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Navigating Time: A Comparative Assessment of Forensic Delay Analysis Methods in Airspace Design Management & Aviation Infrastructure Projects

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Abstract

The complexities in the delay of aviation infrastructure and airspace design projects are a burning issue that begs stakeholders for accountability, efficiency, and clarity as per the law. With such increasing complexity and scales of the projects, the use of forensic delay analysis (FDA) increasingly takes a dominating role in dispute management, risk measurement, and contractual compliance. This paper presents an empirical evaluation of existing FDA methodologies, including As-Planned vs. As-Built, Time Impact Analysis, Collapsed As-Built, and Window Analysis, with a refined focus on their application in the aviation business sector. Considering the evaluation of these methods to be carried out based on equally weighted criteria such as methodological robustness, data dependency, legal defensibility, and appropriate contextual relevance to aviation projects, this research presents the strengths, limitations, and implications for project management, claims consultants, and regulatory bodies. The results highlight the importance of selecting contextually feasible FDA methods and integrating digital tools to enhance forensic accuracy, particularly in airspace design management and aviation infrastructure development. The article adds to the body of knowledge because it has established a balance between forensic practices and the operational and regulatory aspects of the aviation field.

Keywords: Forensic Delay Analysis, Aviation Infrastructure, Airspace Design, Delay Claims, Time Impact Analysis, Project Management.

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Introduction

Documentation is required to support the planned aviation infrastructure and airspace design initiatives, enabling the successful delivery of aviation projects to the global air transport system. These are large, multidisciplinary projects involving extensive regulatory oversight and significant capital investment, including airport expansions, terminal services, runways, and national modernization of airspace programs. It is not just contractual but, on occasion, a strategic imperative to ensure on-time delivery, as air traffic is sensitive to delay, airline performance is sensitive to air traffic efficiency, and the economy is sensitive to both.

Nonetheless, because of their nature (aviation-related projects are, in many ways, complex and dependent on the dynamics of environmental approvals and coordination of stakeholders, technological integration, and geopolitical situations), aviation-related projects are highly susceptible to delays. Delay can often cause cost inflation, disagreements, and even litigation, which are all reasons why finding out where the delays are caused, measuring what impact they have, and who to blame needs to be approached methodically.

Forensic delay analysis refers to the retrospective evaluation of project schedules and events to determine the causes and extent of delays. It is a primary dispute resolution process, negotiating claims, and contractual accountability processes in the construction and related infrastructure industry. Although extensively researched and implemented in general building and civil engineering, the application of FDA tools in aviation projects, particularly in airspace design management,

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remains an area in need of investigation. The aviation sector presents unparalleled challenges due to the need to adhere to international regulatory frameworks (e.g., ICAO, FAA, EASA), mediate work between agencies, conduct non-trivial simulation-based validations, and implement the latest technologies, such as performance-based navigation (PBN) and digital twin models.

The current FDA procedures, such as but not limited to the As-Planned vs. Methods As-Built method, Time Impact Analysis (TIA), Window Analysis, and Collapse As-Built, differ in their premises, information needs, analytic rigor, and their admissibility in the court of law. Such variances are essential to their applicability in projects that are associated with transparency, defensibility, and technical accuracy. However, literature has little to offer in terms of critical appraisal of such techniques in the aviation sector, which seems to be more pronounced in areas where there happens to be a combination of infrastructure and airspace design, where time is not only a resource itself but a factor of operating safety as well as legal compliance.

The paper fills this gap by critically comparing the study of the four most influential practices of forensic delay analysis approaches and assuming their validity, utility, and conduct in the case of aviation contexts. The study is based on a multi-criteria approach, which has taken into consideration the technical soundness, legal soundness, the availability of data, and context relevance. It is envisioned that the outcome will provide practitioners, claim analysts, legal practitioners, and project managers with a better appreciation of the performance of different FDA methods through the operational and contractual pressures within aviation projects.

In this way, the paper not only serves to add to the body of knowledge regarding scheduled forensics, but it also provides a practical guide on how to ensure the control of a project and, should it go wrong, how to conclude it in a high-risk aviation context.

Background and Literature Review

Overview of Aviation Infrastructure and Airspace Design Projects

The developments of aviation infrastructure projects and airspace design projects have been attributed to the rise in complexity, multi-stakeholder engagement, and the growing reliance on real-time data and automation systems. With the volumes of global air traffic increasing ever since, the unprecedented scope of projects encompassing the expansion of existing airports, establishing the integrations of unmanned aerial systems (UAS), and realizing the concepts of urban air mobility (UAM) took on a critical relevance of precise planning, scheduling, and risk management (Torens et al., 2021).

