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Assessing Past Airworthiness Directives And How Safety Management Systems May Benefit Aviation Product Design And Manufacturing

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Abstract

The European Union Aviation Safety Agency (EASA) continues to promulgate Safety Management Systems (SMS) across aviation organizations when it recently issued SMS requirements for EASA certificated Part 145 maintenance, repair and overhaul (MRO) organizations and Part 21 Design & Manufacturing (D&M) organizations. Currently, the FAA has no such rule in place for these U.S. based organizations, which may challenge those doing business in countries where EASA policies apply. Given that most of the United States' D&M and MRO population is made up of smaller organizations, it is likely a U.S. SMS regulation will require justification of the associated costs and benefits. This study explored the potential benefits SMS may provide these organizations by exploring the overall scope and nature of safety controls implemented through Airworthiness Directives (AD), which may help safety practitioners better understand how SMS in D&M organizations may reduce the number of AD related corrective actions. Researchers analyzed a sample of 189 ADs issued over a ten-year period and found that approximately 55% of the sampled ADs were the result of a new risk control, and approximately 45% were the result of a revised risk control. In these cases, the risk controls were not sufficient, and the AD action was necessary to ensure an acceptable level of safety. More effective risk controls have the potential to significantly reduce the number of ADs the industry must address. Every AD involves unplanned costs, often at multiple levels, and other variables that must be managed and implemented as part of the aircraft maintenance and manufacturing process. SMS may further improve the industry's safety performance by reducing the number of corrective actions and their associated costs.

Keywords: safety management systems, Part 21, Part 145, airworthiness directives, design and manufacturing, aviation, safety

Introduction

In March 2006, the International Civil Aviation Organization (ICAO) adopted amendment Annex 6 which requires member states to develop Safety Management Systems (SMS) for aviation service providers by 2010 (ICAO, 2006). In response, the United States (U.S.) Federal Aviation Administration (FAA) issued a rule on January 8, 2015, that requires all air carriers operating under Title 14 of the Code of Federal Regulation (CFR) Part 121 to have an SMS (Safety Management Systems for Domestic, Flag, and Supplemental Operations Certificate Holders, 2015).

Fast forward to today. The European Union Aviation Safety Agency (EASA) continues to promulgate SMS across aviation organizations when it recently issued requirements for EASA certificated Part 145 maintenance, repair, and overhaul (MRO) organizations and Part 21 Design & Manufacturing (D&M) organizations to have an SMS (Franklin, 2022; Gilbert, 2019). Currently, the FAA has no such rule in place for U.S.-based MRO or D&M organizations. This challenges those U.S. organizations doing business or selling products in countries where EASA policies apply.

Furthermore, since the early discussions regarding SMS compliance in the U.S. aviation industry, there has been a divide between smaller and larger organizations (Lercel, 2019). Smaller or less complex organizations are more concerned about the increased administrative burden and cost involved in complying with an SMS regulation with little to no safety or financial benefit (Aircraft Electronics Association [AEA], 2009; Lercel, 2013; Wildes, 2022). Given that most of the D&M population is made up of smaller organizations, including many MROs, it is likely that an SMS regulation applicable to these organizations will meet similar challenges in justifying the cost benefits of such regulation (FAA, 2022b; Lercel, 2013). By understanding the scope and nature of safety controls implemented through Airworthiness Directives (AD), safety practitioners may gain insight into how SMS in D&M organizations may reduce the number of AD-related corrective actions and the associated costs.

Background

Okwera (2016) found companies and agencies within the transportation industry will experience some costs and benefits from the implementation of SMS. However, it is very difficult to quantify the financial return from SMS implementation. The benefits from SMS are derived from the savings made when accidents are avoided (Okwera, 2016). A review of other high-consequence industries found little financial data related to SMS return on investment (ROI). Lercel et al. (2011) explored the financial benefits of SMS and demonstrated the potential cost savings SMS may provide through improved safety performance, but this research was primarily focused on the cost of those incidents that were avoided. It did not explore the organizational costs to develop and administer an SMS program. While Johnson et al. (2012) provide an SMS ROI tool with theoretical examples, their research provides no actual real-world financial data. Many others provide similar ROI examples and tools but also with little financial data from industry organizations.

