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Improving the Organization of Fire Prevention, Firefighting, And Rescue Operations at Vietnamese Airports in Accordance with International Standards

Mai Danh Giang

Faculty of Firefighting and Rescue, University of Fire Prevention and Fighting, Vietnam

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ABSTRACT: Airports constitute critical infrastructure with a particularly high level of fire, explosion, and emergency risks due to the specific characteristics of aircraft operations, the use of aviation fuel, and the concentration of large numbers of people. Therefore, fire prevention, firefighting, and rescue operations at airports are not only specialized technical activities but also a core component of public safety governance. Internationally, the standards frameworks of the International Civil Aviation Organization (ICAO), the Federal Aviation Administration (FAA), and the National Fire Protection Association (NFPA) have established fundamental organizational principles for Airport Rescue and Firefighting (ARFF) forces, emphasizing on-site operational capability, a response time objective of no more than three minutes, and multi-agency coordination under a unified command model [1, 5, 6].

This paper employs a literature review method combined with comparative analysis of international standards to examine the organizational model of fire prevention, firefighting, and rescue operations at airports in Vietnam in the context of the newly promulgated legal framework [23-26]. The research findings indicate that the current model, which integrates on-site ARFF forces at airports with supporting forces from the Fire Prevention, Firefighting, and Rescue Police, is fundamentally consistent with international principles [1, 5]. However, there remain governance gaps related to role allocation across response phases, unified command mechanisms, and performance-based management [10, 14, 19]. Based on these findings, the paper proposes recommendations to improve the organization of fire prevention, firefighting, and rescue operations at airports toward a modern public safety governance approach, enhancing system resilience and aligning more closely with international best practices [12, 20].

KEYWORDS: fire prevention and firefighting; rescue operations; airports; ARFF; public safety governance; ICAO; FAA; NFPA.

1. INTRODUCTION

Airports are among the types of critical infrastructure with the highest level of risk in modern society. Aircraft operations, the storage and use of aviation fuel, large volumes of cargo, and high passenger density create conditions in which fire and explosion incidents at airports can result in particularly severe consequences. International research and standards on aviation safety consistently affirm that the initial response time of airport emergency firefighting forces is decisive for the effectiveness of rescue operations and the control of aircraft fires, with a response time objective of no more than three minutes regarded as a core requirement [1, 5, 6].

From the perspective of public safety governance, fire prevention, firefighting, and rescue operations at airports must be approached as an inter-organizational system, in which effectiveness depends on close coordination among various stakeholders, including on-site ARFF forces, the Fire Prevention, Firefighting, and Rescue Police, medical services, aviation security units, and local authorities [10, 11]. International standards on emergency management emphasize that achieving the three-minute response time objective requires an appropriate organizational design, a unified command mechanism, and standardized coordination procedures [1, 6, 14]. This is not merely a technical requirement but also a governance issue, as it determines the arrangement of personnel, equipment, fire stations, and operational control mechanisms when incidents occur.

In Vietnam, the legal framework for fire prevention, firefighting, and rescue operations has undergone significant development with the promulgation of the Law on Fire Prevention, Firefighting, and Rescue in 2024 and its guiding documents. This new legal framework has clearly defined the state management role of the Fire Prevention, Firefighting, and Rescue Police, established inter-agency coordination mechanisms, and clarified the responsibilities of agencies and organizations in ensuring fire safety at high-risk facilities, including airports [23-26]. However, the practical application of international standards concerning force organization, role allocation across response phases, and performance-based management within the operational model of Vietnamese airports remains challenging and has not yet been fully standardized.

This paper aims to analyze the level of compatibility between the organizational model of fire prevention, firefighting, and rescue operations at Vietnamese airports and international standards, while identifying existing gaps in organizational governance. Based on this analysis, the study proposes

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solutions for improvement in line with modern public safety governance, grounded in the principles of unified command, performance-based management, and enhanced system resilience [12, 19, 20].

2. THEORETICAL BASIS AND INTERNATIONAL STANDARDS FRAMEWORK

International research and standards on fire prevention, firefighting, and rescue operations at airports focus on three key pillars: on-site operational capability, response time, and multi-agency coordination. The International Civil Aviation Organization, through Annex 14 to the Chicago Convention and related operational guidance documents, considers ARFF as an integral component of airport operations. ICAO requires airports to establish specialized forces, deploy appropriate equipment, and implement operational procedures to ensure that the initial response time objective does not exceed three minutes for critical locations within the airfield area [1-3].

