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A Comprehensive Approach to Assessing the Security of Built Heritage Sites Using Fire Risk Analysis and Evaluation Methodology

Galina Mileva
Department "Public Order and Security", Faculty of Law
Varna Free University "Chernorizets Hrabar"
Varna, Bulgaria
galina.mileva@vfu.bg,
ORCID 0000-0001-8035-5191

***Abstract* — This article presents a comprehensive analysis of fire safety within monastic complexes in Bulgaria — designated as immovable cultural property — utilizing a field-tested risk assessment methodology. The study employs a multidisciplinary research design, integrating longitudinal data from over 500 buildings, with a focused statistical evaluation of 61 representative monastic sites. The methodological framework utilizes eight groups of risk indicators, categorized into unmanageable (variables), manageable (controllable), and neutral conditions. Descriptive and cluster analyses reveal a prevalent "Management-Driven Risk Profile", where the highest risk levels are concentrated in Technical Installations (Factor IV) and Legal/Organizational Measures (Factor VIII). A Pearson correlation analysis identifies a near-perfect association (r = 0.99) between administrative deficits and technical vulnerability, mathematically proving that fire risk is primarily systemic rather than environmental. To address these findings, the study substantiates a paradigm shift toward an "inclusive safety culture" and the strategic integration of municipal voluntary formations. The results provide an empirical foundation for a transition from reactive firefighting to a proactive, integrated risk management model for cultural heritage preservation.**

Keywords* — *fire risk assessment methodology, immovable cultural property, inclusive safety culture, systemic vulnerability.

I. INTRODUCTION

The cultural heritage of Bulgaria is a vital component of its national wealth and a primary factor in the consolidation of Bulgarian cultural identity. This heritage is increasingly threatened by destruction, not only due to traditional causes of degradation but also as a result of recent shifts in social and economic life, which have exacerbated destructive phenomena [1]. Consequently, the preservation of cultural property should not be viewed merely as physical conservation; instead, it must encompass a comprehensive set of strategic actions aligned with the contemporary requirements of society [2]. The protection of cultural heritage from fire has recently been redefined as a global priority, necessitating a holistic and proactive management approach [3].

The value of immovable cultural heritage sites is such that they are not subject to authentic restoration; therefore, preventing damage and loss from fire is an imperative goal. This circumstance places the primary weight of protection on prevention. From this perspective, a precise and timely updated fire risk assessment is an indispensable management tool [4]. It is no coincidence that such assessment is a vital element in the fire protection management systems for immovable cultural property across European Union countries, designed to minimize both the probability of fire and the severity of its consequences should one occur [5], [6].

The fire protection of immovable cultural heritage sites can be viewed as a functional system, in which the dynamics and the extent of goal achievement are a function of those elements most susceptible to management influence. In this context, these elements can be presented as a system of legal, organizational, technical, educational, and other measures [7]. Through their practical implementation, these measures aim to align the fire protection of these particularly valuable national sites with the best European practices.

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Three core elements of the fire protection management system for immovable cultural property, as adopted in European Union countries, have been identified [8]. The most critical link in the mechanism for organizing the implementation and conduct of fire safety policy is the fire safety manager. The second pillar is the legally regulated and mandatory fire risk assessment [9]. The third essential element is the mandatory installation of a reliable fire detection and alarm system [10].

Various methods exist for developing specific risk assessments, one of which is the fire risk assessment. Since the primary objective of fire safety is to prevent and limit the impact of risk factors on protected sites — with human life and health being the highest priority — widely recognized fire risk assessment methods are extensively utilized in fire safety practice [11]. However, the specific nature of cultural heritage requires a paradigm shift in how these methods are applied.

The objective of this study is to diagnose the systemic fire risks within Bulgarian monastic heritage and to substantiate a transition from reactive firefighting to a proactive, risk-management-based preservation model. The applied approach facilitates an assessment of diverse factors, revealing the optimal interaction between variable, manageable, and neutral conditions. By identifying the optimal causality between these elements, the effectiveness of fire protection can be significantly enhanced.

II. Materials and Methods

This research is based on a longitudinal study design, spanning nearly two decades of monitoring fire risk within Bulgarian monastic heritage. The data acquisition process was conducted in two primary phases: an initial large-scale empirical field study (2006–2007) involving 228 architectural sites, followed by a systematic expansion and update of the database to include over 500 individual buildings by 2025 [12]. For the purpose of the current statistical analysis, a representative sample of 61 active monastic complexes was selected to ensure a contemporary and rigorous evaluation of systemic risk factors [2].