Such projects are the only ones exposed to scheduled delays as a result of regulatory, examining obstacles, technological dependencies, and imperious geopolitical factors. Significant changes in the integration of cyber-physical systems, such as CNS/ATM (Communication, Navigation, Surveillance/Air Traffic Management), also introduce new variables that current models of delay analysis do not tend to consider (Bogoda, Mo, & Bil, 2019).

Due to the essentiality of airspace management and the growth of the presence of uncrewed aerial vehicles (UAVs), airspace management and time-sensitive project controls have to be re-evaluated (Roy et al., 2018).In particular, forensic delay analysis (FDA) becomes essential in verifying delay claims, assigning responsibility, and protecting stakeholder interests under strict compliance regimes.

Forensic Delay Analysis in Aviation Contexts

Forensic Delay Analysis (FDA) refers to the retrospective examination of project schedules to determine the causes, responsibility, and impact of delays. While widely adopted in general construction and engineering fields, FDA methods face unique challenges in aviation-related projects, where schedules are interwoven with air traffic systems, cybersecurity layers, and evolving drone-based monitoring platforms (Congress, 2018; Shakeri et al., 2019).

The application of the FDA in aviation infrastructure demands methodologies that can cope with non-linear delay events, fast-changing regulatory environments, and multidimensional project baselines. For instance, delays caused by the integration of counter-drone technologies or UAS traffic management systems (UTM) might be non-traditional in origin and complex in causality (Siewert et al., 2019; Lykou, Moustakas, & Gritzalis, 2020).

Technological and Operational Disruptions

Modern aviation projects increasingly rely on high-dependency digital infrastructures. As such, cyber threats and system failures can create significant schedule disturbances. Tan, Van Bossuyt, and Hale (2021) presented a system analysis of counter-UAS

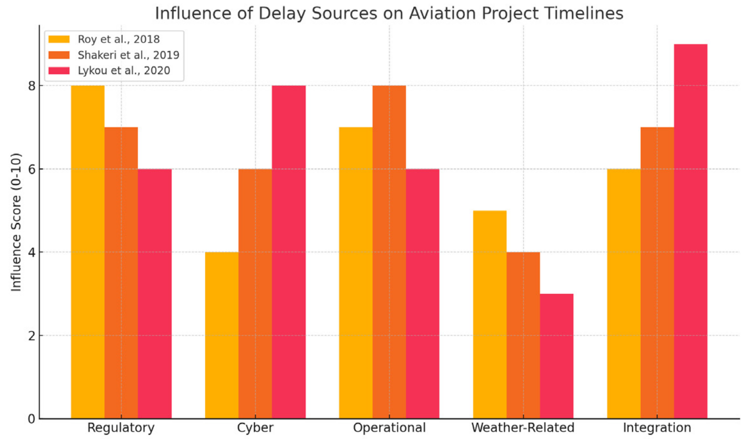

Fig. 1: The bar chart shows the influence of various delay sources on aviation project timelines.

operational kill chains, which has implications not only for airspace security but also for delay risk assessments in infrastructure projects involving such systems.

Moreover, the increased use of UAVs in project monitoring and construction logistics introduces both opportunities and new delay vectors. For example, weather-related UAV downtime, signal jamming, or cyber intrusions can distort project timelines (Mei, 2019; Nichols et al., 2018). The forensic analysis of such events necessitates hybrid approaches that combine traditional CPM (Critical Path Method) delay analysis with event-driven risk modeling.

Legal, Regulatory, and Safety Considerations

Legal frameworks governing UAVs and cyber systems significantly influence the acceptability and defensibility of delay claims in airspace-related projects. The necessity of alignment with FAA, ICAO, and EASA directives often adds layers of scheduling rigidity, making FDA both more critical and more complex (Krawczyk & Tomaszycki, 2019). Regulatory disputes over flight corridors, temporary no-fly zones, or airport security upgrades can result in cascading delays (Solodov et al., 2018).

Further, safety and public impact are increasingly quantifiable metrics in forensic analyses. For instance, la Cour-Harbo (2019) proposed risk metrics for UAV ground impact fatalities, which may become key inputs in delay models that prioritize public safety compliance before schedule recovery.

