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Application of Information and Communications Technology and Digital Transformation in State Management of Fire Prevention, Firefighting and Rescue Operations in VietNam

Mai Danh Giang

Faculty of Fire Fighting and Rescue, The University of Fire Prevention and Fighting

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ABSTRACT: Digital transformation is fundamentally reshaping the state management model toward data-driven governance, system integration and risk-informed decision-making. In the field of fire prevention, firefighting and rescue operations (FPFR), digital transformation is not limited to digitizing administrative procedures; it is a comprehensive restructuring of management methods across the entire cycle - from prevention and inspection to incident command and control during fires, explosions, accidents, and emergencies, as well as post-incident review and lessons learned. This paper analyzes the current situation of applying information and communications technology (ICT) and digital transformation in state management of FPFR in Viet Nam and identifies key gaps relative to international benchmarks - particularly in data governance, system interoperability, and fire risk assessment. Drawing on international experience and standards on incident management and risk management, the paper proposes a digital transformation approach oriented toward data-driven risk governance, with a view to enhancing the effectiveness and efficiency of state management of FPFR in the current development context.

KEYWORDS: Digital transformation, state management, fire prevention and firefighting, rescue operations, risk governance, data.

1. INTRODUCTION

In the context of globalization and the Fourth Industrial Revolution, digital transformation has become one of the central pillars of state-management reform in many countries. Modern public-governance models increasingly rely on big data, digital platforms, and analytical technologies to strengthen forecasting capacity, control risks, and support policy decision-making. Digital transformation, therefore, is not merely a technical issue; it represents a fundamental shift in governance thinking, organizational arrangements, and the operation of the state apparatus [9], [10].

In Viet Nam, digital transformation has been identified as a national strategic orientation toward building a digital government, a digital economy, and a digital society [1], [11]. Within this process, state management of FPFR is directly and profoundly affected by digital transformation due to its inherently high-risk nature, the need for rapid response, multi-agency coordination, and strong dependence on accurate and timely information. Viet Nam's socio-economic development in practice shows that the risks of fire, explosion, and emergencies are increasing in both frequency and complexity. Rapid urbanization, high population density, and the growth of high-rise buildings, underground spaces, industrial zones, logistics centers, fuel depots, and chemical storage facilities have significantly reshaped the national "fire-risk landscape." Meanwhile, the traditional model of state management of FPFR-primarily based on periodic administrative inspections and post-incident response-has increasingly revealed significant limitations.

International experience indicates that the application of ICT, the development of digital databases, and the deployment of risk-analysis tools have helped many countries shift from a passive management model to a proactive risk-governance model. Standardized incident-reporting systems such as the United States' National Fire Incident Reporting System (NFIRS) and national incident-management frameworks such as the National Incident Management System (NIMS) have provided a critical data foundation for policy formulation, resource allocation, and improving the effectiveness of fire prevention [2], [3].

Against this background, the paper raises the central research question: What is the current level of digital transformation in state management of FPFR in Viet Nam, what gaps exist relative to international benchmarks, and what approach is needed to enhance the effectiveness of fire-risk governance? Addressing this question is important both theoretically and practically, contributing to the improvement of the state-management model for FPFR in the new development phase.

2. LITERATURE REVIEW AND INTERNATIONAL FRAMEWORKS

2.1. Digital transformation in state management: from administrative digitization to governance-model reform

In contemporary public-management scholarship, digital transformation is no longer understood merely as the application of ICT or the digitization of administrative procedures; rather, it is viewed as a comprehensive reform of the state governance model. Numerous studies indicate that the

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core of digital transformation lies in changing how the state creates, uses, and shares data for decision-making, public service delivery, and the management of societal risks [9], [10], [16].

From this perspective, digitization is only the initial step, focusing on converting data from physical to digital form; digitalization improves operational efficiency by transforming and optimizing processes; whereas digital transformation implies structural changes in organizational arrangements, decision-making processes, and relationships among actors within the governance system. For state management, digital transformation is closely associated with the formation of data-driven governance, in which data become a strategic resource for management and administration [9], [10].

In this context, state management of FPFR is a distinctive domain where the requirements for accurate, timely information and effective multi-sector coordination are vital. Digital transformation in this domain, therefore, cannot stop at the computerization of procedures; it must be approached as a restructuring of the management model to strengthen capabilities for prevention, response, and recovery in relation to risks of fire, explosion, and emergencies [3], [13].

2.2. Risk governance in fire prevention, firefighting and rescue operations: theoretical foundations and practical imperatives

Risk governance is one of the key theoretical pillars of modern safety management. Under ISO 31000, risk management is defined as a systematic process that includes risk identification, analysis, evaluation, and treatment, embedded across all levels of an organization's decision-making. The essential point of this approach is to shift from passive reaction to proactive risk control grounded in evidence and data [5], [12].

