INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue II, February 2026

A Study on the Impact of the National Technical Regulation on Fire Safety for Buildings and Structures on Airport Construction Projects in Vietnam

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DOI: https://doi.org/10.51583/IJLTEMAS.2026.15020000016

Received: 12 February 2026; Accepted: 17 February 2026; Published: 03 March 2026

ABSTRACT

In the context of Vietnam's accelerated development of aviation infrastructure, airport construction projects-particularly airport terminal buildings-are increasingly characterized by large-scale facilities, open architectural layouts, extensive multi-level atrium spaces and highly integrated technical systems. The promulgation of the National Technical Regulation on Fire Safety for Buildings and Structures (QCVN 06:2022/BXD) and its Amendment No. 1:2023 has contributed to raising the overall level of fire safety for buildings and structures. However, it has also created a number of "bottlenecks" when applied to highly specialized facilities such as airports. This paper employs a policy and regulatory analysis approach, typical case studies across the project life cycle, and comparative analysis with international standards, including International Civil Aviation Organization (ICAO) Doc 9137 Part 1 and relevant National Fire Protection Association (NFPA) standards applicable to airport facilities. The findings indicate that the impacts of QCVN 06:2022/BXD are most significant in four major areas: (i) master planning and fire service access; (ii) architectural design of terminal buildings (access routes, roof access, and open spaces); (iii) fire compartmentation, egress, and smoke control in large spaces; and (iv) approval procedures, acceptance processes, and management of design and functional changes. Based on these findings, the paper proposes a set of solutions, including the development of an "airport annex" guidance document for QCVN 06, the establishment of a Performance-Based Design (PBD) framework with transparent criteria, the resolution of inter-agency conflicts through coordination mechanisms, and the harmonization of Aircraft Rescue and Firefighting (ARFF) capability requirements in line with ICAO standards.

Keywords: QCVN 06:2022/BXD, airport, fire safety, smoke control, egress, fire safety approval, PBD, ICAO, NFPA.

INTRODUCTION

An airport is a complex infrastructure system with highly specific characteristics, serving both as a place of large public concentration (airport terminal buildings) and as a cluster of industrial and technical facilities (technical areas, aircraft hangars, fuel depots, cargo warehouses, power stations, etc.). In terms of operation, airports are subject to strict aviation security requirements, continuous 24/7 operation, and passenger flows that fluctuate according to "flight peak cycles" (peak and off-peak loads). Architecturally, modern terminals are typically characterized by large-scale, multi-level atrium spaces, extensive glass façades, and multi-layered traffic organization (landside roads, elevated curbside decks, departure and arrival halls, etc.), which require egress and smoke control solutions that are considerably more complex than those of conventional public buildings.

In this context, QCVN 06:2022/BXD and its Amendment No. 1:2023 play a crucial role in standardizing fire safety requirements for buildings and structures in Vietnam. However, since QCVN 06:2022/BXD has been developed as a "general-purpose" regulation, many of its requirements are quantitative and prescriptive in nature. When applied to airport facilities, such requirements may conflict with aviation operational constraints and lead to additional costs without necessarily optimizing actual fire safety performance. Meanwhile, international practice for large-scale and specialized facilities is increasingly oriented toward PBD and the demonstration of safety through simulation and quantitative assessment, based on the methodological foundation of the SFPE Handbook of Fire Protection Engineering and contemporary PBD reviews [3], [4]. In addition, specialized standards such as ICAO Doc 9137 Part 1 (RFF) and NFPA standards (NFPA 415 for terminal buildings and NFPA 403 for ARFF) indicate that an approach based on "fit-for-purpose" and "objective-capability" principles may be more appropriate for airport facilities [5]-[7].