In the United States, the FAA approaches this issue from a performance-based management perspective, clearly defining the minimum capability requirements for ARFF forces through the ARFF Index classification mechanism stipulated in 14 CFR Part 139. This approach directly links the readiness level of ARFF forces to aircraft type, operational frequency, and the specific risk characteristics of each airport [5]. In parallel, the FAA issues detailed guidance on the development of Airport Emergency Plans (AEP), emphasizing the importance of a unified command mechanism, responsibility assignment matrices among involved agencies, and the requirement to conduct regular training and exercises to ensure effective inter-agency coordination [6].

3. RESEARCH METHODS AND INSTITUTIONAL ANALYSIS

In addition to ICAO and FAA, the NFPA provides important professional standards for ARFF operations. NFPA 460 - the latest consolidated standard on the organization of ARFF services at airports - specifies detailed requirements regarding competency, training, exercises, readiness maintenance, and resource allocation according to risk levels. At the same time, NFPA 1900 establishes technical requirements for specialized airport firefighting vehicles, contributing to the alignment between human capacity and equipment capability [6,7]. Professional training materials such as the ARFF manuals of the International Fire Service Training Association (IFSTA) also emphasize the importance of specialized training and standardized operational procedures for effective emergency response at airports [8].

In recent years, academic research has expanded its focus from purely technical aspects to organizational and managerial dimensions. Firefighting and rescue operations at airports are increasingly viewed as complex socio-technical systems, in which effectiveness depends on inter-organizational coordination, command capacity, and post-incident learning capability. Studies on resilience in airport firefighting systems indicate that optimizing decision-making processes, coordination mechanisms, and after-action evaluations plays an equally important role as investments in equipment and technology [20-22].

From the perspective of public safety governance, numerous studies have demonstrated that effective emergency response largely depends on organizational design and unified command mechanisms. The emergency management framework of the United States, through the National Incident Management System (NIMS), has established the Incident Command System (ICS) as a standard structure for multi-agency coordination. Classical research on High Reliability Organizations (HRO) also confirms that ICS is an effective tool for minimizing organizational risks and enhancing consistency in decision-making during incidents [12,14].

Furthermore, modern risk management standards, particularly ISO 31000, provide a theoretical foundation for performance-based management in the field of public safety. The risk-based approach emphasizes the importance of establishing performance indicators, continuous evaluation, and systematic improvement - key factors in ensuring the sustainable readiness of ARFF forces at airports [19].

A synthesis of the aforementioned literature and standards identifies six core organizational principles for fire prevention, firefighting, and rescue operations at airports: (i) ensuring on-site operational capability of ARFF forces; (ii) clear role allocation among forces across response phases; (iii) establishment of a unified command mechanism; (iv) readiness management based on performance indicators; (v) maintenance of training, exercises, and continuous improvement; and (vi) promotion of organizational learning to enhance the overall capacity for fire and explosion prevention and emergency response [6,12,14,19,20].

The study was conducted using qualitative research methods with an institutional and policy analysis orientation, consistent with the objective of evaluating the organization of fire prevention, firefighting, and rescue operations at airports at the system level. The research approach is situated within the public safety governance framework, viewing fire safety at airports as the result of interactions among technical factors, organizational structures, legal institutions, and inter-agency coordination mechanisms. This perspective is consistent with international studies on emergency management, which emphasize that response effectiveness depends more on organizational arrangements and coordination mechanisms than on the isolated capacity of individual forces [10,11].

The research data sources consist of three main groups. The first includes international standards and guidelines issued by ICAO, FAA, and NFPA concerning the organization of airport emergency firefighting forces, response time requirements, and unified command mechanisms [1-3, 5, 6]. The second group comprises peer-reviewed academic studies on emergency governance, HRO, the ICS, and the responsiveness of airport firefighting systems [12, 14, 20-22]. The third group consists of current Vietnamese legal documents governing fire prevention, firefighting, and rescue operations, including the Law on Fire Prevention, Firefighting, and Rescue of 2024 and its implementing regulations, which constitute the direct legal basis defining the roles, functions, and responsibilities of the Fire Prevention, Firefighting, and Rescue Police in organizing operations at airports [23-26].

The benchmarking method was employed to compare international organizational principles with the current organizational model in Vietnam, focusing on key criteria such as on-site ARFF capability, response time objectives, unified command mechanisms, and performance-based management. This

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comparison is based on widely recognized international standards, including ICAO Annex 14, FAA Part 139, and NFPA 460 [1, 5, 6]. In addition, institutional mapping was applied to identify the roles, responsibilities, and coordination relationships among actors within the state management system for fire prevention, firefighting, and rescue operations at airports, thereby identifying governance gaps, overlapping functions, and limitations in existing operational mechanisms [10, 12, 14].