In 2012, the FAA Administrator established a Part 21 SMS Aviation Rulemaking Committee (ARC) with the following charter (FAA, 2015, page vii):

> [the committee] is to evaluate certain improvements to the effectiveness and efficiency of existing "certification procedures for products and parts," along with incorporating SMS in the design and manufacturing environment. This includes considering the effects of certain changes to the existing regulations, such as

> applicant qualifications, hazard (or safety) reporting, compliance assurance, and continued operation safety assurance systems for all design approval holders.

The FAA defines design approval holders (DAH) as the holder of a Type Certificate, a Parts Manufacturer Approval or a Technical Standard Order authorization, or the licensee of a Type Certificate (FAA, 2021). In their report, the ARC recommended that an SMS should apply to these DAH organizations (FAA, 2015). A review of the literature found little research on the benefits SMS may provide the D&M industry. Stolzer et al (2011) discuss the implementation of SMS in aviation maintenance and provide some examples where organizations may have benefited from the implementation of SMS. Lercel et al (2011) explore the potential financial benefits of SMS across the aviation industry as a whole and provide examples from one repair station where SMS may provide a benefit. However, research that explores the broader benefits of SMS across the D&M industry is lacking. Similarly, Batuwangala et al (2019) observed that there is less research on management tools that may be more applicable to organizations involved in initial and continuing airworthiness functions including aircraft design, manufacture, and continuing airworthiness management.

According to the FAA (2022a), SMS is the formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk. Moreover, SMS supports a proactive approach to discovering and addressing hazards before any adverse consequences. This includes identifying organizational deficiencies and making the necessary process improvements to address a safety issue before a product becomes unsafe (FAA, 2022a). When systematically applied, an SMS provides a set of decision-making tools that aviation organizations may use to improve safety. With regards to D&M organizations, SMS also includes processes that may allow management to address a safety issue before a non-compliant or unsafe condition results.

This study explored the risk controls implemented through past Airworthiness Directives (AD). Specifically, this research may help safety practitioners better understand how SMS in D&M organizations may change the scope and nature of future AD corrective actions. The benefits that SMS may provide beyond existing safety practices, either when measured in financial terms or improved performance, is a concern for many D&M organizations, especially smaller organizations (AEA, 2009; Aircraft Owners and Pilots Association [AOPA], 2009; Phillips & Herr, 2020).

SMS may have little effect on the initial product design process, but the industry is primarily concerned with adverse effects on the overall product certification budget, where additional personnel and resources may be required (FAA, 2015). Making the case to the aviation industry that SMS may improve safety performance is often a challenge given the industry's historically excellent safety record. Often safety is measured in terms of the rate of incidents or accidents, which often challenges safety practitioners to estimate the return on investments related to proactive safety initiatives (AEA, 2009; AOPA, 2009; FAA, 2010; Lercel et al., 2011; Okwera, 2016). However, a review of past corrective actions may provide insight into the potential benefits of SMS. This study is considered a first step in exploring how SMS may further improve the industry's safety performance by reducing the number of corrective actions and their associated costs. Every AD involves unplanned costs, often at multiple levels, and other variables that must be managed and implemented as part of the aircraft maintenance and manufacturing process.

ADs address any unsafe condition in a type certificated (TC) product or unsafe condition in products of a similar type design (Airworthiness Directives, 2023). ADs are legally enforceable rules that apply to the following TC products: aircraft, aircraft engines, propellers, and appliances. Part 39 of CFR Title 14 requires each operator of a product affected by an AD to comply with the terms of the AD in order to continue using the product (Airworthiness Directives, 2023; FAA, 2021). The AD may mandate operational limitations, maintenance, or alterations for the affected product (FAA, 2021). In the case of accidents and serious incidents arising from factors relating to aircraft design or maintenance error, lessons may be learned through the conduit of AD mandatory communications. ADs require immediate recognition and recipients are legally obligated to comply within defined timeframes (Clare & Kourousis, 2021).