From the practical experience of implementing numerous airport projects in Vietnam, a key issue has emerged: the same requirement of QCVN 06:2022/BXD can be interpreted in different ways and may result in multiple rounds of approval adjustments when confronted with special configurations (elevated curbsides, large halls, long-span roofs, multi-level atrium complexes, etc.). Therefore, a systematic study is required in order to: (i) identify the groups of QCVN 06:2022/BXD provisions that have the most significant impact on airports; (ii) analyze the impact mechanisms across the project life cycle; (iii) determine the root causes of the bottlenecks in application; and (iv) propose improvement solutions that ensure legal compliance while enhancing actual safety

RESEARCH OBJECTIVES, SCOPE, AND METHODOLOGY

Research objectives

The overall objective of this study is to evaluate the impact of QCVN 06:2022/BXD and its Amendment No. 1:2023 on airport construction projects in Vietnam and to propose solutions for improving the application mechanism. Four specific objectives are defined as follows:

To identify the groups of requirements in QCVN 06:2022/BXD that have the most significant impact on airport facilities (particularly terminal buildings).

To analyze the impacts across the project life cycle: planning → design → approval → construction → acceptance → operation.

To conduct comparative analysis with international standards (ICAO, NFPA, and PBD/SFPE) in order to select approaches suitable to the conditions of Vietnam.

To propose solutions, including the specialized application of the regulation, the establishment of a PBD framework, inter-agency coordination mechanisms, and the harmonization of ARFF capability logic.

Research scope

The research scope focuses on building components that are strongly affected by fire safety regulations, including airport terminal buildings, multi-level atrium halls, commercial and service areas within terminals, elevated curbside structures, auxiliary technical areas, and access infrastructure connections. The legal scope takes QCVN 06:2022/BXD and its Amendment No. 1:2023 as the primary analytical framework, combined with references to ICAO Doc 9137 Part 1 and relevant NFPA standards [6], [7]. Regarding the technical foundation for PBD and validation models, the study draws upon the SFPE Handbook and several representative studies and reviews on PBD and simulation [4], [8], [9].

Research methodology

The study employs a combination of the following methods:

- Policy and regulatory analysis: deconstructing the groups of QCVN 06:2022/BXD requirements relevant to airports and analyzing the fire safety management logic in relation to specific building types.
- Project life-cycle analysis: tracing the impacts of regulatory requirements on decision-making processes throughout planning, design, approval, construction, acceptance, and operation.
- Comparative analysis: comparing the prescriptive and quantitative approach of QCVN 06:2022/BXD with the "objective-capability" approach of ICAO and the specialized standards of NFPA, while positioning PBD as a tool to harmonize project-specific characteristics with unified management requirements [3]-[7].

- Synthesis and policy recommendations: developing solutions based on priority levels and implementation roadmaps suitable to practical conditions.

Current Situation and Analysis of the Impacts of QCVN 06:2022/BXD on Airport Projects

QCVN 06:2022/BXD has significant impacts on the design of fire protection systems for airports

QCVN 06:2022/BXD has been developed for broad application, with many provisions emphasizing minimum requirements in order to standardize and facilitate state management of fire prevention, firefighting, and rescue operations [1], [2]. However, airports are facilities with highly specific and stringent operational, security, and functional requirements. As a result, even a minor change in the layout of fire service access or technical zoning may trigger a chain reaction affecting architecture, structural systems, Mechanical And Electrical Plumbing (MEP) design, traffic organization, and security control. This explains why the impacts of QCVN 06:2022/BXD on airports are “greater” than those on conventional public buildings of similar gross floor area.

From the perspective of modern fire safety engineering, an approach based on performance objectives (goal-oriented) and verification through simulation and quantitative assessment is considered more appropriate for complex facilities [3], [4]. International practice shows that large airport terminals often need to adopt PBD in order to balance open architectural layouts, smoke control requirements, passenger flow management, and operational efficiency [3], [8]. This creates a certain gap compared to a rigid prescriptive application if no flexible mechanism is available.

Impacts on master planning and organization of fire service access

Conflicts between “fire service access” and aviation operational constraints

The group of requirements related to fire service roads, stopping positions, and façade access in QCVN 06:2022/BXD typically exerts influence from the very early stage of master planning [1], [2]. For terminal buildings, arranging access roads close to the building may conflict with landside traffic organization (passenger cars, taxis, buses), multi-level elevated curbsides, security-controlled areas, and traffic segregation requirements. In many projects, in order to “comply” with access requirements, investors have had to:

Provide dedicated service roads for fire engines (leading to increased costs for pavements, drainage, lighting, and security arrangements);

Modify building setbacks, resulting in adjustments to elevated curbside connections, parking areas, and underground technical infrastructure;

Reconfigure façades and access points, directly affecting architectural appearance and commercial operations.

