Title: A KPI-Driven Dashboard Framework for Enhanced Safety Management in Airfield Construction

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Abstract:

Airfield construction projects operate within time-sensitive, safety-critical environments that involve concurrent aircraft movements and complex stakeholder coordination. This article proposes a **KPI driven safety dashboard** (Key Performance Indicator) to improve early-stage situational awareness and daily risk management for airfield construction. The framework integrates leading and lagging indicators, a consistent risk scoring method, and structured notification protocols, producing a consolidated view of hazards and mitigations across construction zones. The safety approach uses a **three-party daily confirmation model**, comprising the contractor's representative, the owner's construction management representative, and the airport safety representative, to verify that all risk assessments are completed and to highlight any gaps requiring immediate action. The system design aligns with prevailing airport safety practices, including Safety Management Systems and Safety Risk Management processes, and operational requirements commonly addressed in Construction Safety and Phasing Plans. A practical data integration workflow is outlined that leverages standardized spreadsheets and a business intelligence layer for visualization, without placing additional data entry burden on field personnel. The case context is a large U.S. hub airport, where the approach is structured for piloting and broader scalability. The paper details architecture, stakeholder mapping, high-risk activity identification, mitigation tracking, and implementation considerations, and concludes with guidance for adoption at large hub airports seeking proactive, KPI-oriented safety coordination.

Keywords: airport construction; safety management; key performance indicators; safety risk management; construction safety and phasing plan; safety management system; risk dashboard; stakeholder notifications; leading indicators

1. Introduction

Airfield construction projects are among the most complex and high-risk undertakings in civil engineering, due to their dynamic operational environments, stringent regulatory demands, and the involvement of diverse stakeholders. Unlike conventional construction, airfield projects span extensive areas such as runways, taxiways, aprons, and utility corridors, each with unique safety and operational challenges. The dynamic nature of airports as major transportation hubs leaves little room for error; even minor construction-related incidents can disrupt operations, incur financial penalties, and, most importantly, pose serious risks to workers and passengers.

To ensure operational continuity and safety, construction at active airports requires not only compliance with regulations but also seamless coordination among airport authorities, contractors, air traffic control, airline representatives, emergency response teams, and other stakeholders. Traditional communication methods including email, meetings, and informal updates are often insufficient for timely hazard identification and proactive risk mitigation. Regulatory agencies such as the Federal Aviation Administration (FAA) and Occupational Safety and Health Administration (OSHA) have established strict safety requirements, while major airports have adopted Safety Management Systems (SMS) to promote a robust safety culture. Despite these advances, persistent gaps remain in how safety-critical information is shared and operationalized before construction begins.

This article introduces a novel KPI-driven safety dashboard framework tailored to address these gaps. The framework offers real-time risk assessments, structured notifications, and visual communication tools to enhance situational awareness and facilitate early-stage coordination among all stakeholders. By quantifying and visually presenting safety risks prior to project initiation, the dashboard bridges the divide between regulatory intent and field-level execution, creating a proactive, collaborative safety environment. The proposed system has the potential to reduce operational disruptions and improve safety outcomes across the aviation sector if implemented at large airports in the U.S.

1.1 FAA Guidelines Related to Airfield Construction Safety

The Federal Aviation Administration (FAA) Advisory Circular 150/5370-2G outlines key safety practices for airfield construction projects, particularly those funded through the Airport

Improvement Program (AIP) [1]. This guidance emphasizes the importance of thorough planning to minimize operational disruptions. One of the primary requirements is the development of a detailed Construction Safety Phasing Plan (CSPP), which incorporates safety risk management (SRM), hazard marking, vehicle and pedestrian control within the Airport Operations Area (AOA), and systematic notification procedures. These include Notices to Air Missions (NOTAMs), which inform pilots and relevant stakeholders of potential construction-related hazards [1].

In addition, the advisory circular mandates strict compliance with standards related to runway safety areas (RSAs) and taxiway safety areas (TSAs). Any construction activity within these critical zones requires intensive coordination, comprehensive risk assessments, and clearly defined protocols for emergency response and hazardous material management. By adhering to these established guidelines, airports uphold both regulatory compliance and the safety of personnel, aircraft operations, and all parties involved in the construction effort [1].

1.2 OSHA Standards Relevant to Construction Safety

The Occupational Safety and Health Administration (OSHA) construction safety standards, as outlined in 29 CFR Part 1926 (Code of Federal Regulations), address a comprehensive range of safety concerns specific to construction activities [2]. Core areas of focus include fall protection, scaffolding integrity, proper ladder usage, personal protective equipment (PPE), electrical safety, excavation and trenching protocols, hazardous material communication, material handling procedures, tool safety, fire prevention, and the regulation of explosive materials [2].

OSHA emphasizes mitigation of the "Focus Four" hazards, which account for the majority of fatalities in the construction sector: falls, struck-by incidents, caught-in or between hazards, and electrocution [2]. These standards represent the minimum legal requirements for construction safety. However, OSHA also encourages employers to implement safety management systems (SMS) that extend beyond compliance, fostering a proactive safety culture and reducing exposure to workplace hazards [2].

Despite OSHA's comprehensive guidelines on specific safety practices during the construction execution phase, a critical gap remains. OSHA places limited emphasis on personnel situational awareness, especially concerning the broader operational context of dynamic construction sites.

In airfield construction, for instance, personnel such as truck drivers or crane operators may arrive fully compliant with PPE standards and adequately trained in hazard avoidance yet remain unaware of the day's unique operational risks, including active crane operations, recently established restricted zones, or nearby airside activities introducing unexpected hazards.

A truck driver, for example, may follow all PPE and mobility protocols yet unknowingly enter a zone where a high-risk lift is scheduled. Likewise, a quality control inspector might be unaware of the crane's load limits or whether equipment currently in use has been authorized for operation near active aircraft approach paths. While such oversights may not constitute violations of OSHA standards, they expose broader safety vulnerabilities rooted in communication gaps and the absence of shared operational awareness.

This underscores the need for an additional layer of safety management that complements regulatory compliance. A system emphasizing real-time operational awareness, preemptive planning, and integrated visibility across work units is essential. The proposed KPI-based dashboard framework aims to address this deficiency by providing all stakeholders with early and transparent access to critical operational data, safety parameters, and potential conflicts prior to daily permitting processes, such as those conducted through VEOCI systems. This approach fosters a culture of proactive collaboration rather than reactive enforcement.

1.3 Importance of Safety Coordination in Airfield Projects (FAA & Airport Perspectives)

Effective safety coordination in airfield construction is critical to managing risks due to the operational complexity and high-consequence nature of these environments. The simultaneous presence of aircraft, construction personnel, heavy equipment, and active airport operations across various dispersed zones creates a dynamic setting. In such conditions, even minor communication errors can have severe consequences.

From the regulatory perspective, the FAA has emphasized safety coordination as a foundational principle, reflected in guidance documents like the National Runway Safety Plan (NRSP) and Advisory Circular 150/5370-2G [1,3]. These policies advocate cross-disciplinary collaboration among airport operators, air traffic controllers, engineers, and contractors to proactively mitigate risk. The NRSP promotes a risk-based, data-driven approach to safety planning, while the advisory circular outlines operational safety procedures and construction phasing strategies heavily reliant on multi-party coordination [3].

Some Airports exemplify these principles through their robust Safety Management System (SMS), which provides structured frameworks for hazard identification, centralized data collection, incident reporting, and targeted safety training. Customized departmental protocols, developed through risk-based assessments, reflect a mature and evolving safety culture aligned with FAA regulatory expectations [4].

However, real-world challenges persist, particularly in achieving real-time visibility and alignment among stakeholders before daily work commences. Many airfield construction projects rely on email threads or verbal updates shared during stakeholder meetings. While these methods satisfy basic notification requirements, they often fall short in resolving time-sensitive conflicts, overlapping schedules, or unrecognized hazards across work zones.

Some large-scale projects at the Airports illustrate this challenge. Despite improving operational efficiency, implementation exposed coordination issues, including delays in disseminating critical updates to contractors, airside operations teams, and emergency responders, underscoring the limitations of traditional communication methods. The attempt to unify stakeholders under a single safety umbrella revealed the necessity for integrated digital tools facilitating early-stage collaboration and shared situational awareness.