The FAA created an SMS program for non-Part 121 operators in 2015 “to voluntarily develop and implement an SMS” (FAA, 2015, p. 1). However, of the approximately 5,000 non-Part 121 FAA certificated aviation service providers (FAA, 2022c), less than 5% are currently enrolled in the FAA’s Voluntary SMS Program and no UAS service providers are enrolled (Jadhav & Lercel, 2022; Roberts, 2021). SMS may provide a means for organizations to proactively address these unsafe product conditions and reduce future corrective actions associated with the costlier and more reactive AD process. This study reviewed a sample of ADs issued by the FAA from 2009 through 2018 and assessed whether the AD was a revision to an existing or new risk control. For this study, risk control is defined as a measure taken to avoid, mitigate, reduce, or eliminate known or potential hazards. Examining ADs in this manner may provide safety practitioners insight into the effectiveness of processes and identify opportunities where SMS may provide benefit.

Changes to existing risk controls, implemented through AD actions, may suggest the hazard identification process was sufficient; however, the Safety Risk Management (SRM), or

Safety Assurance (SA) processes may be lacking (FAA, 2022a). New risk controls implemented by AD corrective actions may indicate opportunities for improving the effectiveness of hazard identification and the development of appropriate mitigation actions.

The FAA first established a manufacturer failure, malfunction, and defect reporting process in 1970 through Advisory Circular (AC) 21-9. In 1982 the FAA issued a revision (21-9A) to the AC, which included a requirement that any holder of a type certificate, parts manufacturer approval (PMA), or a technical standard order (TSO) authorization, and licensee of a type certificate to notify the FAA of any failure (FAA, 1982, pp.1). Subsequently, a second revision to this AC (21-9B) broadened this requirement to include manufacturers of aeronautical products (FAA, 2010). Below is an outline of this FAA (2010) reporting process.

a. “Ensure an understanding of the rules,”
b. “Establish the most expeditious means of conveying the required information in a manner and form acceptable to the FAA,”
c. “Determine the person(s) to be contacted,” and
d. “Establish a means of keeping the FAA informed of progress and providing additional information on those cases where only preliminary information was reported.” (p. 2)

The FAA states, “Airworthiness Directives (ADs) are legally enforceable regulations issued by the FAA in accordance with 14 CFR part 39 to correct an unsafe condition in a product. CFR Title 14, Part 39 defines a product as an “aircraft, engine, propeller, or appliance” (FAA, 2021). This process and the resulting corrective action plan contribute to an ongoing assurance that a product is safe.

In 2012, the Small Airplane Directorate (SAD) Continued Operational Safety (COS) Branch surveyed the historical record of past unsafe conditions identified in ADs (FAA, 2012).

This involved examining past ADs, identifying AD causal factors, and looking for patterns or trends that may provide lessons to avoid unsafe conditions in the future. The survey covered ADs applicable to 14 CFR Part 23 and Civil Air Regulation (CAR) 3 approved airplanes issued between 2005 and 2010. Some of the key findings from the SAD study were:

- 90% of ADs fall within the categories of fatigue, corrosion, faulty equipment, interferences, or a breakdown in the manufacturing quality system.
- Fatigue, wear, and corrosion are the reasons for 37% of ADs.
- 21% of ADs are a result of equipment failures.
- 20% of ADs can be attributed to inadequacies in manufacturing quality systems (FAA, 2012).

While the Small Airplane Directorate study did not specifically reference SMS considerations or objectives, the study clearly recognized the value of reviewing AD trends at a system level with the goal of using this information for future systemic improvements.

Methodology

This research was conducted across the following three phases.

1. Data Collection
2. Assessment Criteria
3. Analyst Calibration

Phase 1: Data Collection

Researchers obtained a list of ADs (n = 3737) issued from 2009 through 2018 from the public AD Database available at the FAA’s Dynamic Regulatory System (FAA, 2020). Researchers excluded the subtypes Glider, Balloon, and Airship as combined they comprise less than 1% of the total ADs issued over this timeframe. Below is a breakdown of the results of the

AD database query by their product subtypes.

1. Small aircraft, (n = 377)
2. Rotorcraft, (n = 464)
3. Large aircraft, (n = 2207)
4. Engines, Propellers, Appliances, (n = 593)

Samples of at least 5% from each of the four subtypes were selected using a random integer generator from True Random Number Service (www.random.org). The ADs were analyzed for the cost of compliance based on estimates cited in the AD. The cost information was based only on the direct costs expected to be incurred to comply with that AD. This cost does not capture any other indirect costs that the industry may incur with ADs such as out of service expenses, planning, administrative/recordkeeping activities, and time to access or close out work areas.