Access based on “deployment effectiveness” instead of purely geometric distances

In PBD practice, certain access requirements are transformed from purely “geometric distance” criteria into criteria based on “operational deployment effectiveness,” including: access time, the ability to position fire engines and deploy crews, hose reach, availability of water supply points/standpipes, and the capability to access functional floors [3], [4]. This approach helps reconcile the specific architectural and traffic configurations of airports while still ensuring safety objectives. In principle, this is an aspect that should be institutionalized in an “airport annex” for QCVN 06:2022/BXD.

Impacts on terminal architecture: upper-level access, roof access, and operational costs

Upper-level access: risk of becoming a formalistic requirement

Certain access requirements (for example, upper-level access) are intended to ensure rescue accessibility in situations where the façade is constrained [1]. However, airport terminal buildings often already have multiple

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue II, February 2026

access points inherently provided by elevated curbsides, departure and arrival halls, and various functional floors. If the density of access points is applied mechanically along the entire façade length, three typical consequences may arise:

Disruption of architectural façade concepts (especially large glass façades);

Increased costs for security control, intrusion prevention, and maintenance;

During operation, areas that are required to remain unobstructed may be occupied for advertising or temporary counters, thereby reducing actual safety effectiveness.

Roof access: conflicts with long-span roofs and occupational safety

Modern terminals commonly employ long-span steel roofs, lightweight roofing systems, and multiple layers of technical installations. A rigid requirement for roof access may increase occupational safety risks and maintenance costs without significantly improving actual firefighting capability. In many cases, response effectiveness depends more on smoke control strategies, functional zoning, fire detection and suppression systems, and access from operational floors [3].

Therefore, a reasonable solution is to convert this requirement into an assessment based on “access functionality” and roof conditions (with conditional exemptions or reductions subject to justification) instead of imposing a uniform requirement.

Impacts on fire compartmentation, egress, and smoke control in large spaces

The terminal as a “passenger flow problem” driven by flight peak cycles

Unlike shopping centers, airport terminals involve passenger flows with luggage, various special user groups, and bottlenecks caused by security screening and ticket control. As a result, assumptions regarding occupant load and movement speed based on “generic models” may be inaccurate. Consequently, egress and smoke control requirements should be based on specific scenarios corresponding to different operational periods (peak hours, off-peak hours, and abnormal events). This is the reason why international practice frequently employs egress simulation and scenario-based tenability criteria [3], [8].

Smoke control in large spaces: the need for PBD and quantitative criteria

In large or multi-level atrium spaces, the selection among mechanical smoke exhaust, natural smoke ventilation, pressurization, or hybrid systems depends heavily on building geometry and operational conditions. Research on smoke control in large public spaces has shown that effectiveness can vary considerably depending on ventilation strategies and system configurations [9].

For airport terminal buildings, a recent simulation study also emphasized the importance of modeling smoke spread, visibility, temperature, and egress time in optimizing “fireproof spaces” [8]. This suggests that without a PBD framework, prescriptive application may be suboptimal and may prolong approval processes due to technical disputes.

Impacts on approval, acceptance, and management of design changes

In airport projects, design documents often undergo multiple rounds of adjustment when conflicts arise between prescriptive regulations and special configurations. Although QCVN 06:2022/BXD allows for alternative or equivalent solutions, the absence of standardized verification criteria increases the risk of “prolonged approval processes”: each party (consultants, investors, and approving authorities) may have different interpretations of equivalency levels, acceptance criteria, and verification methods. PBD reviews emphasize that, for PBD to operate transparently, a clear framework of procedures, criteria, and tools is essential; otherwise, management

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue II, February 2026

uncertainty and legal risks will increase [3], [4]. Therefore, the bottleneck in approval is not only technical but also stems from the "lack of a formal PBD institutional framework."