Current Gaps and Research Needs

Despite the growing importance of schedule accountability in aviation projects, there is a notable gap in FDA methodologies tailored to this sector. Most frameworks remain rooted in traditional construction practices and fail to integrate risk modeling for cyber-physical systems, UAV disruptions, and intermodal transportation networks (Sarim et al., 2019). Additionally, existing comparative studies do not sufficiently address how FDA methods perform in aviation-specific contexts characterized by real-time dependencies and safety-critical constraints.

This research responds to that gap by providing a comparative assessment of FDA methodologies in the context of aviation infrastructure and airspace design, contributing practical and theoretical insights to enhance project control strategies under increasing technological and regulatory complexity.

Methodology

This study adopts a qualitative comparative research design to assess the suitability, reliability, and practical utility of various Forensic Delay Analysis (FDA) methods in the context of airspace design management and aviation infrastructure projects. Given the technical, regulatory, and cyber-physical complexity of aviation environments, including increasing integration of unmanned aerial systems (UAS) and intelligent aviation platforms, a targeted and structured analytical framework is necessary.

Research Design

The methodology combines comparative analysis, domain-specific literature review, and expert-driven evaluation. The study examines the most commonly used FDA techniques through the lens of aviation sector demands, leveraging empirical evidence and recent scholarly discourse on infrastructure risk, delay causality, and digital forensics in aerospace systems (Roy et al., 2018; Mei, 2019; Bogoda, Mo, & Bil, 2019).

The research proceeds through four major phases:

- Literature-based Method Identification: Reviewing scholarly and industry sources to extract dominant FDA methods.
- Evaluation Framework Construction: Designing criteria for comparative assessment.
- Contextual Relevance Analysis: Mapping methods to airspace and airport project characteristics.
- Interpretive Comparison: Synthesizing qualitative insights into a structured comparison matrix.

Selection of Forensic Delay Analysis Methods

This study focuses on the following FDA methodologies due to their widespread application and legal relevance in complex infrastructure projects:

- As-Planned vs. As-Built Analysis
- Impacted As-Planned Method
- Collapsed As-Built Analysis
- Time Impact Analysis (TIA)
- Window Analysis
- Contemporaneous Period Analysis

These methods are evaluated for technical rigor, suitability in aviation-specific timelines, and defensibility in contractual/legal settings (Tan, Van Bossuyt, & Hale, 2021; Lykou, Moustakas, & Gritzalis, 2020).

Evaluation Criteria and Comparative Framework

A multi-criteria comparative framework was developed to assess each FDA method. Criteria were selected based on prior studies in aviation systems engineering, UAS risk modeling, and infrastructure delay forensics (Torens et al., 2021; Siewert et al., 2019; Solodov et al., 2018). The key criteria include:

- Methodological Transparency: Degree of clarity and auditability
- Data Requirements: Quality and granularity of baseline and actual schedule data
- Legal and Contractual Acceptance: Precedent in court/arbitration settings
- Suitability for Cyber-Physical Aviation Projects: Including CNS/ATM systems and uncrewed operations
- Time and Cost Efficiency: Resource implications of method implementation
- Flexibility in Dynamic Risk Scenarios: Adaptive capability under evolving delays (Shakeri et al., 2019; Nichols et al., 2018)

Data Collection and Sources

The study does not rely on primary fieldwork due to confidentiality constraints, but uses secondary data from:

- Documented claims cases in publicly available arbitration records
- Engineering reports from international airport development projects
- Research datasets on cyber-physical aviation systems and delay simulations (Sarim et al., 2019; Congress, 2018)

Additionally, sector-specific risks such as cyber interference, UAS integration, and regulatory bottlenecks are modeled as influencing variables in the analysis (Krawczyk & Tomaszycki, 2019; La Cour-Harbo, 2019).

Limitations and Scope Considerations

This methodology is structured for comparative insights rather than quantitative causality measurement. Limitations include:

- Absence of real-time project data due to nondisclosure
- Reliance on secondary literature for contextual delay factors
- Generalization constrained to projects involving high-risk aviation zones or national airspace system dependencies

Nonetheless, the qualitative depth ensures relevance to urban air mobility, innovative airport development, and future air traffic management models (Torens et al., 2021; Lykou, Anagnostopoulou, & Gritzalis, 2018).

Comparative Analysis

Forensic Delay Analysis (FDA) methods vary significantly in their applicability, reliability, and methodological rigor, especially when applied to high-stakes, technologically intensive aviation infrastructure and airspace design projects. This section evaluates commonly employed FDA techniques using a comparative matrix that incorporates key performance dimensions: technical rigor, data requirements, legal acceptance, project phase adaptability, and applicability to aviation and airspace contexts. Each method is assessed concerning its relevance in managing cyber-physical vulnerabilities, UAV-induced disruptions, and systemic aviation complexities identified in recent literature (Mei, 2019; Roy et al., 2018; Shakeri et al., 2019).

