliance was high, the findings indicate that following procedures does not necessarily eliminate errors arising from workload, fatigue, communication, resource limitations, or situational demands. The absence of mediation therefore suggests that additional explanatory mechanisms, such as safety culture, fatigue, workload, leadership, and organizational commitment, warrant investigation.

The finding concerning Time Pressure provides an important practical insight. Although its interaction with the proposed pathway was non-significant, Time Pressure had a significant positive direct effect on Human Factor Errors. This supports Prasad and Raveendran (2024), who identified workload and time pressure as important contributors to maintenance errors and noted that operational urgency may encourage shortcuts and procedural deviations. Thus, reducing maintenance errors may require organizations to complement QMS implementation with realistic scheduling, workload balancing, adequate staffing, fatigue management, and stronger human-factors programs.

Finally, the study contributes context-specific evidence from Pakistan, where the combined relationships among QMS, compliance, time pressure, and maintenance errors remain underexplored. Interpretation should nevertheless consider the cross-sectional, self-reported design and purposive/convenience-based sampling, which limit causal inference and generalizability.

Conclusion

This study demonstrates that QMS Practices significantly strengthen Safety Compliance Behaviour among aviation maintenance personnel in Pakistan. However, QMS Practices and Safety Compliance Behaviour alone did not significantly reduce Human Factor Errors, and no significant mediation or moderation effects were observed. In contrast, Time Pressure had a significant positive direct association with Human Factor Errors. These findings indicate that effective error reduction requires more than procedural compliance and should incorporate workload management, realistic scheduling, fatigue risk management, human-factors training, and stronger safety systems. Integrating QMS with broader human-performance and safety-management initiatives may therefore provide a more effective approach to improving aviation maintenance safety.

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