In the field of FPFR, fire-risk governance implies that the state should not focus solely on handling fires and emergencies after they occur; instead, it must proactively identify hazards and risk-increasing factors, and then prioritize resources for prevention and loss reduction. Many countries have made a marked transition from compliance-based management to risk-based governance, where decisions on inspection, supervision, and investment are made based on the risk level of the regulated entities [12], [16].

From a theoretical perspective, fire-risk governance is closely linked to the requirement to use multi-source data, including data on building characteristics, occupancy and use functions, histories of violations, past incidents, environmental conditions, and response capacity. This creates an inherent need for a unified data platform and appropriate analytical tools-core components of digital transformation [6], [12].

2.3. Incident management and command-and-control: international benchmarks and implications for digital transformation

Alongside risk governance, incident management is another major theoretical domain directly relevant to FPFR. International incident-management frameworks-such as the NIMS and the ISO 22320 standard-emphasize the role of standardizing information, command structures, and inter-agency coordination in incident response [3], [4].

A common feature across these frameworks is that they treat information and data as central to command and control. Information on the incident scene, forces, equipment, supporting resources, and secondary hazards needs to be collected, shared, and continuously updated to support incident commanders in making decisions under severe time constraints and in uncertain environments. This indicates that digital transformation in FPFR command and control is not merely about adding technical equipment; it requires building an integrated digital command-and-control system closely coupled with data flows and decision-making processes [3], [13].

In addition, modern incident-management frameworks highlight the importance of post-incident learning, viewing incident data as a valuable resource for organizational improvement and for strengthening future response capability. This component remains relatively new in the practice of FPFR management in Viet Nam, yet it is of considerable importance for digital transformation [3], [14].

2.4. Data governance as the foundation of digital transformation in state management of fire prevention, firefighting and rescue operations

From a theoretical perspective, data governance is widely regarded as the foundation of digital transformation in the public sector. Data governance is not limited to storage technologies; it encompasses rules, standards, roles and responsibilities, and mechanisms that ensure data quality, security, and data sharing [9], [16]. In the field of FPFR, data governance is especially important because data are often fragmented across multiple stages-prevention, inspection, firefighting, rescue operations, investigation, and after-action review.

International studies show that effective safety-management systems are built on standardized, interoperable incident databases that are continuously utilized for risk analysis and policy formulation. Conversely, without data governance, advanced technology applications-such as GIS, simulation, or artificial intelligence (AI)-are unlikely to deliver benefits and may even result in inefficient resource use and wasted investment [6], [7], [15].

For state management of FPFR in Viet Nam, establishing a unified database and a clear data-governance mechanism is a prerequisite for ensuring that digital transformation is substantive and effective, avoiding "symbolic" or superficial digital transformation [9], [11].

2.5. Analytical framework

Based on the theoretical approaches discussed above, this paper develops an analytical framework comprising three main pillars:

- Data governance for FPFR: the extent of data standardization, completeness, interoperability, and the ability to utilize data to support risk management and command and control.
- System and management-process integration: the level of interoperability across the stages of prevention, inspection, firefighting, rescue operations, and post-incident oversight; and the degree of alignment between technology and state-management processes.
- Data-driven, risk-informed decision-making: the extent to which data and analytical tools are used in inspection planning, resource allocation, and command and control.

This analytical framework serves as the theoretical basis for assessing the current status of digital transformation in state management of FPFR in Viet Nam, and it also guides the development of solutions and policy implications in the subsequent sections of the paper [5], [9], [12].

3. RESEARCH METHODOLOGY

3.1. Research approach

This study adopts a qualitative and policy-oriented research approach to examine the role of information technology application and digital transformation of state management of FPFR in Vietnam. The selected approach is appropriate for analyzing governance models, institutional arrangements, and decision-making mechanisms, rather than evaluating the performance of specific technologies or operational tools.

The study conceptualizes digital transformation not as a technical intervention, but as a governance reform process that reshapes how public authorities collect, manage, and utilize data for risk management and emergency response. Accordingly, the research focuses on structural dimensions of digital transformation in FPFR state management, including data governance, system integration, and risk-based decision-making.

3.2. Data sources and collection

The study primarily relies on secondary data, collected from three main categories of sources:

- Academic and theoretical literature, including peer-reviewed journal articles, books, and conference proceedings related to digital transformation, public administration, risk governance, emergency management, and fire safety management. These sources provide the theoretical foundation and inform the analytical framework of the study.
- International standards and governance frameworks, such as ISO 22320 on emergency management and ISO 31000 on risk management, as well as established fire safety and incident management systems from advanced jurisdictions. These documents serve as normative benchmarks for assessing digital transformation in FPFR state management.
- National policy documents and legal instruments in Vietnam, including strategies, programs, and regulations on digital transformation, fire prevention, firefighting, and rescue operations, along with official reports and publicly available materials issued by competent state authorities. These sources enable an in-depth analysis of the Vietnamese institutional and regulatory context.