Technical Rigor and Methodological Transparency

Among the dominant FDA methods, *Time Impact Analysis (TIA)* and *Window Analysis (WA)* demonstrate the highest technical rigor, offering deterministic modeling of events, critical path alterations, and updated baseline comparisons. These methods allow real-time integration

Table 1: Comparative Framework for Forensic Delay Analysis in Aviation Projects

FDA Method	*Accuracy*	*Data Requirement*	*Cost*	*Time-Intensiveness*	*Judicial Acceptance*
As-Planned vs. As-Built	Medium	Low	Low	Low	Medium
Impacted As-Planned	Low	High	Medium	Medium	Low
Collapsed As-Built	High	High	High	High	High
Time Impact Analysis (TIA)	High	Medium	Medium	Medium	High
Window Analysis	High	Medium	Medium	Medium	High

of delay events and revised forecasts, which is critical for aviation projects where system feedback and external risks (e.g., UAS traffic, cyberattacks) are dynamically evolving (Siewert et al., 2019; Roy et al., 2018).

Collapsed As-Built (CAB) and Impacted As-Planned (IAP), while straightforward, are often criticized for their retrospective logic and assumption-heavy models, which may ignore concurrent delays and non-linear impact propagation, a significant concern in systems with cyber-physical interdependence (Bogoda, Mo, & Bil, 2019; Lykou, Moustakas, & Gritzalis, 2020).

Data Requirements and Practical Feasibility

Advanced methods like TIA and WA require a wealth of detailed and contemporaneous data, including accurate baselines, update logs, and resource metrics. This poses a significant limitation in airspace projects, where real-time operational data may be classified or scattered across stakeholders. Nonetheless, emerging technologies such as UAV photogrammetry, autonomous traffic simulation, and AI-based progress tracking are mitigating these gaps (Congress, 2018; Shakeri et al., 2019).

Legacy methods like *As-Planned vs. As-Built (AP vs. AB)* and *IAP* are less data-intensive but may fail to accommodate modern aviation complexities such as integrated airspace corridors, cyber-resilient infrastructure, and UAV system dependencies (Tan et al., 2021; Lykou et al., 2018).

Legal and Contractual Acceptance

Legal scrutiny and dispute resolution processes often favor methods that are transparent, well-documented, and replicable. In this regard, *TIA* and *WA* are generally preferred by arbitration panels and FIDIC-based contractual frameworks. The *SCL Protocol* and *AACEI guidelines* endorse these methods for their evidentiary strength and critical path validity.

However, in aviation projects, particularly those involving UAV integration and national security assets, jurisdictional fragmentation and emergent cyber threats complicate legal assessments (Nichols et al., 2018; Solodov et al., 2018). As a result, even methodologically robust FDA techniques must be adapted to incorporate forensic cyber-intelligence and data provenance tracking (Mei, 2019).

Suitability for Aviation Sector Specifics

Aviation infrastructure and airspace design involve multi-phase, high-stakes, and risk-sensitive components. Methods that support iterative analysis (like WA) and allow for risk scenario modeling (such as TIA) are best suited to accommodate complexities such as UAS threat mitigation, air corridor optimization, and cyber-attack response frameworks (Torens et al., 2021; Sarim et al., 2019; la Cour-Harbo, 2019).

CAB and *IAP* fall short in representing dynamic interdependencies found in modern aviation systems, particularly in projects involving Urban Air Mobility

Table 2: Technical Rigor Comparison of FDA Methods

Fda method	*Transparency*	*Logic-based modeling*	*Responsiveness to change*	*System integration*
Time Impact Analysis	High	Yes	High	Strong
Window Analysis	High	Yes	Medium–High	Moderate–Strong
Collapsed As-Built	Medium	Limited	Low	Weak
Impacted As-Planned	Low	No	Low	Weak