Phase 2: Assessment Criteria

Researchers developed a defined set of assessment criteria to assist in determining the percentage of AD actions involving new risk controls (conditions that would not have been foreseen based on past industry practices/standards) and the percentage involving revised risk controls (conditions that the industry recognizes as needing to be addressed for safe operations). The terms “new” and “revised” risk controls are not traditionally associated with this type of AD analysis but are to SMS. By categorizing each AD as a new or revised risk control, researchers may better understand how effective current industry practices are at identifying hazards, mitigating these hazards, and verifying the effectiveness of the mitigation actions. Examining the data through these considerations will provide some perspective on the extent to which these issues might be more effectively resolved through strengthened SMS efforts versus continued reliance on managing them through conventional AD corrective actions.

Revised Risk Control AD Actions

This section describes conditions considered revisions to existing risk controls - controls the industry has utilized in broad terms to achieve overall safety objectives. The six specific descriptions provided below were developed by researchers to enable a more consistent categorization of the ADs and are representative (but not all inclusive) of situations where the AD is revising an existing risk control.

1. <u>Actions that restore a control:</u> Situations where risk controls are reasonably assumed to be part of the original design/build/maintenance/support process, but the control was not adequately implemented or maintained to achieve the desired outcome. Example: tasks that were missing from the manufacturing or inspection process, which led to an unsafe condition and the need for an AD to restore the product to its original or equivalent design**.**
2. <u>Actions that correct a defect/error in the manufacturing process</u>: Situations where the manufacturing process had appropriate controls in place, but an error was introduced into the process and led to the unsafe condition.
3. <u>Actions that expand or change the scope of a prior AD:</u> Situations where prior AD action(s) were not sufficient or fully effective in achieving the desired outcome. Note: Consideration was given to not lump all ADs that were superseded into this category as many actions are interim in nature and then later superseded as part of a series of progressive actions implemented at different times.
4. <u>Actions to revise existing operational or maintenance procedures</u>: Situations where existing controls may not have been sufficiently clear or well-defined, which led to an undesired outcome. In this case, it was recognized that risk control was originally needed but this control was insufficient and required revision through an

AD.

5. Actions to address a change that was not properly/thoroughly evaluated: Situations where a change was not thoroughly evaluated prior to being introduced into service. In this case the action is in response to a likely adverse event occurring had the normal compliance practice/process been followed. Example: an AD action required to address a process breakdown that allowed a non-compliant change or introduced an unsafe condition.
6. Actions that add details to what would be considered an existing risk control: Situations where existing controls may not provide sufficient detail to ensure success. Example: more detailed installation instructions for a known critical system/function. Such systems normally have detailed installation instructions that at times prove deficient in practice, and the revision is required to address missing details or tasks.

New Risk Control AD Actions

The following section describes conditions considered to represent new risk controls required to address unforeseen unsafe conditions. Again, researchers defined four specific descriptions to enable consistency in reviewing the ADs. These four descriptors described below are representative and not inclusive of all ADs that implement a new risk control.

1. Actions that address specific structural issues: Situations where despite best practices there is a unique need to implement a control to maintain safety of the product. In this case, there was a discovery that went beyond the normal expectations of knowledge and past industry practices, hence a need for new risk control.
2. Actions implementing a new procedure - operational or maintenance**:** Situations

where new information invalidates past assumptions/experience and requires a new risk control.

3. Actions adding a new feature that was not part of the original design: Situations based on in-service experience or new knowledge, a new system feature is needed to maintain safe operations.
4. Actions changing system functionality through the implementation of new risk controls: Situations where the current system operating functions or procedures introduce a risk and require revision.

Origin of Unsafe Condition

The FAA has four methods by which designs are approved, these are (FAA, 2017):

1. Type Certification (TC)
2. Technical Standard Order (TSO)
3. Parts Manufacturing Approval (PMA)
4. Supplemental Type Certificate (STC)

For each AD examined, the review identified the design approval method corresponding to the origin of the unsafe condition. If the origin of the unsafe condition was associated with components/systems approved through the Parts Manufacturer Approval (PMA), Supplemental Type Certificate (STC) or Technical Standard Order (TSO) process, they were categorized as such. If not, it was assumed the AD action was directed at the product approved through the Type Certification (TC) process. Determining the distribution of AD corrective actions across all FAA design approval processes may provide insight into areas of greater risk, which may be opportunities for future safety and efficiency improvements supported through SMS.