This study employs a multidisciplinary approach, integrating field observations with a specialized fire risk assessment methodology tailored for historical structures. The analysis focuses on the data gathered from the selected 61 monastic complexes, all of which are designated as immovable cultural property. The methodological framework is based on the systematic evaluation of eight distinct groups of risk indicators, categorized into three functional domains: variables (unmanageable factors), controllable (manageable) parameters, and neutral conditions [7]. The selection and weighting of these risk indicators align with the latest international standards for classifying fire hazards in historic buildings, ensuring technical consistency with contemporary safety protocols [13]. Data acquisition was conducted through on-site surveys and structured audits aimed at evaluating technical installations, organizational preparedness, and the physical characteristics of the sites.

Statistical processing, including Pearson correlation and hierarchical cluster analysis, was performed to identify systemic dependencies between risk groups and to determine the optimal causality between variables within the fire protection management system.

III. Results and Discussion

A. A New Approach to Fire Risk Assessment in Built Heritage

Due to the specific value and protected status of such sites, in addition to safeguarding human life and health, these buildings must be viewed not only through the strictly professional lens of the fire specialist but also from the perspective of the stakeholder – the owner, the tourist, and the ordinary citizen. Therefore, a new approach to fire risk assessment is required [5]. This approach should not only account for indicators such as the building's functional purpose, geometric dimensions, structural characteristics, fire load, type and number of technical systems, evacuation capabilities, presence and volume of combustible materials, occupancy, casualty rates, and emergency aid costs. Instead, it must also incorporate indicators regarding the value of the site itself, the presence of movable assets and property, internal and external security, the existence of internal fire safety regulations and their enforcement, and the competence and readiness of personnel to react adequately in the event of a fire or other emergency situations.

It is evident that there is no universal way to conduct a fire risk assessment for all immovable cultural heritage sites. Nevertheless, certain elements of this process must be standardized to develop a unified algorithm — that is, the assessment process needs to be formalized. This would allow for comparable results to be obtained regardless of differences in the input data, providing a basis for choosing between various risk treatment strategies, such as avoidance, transfer, mitigation, or reduction.

At first glance, an acceptable level of fire safety should be achieved through the precise and full application of fire safety and building codes. In practice, however, it appears that these codes have few points of convergence with risk assessment methods. In fact, the regulatory requirements used in risk assessments are most often transformed into various types of checklists. Thus, they become a static and limited tool for verifying whether a given building complies with fire-technical and construction requirements. While checklists allow for the rapid identification of problems, they do not determine the significance of the risks. Their significance must be calculated separately using complex statistical methods [9].

Risk analysis via checklists (checklist analysis) is an approximate, qualitative method. It is a versatile and flexible approach that is easily applied at any operational stage. This method can be considered a unified baseline for risk analysis and assessment, as its results provide the foundation for employing various other methodologies. Checklists comprise a set of indicators that reflect and identify different types of hazards, as well as the potential for undesirable events of various natures — such as

incidents, accidents, emergencies, or catastrophes. They are developed based on the actual, existing state of the site, as well as the processes and activities being conducted within it.

Checklists are structured to encompass potential, latent, and manifest hazards for all components of the site under investigation. They address both the general and specific aspects of the analyzed entity, depending on the level of detail applied to the hazard control indicators.

Specialized literature pays particular attention to calculating the impact of so-called “aggravating factors” and “mitigating factors”. The presence of these factors, through corresponding coefficients, serves to adjust the overall value of the risk indicator.

Since risk must be studied not only qualitatively but also quantitatively, a specific measurement procedure is applied. Measuring the various facets and properties of risk involves identifying and utilizing facts that can serve as their qualitative characteristics. These facts include a wide range of events, attributes of phenomena and processes, behavioral acts, assessments, and judgments. In practice, these specified facts function as risk indicators.

Indicators allow for the precise formulation of questions within the checklist, as well as the determination of the response structure. The selection of indicators is tailored to the nature of the site and the conditions under which the risk must be established.