This reinforces the central argument of this article: existing FAA frameworks and airport practices often lack mechanisms for proactively aligning safety-critical information. Bridging this gap requires an additional integration layer, specifically a KPI-based safety dashboard providing project-wide visibility, structured risk data, and coordinated safety intelligence before physical construction activities. Such a system acts as a critical link between regulatory intent and field-level execution, fostering a proactive planning culture and collaborative accountability.

2. Literature Review and Current State of Practice

2.1 Key Performance Indicators (KPIs) in Construction Safety

Key Performance Indicators (KPIs) serve a critical function in managing construction safety across civil and infrastructure projects. KPIs are measurable indicators of safety performance, designed to assess the effectiveness of safety controls and practices on construction sites [5]. Historically, the construction industry has emphasized lagging indicators such as the number of recordable injuries, lost-time incidents, or fatalities to evaluate safety outcomes. However, recent research demonstrates that lagging metrics, while informative, are inherently retrospective and do not reliably predict or prevent future safety incidents [6]. A low accident rate in past reporting periods does not necessarily indicate that current safety systems are effective or that future incidents are unlikely to occur [6]. Furthermore, lagging indicators often obscure root causes of safety deficiencies. Corrective actions derived from these metrics tend to be broad and reactive, lacking specificity needed for targeted intervention [6]. There is also a recognized risk of under-reporting or data manipulation when such metrics are tied to contractor performance evaluations or project incentives [6]. Modern approaches emphasize proactive leading indicators as key performance metrics. Researchers increasingly advocate shifting toward forward-looking measures, such as management's demonstrated safety commitment, frequency and quality of safety training, safety climate assessments, and near-miss reporting rates [6,7]. These leading indicators provide early warnings of emerging safety risks, supporting timely interventions before incidents occur. A systematic literature review identified sixteen leading indicators commonly applied in construction safety, classified into two overarching categories: indicators evaluating safety performance across various organizational levels (enterprise, project, team, individual) and indicators identifying potential incidents linked to organizational structure, operational practices, or human behavior [7]. This classification reflects a growing understanding that construction safety is inherently multi-dimensional, requiring both top-level cultural metrics and detailed field-level hazard tracking. Studies consistently highlight widely cited leading indicators, including workforce perceptions of safety (safety climate), visible management commitment, safety orientation and training efforts, site safety audit frequency, and structured near-miss reporting programs [5,7]. Monitored systematically, these indicators allow project managers to assess the health of safety management systems (SMS) in real-time and implement corrective actions promptly. In summary, extensive academic research supports a balanced safety performance framework integrating lagging outcome measures with leading process indicators, essential for advancing safety outcomes in construction [6,7]. This integrated approach is crucial for large-scale civil infrastructure projects, where operational complexity and risk exposure are significantly heightened, necessitating proactive safety systems to prevent incidents effectively.

2.2 Safety Coordination and Risk Management in Airport Construction

Maintaining safety in airport construction environments demands rigorous coordination and robust risk management frameworks. Unlike standalone construction sites, airfield projects are executed within active aviation environments, where ongoing flight operations, airside vehicle movements, and passenger activities introduce unique, high-consequence hazards. Any lapse in coordination can endanger construction personnel and aircraft operations alike [8].

The Federal Aviation Administration (FAA) established detailed guidelines for operational safety during airport construction, notably Advisory Circular AC 150/5370-2G [1,8]. This document mandates federally funded airport construction projects to develop a comprehensive Construction Safety and Phasing Plan (CSPP) before initiating work [8]. The CSPP functions as a formal safety management plan outlining construction phasing, designation of safety areas, barrier and marking requirements, communication protocols, and risk mitigation measures, ensuring construction activities do not interfere with aircraft operations [8].

Developing a CSPP requires early coordination with major stakeholders, including airport operations personnel, air traffic control, airlines, contractors, and ground service providers [9]. Early engagement enables project teams to identify operational constraints, integrating them into construction logistics and phasing strategies [9]. Industry best practices encourage stakeholder consultations as early as the design phase, establishing haul routes for construction vehicles, defining work-hour restrictions, and developing standardized communication protocols [9]. At larger hub airports where construction is continuous, construction safety committees regularly convene to review upcoming work scopes, coordinate logistics, and update safety strategies among stakeholders [9].

Formal risk management processes increasingly integrate into airport construction project oversight. The FAA requires Safety Management System (SMS) implementation at all Part 139 (14 CFR Part 139) certificated airports, emphasizing Safety Risk Management (SRM) for significant operational changes, including construction [10]. FAA Order 5200.11 mandates SRM panels systematically identify hazards, analyze risks, and define mitigation strategies [10]. Airports evaluate potential scenarios such as temporary runway closures, equipment operation near active runways, and modified taxi routes. Identified risks lead to mitigation controls including physical barricades, warning lights, revised operating procedures, or temporary operational restrictions, all designed to ensure safety risks within acceptable thresholds [10].

Researchers have proposed quantitative models for construction-related safety assessments. For example, Hu et al. developed a hybrid methodology combining fuzzy Analytical Hierarchy Process (AHP) and Bayesian Belief Networks assessing safety risks during ongoing airport construction scenarios.These models help prioritize risks under uncertainty, enabling decision-makers to evaluate event likelihood and severity (e.g., aircraft incursions, construction vehicle conflicts) and compare mitigation strategies' effectiveness.

Additionally, the Airport Cooperative Research Program (ACRP) published technical resources, including ACRP Report 131, assisting airports in integrating construction safety risk management (SRM) into daily operations [10]. These guidelines emphasize a coordinated framework combining early planning, cross-stakeholder communication, and structured risk analyses, comprehensively managing safety during airfield construction [10].

Case studies and official reports reveal best practices and recurring challenges in construction safety at U.S. airports, particularly at major hub facilities. The FAA has long recognized inherent airport construction risks, consistently emphasizing enhanced safety measures. FAA leadership notes that maintenance and development activities are essential yet carry substantial risk, requiring appropriate mitigation strategies [11]. These include comprehensive CSPPs, physical separation of work zones, carefully scheduled closures, and rigorous oversight during execution.

Despite these safeguards, incidents still occur, highlighting coordination and on-site hazard management needs. For example, in 2016, a construction subcontractor at a large U.S. hub airport died after falling into an unprotected elevator shaft during terminal renovations, illustrating lapses in hazard controls [12]. Similarly, in 2022, a hangar under construction at Boise Airport collapsed, causing fatalities and injuries; OSHA cited egregious safety failures [13].

Airside safety events often result from coordination challenges. A Skybrary survey of global incidents indicates airport construction introduces new hazards and procedural changes that are potentially confusing to pilots and controllers, sometimes with catastrophic outcomes [14]. FAA runway safety reports document elevated risk during major construction, especially when stakeholder communication is fragmented or unclear.

Common incident themes include information overload, visual confusion on airfields, and out-of-sync charts and procedures [14]. Airports address these through simplified NOTAM formats, consistent visual cues (e.g., barricades, signage), and updated navigation charts [14]. In response, structured coordination practices have emerged at U.S. airports, such as daily or weekly safety meetings among airport personnel, FAA representatives, contractors, and inspectors [10]. Many large hub airports have integrated comprehensive Safety Management Systems (SMS), institutionalizing hazard reporting, trend analysis, and continuous safety enhancement [4]. A core element of such SMS programs is Safety Assurance, which uses data from incident reports, audits, and safety KPIs to inform ongoing improvements [4].

By tracking leading KPIs (incident frequency, near-miss rates, safety training), airports monitor site conditions in real-time, promptly addressing emerging hazards. Lessons learned from past incidents systematically inform training programs, planning efforts, and communication strategies supporting continuous improvement.

In summary, literature and industry reports endorse KPI-based frameworks integrating proactive safety indicators, structured planning tools (e.g., CSPPs), formal risk assessments (SRM, SMS), and ongoing performance monitoring [5,6,10]. Indicators such as management commitment, training frequency, safety climate assessments, and incident reporting rates effectively minimize risks and protect workers and passengers alike [5,7].