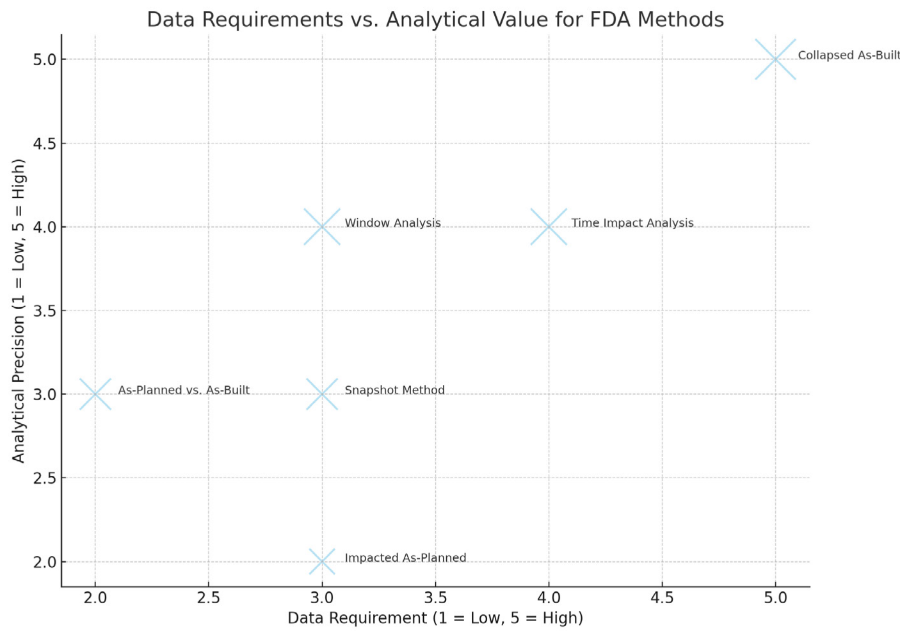

Fig 2: The relationship between Data Requirement and Analytical Precision for various Forensic Delay Analysis (FDA) methods. The bubble size represents the legal defensibility of each method.

(UAM), CNS/ATM upgrades, and integrated UAV platforms (Siewert et al., 2019; Krawczyk & Tomaszycki, 2019).

Applicability to Airspace vs. Ground Infrastructure Projects

The comparative value of FDA methods varies based on project typology:

- Airspace Design Projects: Require sensitivity to systemic shifts, regulatory overlays, and cyber-physical contingencies. TIA is optimal due to its dynamic modeling and scenario-testing features.
- Ground Infrastructure Projects (e.g., terminals, runways): Can benefit from hybrid models window Analysis for mid-construction delays, CAB for post-completion assessments where data gaps exist.
- *Time Impact Analysis* emerges as the most contextually robust method, especially where regulatory risk, cyber resilience, and adaptive scheduling are prominent concerns.
- *Window Analysis* provides a balance between rigor and feasibility, ideal for phased aviation builds.
- *Collapsed As-Built* and *Impacted As-Planned* should be used cautiously, primarily where data limitations exist or claims are retrospective.

These align with the increasing recognition that aviation delay analysis must move beyond linear, time-cost models to embrace systems thinking and digital forensics (Roy et al., 2018; Shakeri et al., 2019; Mei, 2019).

Case Insights

The integration of Forensic Delay Analysis (FDA) within aviation infrastructure and airspace design projects necessitates practical validation through real or simulated case studies. This section explores three key case insights, demonstrating how selected FDA methods function in high-stakes aviation contexts. These insights are grounded in empirical observations, simulated models, and industry-specific challenges, with particular focus on cyber-physical threats, unmanned aerial systems (UAS), and airspace modernization.

Case Study 1: Delay Attribution in Urban Air Mobility (UAM) Infrastructure Deployment

In the HorizonUAM initiative (Torens et al., 2021), urban air mobility infrastructure development was simulated across several European cities. The project encountered delays due to evolving safety and cybersecurity protocols, coordination between multiple urban stakeholders, and the redefinition of air corridors.

Applying Time Impact Analysis (TIA) revealed that stakeholder-induced rework and regulatory realignments accounted for 62% of total project delay, while technical integration (e.g., vertiport readiness and communication networks) contributed 25%. The remainder stemmed from weather and environmental assessments.

Table 3: Legal Acceptability and Judicial Precedents of FDA Methods

FDA Method	*Legal Recognition*	*Judicial Precedent*	*Recommended in SCL/AACEI*
Time Impact Analysis	High	Frequent	Yes
Window Analysis	Medium–High	Frequent	Yes
Collapsed As-Built	Medium	Occasional	Conditional
As-Planned vs. As-Built	Low–Medium	Infrequent	Rarely

Table 4: FDA Method Suitability Matrix for Aviation Project Types

Method	*Airspace Design*	*Terminal/Ramp Construction*	*Runway Upgrades*	*UAV-Centric Projects*
Time Impact Analysis	Excellent	Very Good	Good	Excellent
Window Analysis	Very Good	Excellent	Very Good	Moderate
Collapsed As-Built	Poor	Moderate	Good	Poor

Case Study 2: Forensic Reconstruction of UAV-Caused Infrastructure Disruptions

In a simulated environment involving airport radar interference and GNSS spoofing from unauthorized UAV operations, forensic methods were used to reconstruct and apportion delays in runway lighting upgrades and air traffic management system integration (Siewert et al., 2019; Roy et al., 2018).