Moreover, the study applied the risk management framework of ISO 31000 to assess the level of readiness and the performance-based management approach in fire prevention, firefighting, and rescue operations at Vietnamese airports. Integrating the risk management perspective enables a shift from a purely compliance-based approach to an approach centered on risk assessment and practical effectiveness [19].

4. RESULTS AND DISCUSSION

4.1. Organizational Model of Fire Prevention, Firefighting, and Rescue Operations at Vietnamese Airports

The analysis results indicate that the organization of fire prevention, firefighting, and rescue operations at Vietnamese airports is currently structured according to a combined model consisting of two main capability components: (i) on-site Airport Rescue and Firefighting (ARFF) forces of the airport, and (ii) external support provided by the Fire Prevention, Firefighting, and Rescue Police. This organizational configuration is relatively common worldwide, reflecting the fundamental principle that incidents involving aircraft require immediate response within the airport premises and cannot rely on external forces due to strict response time constraints [1,5,6].

Under the provisions of the new legal framework on fire prevention, firefighting, and rescue operations, the Fire Prevention, Firefighting, and Rescue Police play the role of state management authority, including appraisal, safety inspection, professional guidance, operational training, and participation in handling complex incidents beyond on-site capabilities. Meanwhile, airports are responsible for maintaining dedicated ARFF forces with appropriate equipment, personnel, and continuous standby readiness to ensure operational safety. This functional allocation is fundamentally consistent with the approach of ICAO and FAA, whereby ARFF is regarded as an inseparable component of the airport operational system [1-3,5], and is clearly stipulated in the current legal framework of Vietnam [23-26].

Overall, the existing organizational model demonstrates appropriate recognition of the principle of "on-site capability" - a critical requirement for aviation safety. The approach of not expecting external forces to meet the two-to-three-minute response time objective for the initial response phase aligns with international logic and reflects a practical understanding of the specific characteristics of the airport environment [1,6].

4.2. Compatibility with International Principles of Fire Prevention, Firefighting, and Rescue Organization

A comparison with the standards of ICAO, FAA, and NFPA shows that the fire prevention, firefighting, and rescue system at Vietnamese airports has achieved several important areas of compatibility. First, the requirement to maintain on-site emergency firefighting forces equipped with specialized vehicles, trained personnel, and 24/7 standby readiness has been implemented at most major airports, consistent with ICAO requirements regarding response time and safety assurance levels [1-3].

Second, the development and regular updating of Airport Emergency Plans, along with the organization of periodic joint exercises between ARFF forces and external agencies-including the Fire Prevention, Firefighting, and Rescue Police-have been carried out in accordance with current regulations. This practice is consistent with FAA requirements for emergency planning and inter-agency exercises to ensure effective coordination in real-life situations [6].

Third, Vietnam's new legal system has established a relatively comprehensive legal framework for fire prevention, firefighting, and rescue operations, including provisions on the responsibilities of relevant stakeholders, coordination procedures, and mechanisms for force mobilization. These elements demonstrate that Vietnam has adopted many fundamental principles of public safety governance in the airport sector [23-26].

However, the level of compatibility mainly remains at the level of general principles and regulatory provisions, while the detailed operational mechanisms and system-level standardization remain limited. This situation gives rise to governance gaps that need to be identified and addressed [10,14].

4.3. Governance Gaps in Role Allocation by Response Phases

The first notable gap is the absence of a clear role-by-phase framework. International guidance documents from ICAO and FAA emphasize that ARFF forces must assume primary responsibility during the initial response phase-including scene approach, fire suppression, ensuring escape routes, and rescue operations-while external forces mainly participate in extended response and recovery phases [2,6].

In Vietnam, this principle is often implicitly understood in practice but has not yet been institutionalized into specific regulations within airport emergency plans or professional guidance documents. The lack of a clearly defined role allocation matrix by response phase may lead to overlapping functions or confusion in the transfer of command when incidents exceed on-site capabilities. From a public safety governance perspective, this constitutes a form of organizational risk that can undermine response effectiveness even when adequate personnel and equipment are available [10,12].