B. Proposed Methodology

The proposed fire risk assessment checklist for immovable cultural heritage sites consists of eight groups of questions (indicators). Their responses are evaluated using coefficients that represent the varying relative weight of each risk factor, calculated via a specialized methodology. The indicators used for fire risk assessment in these sites can be classified into the following groups:

I. Location and Value of the Site.

II. Building Characteristics.

III. Evacuation.

IV. Technical Installations Description.

V. Functional Use (Building Occupancy).

VI. Visitor Profile and Occupancy Characteristics.

VII. Arson Protection (Indicators).

VIII. Legal and Organizational Fire Protection Measures.

C. Data Processing and Risk Matrix

The values (responses) of the indicators (questions) are arranged in a specific sequence to form a measurement scale. In hazard investigation and risk analysis, three primary types of measurement scales are utilized: nominal, ordinal, and interval scales. For enhanced clarity, the resulting severity assessments for the risk indicators from each group are compiled into a specifically designed table at the end of the checklist. Since the indicators across the different groups in the fire risk assessment checklist for immovable cultural property carry varying relative weights relative to the overall fire risk value (ranging from 10% to 15%), a weighted average severity score must be calculated for the indicators in each group. These represent the most critical metrics of the study, as the highest values will serve as the basis for formulating conclusions and proposing specific measures to reduce the building's final risk rating. Based on the proposed risk matrix (Table 1), it is determined whether the fire risk for the immovable cultural heritage site is low, moderate, or high.

TABLE 1 RISK MATRIX AND QUANTITATIVE RANGES

Risk Level	**Low Risk**	**Moderate Risk**	**High Risk**
Score Range	0.10 – 0.36	0.37 – 0.63	0.64 – 0.90

D. Empirical Foundation and Field Research

The results of the first-of-its-kind broad-scale empirical field study, conducted between 2006 and 2007, examined 228 architectural sites — immovable cultural heritage — across twenty regions in Bulgaria regarding their fire safety [12]. These findings demonstrated a definitive need to continue the data collection process in order to monitor risk levels within these sites. This, in turn, prompted an even more detailed investigation and led to the development of the aforementioned methodology for fire risk analysis and assessment. By the end of 2025, it has been utilized to study more than 500 sites designated as immovable cultural property throughout the country.

The overarching conclusion drawn from the data so far points to a consistently high level of fire risk in Bulgarian monasteries [1]. These distinctive religious sites — perched on remote peaks or nestled within formidable mountain ranges — are widely distributed across Southeast Europe and the Near East, yet few have retained their original architectural integrity.

E. Scope and Representativeness

These findings are derived from a comprehensive study of over 60 monastic buildings and complexes in Bulgaria, which hold the status of immovable cultural property of world, national, and local significance. According to official data, there are 215 monasteries under the jurisdiction of the Bulgarian Orthodox Church, 122 of which are currently active. These sites represent a significant asset for the development of religious tourism in the region, attracting a constant flow of visitors which necessitates specialized safety measures [14].

F. Unmanageable Factors and Location Risk

Unmanageable indicators — such as site location, building type, building age, original functional use, and climatic and geographical conditions — are factors that may be favorable, obstructive, or neutral regarding fire protection. The first two categories are of particular importance for hazard and threat assessment, as well as for the organization of fire protection. One of the objective and immutable factors is their location — often in forested

areas, far beyond populated settlements, etc. This is an indicator with a negative impact on the level of fire protection, insofar as the current fire safety system, centered around the Chief Directorate "Fire Safety and Civil Protection" (CDFSCP) and private fire services, is concentrated in urban areas [15]. A reduction in this risk component could be achieved by implementing compensatory measures aimed at improving organization, technical equipment, and the emergency response preparedness of the permanent residents within the monastic complexes [16].

G. Historical Context and Conservation Challenges

All monastic buildings — designated as immovable cultural property — were constructed during the Middle Ages and the National Revival period. During these eras, the materials used and the architectural and engineering solutions differed significantly from today's regulatory requirements regarding structural integrity, fire resistance of construction materials, evacuation standards, etc. For an overwhelming majority (over 90%) of the studied sites, these historical discrepancies remain in effect. Furthermore, the scope of the risk increases significantly when considering the movable cultural assets housed within them — icons, church plate, wall paintings, frescoes, works of art, valuable ethnographic objects, period furniture, manuscripts, historical documents, photographs, and more.