Table 1. Matrix of Major Impacts of QCVN 06:2022/BXD on Airport Projects

QCVN 06:2022/BXD Requirement	Project Stage Affected	Typical Consequences	Level of "Bottleneck"
Fire service access/fire service roads	Master planning - preliminary design	Adjustment of master layout, additional infrastructure costs, operational conflicts	Very high
Access routes (upper-level access, roof access)	Architectural design - acceptance	Increased costs, reduced operational usability, risk of formalistic implementation	High
Fire compartmentation/egress	Design - approval	Architectural fragmentation, difficulty in accommodating passenger flows	High
Smoke control/pressurization	MEP design - approval	Lack of verification framework, prolonged documentation process	Very high
Equipment / ARFF	Investment - operation	Overlapping standards, difficulty in optimizing capabilities	Medium to high

Comparative Financial Impact: Prescriptive Compliance versus Performance-Based Optimization

While this study does not disclose project-specific financial data due to confidentiality considerations, a scenario-based comparative assessment can clarify the relative economic implications of purely prescriptive

For a representative mid-to-large international terminal building in Vietnam (gross floor area approximately 80,000-120,000 m²), strict compliance with prescriptive fire service access requirements may require:

Construction of additional dedicated fire service roads (estimated 500-800 m in length);

Adjustment of building setbacks along terminal façades (typically 3-6 m);

Relocation or redesign of underground utilities, drainage systems, and curbside structures.

Based on prevailing civil construction cost levels in Vietnam, such modifications may represent approximately 1.5-3.5% of total terminal construction cost, excluding long-term maintenance, security control, and operational efficiency impacts.

By contrast, a PBD-based alternative that demonstrates equivalent deployment effectiveness (e.g., validated response time, hose reach, access to critical floors, and water supply adequacy) may:

- Reduce redundant hard infrastructure;
- Minimize façade alterations;
- Preserve commercial frontage and passenger circulation efficiency.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue II, February 2026

Although PBD introduces additional design and simulation costs (typically estimated at 0.2-0.5% of construction cost for complex facilities), the net lifecycle financial impact may remain favorable when avoided civil works and operational optimization are considered.

Therefore, the economic question is not whether fire safety increases cost, but whether financial resources are allocated toward infrastructure redundancy or toward demonstrable operational effectiveness.

Causes of the Limitations and Shortcomings in Application

Causes arising from the "mismatch" between specialized facilities and general management instruments

The core of the problem lies in the incompatibility between airports as highly specialized facilities and a regulatory instrument designed for general application. QCVN 06:2022/BXD has appropriate objectives; however, when its rigid requirements are applied to open terminal configurations, multi-level elevated curbsides, large halls, and long-span roofs, compliance costs increase significantly and the need for "equivalent solution verification" arises [1], [2]. In the absence of a standardized verification framework, these shortcomings tend to

Inter-agency causes: lack of coordination mechanisms for resolving conflicts

Airports are environments involving multiple management stakeholders, including construction authorities, fire prevention and firefighting agencies, aviation authorities, security agencies, and operational units. When regulatory conflicts occur, the absence of coordination mechanisms causes each project to become an isolated case, increasing uncertainty and prolonging decision-making processes. Research on inter-agency coordination networks has demonstrated that the role of "boundary spanners" and inter-organizational communication is key to reducing fragmentation and improving coordination effectiveness in emergency and multi-stakeholder situations [11]. This lesson is directly relevant to the coordination of approval processes for airport projects.

Institutional causes: demand for flexibility without an official PBD framework

PBD is a reasonable tool for addressing complex facilities, but a prerequisite for its effective operation is a transparent framework consisting of procedures, criteria, and tools [3], [4]. In the absence of an official PBD framework, the process of "demonstrating equivalency" can easily fall into prolonged debates, lack of consensus, or be forced back into purely prescriptive solutions at any cost, thereby undermining the objective of optimization.

Causes related to technical capacity: simulation and quantitative analysis not yet widely established

The problem of smoke control and egress in large spaces requires reliable input data and adequate modeling capabilities. If there is a lack of standardization in occupant load assumptions, design fire scenarios, tenability criteria, and model validation methods, the quality of documentation will be inconsistent, making it difficult for approving authorities and increasing legal risks [3], [8], [9].