3. Methodology

3.1 Problem Identification

Safety coordination during airfield construction at large U.S. hub airports continues to face operational challenges due to fragmented communication systems. Although platforms such as the Virtual Emergency Operations Center (VEOCI) are widely used for pre-task planning, submissions are typically made only 24 to 48 hours before task execution and are primarily reviewed by operations personnel and the submitting contractor. Other safety-critical stakeholders, such as airfield police, terminal construction teams, and air traffic control (ATC) liaisons, may remain unaware of high-risk activities unless they are specifically included in email communications or briefed directly.

Email notifications are often missed or ignored, and they cannot be reliably tracked for acknowledgment. In addition, stakeholder meetings often lack the level of detail needed to address daily hazards with sufficient precision. These disconnected methods hinder proactive conflict mitigation, particularly in overlapping or rapidly changing work zones within the airfield environment.

3.2 Proposed Solution

To address these coordination gaps, this study proposes a centralized, KPI-based safety dashboard. The dashboard aggregates all scheduled construction tasks by zone, time, and activity type (e.g., concrete pouring, crane operation, trenching). Each task receives a risk score based on predefined assessment criteria, facilitating targeted risk management and cross-team accountability.

Table 1: Key performance indicator tracked by the dashboard

KPI	**Responsible Party**	**Update Frequency**	**Description**
Risk assessments completed	Contractor representative; Owner's CM (Construction Manager); Airport safety representative	Daily	Each day, three parties independently confirm risk assessments have been conducted and documented for all active zones and activities. This ensures cross-verification and shared accountability.

Risk scoring. Each scheduled task is assigned a risk score calculated as:

Risk Score = Severity (1–5) × Likelihood (1–5) × Context Modifier (0.8–1.2).

The *Severity* rating reflects the potential impact on safety, *Likelihood* measures the probability of occurrence, and the *Context Modifier* adjusts for site-specific factors such as time of day, proximity to active movement areas, and concurrent operations.

Thresholds are defined as:

- **High-risk:** Risk Score ≥ 16 — triggers immediate notifications to all listed recipients and requires same-shift verification of mitigations.
- **Medium risk:** Risk Score 9–15 — flagged for standard mitigation and daily monitoring.

- **Low risk:** Risk Score ≤ 8 — monitored through routine safety checks.
  This structured approach ensures consistent classification and prioritization of hazards across all project zones.

As a core function, the proposed safety dashboard will track daily completion of risk assessments, with explicit confirmation required from three key stakeholder roles: a representative of the contractor, a representative from the construction management team (acting on behalf of the owner), and an airport safety representative. This three-party verification is a unique feature tailored to the operational environment at large U.S. hub airports, designed to maximize accountability and transparency. The dashboard prompts each responsible party to input or confirm completion data by the end of each shift and automatically highlights any gaps or missed confirmations. This approach not only meets but exceeds standard FAA and OSHA requirements by establishing a verifiable, shared record of proactive safety management.

Table 2: Notification Triggers and Recipients

Event Trigger	**Recipients**	**Notification Content**	**Delivery Method**
New high-risk activity scheduled	Contractor rep, Owner’s CM rep, Airport safety rep, Project manager, Airport safety leadership	Location, time, activity description, risk rating, action required	SMS, app (optional)
Missed daily risk assessment confirmation	Responsible party who missed confirmation: project manager, safety leadership	Reminder: missed confirmation for specific zone/activity and due time	SMS, app (optional)
Risk assessment completed for high-risk task	All responsible parties, the project manager	Confirmation of completion, zone/activity, risk level	Text message, App (optional)

The safety dashboard would send automated notifications in response to key safety events. For instance, whenever a new high-risk activity is scheduled, all three responsible parties, the contractor representative, owner’s construction management representative, and the airport safety representative, as well as the project manager and airport safety leadership, receive an instant alert via SMS or, optionally, through the app. The notification includes all relevant task details (location, time, activity, and risk rating) as illustrated in the dashboard's push notification feature (see Figure 1). Similarly, if any required daily risk assessment confirmation is missed, a targeted reminder is sent to the relevant individual and copied to project and safety leadership. Confirmation messages are distributed upon successful completion of risk assessments for high-risk activities. This multi-channel, real-time notification system ensures that critical information is delivered promptly and actionably. Notification triggers, recipients, and delivery methods are summarized for quick reference (see Table 2).

A linked mobile application would deliver customized push notifications to designated personnel, including OPS staff, Department of Public Safety (DPS) officers, quality control inspectors, and project managers. Each notification includes task location, timing, type, and assessed risk level. This structure enables real-time situational awareness and supports informed planning.

The safety dashboard is designed to support limited two-way communication to streamline coordination and ensure accountability. Upon receiving notifications such as alerts regarding scheduled high-risk activities or pending confirmations, authorized users including the contractor representative, owner's construction management representative, and airport safety representative can acknowledge receipt directly within the dashboard using a confirmation button. Additionally, users have the option to add brief comments or upload relevant files such as supporting documents or photographs linked to specific risk assessments or confirmation steps. These features facilitate immediate context specific clarification and documentation among responsible parties. However, the dashboard does not currently support direct submission of new hazard or near-miss reports, nor does it retain user feedback for long term audit trails or safety reviews. The primary focus remains on daily risk assessment confirmation and efficient real-time communication between key stakeholders.

3.3 Situational Awareness in the Dashboard

A central goal of the proposed safety dashboard is to improve situational awareness for all parties involved in airfield construction. The dashboard achieves this by providing a live visual overview of all active zones, scheduled activities, and associated risk levels across the airfield. Each zone is clearly marked with its current status and any special hazards or operational restrictions, allowing users to quickly identify high-risk areas and prioritize resources accordingly.

A consolidated view of zones, scheduled work, and risk levels is illustrated in the proposed dashboard (see Figure 1).

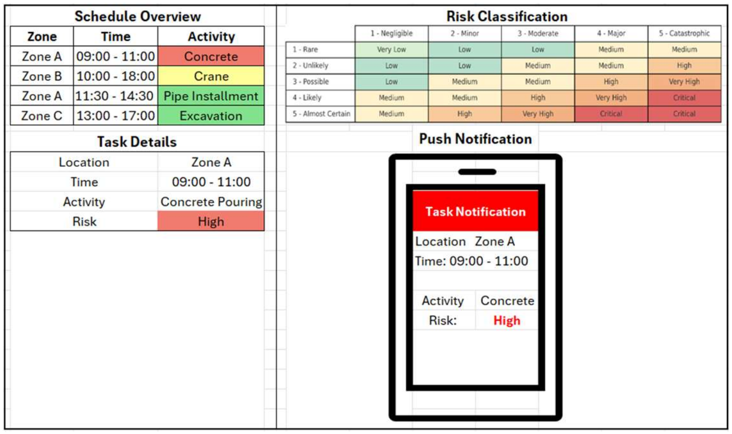

Figure 1. Centralized KPI-based safety dashboard integrating task schedules, severity–likelihood classification, and mobile notifications. Supports proactive communication and operational visibility.

The dashboard would display daily risk assessment results as color-coded indicators that are updated in real-time as confirmations are entered by the contractor, owner’s construction management representative, and airport safety representative. This system ensures that any missing or delayed confirmations are immediately visible to all stakeholders and triggers prompt reminders or escalations as necessary. The dashboard’s interface also integrates supporting details such as planned work times, responsible teams, and location specific notifications, so that field personnel and leadership have access to all relevant safety information at a glance.

By presenting up to date risk maps and notifications in a single platform, the dashboard bridges communication gaps between different teams and supports rapid decision making. Situational awareness is no longer limited to individual reports or siloed meetings but is maintained continuously and transparently for the entire project team. This proactive approach reduces the likelihood of overlooked hazards and supports a shared commitment to safe, efficient operations.

3.4 Stakeholder Integration

A stakeholder mapping module embedded within Microsoft Power BI links teams and individuals to construction zones. For example, crane activity near an Airport Operations Area (AOA) automatically triggers alerts to FAA tower coordinators and airport law enforcement personnel.

This targeted, risk-prioritized alert system replaces passive communication with structured messaging. A color-coded risk matrix or numerical scale (e.g., 1 to 5 or low/medium/high) visually communicates operational risk levels. Risk scoring accounts for multiple factors, including proximity to aircraft movement areas, the nature of the equipment used, and the time window for activity. These assessments align with FAA guidelines on Runway Safety Areas (RSAs), Taxiway Safety Areas (TSAs), and Part 139 compliance requirements [1,3].