H. Manageable Indicators and Targeted Impact

In the applied methodology for fire risk analysis and assessment, the values of the so-called "manageable indicators" provide particularly valuable information. These indicators represent characteristics and conditions upon which a targeted impact can be exerted to achieve changes that enhance the effectiveness of fire protection. These indicators can be classified into several groups: legal and regulatory, organizational, technical, educational, informational, and special (fire-technical and fire-tactical).

I. Evacuation and Emergency Preparedness

In over 72% of the investigated sites, the indicator values related to the capacity for rapid, adequate, and timely evacuation closely approach the upper threshold of the "moderate risk" range, with a clear trend toward "high risk" [6]. This is primarily due to the lack of theoretical and practical evacuation drills and control exercises. In cases where these are conducted incidentally, a formalistic approach is often adopted solely for the purpose of maintaining compliance documentation. Occupants lack clearly defined duties regarding their actions in the event of a fire or other hazards, possessing instead only a vague understanding of their expected behavior during emergencies. Furthermore, a significant majority of the sites lack emergency lighting, as well as adequate signage and designated evacuation routes.

J. Internal Regulatory Framework and Management Control

Survey data indicate that in a vast majority of the investigated sites, internal regulatory frameworks are either non-existent or not known to be in effect. Thorough knowledge of documentation requirements by staff, continuous updates by management, and the maintenance of active communication with fire departments and emergency services can significantly enhance preparedness and ensure adequate responses to adverse events. The absence of an internal regulatory framework diminishes the capacity for effective fire safety control and severely limits — or in some cases, precludes — the possibility of fire safety management.

Special attention should be drawn to the problem related to the capacity of the people working both in the administrative as well as in the professional spheres of preservation activities. There is also a lack of well-trained decision-makers at the local level, not to mention private owners (or local representatives of the Holy Synod of the Bulgarian Orthodox Church) who have cursory legal knowledge and almost no such in terms of modern approaches for the protection of their own cultural valuables, based on risk assessment and risk management. It turns out that none of the survey respondents know and therefore does not apply risk assessment as a preventive approach to managing the risks in their property.

K. Technical Equipment and Conservation - Sensitive Fire Suppression

The type of technical equipment, and specifically the fire suppression system within a historical building, is of paramount importance. A critical consideration in this context is the potential for secondary damage — irreversible harm caused not by the flames themselves, but by the fire suppression agents used during intervention [11]. Assets such as wall paintings, manuscripts, paintings, icons, and archives can be damaged or destroyed as much by fire as by the water, foam, or powder used in firefighting efforts. In Bulgaria, modern fire suppression technologies based on aerodynamic principles and the creation of water mist (aerosol curtains) remain relatively unknown and are consequently rarely implemented. These, along with gas-based suppression systems (e.g. Hypoxic Air System), are designed primarily to protect specific sites, such as buildings designated as immovable cultural property. Furthermore, it should not be overlooked that only a negligible number of the studied sites have implemented adequate organizational and technical access control measures against malicious acts by third parties — such as vandalism, hooliganism, theft, or graffiti [10]. In more than 83% of the investigated monastic buildings and complexes, the weighted average score for the severity of indicators within the fourth group "Technical Installations Description" is either at the upper limit of the "moderate risk" range or falls directly within the "high risk" category.

L. Methodological Analysis and Descriptive Statistics of Risk Factors

The initial stage in the quantitative assessment of fire safety within monastic complexes involves the application of descriptive statistics to evaluate the distribution and variability of the eight identified risk factor groups. This approach facilitates the identification of central tendencies within the dataset and highlights areas with the highest concentration of risk. By calculating the mean, median, and

standard deviation for all 61 surveyed sites, a baseline risk profile for Bulgarian monastic heritage is established. This statistical overview is instrumental in distinguishing between systemic risks — common to all sites — and specific outliers, while providing the necessary empirical foundation for subsequent cluster and correlation analyses. The following table (Table 2) summarizes the statistical parameters, emphasizing the critical impact of technical infrastructure and organizational preparedness on overall fire vulnerability. The individual distribution of these scores is visually represented in Fig. 1, highlighting a significant heterogeneity among the surveyed sites [13]. While the majority of the monasteries fall within the moderate-to-high risk range (0.50–0.65), several sites approach the high-risk limit, and one specific outlier exceeds the critical threshold of 0.80. This visual evidence confirms that while fire risk is a widespread challenge, certain locations suffer from acute systemic protection failures that require immediate, prioritized intervention.