Phase 3: Analyst Calibration

The analyst team was composed of five subject matter experts with extensive industry experience in aircraft maintenance and manufacturing, safety and quality, and experience conducting research in the aviation maintenance and manufacturing industries. Collectively the team had over one hundred years of aviation experience with two members also having aviation related doctoral degrees. All members possessed an FAA airframe and powerplant technician certificate, and three members possessed an FAA pilot certificate. Additionally, all members were familiar with FAA ADs, including experience completing ADs, documentation, and regulatory policy.

Inter-Rater Reliability

The research team collectively reviewed the assessment criteria developed in Phase 2, in particular the definition of new and revised risk controls. This review helped to calibrate the assessment criteria for the team and clarify their tasks and research objectives. The team developed an Excel table (Table 1) that listed the selected ADs with the assessment criteria. Each reviewer used this table when assessing each AD and selected whether the AD was a new or revised risk control, the approval method of origin, and the cost. The AD number and product subtype columns were prefilled by researchers. Reviewers completed their review independently. Once a reviewer completed their assessment of the selected ADs, they then submitted their completed table to the researchers. The researchers then compiled the reviewer responses into a single Excel spreadsheet to facilitate data analyses. Table 1 provides an example of a reviewer’s completed entry.

Table 1

AD Review Form

		Risk Control		**Approval method where the unsafe condition likely originated**				
AD Number	**Product Subtype**	**New**	**Revised**	**TC product**	**TSO product**	**PMA product**	**STC product**	**Cost of AD (USD)**
2014-26-03	Large Aircraft		X	X				$85

Overall, the analyst team had an 87% agreement rate when deciding whether the ADs were new or revised risk controls and 92% agreement on the origin of the AD. An inter-rater reliability analysis using the Kappa statistic was performed to determine consistency among raters. The advantage of the Kappa coefficient over the percentage agreement is that the Kappa coefficient takes into consideration the probability of rater agreement occurring purely by chance (Marston, 2010; McHugh, 2012; Viera & Garrett, 2005).

A Kappa coefficient was calculated from a sample of 10 ADs from each of the four AD categories. This resulted in a significant kappa of .845, (p = .001) (see Table 2).

Table 2

Kappa Coefficient

		Value	Sig.
Measure of Agreement	Kappa	.845	.001
N of Valid Cases		40	

Interpretation of Kappa indicates that there was strong inter-rater agreement while the significance of .001 indicated that there was only a 1% chance that this calculation was incorrect (Marston, 2010; McHugh, 2012).

The predefined AD descriptors provided to the raters before AD categorization likely positively influenced the reliability rating. Kappa scores may have improved if the raters reviewed the ADs together to discuss interpretation. In general, the raters agreed that the well-defined descriptors made it fairly easy to assign an AD to a category. The raters agreed that the information and terminology were inconsistent across the ADs. Some ADs provided better information regarding the reason for the AD, while some ADs required the reviewer to decide. Standardized information and terminology would likely further improve these types of analyses.

Results

Overall, initial analysis of the ADs (see Table 3) found that approximately 55% of the sampled ADs were the result of a new risk control and approximately 45% were the result of a revised risk control. The sample of large aircraft ADs had the highest percentage of new risk controls (66%) while the sample of rotorcraft ADs had the highest percentage (70%) of revised risk controls.

Table 3

AD Data Analysis

	FAA Airworthiness Directives								
Product Type	**Issued 2009-2018**	**Analyzed in this study**	**New risk control**	**Revised risk control**	**TC product**	**TSO product**	**PMA product**	**STC product**	**Cost of AD (USD)**
Small Airplanes	377	19 (5%)	9 (50%)	9 (50%)	16	1	0	2	$533,375
Rotorcraft	464	23 (5 %)	7 (30%)	16 (70%)	21	1	0	1	$12,135,481
Large Aircraft	2207	115 (5.2%)	76 (66%)	39 (34%)	105	7	0	3	$84,904,937
Engines, Accessories, Appliances	593	32 (5.4%)	13 (40%)	19 (60%)	27	1	2	2	$83,448,216
Totals	**3,641**	**189 (5.2%)**	**105 ~55%**	**84 ~45%**	**169 (90%)**	**10 (5%)**	**2 (1%)**	**7 (4%)**	**$181,022,009**