3.5 System Architecture and Flow

The data integration process for the KPI-driven safety dashboard is designed to align with existing airport workflows and digital infrastructure. Rather than requiring direct manual entry by all field personnel, the process streamlines data collection and ensures quality control through centralized coordination. The workflow is as follows:

Each day, the Airfield Safety Office coordinator compiles all confirmation inputs into a standardized Excel sheet, which serves as the authoritative data source for the dashboard.

This Excel file is uploaded to a secure server, where it is automatically ingested by the dashboard's Power BI engine.

The dashboard application visualizes the risk assessment status for all zones and activities, tracks confirmation by each party, and highlights any gaps or overdue confirmations.

The system is integrated with other airport software (such as VEOCI), allowing for seamless data sharing and automated updates.

Notifications and alerts are generated automatically: for example, when a risk is entered, when a required confirmation is missing, or when a new high-risk activity is scheduled. Notifications are sent via email, SMS, or app alert to the relevant stakeholders.

This approach minimizes redundant manual data entry, leverages existing digital tools, and ensures that safety-critical information is updated, visualized, and communicated in real-time.

Daily RACI (Responsible, Accountable, Consulted, Informed) summary:

- Responsible: Contractor representative, Owner's CM, Airport Safety representative
- Accountable: Airfield Safety Office coordinator

- Consulted: Operations (OPS), Department of Public Safety (DPS)
- Informed: Air Traffic Control (ATC) liaison

3.6 Underlying Experience and Practical Relevance

The proposed methodology is grounded in direct observations and experience from ongoing airfield construction at major U.S. hub airports. Examples of such projects that informed this methodology include runway and taxiway rehabilitations, drainage relocations, and the installation of utility corridors for terminal expansions. These projects often operate in decentralized formats, leading to limited visibility across teams. The dashboard is intended as a pilot implementation to centralize safety coordination and task visibility. It presents a scalable model applicable at other large airports facing similar coordination and communication challenges.

3.7 High-risk Activity Identification and Definition

High-risk activities in airfield construction are identified through a structured process that incorporates regulatory guidance, project specific conditions, and daily operational planning. The dashboard framework requires the contractor representative, owner's construction management representative, and airport safety representative to review upcoming construction tasks each day. Activities are classified as high-risk when they involve factors such as work in active movement areas, proximity to aircraft operations, use of heavy equipment near critical infrastructure, night-time work operations, or any activity listed as high-risk by the Federal Aviation Administration or local safety protocols.

For each scheduled activity, the responsible parties complete a risk assessment checklist that evaluates potential hazards based on standardized criteria. The checklist addresses factors such as likelihood and severity of potential incidents, required mitigations, coordination with air traffic control, and compliance with site specific safety plans. Any activity meeting or exceeding the defined risk threshold is flagged by the dashboard as high-risk and triggers immediate notifications to all key stakeholders. The dashboard maintains a record of all high-risk activities for each zone and provides clear visual indicators to support planning and oversight.

By explicitly defining high-risk activities and requiring daily assessment and confirmation, the dashboard supports consistent application of best practices and ensures that special precautions are in place before work begins. This approach goes beyond minimum regulatory requirements and establishes a higher standard of care for airfield construction safety management.

3.8 Near-miss and Incident Reporting

The current dashboard framework focuses primarily on daily risk assessment confirmations and high-risk activity management by key responsible parties. While the system does not support direct submission of new near-miss or incident reports by field users, all incidents and near-misses identified through established channels such as site meetings, supervisor reports, or official safety logs are reviewed daily by the risk department. These events are then included in the risk assessment Excel file that is uploaded and processed by the dashboard.

Once uploaded, the dashboard would highlight zones or activities where incidents or near-misses have been recorded, using visual indicators and notifications to alert all stakeholders to emerging risks. This ensures that lessons learned and required mitigations are quickly visible to the project team. Although the dashboard does not currently enable interactive reporting by field personnel, it ensures that all verified incident and near-miss data are centralized, tracked, and communicated in real-time for continuous improvement of the safety program.

This approach maintains the integrity of official reporting channels while enhancing visibility and response to safety events through the dashboard's integrated visualization and notification features.

In addition, the dashboard retains all acknowledgments, comments, and uploaded files with associated timestamps and user identifications. This permanent record supports Safety Assurance requirements, enables post-event analysis, and provides an auditable trail for regulatory compliance and internal reviews.

3.9 Mitigation Tracking

The safety dashboard framework supports tracking of mitigation actions associated with each identified risk or incident. When a risk assessment identifies a hazard requiring specific mitigation, the required action is recorded in the Excel file by the risk department along with the responsible party and the expected completion date. Once a mitigation is implemented, the responsible party notifies the risk department. The risk team then updates the Excel sheet to reflect the mitigation's completion.

The dashboard would automatically display the status of each mitigation action for all relevant zones and activities. Pending or overdue mitigations are highlighted, prompting timely follow-up and accountability from the assigned stakeholders. Completed mitigations are visually confirmed on the dashboard, ensuring that all team members are aware when risks have been addressed.

This transparent process helps ensure that hazard controls are not only identified but fully implemented, closing the loop between risk identification and safety improvement. By making mitigation tracking visible and actionable, the dashboard enhances compliance with best practice safety management standards.
Each mitigation record also includes a clearly defined verification method, such as visual inspection, photographic evidence, or completion sign-off, to confirm that the control has been fully implemented. Following verification, a residual risk rating is assigned to document the effectiveness of the mitigation and to determine whether additional controls are required.

3.10 Integration with SMS Principles

The dashboard framework is designed to align with the core elements of the Federal Aviation Administration's Safety Management System (SMS) requirements for airports. Specifically, the system supports the following SMS principles:

Safety Policy: The dashboard formalizes the requirement for daily risk assessment confirmation and high-risk activity identification, making safety policy visible and actionable for all stakeholders.

Safety Risk Management (SRM): Through structured assessment, classification, and real-time tracking of hazards and mitigations, the dashboard enables proactive risk identification, analysis, and control before work begins.

Safety Assurance: The dashboard continuously monitors risk assessment completion, mitigation status, and incident trends, providing data driven assurance that safety processes are being followed as intended.

Safety Promotion: By centralizing and visualizing safety critical information, the dashboard enhances safety awareness, facilitates communication, and reinforces a culture of shared responsibility across the project team.

Together, these features would enable the dashboard to operationalize key SMS concepts in daily construction activities, bridging the gap between regulatory intent and practical field execution.

3.11 Visual Analytics and Risk Trend Display

The dashboard would utilize visual analytics to present risk information and safety trends in an accessible and actionable format. Key performance indicators such as the number of completed risk assessments, outstanding mitigations, and recorded incidents are displayed using intuitive charts and graphs. The dashboard visualizations refresh every 15 minutes, with an expected data latency of less than 5 minutes from the time the Excel source file is updated to when changes appear on the dashboard. This update frequency ensures that risk classifications, activity statuses, and mitigation records remain current for operational decision-making. The dashboard's main interface features a live risk map, with color-coded zones that update as new data is entered and confirmations are received.

Users can view historical trends for risk assessments and incidents across specific zones or time periods, helping project managers and safety leadership identify recurring issues or areas requiring additional attention. Bar charts and line graphs highlight changes in safety performance over time, while summary statistics make it easy to track daily and weekly progress. All visual analytics would update automatically whenever new data is uploaded, ensuring that the project team has access to current information at all times.

This approach enables fast, informed decision making and supports continuous improvement by making risk and safety performance data transparent for all stakeholders.

3.12 Relationship with Existing Airport Systems

The safety dashboard is designed to complement, rather than replace, existing digital platforms commonly used at major airports, such as project-tracking portals and digital operations log systems (e.g., VEOCI). While project-tracking platforms serve as centralized repositories for general project documentation and VEOCI provides digital logbook and incident tracking capabilities, these systems are not tailored for daily risk-assessment confirmation and real-time mitigation tracking at the construction zone level.

The proposed dashboard would bridge this gap by focusing specifically on proactive safety management tasks. It would integrate data from current systems where possible, and its output can be shared back into broader project documentation platforms to ensure consistency. The dashboard's unique contribution would be the structured tracking of risk-assessment confirmations by three key responsible parties, the daily visualization of risk across zones, and automated notifications to drive timely action.