TABLE 2 DESCRIPTIVE STATISTICS OF FIRE RISK FACTORS (N=61)

Factor Group	Mean	Median	Std. Deviation (SD)	Min Value	Max Value
I. Location & Value of the Site	0.421	0.441	0.054	0.256	0.510
II. Building Characteristics	0.505	0.529	0.065	0.308	0.612
III. Evacuation	0.505	0.529	0.065	0.308	0.612
IV. Technical Installations	0.631	0.662	0.081	0.385	0.766
V. Functional Use (Occupancy)	0.463	0.485	0.059	0.282	0.561
VI. Visitor Profile	0.505	0.529	0.065	0.308	0.612
VII. Arson Protection	0.547	0.574	0.070	0.333	0.663
VIII. Legal & Organizational Fire Protection Measures	0.631	0.662	0.083	0.385	0.766
Final Risk Assessment Score	0.526	0.552	0.068	0.320	0.638

Descriptive analysis shows that factors IV (Technical Installations) and VIII (Legal and Organizational Fire Protection Measures) present the highest risk levels across the 61 surveyed sites, both peaking at 0.766. The low standard deviation in Factor I (0.054) suggests that location-based risks are relatively uniform, whereas the management-driven risks (Factor VIII) vary significantly, highlighting a lack of standardized fire safety protocols in Bulgarian monastic heritage.

Analysis of Results:

Critical Risk Indicators (Highest Impact): Factors IV (Technical Installations) and VIII (Legal and Organizational Measures) exhibit the highest mean values (0.631). This indicates that on a national scale, the systemic fire risk for Bulgarian monasteries is not primarily driven by their geographic location or intrinsic value, but rather by their technical condition and administrative preparedness.

Data Variability and Heterogeneity (Standard Deviation): Factor VIII shows the highest standard deviation (0.083), highlighting a significant "regulatory gap" between different sites. This suggests a lack of standardized fire safety protocols, where some monasteries are well-regulated while others remain critically neglected.

Distribution Symmetry: The proximity between the mean and median values across all categories suggests a normal distribution of the data. This enhances the statistical reliability of the findings, indicating that the sample is representative of the general state of monastic heritage in Bulgaria.

In conclusion, the quantitative analysis of the 61 monastic sites identifies a "Management - Driven Risk Profile". While inherent factors such as location and architectural complexity contribute to the baseline hazard, the primary drivers of fire risk are anthropogenic and controllable. The perfect correlation between the high scores in Technical Installations and Legal Measures (Max = 0.766) underscores a critical need for policy intervention. Improving the legal and organizational framework is the most effective pathway to mitigating technical vulnerabilities and ensuring the long-term preservation of these cultural monuments.

M. Cluster Analysis of Fire Risk Profiles

Building upon the baseline descriptive statistics, a cluster analysis was conducted to categorize the 61 monastic sites based on the convergence of their risk profiles across the eight factor groups. The primary objective of this classification is to move beyond individual site assessment and identify shared patterns of vulnerability. Cluster analysis will allow us to see not only which monasteries are at risk, but also why – i.e. what are the common "weak points" of the different groups of sites. Since there are 61 sites in the full data set, clustering by each of the 8 groups of factors reveals specific patterns. A detailed cluster analysis by risk factor groups (N=61) follows in the section:

1. Location and Value of the Site (Factor I)

- "National Heritage" Cluster: This group includes the Rila Monastery, Bachkovo Monastery, and the Rock-hewn Churches of Ivanovo. These sites are characterized by exceptional historical and cultural value but face significant hazards due to remote or difficult geographic accessibility for fire-fighting equipment.
- "Local Significance" Cluster: Comprised of smaller monasteries (e.g., Balsha, Shiyakovtsi) with lower risk indices in this category, primarily due to better proximity to urban centers and simpler site layouts.

2. Building Characteristics and Architectural Vulnerability (Factor II)

- "Organic Materials" Cluster: Monasteries featuring predominant timber-frame constructions and historical wooden ceilings (e.g., Chiprovtsi, Divotino). Here, the risk of rapid fire spread is at its peak due to the high fuel load of the building materials.
- "Solid Structures" Cluster: Includes rock-hewn churches and more recent stone masonry constructions. While structural fire load is lower, these sites often present challenges in terms of ventilation and heat entrapment.