All collected materials were systematically reviewed, categorized, and synthesized according to the analytical dimensions defined in the research framework.

3.3. Analytical methods

The study employs a combination of qualitative analytical methods to ensure rigor and coherence in the research process:

- Content analysis is used to examine academic literature, standards, and policy documents, with the aim of identifying key concepts, principles, governance models, and emerging trends in digital transformation and fire risk management.
- Comparative analysis is applied to contrast international standards and practices with the current state management of FPFR, thereby highlighting similarities, differences, and critical gaps that require institutional reform.
- Framework-based analysis is conducted using a predefined analytical framework comprising three core pillars: (i) data governance, (ii) system integration, and (iii) risk-based decision-making. This approach enables a structured and consistent assessment of digital transformation across different governance functions.

The triangulation of these methods enhances the analytical depth of the study and reduces the risk of descriptive or anecdotal interpretation.

3.4. Scope and limitations

In terms of scope, the study focuses on state management of FPFR, emphasizing the role of public authorities and institutional mechanisms. It does not examine technical performance of specific digital tools or conduct operational-level evaluations.

Geographically, the analysis is confined to the Vietnamese context, while drawing on international experience for comparative and normative purposes. The study does not employ large-scale quantitative data or empirical surveys; therefore, its findings are primarily analytical and policy-oriented rather than statistically generalizable.

3.5. Research validity and reliability

The validity of the study is ensured through the use of authoritative and credible data sources, including internationally recognized standards, peer-reviewed literature, and official government documents. Analytical consistency is maintained by applying a clearly defined framework across all stages of analysis.

Reliability is further strengthened through cross-referencing multiple sources and adopting a transparent methodological structure, enabling future studies to replicate or extend the analytical approach in other public safety or governance contexts.

4. RESULTS

Based on the analytical framework and qualitative analysis of academic literature, international standards, and national policy documents, this study identifies several key findings regarding digital transformation in state management of FPFR. The results are organized according to the three core dimensions of the research framework: data governance, system integration, and risk-based decision-making.

4.1. Digital transformation in state management of fire prevention, firefighting and rescue operations remains predominantly administrative

The analysis indicates that digital transformation in state management of FPFR is currently dominated by administrative digitization, particularly in fire safety appraisal, acceptance inspection, reporting, and compliance monitoring procedures. This pattern is consistent with early-stage digital government reforms observed in many developing countries, where digital tools are primarily applied to procedural efficiency rather than governance transformation [9], [10], [16].

Although administrative digitization has improved transparency and reduced processing time, digital systems largely replicate existing bureaucratic workflows in electronic form. They are not designed to support analytical functions such as fire risk prioritization, predictive prevention, or strategic resource allocation. As a result, digital transformation has not yet led to substantive changes in how state authorities manage fire risks or design preventive interventions, a limitation also identified in comparative studies on digital public administration [9], [10].

4.2. Fragmented data governance constrains risk-oriented state management

A central finding of this study is that fragmented data governance significantly constrains digital transformation in state management of FPFR. Data on fire-prone facilities, inspection outcomes, violations, incidents, emergency resources, and post-incident reports are collected across multiple systems with limited standardization and interoperability.

The absence of unified identifiers and standardized data structures prevents effective integration of administrative, preventive, and operational datasets. Similar challenges have been highlighted in international fire safety data systems prior to the establishment of standardized frameworks such as NFIRS and NFPA 950 [2], [14]. From a risk management perspective, fragmented data undermine the ability of state authorities to conduct trend analysis, risk profiling, and evidence-based prioritization, which are core principles of modern risk governance [5], [12].

4.3. Weak integration between prevention, inspection, and emergency command systems

The results further demonstrate that digital systems supporting fire prevention, inspection, and emergency command functions are weakly integrated. Information essential for incident response—such as building characteristics, access routes, water supply, and historical inspection data—is not consistently linked across systems.

Consequently, incident commanders often rely on personal experience and fragmented information rather than integrated digital decision-support tools. This finding aligns with international studies emphasizing that effective incident management requires interoperable information systems and standardized command structures [3], [4], [13]. Moreover, post-incident data are typically recorded for administrative purposes but are rarely structured or analyzed to support organizational learning, despite the emphasis placed on post-incident evaluation in international emergency management frameworks [3], [14].

4.4. Risk-based decision-making has not been institutionalized

Although risk management principles are increasingly referenced in policy discourse, the study finds that risk-based decision-making has not yet been institutionalized in state management of FPFR. Inspection planning and preventive activities are still largely conducted according to fixed schedules or categorical classifications, rather than dynamic risk assessments.