By integrating with, but remaining functionally distinct from, existing airport management systems, the dashboard avoids duplication and would deliver targeted safety benefits that address operational gaps commonly observed in current construction practices.

3.13 Customizable Notifications

The safety dashboard would provide users with the ability to customize notification preferences according to their individual roles and operational needs. Each responsible party could select which types of alerts they wish to receive, such as notifications for new high-risk activities, missed confirmations, or completed mitigations. Users could also choose their preferred delivery method, including text message (SMS), app notifications, or both, helping ensure that critical information is received in the most convenient and reliable format.

This customization would support efficient workflow by allowing users to focus on the most relevant updates for their responsibilities, reducing alert fatigue while maintaining high levels of awareness and accountability. The flexible notification settings help ensure that all stakeholders remain informed and responsive to evolving safety conditions throughout the project lifecycle.

4. Framework

4.1 Digital Safety Dashboards and SMS Tools

U.S. airports are increasingly implementing digital dashboards to manage airfield construction safety as part of their Safety Management Systems (SMS). For example, Denver International Airport (DEN) has adopted a comprehensive software platform called ProSafeT, which consolidates safety data into a single interface that reflects the four SMS pillars [15]. By integrating inputs from maintenance systems, airfield operations, and safety inspections, these platforms enable trend analysis and predictive risk modeling [16].

Airport safety managers report that presenting key performance indicators (KPIs) on centralized dashboards improves the ability to proactively monitor construction safety programs [16]. While many airports begin by using regular meetings and email reports, most eventually develop centralized dashboards to replace fragmented paper-based and siloed systems [17]. These dashboards typically include modules for hazard reporting, incident tracking, and risk assessment [18].

The industry trend favors real-time dashboards capable of issuing alerts and displaying critical safety metrics at a glance, thereby reducing reliance on manual logs or informal communication [16,17].

4.2 Framework Architecture and Key Components

Effective safety coordination frameworks follow a layered structure that supports hazard visibility, prioritization, and collaborative decision-making among stakeholders. These frameworks are designed to identify risks, analyze their significance, and drive safety actions that specify what must be done, when, and by whom [20,21].

Figure 2. Safety coordination system architecture, showing hazard intake, central database, risk analysis, collaborative decision making, and mitigation assignment.

The first layer consists of hazard identification and reporting, wherein construction crews, inspectors, or operations staff report safety concerns through established channels such as radio, phone hotlines, or web-based portals. These reports are typically funneled to an Airport Operations Center or the airport's safety office [22]. The second layer involves data recording and analysis, where reports are logged into a central database that may be linked to existing airport maintenance or event management systems [23].

Next, a risk assessment module classifies each hazard using a standardized matrix based on severity and likelihood, ranging respectively from minor to catastrophic and from frequent to improbable. The outcome is a risk level that is typically color-coded using a red, yellow, and green traffic light system to indicate the need for escalation [24]. This step prioritizes hazards based on criticality. For example, a potential runway incursion would be flagged as high-risk (red), while a hazard in a closed construction zone might be classified as low risk (green).

The framework also includes a spatial mapping function that links each hazard to a physical zone on the airfield. This location-based classification allows stakeholders to assess whether a hazard lies within a high-priority area, such as a Runway Safety Area (RSA), or in a lower-risk, remote part of the airfield. This mapping informs the urgency and type of mitigation required. The final layer of the framework supports collaborative risk response, bringing together representatives from operations, safety, contracting teams, and air traffic control to review the hazard profiles and agree on corrective actions [21,25]. This collaboration typically occurs through regular safety coordination meetings or centralized operations centers.

4.3 Zone-Based Risk Classification and Phase Mapping

A defining feature of airport construction safety frameworks is the use of zone-based risk classification. In this approach, the airfield is divided into zones that are assigned predefined risk profiles. Critical zones, such as Runway Safety Areas (RSAs), Taxiway Safety Areas (TSAs), and aircraft approach surfaces, are treated as high-risk areas where construction is either prohibited or allowed only under strict controls. FAA guidelines clearly prohibit construction within active RSA or TSA zones unless specific safety precautions are implemented [1]. When construction is necessary near these zones, measures such as temporary runway closures or physical buffer zones are established to mitigate risk.

Worked example. A 160-foot crane operating within 500 feet of a Taxiway Safety Area (TSA) is initially scored as Severity 4, Likelihood 3, and Context Modifier 1.1, producing a total risk score of 13 (Medium). If the operation is scheduled during peak arrival periods, the Context Modifier increases to 1.25, raising the score to 15, which elevates the classification to High. Controls include night-work restrictions, coordinated ATC briefings, physical barricades, and supplemental lighting. The map view displays the affected work zone in red for the duration of the activity, reverting to green after the mitigation is verified.

Less critical areas of the airfield, including remote infield regions, may allow construction activities under procedural safeguards such as flaggers, temporary fencing, or barricades. Construction phasing plans are overlaid onto the airfield zoning map to manage these risks over time. Each construction phase, such as demolition, paving, or lighting installation, is represented on the map to show which zones are affected [26].

Before the start of each phase, the framework evaluates its potential hazards within affected zones. For instance, a crane operating near an approach zone would be flagged as high-risk and trigger mitigation measures, such as restricting operations to nighttime hours or requiring additional visual alerts. Airports have used Safety Risk Assessments (SRAs) to evaluate large construction phases adjacent to critical airfield areas, predefining mitigation measures for each risk scenario [10].

Visual tools such as heatmaps and color-coded overlays help planners and contractors identify “hot spots” requiring increased vigilance. A construction phase that introduces a trench adjacent to an active taxiway, for example, would be flagged as red on the map, indicating that immediate backfilling or physical separation is necessary before any aircraft are cleared to operate nearby.

Dynamic updates are an essential feature of this approach. If a project phase changes location, schedule, or scope, the risk classification must be updated accordingly, and all stakeholders must be notified. This ensures that the safety plan remains synchronized with real-time project conditions and prevents crews from inadvertently encroaching on critical airspace without proper clearance.

4.4 Stakeholder Notification and Communication Protocols

Timely communication is essential to effective construction safety management in airport environments. Safety coordination frameworks include formal stakeholder notification protocols to ensure that all relevant parties are promptly informed about hazards, schedule changes, or operational impacts. This includes both internal stakeholders such as airport operations, safety managers, maintenance staff, and contractors, and external stakeholders such as air traffic control, airlines, and FAA regional offices [27,28]. Many airports assign an Airport Operations Center (AOC) to serve as the central coordination hub. The AOC receives hazard reports, assesses the severity of each situation, and issues notifications to appropriate departments. For example, if a construction vehicle enters an active taxiway without clearance, the AOC would immediately alert air traffic control and notify airport operations and contractor supervisors to initiate emergency response [28].

FAA guidelines mandate specific notifications as part of any Construction Safety and Phasing Plan (CSPP). The airport operator must coordinate safety critical changes with air traffic control and the FAA. For instance, if a runway's safety area will be shortened or altered by construction, the airport is required to coordinate the adjusted safety area dimensions with the control tower and FAA Airport District Office and issue a NOTAM (Notice to Air Missions) to alert pilots [24]. These protocols are built into the project's communication plan. Many frameworks establish notification triggers tied to KPIs or hazard levels, for example, "Red" hazards (high-risk) automatically prompt an immediate briefing to senior management and ATC, whereas "Yellow" (medium risk) issues may be handled in routine daily coordination meetings [19]. Regular construction coordination meetings (often daily or weekly) are a cornerstone: they bring together contractors, operations, safety officers, airline representatives, etc., to review upcoming work, assess new hazards, and ensure everyone has the latest information [19]. This collaborative approach prevents siloed knowledge and ensures unified decision-making.

Figure 3. Airport stakeholder coordination model, with Airport Operations Center as hub, interfacing with Operations, Public Safety, Terminal Management, Asset Management, FAA, and airline teams.

Additionally, specialized channels like text alert systems or dedicated radios are used for rapid dissemination of urgent safety information (for example, an on-site supervisor might receive a text alert from the dashboard if a critical threshold KPI, such as "foreign object debris (FOD) incidents," spikes in their zone). Some airports have even created construction safety hotlines or mobile apps for stakeholders. LAX (Los Angeles International Airport), for instance, provides a Construction Hotline for anyone to report urgent safety concerns on the Air Operations Area [29]. In summary, these frameworks embed robust communication loops: from daily shift briefings and hazard bulletins, up to real-time alerts for critical issues, ensuring that all stakeholders are aware of risks and mitigation actions in a timely manner.