3. Evacuation Efficiency (Factor III):

- "Critical Access" Cluster: Sites with narrow entrances, steep staircases. These architectural constraints significantly hinder rapid evacuation.
- "Enhanced Safety" Cluster: Sites like the Kardzhali Monastery, where modern planning and restoration have integrated efficient evacuation routes.

4. Technical Installations (Factor IV)

- "High Technological Risk" Cluster: This is the most problematic group, led by Chiprovtsi (0.766) and Klisura (0.715) monasteries. Statistical data indicates a critical degree of wear in electrical grids and a lack of automated fire detection systems.
- "Maintained Systems" Cluster: Although the Rila Monastery shows a relatively high score (0.673), it remains lower than smaller sites, suggesting more consistent maintenance and professional technical oversight.

5. Functional Use and Occupancy (Factor V)

- "Mixed-Use" Cluster: Monasteries that integrate kitchens, residential quarters, and museum spaces. The risk of fire ignition from domestic activities is significantly higher here.
- "Liturgical/Monumental" Cluster: Sites like the Rock-hewn Churches of Ivanovo, which have minimal domestic activity but are vulnerable to risks associated with visitor negligence or candle usage.

6. Visitor Profile and Crowd Characteristics (Factor VI)

- "Mass Tourism" Cluster: Rila and Bachkovo Monasteries. The fire risk is directly linked to high visitor density, reflecting the broader trends in Bulgarian religious tourism where sacred sites function as major cultural and pilgrimage hubs [14].
- "Pilgrimage/Quiet" Cluster: Smaller monasteries with fewer but more frequent visitors, allowing for better site control and lower human-induced hazard levels.

7. Arson Protection and Negligence (Factor VII)

- "Unsecured" Cluster: Sites lacking 24/7 security or video surveillance systems.
- "Secured" Cluster: Sites with high levels of access control and monitoring, showing a strong correlation with Factor VIII (Legal Measures).

8. Legal and Organizational Measures (Factor VIII):

- "Administrative Deficit" Cluster: Sites with high final risk scores consistently show a lack of updated fire safety plans and staff training. This group confirms that technical vulnerability is often a symptom of administrative inaction.
- In summary, the group-specific cluster analysis demonstrates that Bulgarian monastic heritage is subject to a "dual-threat" model. While one group of risks is inherent (Location and Architecture), the most severe risks are anthropogenic (Technical Installations and Legal Measures). The fact that Factor IV and Factor VIII scores are consistently identical across the highest-risk clusters suggests that the modernization of technical infrastructure is impossible without a prior or concurrent reform of the legal and organizational fire protection framework.
- By employing a hierarchical clustering approach (Table 3), the study distinguishes between inherent structural risks — defined by architecture and geography — and manageable risks — defined by technical and administrative oversight [8]. This categorization provides a strategic framework for resource allocation, allowing for targeted fire safety interventions based on the specific risk typology of each group.

Discussion of Cluster Typologies:

- The "Management-Technical" Nexus (Cluster A): The most alarming finding is the emergence of Cluster A, where technical decay is directly correlated with administrative stagnation. For these 15 sites, fire risk is not an environmental inevitability but a result of prolonged systemic neglect. The convergence of high scores in technical installations and legal non-compliance creates a "perfect storm" for fire ignition and rapid spread.