4.4. Challenges in Unified Command Mechanisms and Inter-Agency Coordination

The second gap relates to the mechanism of unified command. Airport incidents often require the simultaneous involvement of multiple forces, including ARFF, the Fire Prevention, Firefighting, and Rescue Police, medical services, aviation security, air traffic control, and local authorities. International experience shows that response effectiveness depends heavily on the application of a unified command model with a clear structure, common terminology, and standardized decision-making processes, as exemplified by the NIMS and the ICS [14].

In Vietnam, although general regulations on inter-agency coordination in emergency situations exist, particularly at airports, the command mechanism in airport emergencies has not yet been standardized into a specific organizational model equivalent to ICS. Operational command often relies more

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on the practical experience of individual commanders than on a unified professional framework. This situation increases the risk of information fragmentation, conflicting priorities, and delays in decision-making, especially in large-scale or prolonged incidents [10,11,14].

4.5. Limitations in Performance-Based Management and Organizational Learning

The third gap is the lack of a comprehensive performance-based management system. FAA and NFPA require airports to regularly monitor indicators such as turnout time, scene arrival time, equipment readiness, and personnel competency. These indicators serve not only to ensure regulatory compliance but also as tools for continuous improvement and readiness maintenance [5-7].

In Vietnam, although training and exercises have been conducted at many airports, the establishment of a unified and mandatory performance indicator system for the entire sector remains limited. Post-exercise or post-incident evaluations often focus more on administrative reporting than on in-depth system analysis, resulting in lessons learned that are insufficiently comprehensive and difficult to translate into organizational improvements. Recent studies on the resilience of airport firefighting systems emphasize that post-action learning is a decisive factor in enhancing long-term effectiveness [20-22].

The absence of performance measurement mechanisms also reduces the ability to detect potential weaknesses at an early stage and limits evidence-based resource allocation. This is inconsistent with modern safety governance trends, which regard operational data and organizational learning as the foundation of system resilience [19,20].

4.6. Discussion Implications from the Perspective of Public Safety Governance

The overall findings suggest that the main challenges facing fire prevention, firefighting, and rescue operations at Vietnamese airports do not primarily stem from a lack of equipment or personnel, but rather from issues related to system organization and coordination. These are "non-technical" factors, yet they have a decisive impact on the actual effectiveness of emergency response.

From a public safety governance perspective, the airport fire prevention, firefighting, and rescue system should be viewed as an inter-organizational system in which effectiveness depends more on the quality of coordination among multiple actors than on the individual capacity of any single force [10-12]. The transition from a "compliance-based" approach to a "performance-based and resilience-oriented" approach is an inevitable requirement to enhance safety levels in an increasingly complex risk environment [19,20].

Therefore, improving the organization of fire prevention, firefighting, and rescue operations at airports is not merely a matter of adding equipment or training personnel, but first and foremost involves refining organizational design, command mechanisms, and performance evaluation systems in accordance with international standards [6,14,19].

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. General Conclusions

This study has analyzed the organization of fire prevention, firefighting, and rescue operations at Vietnamese airports from the perspective of public safety governance and in comparison with international standards issued by ICAO, FAA, and NFPA. The results indicate that the current organizational model-combining on-site ARFF forces with external support from the Fire Prevention, Firefighting, and Rescue Police-is fundamentally consistent with international principles, particularly regarding the requirement for on-site capability and the objective of an initial response time of no more than three minutes during the first response phase [1,5,6].

However, this compatibility primarily exists at the level of overall structure, while detailed operational mechanisms and the performance-based governance framework still reveal significant limitations. The gaps identified in this study do not stem from a lack of material resources, but rather relate mainly to organizational design, role allocation, and coordination mechanisms. This implies that the core challenge in fire prevention, firefighting, and rescue operations at Vietnamese airports is a matter of system governance, rather than purely technical or equipment-related issues [10,11].

5.2. Conclusions on Key Issues

First, the study confirms that response time requirements in the airport environment are the dominant factor shaping the entire organizational design of fire prevention, firefighting, and rescue operations. Accordingly, on-site ARFF forces must be regarded as the central actor during the initial response phase, while the Fire Prevention, Firefighting, and Rescue Police should assume the roles of state management and reinforcement in extended response phases. A proper understanding of this principle is a prerequisite for standardizing coordination mechanisms and minimizing the risk of overlapping responsibilities [1-3,6].

Second, although Vietnam's new legal framework has established a relatively comprehensive institutional basis for fire prevention, firefighting, and rescue operations, existing regulations remain largely general in nature and have not yet been translated into specific operational procedures tailored to the unique environment of airports. The gap between "general regulations" and "specific operational guidelines" constitutes a direct cause of inconsistencies in command and coordination practices when incidents occur [23-26].