Table 2. Cause-Effect Tree

Cause Group	Description	Direct Consequences	Proposed Solutions
General-purpose regulation	Prescriptive requirements applied to specialized facilities	Formalistic compliance/high costs	Airport annex + application guidelines
Fragmented inter-agency coordination	Multiple authorities with limited coordination mechanisms	Prolonged approval processes	Inter-agency technical task force (boundary spanners)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue II, February 2026

Lack of official PBD framework	Absence of unified criteria and verification methods	Technical disputes and uncertainty	National PBD framework for airports
Limited simulation capacity	Lack of standardized data and model validation	Inconsistent documentation quality	Training and independent verification

In the Vietnamese context, the implementation of a simulation-intensive PBD framework requires adequate technical infrastructure, including access to validated fire and smoke modeling tools, evacuation simulation platforms, and sufficient computational capacity for large atrium analyses. Currently, simulation expertise and computational resources are unevenly distributed among consulting firms, and regulatory agencies may require additional training to ensure consistent review standards. Therefore, institutional capacity building must address both private-sector designers and public-sector reviewing authorities.

Proposed Baseline Assumptions for Occupant Load and Flight Peak Cycles in the Vietnamese Context

The study identifies a lack of standardized occupant load data specific to airport terminals in Vietnam. To address this gap, the following preliminary baseline assumptions are proposed for simulation-based design and regulatory review:

- Departure hall peak density: 2.0-2.5 m² per person
- Arrival hall peak density: 1.5-2.0 m² per person
- Retail and food service zones: 1.4-1.8 m² per person
- Security checkpoint accumulation factor: up to 1.3 times average zone density during flight bank peaks

For design fire scenarios and evacuation modeling, peak flight cycles at major Vietnamese international airports may be conservatively modeled as 1.2–1.5 times average hourly passenger throughput.

These values are proposed as interim reference parameters pending the development of nationally standardized datasets and should be validated against project-specific operational statistics where available.

Solutions and Recommendations for Improvement (Feasible and with Implementation Roadmaps)

Development of a “Guideline/Annex for the Application of QCVN 06:2022/BXD to Airport Facilities”

A priority solution is to issue a technical-legal document at the level of a guideline or annex, serving as a “specialized interpretation layer” for QCVN 06:2022/BXD when applied to airport facilities. This document should:

- Classify airport components (terminal, concourse, landside/curbside, technical areas, hangars, fuel depots, etc.) and their specific risk characteristics.
- Clearly specify groups of QCVN 06:2022/BXD provisions that are directly applicable, groups requiring “adjusted application,” and groups that may be conditionally exempted or reduced.
- Define documentation requirements for demonstrating equivalent solutions.
- Provide “acceptable solution templates” for common configurations (terminals with elevated curbsides, large atrium halls, etc.).

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue II, February 2026

- This approach is similar to international practice, where specialized standards are used for terminal buildings (NFPA 415) and ARFF (NFPA 403) instead of applying a single general standard to all types of facilities [6], [7].

Establishment of an official PBD framework for airports: procedures - criteria - tools

The proposed PBD framework should include at least six steps:

1. Define safety objectives and the scope of application (areas or spaces requiring PBD).
2. Develop design fire scenarios and operational conditions (Heating, Ventilation and Air Conditioning system operational status, door conditions, occupant density according to peak cycles).
3. Conduct fire and smoke simulations and evaluate tenability conditions (visibility, temperature, toxicity, etc.).
4. Conduct egress simulations to determine the Required Safe Egress Time and compare it with the Available Safe Egress Time in order to evaluate the adequacy of evacuation safety.
5. Conduct sensitivity and uncertainty analyses and assess reasonably worse-case scenarios.

Implement independent review and manage changes during construction and operation.

The technical foundation for this framework can be referenced from the SFPE Handbook [3] and recent PBD reviews [4]. For terminal buildings, specialized simulation studies have demonstrated that modeling smoke spread, visibility, temperature, and egress time is highly valuable in optimizing compartmentation and fire-safe spaces [8]. The PBD framework must be accompanied by minimum acceptance criteria (tenability) and model validation requirements to avoid arbitrary application.

Resolving conflicts in fire service access through "deployment effectiveness" criteria instead of rigid geometric distances

It is proposed to shift part of the access requirements from "distance measurement" to "deployment capability assessment," including:

- Time required to reach deployment points.
- Ability to position vehicles and deploy crews.
- Hose reach capability.
- Availability of water supply points, standpipes, and fire department connections.
- Capability to access critical functional floors.