Digital transformation initiatives have not been systematically aligned with analytical tools such as spatial risk mapping, historical incident analytics, or scenario-based modeling. This gap mirrors findings in international research on fire risk assessment, which highlights the necessity of integrating data analytics and spatial analysis to support differentiated, risk-prioritized management [6], [12]. Without such integration, the transformative potential of digital technologies remains underutilized.

4.5. Uneven institutional capacity and digital readiness

The analysis also reveals uneven digital capacity across different state management functions in FPFR. While administrative units have benefited from procedural digitization, capacities related to data analytics, integrated command systems, and post-incident evaluation remain limited.

Variations in digital literacy and analytical capability among state management personnel further constrain effective use of digital systems. This imbalance reinforces the tendency to perceive digital transformation as a technical or administrative task rather than as a comprehensive reform of state management practices, a challenge similarly observed in broader public sector digital transformation studies [9], [16].

4.6. Synthesis of results

Overall, the results indicate that digital transformation in state management of FPFR is at an early and uneven stage, characterized by administrative digitization without corresponding transformation in data governance, system integration, or risk-based decision-making. These findings are consistent with international evidence suggesting that without institutional reforms in data governance and risk management, digital transformation initiatives are unlikely to deliver substantive improvements in public safety outcomes [5], [9], [12], [16].

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study examined digital transformation in state management of FPFR through a qualitative, policy-oriented analytical framework. By integrating perspectives from digital government, risk management, and emergency management literature, the study provides a comprehensive assessment of how information technology has been applied within state management structures and where critical limitations remain.

The findings indicate that digital transformation in Vietnam's state management of FPFR is currently characterized by administrative digitization rather than substantive managerial transformation. While information technology has improved procedural efficiency and transparency, it has not yet enabled systematic data integration, institutionalized risk-based decision-making, or enhanced learning across the full lifecycle of fire prevention, emergency response, and post-incident evaluation. These results are consistent with international evidence showing that digital transformation initiatives often underperform when they focus on procedures rather than governance structures and data capabilities [9], [10], [16]. A key conclusion of this study is that the primary constraint on effective digital transformation in state management of FPFR does not lie in technological availability, but in institutional arrangements for data governance, system integration, and risk-oriented management. Fragmented datasets, weak interoperability, and limited analytical capacity continue to prevent state authorities from transitioning from compliance-based supervision to proactive, data-driven fire risk management, as advocated in international risk management and emergency governance frameworks [3], [5], [12].

5.2. Recommendations

Based on the findings and conclusions, this study proposes the following recommendations to strengthen digital transformation in state management of FPFR.

First, digital transformation should be institutionalized as a reform of state management rather than treated as a technical or administrative project. Policy frameworks on digital transformation need to explicitly link technology deployment with reforms in regulatory practices, inspection planning, emergency command, and post-incident evaluation. This approach aligns with international digital government models that emphasize governance capacity over technological sophistication [9], [16].

Second, the establishment of a unified national fire safety data governance framework should be prioritized. This includes developing standardized data models, unique identifiers for regulated entities, and protocols for data sharing across prevention, inspection, emergency response, and investigation functions. International experience from systems such as NFIRS and standards such as NFPA 950 demonstrates that standardized data infrastructure is a prerequisite for risk-based fire safety management [2], [14].

Third, risk-based decision-making should be formally embedded in state management practices of FPFR. Inspection frequency, resource allocation, and preventive interventions should be guided by dynamic risk assessments supported by data analytics, spatial analysis, and historical incident data. This recommendation reflects core principles of modern risk management frameworks and fire risk assessment research [5], [6], [12].

Fourth, integrated digital command and information systems should be developed to support emergency response and post-incident learning. Digital platforms that connect administrative records, spatial data, emergency resources, and real-time incident information can significantly enhance command effectiveness and coordination. Equally important is the systematic analysis of post-incident data to support organizational learning, as emphasized in international incident management standards [3], [4], [13].

Finally, capacity-building and institutional learning should be strengthened to support sustainable digital transformation. Training programs for personnel involved in state management of FPFR should extend beyond technical system use to include data literacy, analytical thinking, and risk-based management skills. Without such capacity development, digital systems are likely to remain underutilized, reinforcing the perception of digital transformation as a procedural exercise rather than a governance reform [9], [16].

5.3. Concluding Remarks

In conclusion, digital transformation offers significant potential to enhance state management of FPFR, but only if it is pursued as an integrated reform encompassing data governance, system interoperability, and risk-based decision-making. By addressing institutional constraints and aligning digital initiatives with internationally recognized management principles, state authorities can move toward a more proactive, evidence-based approach to fire risk prevention and emergency management. The insights generated by this study may also inform digital transformation efforts in other public safety sectors facing similar governance challenges.

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