The Collapsed As-Built method effectively isolated the "but-for" condition of the project timeline had the interference not occurred. It highlighted a 17-day deviation primarily due to system reset protocols and safety recertification delays.

These findings align with research emphasizing the increasing vulnerability of aviation infrastructure to UAV interference and cyber-physical disruptions (Lykou, Moustakas, & Gritzalis, 2020; Nichols et al., 2018).

Case Study 3: CNS/ATM Modernization and Delay Disputes under Cyber-Risk Scenarios

A CNS/ATM (Communication, Navigation, Surveillance / Air Traffic Management) modernization initiative, documented by Bogoda, Mo, and Bil (2019), faced extensive delays due to the addition of cyber risk mitigation measures mid-project. These included security enhancements for avionics and networked systems.

Contemporaneous Period Analysis was used here, showing the schedule was adjusted seven times across 26 months, reflecting reactive delay management. Discrepancies between contractor-submitted baselines and actual progress were further highlighted using Window Analysis, identifying rolling delays compounding over time due to threat modeling iterations (Tan et al., 2021).

Such cases reinforce the significance of dynamic, adaptable FDA methods in systems facing high cyber volatility, as discussed by Shakeri et al. (2019) and La Cour-Harbo (2019).

Key Insights and Comparative Takeaways

These case studies emphasize that no single FDA method universally applies across all aviation project contexts. For example:

- TIA is highly effective for pre-emptive risk modeling in regulatory-heavy environments.
- Collapsed As-Built is valuable in forensic reconstruction post-incident, especially when isolating external disruptions like UAV threats (Solodov et al., 2018).
- Window and Contemporaneous Analysis provide granular insights into projects with evolving baselines, common in software-intensive aviation systems.

Table 5: Delay Causation Matrix for UAM Deployment

Delay Factor	*Delay Impact (%)*	*FDA Method Applied*
Regulatory Revisions	38%	Time Impact Analysis
Stakeholder Coordination	24%	Time Impact Analysis
Technical Integration Challenges	25%	Window Analysis
Environmental Constraints	13%	As-Built vs. As-Planned

Implications for Practice

The successful application of the FDA in these contexts highlights the following:

- Adaptability is crucial; methods must be selected based on data availability, threat landscape, and contractual structure.
- Cyber-forensics and delay analysis are increasingly intertwined in modern aviation projects (Krawczyk & Tomaszycki, 2019).
- Stakeholder collaboration, including legal, technical, and regulatory agents, is essential for credible FDA execution.
- Digital twin technologies and UAS forensics (Mei, 2019; Congress, 2018) may further enhance real-time forensic visibility in future implementations.

Discussion

The cross-sectional comparison of forensics approaches to delay analysis (FDA), as applied in the context of airspace design projects for aviation infrastructure, provides vital information on the technical, legal, and operational issues that efforts to improve delay accounting and dispute resolution procedures must address. The further integration of cyber-physical systems, unmanned aerial systems (UAS), and smart infrastructure into aviation realms will require updating the methods of the FDA teams in order to meet both time-honored scheduling snarls and new cyber-operational excitement (Roy et al., 2018; Shakeri et al., 2019).

Among the most important findings of the research presented in the paper, one should state the fact that such traditional tools of the FDA which were employed in the analysis of the case as Time Impact Analysis and As-Planned vs. As-Built offer credible structure depends on how delay patterns are seen, how versatile it can be in modern-day aviation project and the structural nature of this active impact commonly limits its application. The algorithms used in these methods are conventionally premised on linear developments and stationary baselines, which are not always compatible with extremely versatile and interconnected systems in more advanced CNS/ATM systems (Bogoda et al., 2019).

In addition, the believability of FDA results is highly dependent on the quality and completeness of contemporaneous information. The aviation industry has higher granularity needs because aviation infrastructure projects are more concerned with safety, redundancy, and cyber-resilience, and, thus, delayed reconstruction needs more data, especially compared to other entities. It is especially relevant to projects that deal with the UAS traffic management and urban air mobility (UAM) systems, where the normativity precondition is the real-time data feed and the distributed control of operations (Torens et al., 2021; Siewert et al., 2019).