Third, the study highlights that the absence of a comprehensive performance-based management system represents the most significant limitation in the current context. International standards emphasize that regular measurement, verification, and evaluation of performance indicators-particularly turnout time, response time, equipment readiness, and personnel competency-are essential to maintaining ARFF readiness [5-7]. The incomplete establishment of such mechanisms in Vietnam reduces the capacity for objective monitoring, organizational learning, and continuous improvement [19,20].

5.3. Recommendations for Institutional and Policy Improvement

Based on the analytical findings, the study proposes several key policy recommendations.

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First, it is necessary to develop and promulgate a specialized guideline framework for organizing fire prevention, firefighting, and rescue operations at airports within the system of sub-law regulatory documents. This framework should specify requirements regarding force organization, station deployment, standby readiness, information reception and processing procedures, training standards, and coordination mechanisms between ARFF forces and the Fire Prevention, Firefighting, and Rescue Police, in order to ensure nationwide operational consistency [1,6,23-26].

Second, role allocation by response phases should be standardized within airport emergency plans. Specifically, ARFF forces must be clearly designated as primarily responsible for the initial response phase (including scene approach, fire suppression, and rescue), while external forces, including the Fire Prevention, Firefighting, and Rescue Police, should participate mainly in extended and recovery phases. Institutionalizing this principle in a clear and formal manner is consistent with international airport operational guidelines and would significantly reduce the risk of task overlap [2,6].

Third, a unified command mechanism based on the principles of the ICS within the NIMS framework should be developed and applied. The establishment of a standardized command structure, common terminology, and consistent decision-making processes would enhance inter-agency coordination, reduce information fragmentation, and ensure coherent on-scene leadership, particularly during complex and prolonged incidents [14]. Furthermore, research on HRO confirms that ICS represents an effective organizational mechanism for operating in high-risk and dynamic environments such as airports [12].

Fourth, it is essential to transition toward performance-based management in airport fire prevention, firefighting, and rescue operations. This should include: (i) the development of a national set of ARFF performance indicators (turnout time, response time, equipment availability rate, and personnel competency); (ii) the establishment of periodic verification mechanisms; and (iii) the linkage of evaluation results to resource allocation and capacity-building programs. This approach aligns with the performance-based management logic of the FAA and the readiness maintenance requirements of NFPA standards [5-7], while also corresponding to risk-based management principles under ISO 31000 [19].

Fifth, mechanisms for post-incident and post-exercise learning should be institutionalized in a mandatory and evidence-based manner. Each exercise or real incident should be followed by independent evaluation, systemic root-cause analysis, standardized lessons-learned reporting, and the translation of findings into improvements in procedures, coordination mechanisms, and training programs. Recent studies on resilience in airport firefighting emphasize that "after-action learning" is a decisive factor in enhancing long-term effectiveness and system adaptability [20-22].

5.4. Implications for Management Practice

The above recommendations are not only of theoretical significance but also carry clear practical value. Improving the organization of fire prevention, firefighting, and rescue operations at airports toward a performance-based governance model will contribute to enhanced aviation safety, reduced risk of operational disruptions, and increased public confidence in national emergency response capabilities. At the same time, reforms oriented toward unified command and inter-organizational coordination will help optimize resource utilization and improve the professionalism of participating forces [10,11,14].

Moreover, lessons learned from the airport sector can be extended to other forms of critical infrastructure such as seaports, industrial zones, energy facilities, and public transportation systems-sectors that likewise require rapid response, multi-agency coordination, and risk-based management in emergency situations [16,19].

5.5. Research Limitations and Future Research Directions

This study primarily relied on institutional analysis and benchmarking against international standards; therefore, it has not incorporated empirical data on actual operational performance at individual airports. Future research should adopt quantitative approaches, including: (i) measurement of actual response times across different areas and scenarios; (ii) evaluation of exercise effectiveness based on performance indicators; and (iii) in-depth analysis of typical incidents to identify organizational factors influencing response outcomes [5,6,19].

In addition, comparative studies among airports of different sizes should be conducted to assess the suitability of organizational models and coordination mechanisms. Further research is also needed to examine the impact of emerging technologies-such as digital command systems, real-time data analytics, and simulation-based training-on organizational capacity and readiness in airport fire prevention, firefighting, and rescue operations, particularly in the context of a transition toward data-driven and performance-based public safety governance [19-22].

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Corresponding Author: Mai Danh Giang