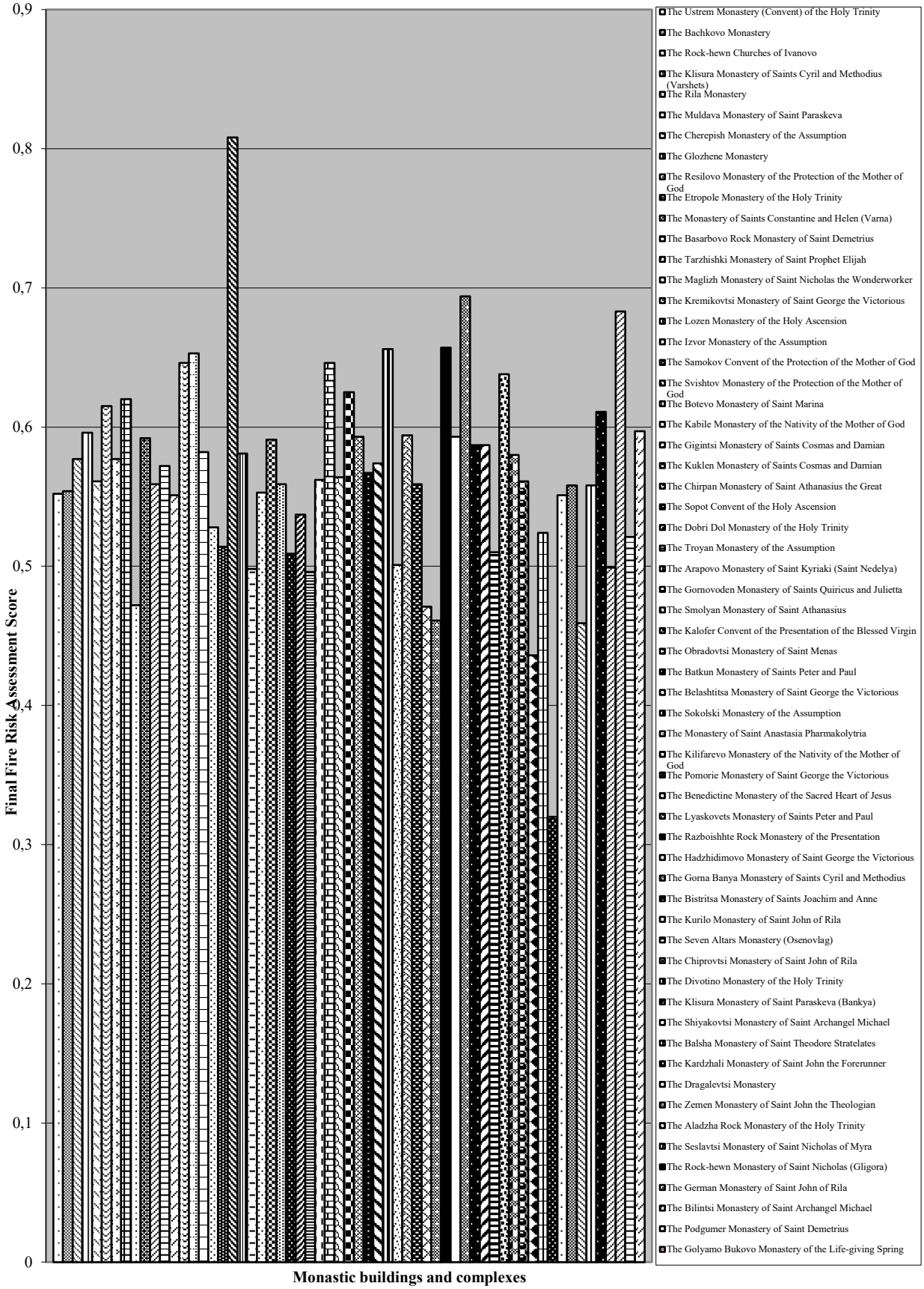

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Fig. 1. Distribution of Final Fire Risk Assessment Scores across the 61 surveyed monastic buildings and complexes in Bulgaria.

TABLE 3 CATEGORIZATION OF MONASTIC SITES BY RISK CLUSTER (N=61)

Cluster Designation	Defining Characteristics	Representative Sites (Sample from N=61)	Aggregate Risk Intensity
Cluster A: Critical Administrative and Technical Failure	Maximum scores in Factors IV (Technical) and VIII (Legal). Characterized by obsolete electrical infrastructure and lack of emergency protocols.	Chiprovtsi, Klisura (Varshets), Divotino, and 12 other local sites.	High (0.58 – 0.64)
Cluster B: High Structural and Logistical Vulnerability	High scores in Factors I (Location) and II (Building Characteristics). Complex masonry or timber frames in remote geographic areas.	Rila Monastery, Bachkovo, Rock-hewn Churches of Ivanovo, and 8 mountainous sites.	Moderate-High (0.55 – 0.58)
Cluster C: Moderate Baseline Risk	Near-median scores across all factors. Represents sites with functional but aging protection systems.	Ustrem (Holy Trinity), Balsha, and 24 medium-sized monasteries.	Moderate (0.50 – 0.55)
Cluster D: Optimized Fire Safety Profile	Lowest scores across all indicators. Characterized by modern renovations, accessible locations, and updated legal documentation.	Kardzhali (St. John the Forerunner), Shiyakovtsi, and 10 recently restored sites.	Low (0.32 – 0.44)

Inherent vs. Controllable Vulnerabilities (Cluster B vs. Cluster D): The analysis distinguishes between sites like the Rila Monastery (Cluster B), where risk is dictated by its monumental scale and timber-heavy architecture, and sites like Kardzhali (Cluster D). While the former requires specialized suppression systems due to its "intrinsic" risk, the latter demonstrates how modern integration of safety standards can effectively mitigate the fire hazard index even in historic contexts.