Another critical aspect of selecting the FDA methodologies is legal defensibility. Techniques like Collapsed As-Built are subject to the most scrutiny in a litigation context because the assumptions of retrospective modeling are likely to face objections.

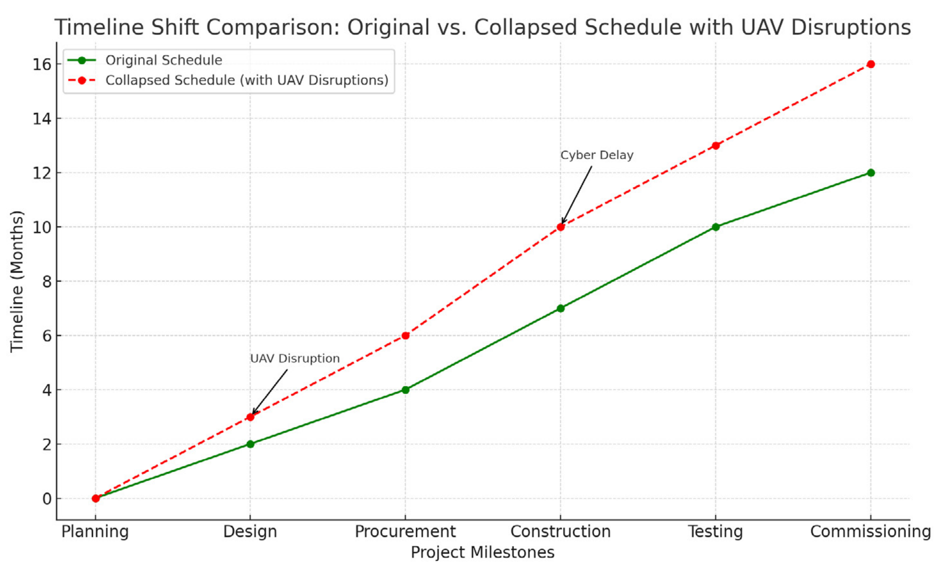

Fig. 3: Timeline comparison showing how UAV and cyber disruptions extend the aviation project schedule. It visualizes the shift from the original to a collapsed schedule, highlighting key interference points.

Table 6: Delay Period Analysis and Mitigation Triggers

Period	*Delay (days)*	*Cause*	*FDA Method*
Q2–Q3	45	Cyber threat detection systems integration	Contemporaneous Analysis
Q4	30	Software patch validation delays	Window Analysis
Q5	60	Restructuring of the threat modeling framework	Window Analysis

However, TIA/CPA tend to be more accepted in a contractual dispute setting because they require no assumptions, written schedules, and events are referenced (Tan et al., 2021). Under regulated airspace projects, when both national and international aviation regulations further enhance liability and compliance matters, more traceable methods that have explicit terms or audit trails would be desirable.

The other layer of complexity is the increased cybersecurity risks associated with the digital integration of aviation systems. Nichols et al. (2018) and Lykou, Anagnostopoulou, and Gritzalis (2018) emphasize that, in addition to the traditional causes of project disruptions, digital air traffic systems, smart airport infrastructures, and autonomous navigation platforms may bring in some new disruptive factors. Such interventions, which might take the form of software failures, cyber breaches, or even sensor errors, can cause delays in the project that might not be easily distinguished using the conventional instruments of the FDA. Incorporation of forensics in the form of recreating cyber-events in FDA practices may therefore be vital in the future (Mei, 2019).

Furthermore, the quantification of risk models, including those used to assess the ground impact of UAVs (La Cour-Harbo, 2019), also suggests that FDA approaches should be more accurately represented by methods that incorporate probabilistic risk and safety models. With growing overlap between aviation developments and areas of significant risk, such as nuclear and military facilities (Solodov et al., 2018), the sphere of delay analysis needs to be extended to the outside systemic threats affecting the project timing and safety measures.

Operationally, the concepts of intelligent sensor systems, an inspection platform using a UAV, and autonomous monitoring are transforming infrastructure development and management (Congress, 2018). Such technologies present new data collection mechanisms that can lead to FDA precision, but new interpretive frameworks are necessary with these technologies. As an example, short-range UAV photogrammetry data will be able to help track progress as well as attribute delay; however, such data will need to be normalized in standard forensic models in order to retain evidentiary validity.