Rather than just analyzing individual ADs, this study was unique in that it looked holistically at ADs and some of the underlying process related issues that prompted the AD. The analysis revealed the following findings:

1. A review of a 10-year period of ADs indicates a large number of FAA actions were required to correct unsafe conditions associated with aviation products operating in the National Airspace System (NAS). These safety actions are in addition to the countless existing safety actions that the industry fulfills through compliance with airworthiness standards, conformance to the type design, adherence to established operational and maintenance practices and any other industry practices/standards that have been used. The period of study corresponds to a time when accident rates (high level safety indicators) were showing improvements for general aviation, helicopter operations, and significant improvements for transport aircraft operations. This interval also corresponds to a period where collaborative safety initiatives were being developed and implemented involving broad industry and government participation, such as SMS and Aviation Safety Action Programs.
2. There is considerable effort expended today by manufacturers, operators, and the FAA to maintain the safety of the products operating in the NAS. While these efforts have been very successful in terms of accident avoidance or reduction, implementation of SMS into the aviation product design and manufacturing processes may reduce the number of AD corrective actions. While the study was not able to establish a specific figure to illustrate the scope of reduced AD actions, there appears to be significant potential for improvement in reducing ADs through SMS hazard identification and mitigation processes. Similarly, SMS includes processes that provide ongoing validation of the effectiveness and improvement of existing risk controls.

3. ADs can be categorized in terms that have relevance to SMS to assess the effectiveness of current industry practices and identify opportunities for improvement through the development and implementation of SMS.
4. There were similarities in AD actions despite the different categories of aircraft and engines examined. This suggests some level of commonality for underlying contributing factors to AD actions, which further suggests the potential for improvements across the industry by identifying and addressing these common factors.
5. The vast majority (90%) of AD actions were directed at products approved through the Type Certification process. A relatively small number (10%) of ADs have been necessary to directly address issues associated with STC, TSO, or PMA approvals. This is one of several factors that should be further considered when assessing the effectiveness of existing industry practices and identifying the segments of the D&M community that may realize greater benefits from SMS.
6. The ADs reviewed correspond to a wide range of products, from current and past products and U.S. and foreign manufacturers. This is relevant in that the greatest opportunity to realize the benefits of SMS lies in current and future products. These distinctions were not captured as part of this initial study and may be an area for future examination.
7. Ten different descriptors were developed to guide the evaluation of ADs and determine whether the AD introduced a “new” or “revised” risk control. This study did not explore any trends associated with each of these descriptors. Further work in this area may provide insight into how the industry can adjust current safety practices to more effectively preclude future events.
8. The utility of examining AD data at a system level could be improved through a

standardized format of key information (nature of unsafe condition, root cause factor(s), number of products affected in US and world operations, costs, etc.) associated with every AD.

9. The use of standardized criteria for assessing if the AD action was a new or revised risk control was helpful and easy to use by all evaluators.
10. Future AD analyses should utilize a diverse group of analysts with extensive industry experience and proper training to maximize the consistency of observations/findings.

Conclusion

Researchers found that approximately 55% of the sampled ADs were the result of a new risk control, and approximately 45% were the result of a revised risk control. In these cases, the research suggests that regular risk controls as part of the original design process were not sufficient, and an AD action was necessary to ensure an acceptable level of safety. Furthermore, the research found 90% of the AD actions originated during the original type certificate design. This suggests that there is an opportunity to significantly improve current risk control methods in the design process and review the related continuous risk assessment processes, which may have the potential to significantly reduce the overall number of ADs.

The total cost estimate for the ADs analyzed (n=189) in this study was over $181M, which is about $1M per AD. Thus, more effective risk controls have the potential to significantly reduce the overall cost to the industry while also lowering the risks associated with unplanned maintenance. However, like previous research (Batuwangala et al, 2018; Lercel et al, 2011; Okwera, 2016; Stolzer et al, 2011), further exploration is required to gain better insight into these financial implications. In addition, this type of analysis may help assess if organizations are learning from these past events or if they are prone to make similar mistakes in the future. Every

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AD involves unplanned costs, often at multiple levels, and other variables that must be managed and implemented as part of the aircraft maintenance and manufacturing process. This study suggests that SMS may further improve the D&M industry’s safety performance by reducing the number of corrective actions and their associated costs.

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