4.5 Data Visualization: Risk Heatmaps and Dashboards

A key feature of high-level safety coordination systems is the use of intuitive data visualization to convey risk information. Rather than relying on text-heavy reports, airports use visual dashboards that can display the status of safety KPIs and hazards at a glance. A common visualization is the risk matrix or heatmap. This is typically a color-coded grid (likelihood vs. severity) where each identified hazard is plotted. Hazards in the red zone (high severity, high likelihood) demand immediate action, yellow indicates moderate risk, and green indicates low risk. Such matrices are often embedded in the dashboard, updating as risk assessments are entered. Some airports' SMS implementations, for example, included the development of a software tool that produces graphical risk assessments. Their staff noted that identifying hazards with associated initial risk ratings and post-mitigation risk levels was an important outcome of the safety risk assessment process [10]. In training sessions, they found that sometimes participants overestimated risk until the most credible consequence was clarified, underscoring the value of using a standardized visual risk model to calibrate perceptions [24].

Airports also employ traffic-light models to monitor safety performance indicators. This might appear as a dashboard panel showing each KPI with a red, amber, or green status light depending on whether the metric is exceeding a threshold. For instance, if "days since last incident" falls below a target, the indicator might turn red to prompt management attention. Many systems allow drilling down on visuals, such as clicking a red KPI to bring up a trend graph over time, or an interactive map highlighting where recent incidents occurred. Geo-visualizations are especially powerful: some airports use GIS (Geographic Information System)-based dashboards to display the airfield map with active construction areas shaded by risk level (a form of heatmap). The FAA's Airport Construction Advisory Council has even developed graphical construction notice diagrams for about 65 airports, which use easy-to-read maps to highlight construction sites and areas pilots should avoid [25]. These visual notices, when integrated into tools like the Foreflight app, significantly improve pilots' situational awareness of construction hotspots [25]. Within the airport's own management team, similar map-based dashboards help safety officers and project managers see spatial risk distribution. For example, a cluster of incidents or rule violations in one taxiway work area can be immediately spotted and addressed. Overall, the emphasis on visual elements (charts, maps, color codes) in these frameworks makes large volumes of safety data comprehensible and actionable at a glance, which is crucial for quick decision making in a busy airport environment.

4.6 Common Safety KPIs in Airport Construction

To gauge and improve safety performance during construction, airports track a range of Key Performance Indicators (KPIs). Many of these align with general construction safety metrics, but are tailored to the airport context. A fundamental KPI is the OSHA Recordable Injury Rate for construction workers on the project. This rate (per 200,000 work-hours) captures how many work-related injuries occur and is widely used in the airport industry to evaluate the safety performance of a project or contractor [26]. A low injury rate indicates an effective safety program, and airports often require contractors to report this metric. In addition to the rate, the absolute number of OSHA-reportable injuries (any injury requiring more than first aid, or causing lost work days) is tracked [27,28]. Some airports set goals of zero reportable injuries and will benchmark projects against each other on this count.

Another common indicator is "Days Without a Serious Accident" on the project. Airports measure the number of consecutive days with no serious construction-related injury or accident, essentially a safety streak [29]. This KPI is a positive reinforcement tool (often displayed on signage for workers) and resets to zero after any serious incident. Conversely, they also monitor the number of serious accidents or injuries on airport construction projects per year [28]. The aim is to keep this at zero, and any occurrence triggers a thorough review. Fatalities are separately tracked (and are extremely rare but critically reported if they occur) [29].

Airfield-specific safety KPIs are also crucial. Runway incursions or vehicle deviations related to construction are monitored closely. These include any instance of construction vehicles or personnel entering protected runway or taxiway areas without authorization. Airports classify such events by severity and count them, since they indicate breakdowns in coordination. The goal is zero incursions; even a minor violation is taken seriously. Similarly, Foreign Object Debris (FOD) incidents, which are debris from construction (such as tools or materials) found on runways, are tracked, as they pose aircraft safety hazards. A high frequency of FOD findings would signal inadequate housekeeping and is flagged for corrective action [30]. Other KPIs focus on safety compliance and culture: for instance, number of safety inspections conducted, or findings from those inspections (safety code violations) [28,31]. An airport might track how many safety meetings or trainings have been held for construction staff (ensuring continual safety education). Some also measure PPE compliance rates or near-miss reports submitted; a higher rate of reporting near-misses can indicate a proactive safety culture.

The Resource Guide to Airport Performance Indicators (ACRP Report 19A) provides a useful compilation, listing metrics like “Workers’ Compensation claims paid,” “Safety code violations,” “Vehicle accidents on airport premises,” as part of safety and risk management KPIs [32]. For construction projects specifically, it highlights the OSHA injury rate as well as counts of days without accidents and number of construction project injuries or fatalities [29,32]. These KPIs serve both as lagging indicators (measuring outcomes like injuries, incidents) and as leading indicators (measuring preventive actions like trainings or inspections completed). By monitoring this balanced set of KPIs on dashboards, airport authorities and contractors can identify trends. For example, if injury rates are creeping up or if FOD incidents spike on a particular runway project, the system will flag it (often turning the metric from green to amber or red) prompting management intervention.

4.7 Pilot Implementations and Academic Insights

The push for formal safety coordination frameworks in U.S. airport construction gained momentum through pilot programs and research in the past decade. The FAA initiated Airport SMS Pilot Studies at several airports (including ATL, BOS, and other major hubs) to evaluate how SMS principles, including construction safety risk management (SRM), could be integrated at airports of varying size [33].

These pilot initiatives provided valuable lessons. For example, project teams identified the need for better staff training in formal safety terminology and underscored the importance of data quality in hazard reports [35,36]. In some cases, the introduction of web-based reporting portals initially led to an increase in general or non-safety reports, which later became more focused and actionable after targeted training [37,38]. This highlights an academic insight that technology alone is not enough; organizational culture and education must evolve alongside digital tools [38].

Another recurring challenge noted in the pilot studies was the difficulty of delving into specific hazards during risk assessments and the substantial time commitment required from stakeholders. These experiences reinforced that strong facilitation is critical to keep collaborative risk analyses on track and ensure meaningful outcomes [19,39].

Research from the Airport Cooperative Research Program has further informed best practices. ACRP Synthesis 58, for example, documented safety reporting systems at Part 139 airports and noted that some airports were developing management dashboards to review safety metrics, as well as sharing safety performance in monthly meetings [18,40]. ACRP Report 131 provided a Guidebook for Safety Risk Management (SRM) for Airports, including templates for conducting Safety Risk Assessments (SRAs) on construction projects [41]. It emphasized scalable processes so that even smaller airports could implement risk-based decision-making during construction [42]. One finding from industry studies is that engaging a broad range of stakeholders (operations, maintenance, ARFF, airlines, etc.) in the risk assessment process brings diverse perspectives that improve hazard identification, but it also requires clear communication and occasionally mediating differing risk perceptions [19]. Academic evaluations (e.g. ASCE conference papers) have echoed that consistent requirements and "best practice" models for Construction Safety and Phasing Plans (CSPPs) are needed internationally [43,44]. While regulations may differ, the high-level frameworks such as hazard logging, risk analysis, KPI monitoring, and stakeholder coordination are recognized globally as critical to construction safety in active airfields [45,46].

In recent years, major airports like Los Angeles (LAX) and Chicago O'Hare have launched SMS programs that encompass construction safety, often referencing the lessons from these pilots and research. The FAA's 2023 rule now mandates SMS for many U.S. airports, which explicitly includes construction-related risk management as part of the safety assurance process [47,48]. This regulatory push has accelerated adoption of the described frameworks. Many airports are either piloting or fully deploying digital safety management tools (some in-house, others commercial like DEN's ProSafeT or tailored GIS solutions) to manage construction safety in compliance with SMS requirements. Early adopters have reported tangible benefits: better hazard visibility, improved inter-department coordination, and the ability to detect and correct safety problems before they result in accidents, as FAA officials note [47].