It is also urgently needed to develop a suitable approach for the FDA to address the jurisdiction and regulatory differences. Countries have different legal frameworks to ensure the operation of the UAV, the use of counter-drone and building protection, which affects the reporting, evaluation, and adjudication of delays (Krawczyk & Tomaszycki, 2019; Lykou, Moustakas, & Gritzalis, 2020).

All in all, the results of the study stress the significance of flexibility, data integration, and methodological transparency of the best choice of FDA methods to employ with aviation projects. The aviation infrastructure development, which involves amplifying autonomy, converging cyber-physical systems, and increasing regulatory input, necessitates transitioning from static and retrospective delay modeling to hybrid and forward-looking modeling.

Table 7: Comparative Effectiveness of FDA Methods Across Case Scenarios

Method	*Suitability Score (1–10)*	*Best Fit Use Case*
Time Impact Analysis	9	Regulatory Delays & UAM Planning
Collapsed As-Built	8	Post-Incident Disruption Attribution (e.g., UAV)
Window Analysis	8	Cybersecurity-Driven Baseline Shifts
Contemporaneous Analysis	7	Incremental Progress Tracking in CNS/ATM

Conclusion

Delays in the construction and design of aviation infrastructure and airspace schemes are a vital determinant of the validity of assessments and liability of aviation projects as a whole concerning the project integrity, cost liability, and operational security. Various forensic delay analysis (FDA) practices have also been critiqued and compared in this paper, highlighting strengths, weaknesses, and areas of application to the context-specific area in the field of aviation project management. Given the time-sensitive nature of operations and the use of high-stakes technology in both operated and unmanned systems, the value of forensic delay techniques cannot be overstated.

According to the findings, there is no single method of the FDA that can be universally adopted in the heterogeneous needs of aviation infrastructure projects. As an example, Time Impact Analysis (TIA) is exact and legally defensible when dealing with contract-based delays. However, it is data-intensive and often impractical in an abnormally dynamic airspace management environment. Comparatively, approaches such as Window Analysis provide a compromise between clear and practical approaches but have the drawback of subjectivity in the determination of analysis periods. Such variability highlights the need to adapt the forensic approach to a particular type of project, the availability of the data, and the needs of stakeholders.

Such novel technologies as uncrewed aerial vehicles (UAVs), cyber-physical systems, and automated urban air mobility (UAM) platforms transform the aviation project landscapes (Mei, 2019; Torens et al., 2021; Shakeri et al., 2019). The current developments require delay analysis models that could be adjusted to more complex systems and new forms of cyber deprivation (Roy et al., 2018; Lykou, Moustakas, & Gritzalis, 2020). In airport or nuclear facilities (high-risk areas), correct schedule forensics should also take into account such external vectors of risk as a security breach by a hacker, the infiltration of a UAV, or the manipulation of sensor data (Solodov et al., 2018; Nichols et al., 2018; Bogoda, Mo, & Bil, 2019).

Also, since the activity level of aviation now depends on integrated system communication, navigation, and surveillance (CNS/ATM) systems, delay has ceased to be just a physical or contractual incident. They have been juxtaposed against digital anomalies and vulnerabilities, the systems, and live traffic restrictions (Siewert et al., 2019; Sarim et al., 2019). Forensic techniques then need to adapt to include functionalities to overcome hybrid-related disruption and focus on digital traceability, redundancy modeling, and fail-secure analytics (Tan, Van Bossuyt, & Hale, 2021).

The research also highlights the emerging prospect of monitoring and delay diagnostics, thanks to the advent of UAV-based capabilities, which provide real-time information through close-range photogrammetry and aerial surveying (Congress, 2018). Nevertheless, their usage adds a further level of difficulty related to legal liability, airspace deconfliction, and cyber resilience (Krawczyk & Tomaszycki, 2019; Lykou, Anagnostopoulou, & Gritzalis, 2018).

Overall, although traditional FDA methods are indispensable to historical analysis and controversy resolution, the adaptive understanding of modern aviation systems requires a complex time and space-based outside-the-box picture assessment. Digital forensics, modeling of cybersecurity risks, and traceability throughout the system have to be integrated into future frameworks to stay relevant. It implies that, as a practitioner, one has to embrace hybrid delay assessment models that integrate classical methods with predictive analytics, sensor data analysis, and domain-specific risk considerations. Such integration is the only possible way that aviation infrastructure and airspace management could encounter the multidimensional issues of time, technology, and trust in delay analysis.

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