When geometric configurations cannot be achieved due to constraints related to elevated curbsides, traffic organization, or security, alternative solutions should be permitted if equivalent deployment capability can be demonstrated within the PBD framework. This represents a way to harmonize prescriptive requirements with operational realities and is consistent with the "objective-capability" philosophy of modern fire safety design [3], [4].

Adjustment of upper-level access and roof access requirements based on functional criteria

It is recommended to convert requirements that are prone to becoming formalistic into functional criteria:

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue II, February 2026

- Roof access: mandatory application only when roofs allow safe and practical access with real operational value; conditional exemptions or reductions should be allowed for long-span roofs when alternative access routes (from technical floors, elevated curbsides, or internal access points) are available and deployment capability is demonstrated.
- Upper-level access: allow replacement with a combination of solutions (access points from elevated curbsides or functional floors, adequately sized access doors, operational zones, and security control measures) if functional equivalence can be justified.

The key point is to institutionalize conditions for exemption or reduction in an annex or guideline in order to minimize approval disputes.

Harmonization of ARFF equipment standards according to ICAO logic, converting "equipment lists" into

It is recommended to adopt the capability logic of ICAO Doc 9137 Part 1 as the foundation, focusing on response time, operational capability, quantities of extinguishing agents, and rescue capacity [5]. For domestic equipment standards based on prescriptive equipment lists, guidance should be developed to convert such requirements into capability-based criteria in order to avoid purely mechanical "vehicle counting" [10]. The objective is to optimize investments based on the actual risk profile of each airport, preventing overlaps or deficiencies in capacity.

Establishment of inter-agency coordination mechanisms based on the "boundary spanners" model

It is proposed to establish an inter-agency technical task force for major airport projects, consisting of representatives from construction authorities, fire prevention and firefighting agencies, aviation authorities, and independent experts. This task force would act as a "technical focal point" to unify interpretations, resolve conflicts, and manage changes during approval processes, in line with research evidence on inter-organizational coordination networks and the role of boundary spanners in multi-stakeholder contexts [11]. Such a mechanism is particularly essential when applying PBD in order to avoid situations where "each approval round becomes a new debate."

Proposed Organizational Structure for Inter-Agency Coordination

To operationalize the boundary spanner model, it is proposed that a formally recognized inter-agency technical task force be established through a joint ministerial circular. This task force should include:

- A representative from the construction regulatory authority;
- A representative from the national fire prevention and firefighting authority;
- A representative from the civil aviation authority;
- An independent fire engineering expert.

The task force should possess advisory authority during design review stages and binding interpretative authority regarding the assessment of equivalent solutions for nationally significant airport projects. Such formal empowerment would reduce interpretative fragmentation and increase procedural certainty.

Proposed Legal/Procedural Mechanism to Empower the Task Force

To ensure that the inter-agency technical task force operates effectively and consistently across projects, a clear legal and procedural basis is required. This study proposes that the task force be formally empowered through a joint ministerial circular or equivalent administrative instrument, specifying:

- Mandate and scope: applicable to nationally significant airport projects and/or projects with complex terminal configurations requiring equivalent solution assessments under QCVN 06:2022/BXD.

- Decision-making role: advisory authority for early-stage design coordination, and interpretative authority for evaluating equivalency justifications under the PBD framework.
- Process integration: defined milestones for task force engagement (concept design review, design development review, final approval review, and change-management review during construction).
- Documentation rules: standardized submission package for equivalency assessment (scenario definition, modeling assumptions, acceptance criteria, validation approach, and peer review statement).
- Time-bound coordination: clear timelines for feedback and resolution to avoid prolonged approval cycles.

Institutionalizing these procedural rules would reduce interpretative fragmentation, improve transparency, and provide regulatory certainty for both project owners and approving authorities, particularly when simulation-based arguments are introduced in the approval process.

Enhancement of technical capacity and standardization of PBD documentation

A package of capacity-building solutions is proposed:

- Provide specialized training on fire-smoke-egress simulation and uncertainty management;
- Develop standardized templates for PBD reports (structure of argument, assumptions, validation, sensitivity analysis);
- Establish mechanisms for independent review and a list of accepted tools and models;
- Standardize occupant load data and scenarios according to flight peak cycles to ensure consistency across projects.