5. Case Study: End-Around Taxiway Project at a Large U.S. Hub Airport

An end-around taxiway project at a major U.S. hub airport represents a large-scale airfield construction effort aimed at enhancing airfield safety and efficiency [1]. Specifically, the project will add a third end-around taxiway on the airport's west side, allowing aircraft to taxi around active runways instead of crossing them, thereby improving operational safety [49]. Work began in 2024 and is scheduled for completion in 2027, when the new end-around taxiway is expected to open for use [50]. The project scope includes constructing new taxiway segments to FAA Design Group VI standards, extending an Aircraft Rescue and Fire Fighting (ARFF) service road, realigning access roads, and adjusting airfield fencing [51]. All elements are designed to increase safety on the southwest side of the airfield [52].

5.1 Purpose and Significance

The end-around taxiway will enhance runway safety by eliminating the need for aircraft to cross active runways, a known risk factor in runway incursions. By routing aircraft around the runway end, the airport aims to reduce potential collision hazards and delays. This aligns with the overall safety strategy at large hub airports, as end-around taxiways "provide additional operational safety" for ground movements [52] and improve efficiency (saving time and fuel) for airlines [49]. In short, this project is a safety-driven infrastructure upgrade, forming a key part of a multi-phase capital improvement program aimed at modernizing and expanding airfield and terminal operations [1].

5.2 Safety Communication and Coordination Issues

Despite the project's safety-centric goals, challenges have arisen in managing and sharing safety information during construction. A critical problem identified is the lack of an integrated communication system for safety-related information among all stakeholders. Several issues contribute to this problem:

5.3 Siloed Digital Requests

Airports often use a central operations log platform to submit construction requests, such as runway or taxiway closure notices. While such systems are powerful tools for operations and incident management [53], not all personnel involved in a project may have access to or actively monitor them. As a result, some teams may not see closure requests or hazard notifications entered into the system. Important information (e.g., a taxiway closure schedule or safety procedure) may remain confined to the digital log, limiting awareness to only those departments that regularly use the platform. This fragmented visibility means field crews, contractors, or other airport departments might miss critical updates if they are not users of the system.

Reliance on Paper Notices: In certain cases, temporary closures of airport infrastructure are communicated via paper memos and manual notices. For example, if a section of a service road must be closed for construction, notifications have sometimes been distributed as hard-copy announcements. These are passed to departments that use those routes (e.g., cargo operators or shuttle services). Relying on physical notices and ad-hoc distribution is not only slow but prone to information gaps, as notices might not reach all intended recipients or may be overlooked, leading to some staff being unaware of the closure until they encounter it.

5.4 Limited Shift Handover of Risk Information

Construction also occurs during overnight shifts (when runway/taxiway closures are more feasible). However, the level of risk associated with specific night operations is not always clearly communicated to all teams. The project may have hazard assessments or risk ratings for certain high-risk activities (e.g., working next to an active taxiway at night), but if these risk levels are not labeled or conveyed in requests and briefings, personnel may underestimate the hazards. The risk assessment details can remain siloed, and without an integrated briefing, night-shift crews, supervisors, and supporting units may have differing understandings of the operation's risk level.

5.5 Root Cause

All the above issues boil down to one root problem: safety-related information is not centralized or universally accessible to every stakeholder when needed. Instead of one unified system or channel, there are multiple disjointed channels (digital logs, paper memos, verbal handovers) that do not consistently reach everyone involved. This fragmentation runs counter to the best practices recommended for airport construction safety. According to FAA guidelines (Advisory Circular 150/5370-2F), a Construction Safety and Phasing Plan (CSPP) should include "procedures for the immediate notification of airport users and the FAA of any conditions adversely affecting operational safety," and maintain a single contact list for all parties affected by the project [54]. In practice, information may exist across multiple channels but not be integrated into one transparent system accessible by all departments, contractors, and relevant personnel in real time.

5.6 Impact of Fragmented Safety Information

Failing to share safety information in an integrated way can have several negative consequences:

1. **Safety Risks:** The foremost concern is the potential for safety incidents or near-misses. If a crew or vehicle operator is unaware of a taxiway or runway closure, they might inadvertently enter an active area, creating a risk of runway incursions or accidents. Inadequate dissemination of risk assessments means some workers might not take necessary precautions for high-risk tasks, increasing the chance of injuries or operational errors. A proactive safety culture requires that everyone understands the current hazards and mitigation measures, something a Safety Management System (SMS) emphasizes through "open communication channels for reporting safety concerns without fear" and cross-department safety awareness [55]. Gaps in communication can undermine this principle.
2. **Operational Inefficiencies:** Poor information flow can also lead to delays and inefficiencies. For instance, a cargo driver who did not get the memo about a road closure may waste time rerouting on the spot, or construction crews might have to halt work if operations staff show up unaware of a coordinated closure. Lack of real-time updates can cause last-minute conflicts. These inefficiencies can cascade into schedule delays and inconvenience for airport operations.
3. **Inconsistent Risk Mitigation:** When risk information is not uniformly shared, different groups might implement safety measures inconsistently. One team might treat an activity as high-risk while another team treats it as routine. This inconsistency can reduce the overall effectiveness of safety controls. A unified approach ensures all stakeholders align on the same risk level and mitigation steps, fulfilling the SMS principle of "risk assessment to evaluate potential safety impacts" [56].
4. **Stakeholder Frustration:** The current communication gaps can cause frustration or reduce trust among stakeholders. Contractors may feel that critical information is not being shared with them, while airport departments (operations, maintenance, etc.) might be concerned they are "the last to know" about impacts. Overreliance on informal communication can also lead to blame and confusion when something is missed. In contrast, having a single source of truth for all safety-related notices would improve transparency and accountability.

In summary, the lack of an integrated safety information system poses both safety hazards and logistical problems. It contradicts regulatory recommendations for comprehensive communication during airport construction, and it can weaken the very safety improvements the project aims to achieve. Recognizing these impacts is the first step toward advocating for a solution. Some airports have already introduced central project-tracking portals to consolidate schedules and activities [57]. However, integration of safety-specific information (hazards, closures, risk levels) into such systems is not yet widespread. In practice, communication often remains distributed across multiple channels. No dedicated "one-stop" safety information hub or unified notification system has been deployed in many projects.

5.7 Future Outlook: Toward Integrated Safety Information Sharing

Although no integrated system was implemented in this project, the experience highlights a clear improvement area for future work at large airports. Going forward, the main idea is to establish an integrated safety information system for construction projects. Such a system would ensure that all safety-critical information is centralized, visible, and promptly communicated to every stakeholder. Key features of this future integrated approach could include:

1. **Unified Communication Platform:** Airports could expand the use of a single digital platform for all construction safety communications. The goal would be that any closure request, safety memo, or hazard alert is entered once into this platform and instantly shared with all relevant groups (operations, contractors, airlines, ground service, safety officers, etc.). For example, if a taxiway will close next Tuesday night, one entry in the system would trigger notifications to all subscribed parties (via email/app alerts) and be viewable on a common dashboard.
2. **All-Party Visibility:** The system should maintain a single up-to-date contact list of everyone impacted by the project. This ensures no group is left out. Each stakeholder would have access to the platform at some level. Even those who do not use the system daily could receive automated summaries or text alerts.
3. **Integrated Risk Assessment Sharing:** The platform should allow documentation of risk assessments and hazard mitigations for each work activity, visible to all. If an operation is deemed "high-risk," that designation and the required precautions can be flagged so every shift and team is aware.

4. **Real-Time Updates and Notifications:** Tools like mobile apps or automated alerts can push immediate updates when conditions change, keeping all stakeholders synchronized.
5. **Culture of Safety Communication:** Fostering a culture where reporting and accessing safety information is second nature is essential. By implementing a user-friendly integrated system and training project participants, airports can reinforce that safety information is for everyone.

5.8 Broader Applicability

The idea of integrated safety information is not limited to one project. Future large-scale capital works, including new terminals, runways, and roadway projects [60,1], will only increase the complexity of coordination. A centralized project information hub combined with a safety communication module could become a standard practice. This would position large hub airports as leaders in airfield construction safety management, ensuring that lessons learned from past projects translate into improved processes across the industry.

6. Discussion and Implications

The complexity of airfield construction projects, particularly in high-traffic hub airports, underscores the critical importance of comprehensive safety management. The findings of this study demonstrate that the current reliance on fragmented communication tools such as digital logs, email notifications, and paper notices often fails to deliver the level of real-time situational awareness required for effective hazard mitigation. As supported by industry research and FAA reports, such gaps in information flow can directly contribute to operational incidents, increased project costs, and reduced stakeholder confidence [10,24,47].

The proposed KPI-driven safety dashboard would directly address these gaps by offering a centralized platform for risk assessment, stakeholder notification, and visual management of safety data. Integrating best practices from FAA Advisory Circular 150/5370-2G and OSHA 29 CFR Part 1926, the system provides an evidence-based approach to quantifying and communicating safety risks before construction activities begin [1,2]. In the context of large hub airport projects, the lack of a unified communication system is often a primary contributor to information silos and inconsistent risk management. The dashboard framework developed in this study was designed not only to enhance compliance with regulatory mandates but also to create a proactive safety culture, one that emphasizes real-time hazard identification and collaborative problem-solving among all involved parties [4,9].

Broader implications of this research extend to the national and international aviation construction sectors. With the FAA mandating formal Safety Management Systems (SMS) at all major U.S. airports [47], there is a growing need for digital tools that operationalize SMS principles, such as hazard logging, risk prioritization, and stakeholder engagement, within daily project workflows. The adoption of KPI-based dashboards aligns with trends observed at leading airports, where software platforms have enabled trend analysis, predictive modeling, and improved safety outcomes [15,16]. By making risk information visible to every stakeholder in real time, these systems could reduce the likelihood of operational surprises, minimize the frequency of incidents, and support continuous improvement [19,47].

Nevertheless, successful implementation presents several practical challenges. Chief among these are ensuring data accuracy, maintaining up-to-date risk logs, and promoting consistent user adoption. As noted in previous pilot studies at U.S. airports, even the most advanced digital systems are only as effective as the organizational culture and training that support them [19,40]. Without dedicated personnel to oversee data entry, system updates, and user training, the benefits of digital dashboards can be diminished, and the risk of outdated or incomplete information increases [10,18]. Financial considerations, such as initial investment in software development, ongoing maintenance, and cybersecurity measures, must also be addressed, particularly for smaller airports with limited resources [15,47].

The scalability and transferability of the KPI dashboard framework are promising. The modular architecture allows for adaptation to airports of varying sizes, regulatory environments, and project complexities. As large-scale construction programs continue to expand across the U.S., the lessons learned from past projects can inform best practices and policy development at a national level. The emphasis on centralized, transparent, and accessible safety information sets a new standard for stakeholder collaboration, compliance, and project efficiency [5,16,41].

From a policy and management perspective, integrating such dashboards into routine airport safety operations could facilitate regulatory audits, improve documentation for incident reviews, and foster a shared culture of safety accountability. The ability to track KPIs in real time would enable management to identify emerging trends, allocate resources effectively, and implement targeted interventions, which could lead to safer, more resilient airport infrastructure [32,41].

6.1 Proposed success criteria for pilot implementation

- Increase in daily risk-assessment completion rate to 100% within 60 days of system deployment.
- Reduction in missed confirmation alerts by at least 80% within 90 days.
- Reduction in foreign object debris (FOD) incidents linked to construction zones by 30% within 6 months.
- Zero runway or taxiway incursions attributable to construction communications during the pilot period.
- Median stakeholder notification time for high-risk activities under 2 minutes.

In conclusion, the findings of this research highlight the transformative potential of digital, KPI-driven safety management frameworks for the aviation construction sector. By bridging the gap between regulatory intent and field-level practice, the proposed system advances the goals of proactive risk management, stakeholder engagement, and operational excellence.

7. Cybersecurity and Future Work

Despite the promising outcomes demonstrated by the proposed KPI-driven safety dashboard framework, several limitations must be acknowledged. First, the effectiveness of the system relies heavily on the timely and accurate input of construction schedule data, risk assessments, and stakeholder contact information. In fast-paced airport environments where project scopes and daily operations can change rapidly, there is a risk that outdated or incomplete data may undermine the dashboard's accuracy and utility [10,18]. Ensuring that information remains current requires a sustained commitment from project managers and dedicated personnel responsible for system maintenance and data validation [19].

7.1 Security and governance

The dashboard enforces role-based access control, multi-factor authentication, and least-privilege permissions to protect sensitive operational data. All records are encrypted in transit and at rest, supported by daily backups and tamper-evident audit logs. A defined data retention schedule aligns with airport policy and applicable records management regulations. Quarterly access reviews and periodic tabletop exercises are conducted to validate the effectiveness of the cybersecurity posture and incident response plan.

Second, the dashboard's value is closely linked to user engagement and organizational culture. As evidenced by previous pilot studies at major airports, the introduction of digital safety platforms alone is insufficient to guarantee improved safety outcomes [19,40]. Training, change management, and stakeholder buy-in are critical for maximizing adoption and effective use. Without consistent usage and feedback from all involved parties, such as contractors, airport operations staff, safety managers, and regulatory authorities, the benefits of centralized risk communication may be diluted [10,40].

Third, financial and resource constraints may limit the feasibility of implementing such advanced digital tools at smaller airports or in organizations with limited IT infrastructure. While the dashboard is designed to be modular and scalable, initial investment in development, ongoing software maintenance, and cybersecurity compliance could present barriers to widespread adoption [15,47]. Collaboration with airport authorities, industry partners, and regulatory bodies may be required to develop cost-effective, standardized solutions that can be tailored to airports of different sizes and needs [5,41].

Another limitation is the focus of this study on a single, large-scale U.S. airport project. While the case study approach provides valuable real-world insights, future research should explore the framework's applicability in different operational contexts, including smaller regional airports and projects with differing regulatory environments or stakeholder structures [42,43]. In addition, the framework's reliance on structured KPIs may not capture all dimensions of safety culture, human factors, or emergent risks that arise in complex, adaptive construction environments [7].

Future work should focus on several key areas. First, pilot implementations at a broader range of airports, including those outside the United States, would provide valuable data on the generalizability, scalability, and cultural adaptability of the KPI dashboard framework. Comparative studies between digital and traditional safety management systems (SMS) could further clarify the framework's added value in different organizational settings. Second, the integration of advanced analytics, such as machine learning for predictive risk modeling, automated data validation, and user behavior analysis, may enhance the dashboard's ability to identify emerging hazards and optimize communication workflows [16,48]. Finally, longitudinal studies are needed to measure long-term impacts on safety performance, stakeholder collaboration, and regulatory compliance, ensuring that the framework continues to evolve in response to changing industry needs and technological advancements [17,41].

By addressing these limitations and pursuing targeted future research, the field can continue to advance toward safer, more efficient, and more resilient airport construction practices worldwide.

8. Conclusions

This study presents a novel, KPI-driven safety management dashboard designed to address the persistent challenges of information fragmentation and stakeholder misalignment in airfield construction projects. Focusing on a large U.S. hub airport project, the proposed framework demonstrates how the integration of real-time risk grading, centralized communication, and structured stakeholder notifications can enhance situational awareness, regulatory compliance, and operational efficiency.

By embedding industry best practices and regulatory guidelines from the FAA and OSHA into an accessible digital platform, the dashboard enables project managers, contractors, and airport authorities to identify, communicate, and mitigate safety risks proactively. The evidence from the literature and practical applications at major airports highlights the value of centralized, transparent information systems in fostering a safety-first culture and reducing the likelihood of operational disruptions and personnel injuries.

The implications of this research extend beyond a single airport or project. The modular, scalable architecture of the KPI dashboard framework makes it adaptable to a range of airport sizes, construction types, and regulatory contexts. As the aviation industry continues to evolve, embracing digital solutions that support proactive, data-driven safety management will be essential for meeting new regulatory requirements and industry benchmarks.

Executive Recommendation:

Given the demonstrated benefits and the critical importance of safety in airfield operations, it is recommended that airport authorities and industry stakeholders consider pilot implementation of the proposed dashboard in active construction environments. Collaboration among regulatory bodies, airport operators, and technology providers will be key to refining, validating, and scaling this approach. Through continued research and practice, the aviation sector can establish new standards for construction safety, ultimately contributing to safer, more resilient airport infrastructure worldwide.

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