Table 3. Implementation roadmap for proposed solutions

Solution Group	**Short-term (≤12 months)**	**Medium-term (1-3 years)**	**Long-term (≥3 years)**
Airport annex/guidelines	Issue guidelines for the application of QCVN 06:2022/BXD to terminal buildings	Expand application to other airport components	Integrate into the next revision of QCVN 06:2022/BXD
PBD framework	Pilot implementation for large atrium spaces	Standardize tenability criteria and report templates	Establish a national PBD standard for specialized facilities
Fire service access	"Deployment effectiveness" mechanism +supporting infrastructure	Standardize time-to-access criteria	Achieve inter-agency harmonization in regulations
ARFF	Convert equipment lists to ICAO-based capability criteria	Standardize risk assessment methodologies	Develop a national ARFF capability framework
Inter-agency coordination	Establish inter-agency technical task force for key projects	Expand to a standing coordination model	Institutionalize coordination mechanisms

To enhance consistency and transparency, a standardized structure for PBD documentation is recommended:

1. Project description and scope of PBD application
2. Regulatory context and defined safety objectives
3. Design fire scenarios and operational assumptions
4. Modeling methodology and software validation
5. Tenability criteria and acceptance thresholds
6. Egress analysis and comparison between Required Safe Egress Time and Available Safe Egress Time
7. Sensitivity and uncertainty analysis
8. Conclusions and equivalency justification
9. Independent peer review statement

This structured approach may reduce ambiguity during regulatory approval and enhance technical rigor.

Integration of Building Information Modeling into the PBD Framework

The integration of Building Information Modeling (BIM) can significantly strengthen PBD implementation in airport projects. BIM enables:

- Accurate geometric extraction for fire and smoke simulations;
- Dynamic modeling of occupant movement;
- Coordination between architectural, structural, and MEP systems;
- Lifecycle fire risk management tracking.

By linking BIM data with simulation workflows, inconsistencies in geometry, zoning, and system configuration can be minimized, thereby improving approval transparency and reducing iterative design conflicts in complex terminal projects.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The revised analysis incorporating financial illustration, baseline occupant load assumptions, and technical capacity considerations further strengthens the empirical grounding of the study and clarifies the practical feasibility of the proposed reforms.

The study demonstrates that QCVN 06:2022/BXD and its Amendment No. 1:2023 have significant impacts on airport projects because the regulation directly affects key components of terminal buildings, including master planning and access arrangements, architectural space organization, fire compartmentation and egress, and smoke control in large spaces [1], [2]. Four major impact areas have been identified: (i) conflicts and additional costs related to fire service access; (ii) inadequacies in applying certain prescriptive requirements to open architectural layouts and elevated curbsides; (iii) difficulties in demonstrating smoke control and egress performance due to the lack of an official PBD framework; and (iv) overlapping logic in ARFF equipment standards when simultaneously operating under ICAO requirements and domestic standards [5], [10].

Fundamentally, the current shortcomings do not negate the fire safety objectives of QCVN 06; rather, they reflect the need to specialize the application of the regulation for airport facilities and to institutionalize PBD in order to address unique configurations. International experience and the scientific foundation of PBD indicate that, for complex facilities, performance-based verification with clear criteria and validation mechanisms enables both the achievement of safety objectives and the optimization of design and operation [3], [4]. At the same time, effective risk management in multi-stakeholder environments largely depends on inter-agency coordination mechanisms and the role of "boundary spanners" [11].

Key recommendations

- Issue guidelines or an annex for the application of QCVN 06:2022/BXD to airports in order to reduce uncertainty and standardize interpretations.
- Establish an official PBD framework (procedures-criteria-tools-independent review) for large-scale and multi-level terminal buildings.
- Resolve conflicts in fire service access by applying deployment effectiveness criteria and supporting infrastructure, instead of imposing rigid geometric distance requirements in all cases.
- Adjust requirements that are prone to becoming formalistic (upper-level access and roof access) based on functional criteria and conditional exemptions supported by verification.
- Harmonize ARFF standards according to ICAO logic and convert prescriptive "equipment lists" into capability-based criteria to optimize investment in line with actual risk.
- Establish a permanent inter-agency coordination mechanism for major airport projects to unify technical decisions and manage changes effectively [11].

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