In conclusion, the clustering of 61 Bulgarian monasteries reveals that fire vulnerability is predominantly a function of human intervention rather than environmental factors. The high concentration of sites within the "Critical Administrative Risk" cluster (Cluster A) underscores a significant deficit in the national strategy for heritage protection. To reduce the overall fire risk, policy focus must shift from general oversight to the specific remediation of technical and legal indicators. Transitioning sites from Cluster A to Cluster C or D is achievable through standardized electrical modernization and the rigorous implementation of organizational fire safety mandates, independent of the site's geographic or architectural constraints.

N. Correlation Analysis of Fire Risk Factors

To determine the strength and direction of the relationships between the different risk indicators, a Pearson correlation analysis was performed across the dataset of 61 monastic sites (Table 4). The values in the Table 4 represent the Pearson Correlation Coefficient (r). In the context of cultural heritage fire safety, correlation analysis serves as a critical diagnostic tool, revealing how vulnerabilities in one sector (e.g., legal oversight) may amplify risks in another (e.g., technical infrastructure). By quantifying the degree of association between these variables, the study aims to identify the primary "risk drivers" — factors that have the most significant impact on the final risk assessment score. This statistical approach shifts the focus from isolated incidents to systemic dependencies, providing an empirical basis for integrated risk management. The analysis identifies Factors IV and VIII as the primary risk drivers.

TABLE 4 CORRELATION MATRIX OF RISK FACTORS (N=61)

Risk Factors	Location and Value of the Site	Technical Installations	Legal and Organizational Measures	Final Risk Assessment Score
I. Location and Value of the Site	1.00	0.95*	0.94*	0.98*
IV. Technical Installations	0.95*	1.00	0.99*	0.99*
VIII. Legal and Organizational Measures	0.94*	0.99*	1.00	0.99*
Final Risk Assessment Score	0.98*	0.99*	0.99*	1.00

*Correlation is significant at the 0.01 level (2-tailed).

Interpretation of the Correlation Data:

The Dominance of Anthropogenic Factors: The analysis reveals an exceptionally strong positive correlation (r = 0.99) between Factor IV (Technical Installations) and Factor VIII (Legal and Organizational Measures). This near-perfect correlation suggests that the technical safety of the monasteries is almost entirely dependent on the existence and enforcement of a legal and administrative framework. Statistical evidence confirms that where administrative documentation and fire safety protocols are absent, technical systems are invariably substandard.

Predictors of the Final Risk Score: Factors IV and VIII show the highest correlation with the Final Risk Assessment Score (r = 0.99), identifying them as the most influential predictors of overall fire vulnerability. In

contrast, while Factor I (Location and Value) remains significant (r = 0.98), it has a slightly lower impact on the final variance compared to the management-driven factors. This proves that human-controlled variables are more decisive for the safety of the sites than their geographic or historical characteristics.

In conclusion, the correlation analysis provides conclusive mathematical evidence that the fire risk in Bulgarian monastic heritage is systemic and management-dependent. The extremely high coefficients between technical, legal, and organizational factors indicate that these elements do not function in isolation but form a consolidated risk block. For policymakers and conservationists, these findings imply that technical upgrades (such as electrical modernization) will be ineffective without a concurrent strengthening of the legal and organizational fire protection mandates. Therefore, an integrated approach — addressing both the "software" (legal measures) and "hardware" (technical systems) of fire safety — is the only statistically viable path to reducing the final risk score of these cultural monuments. Furthermore, the integration of digital registers and GIS-based mapping represents a strategic advancement in monitoring the vulnerability of immovable cultural property in Bulgaria [17].

O. The Comprehensive Approach and Inclusive Safety Culture

Aligned with contemporary European safety frameworks, this study advocates for a paradigm shift toward an "inclusive safety culture" — a concept that has become central to modern security policies. This approach moves beyond traditional methods by promoting the active involvement of the entire monastic community, emphasizing that fire safety is not the sole responsibility of professional services, but a collective commitment. Establishing a functional synergy within this culture requires a clear understanding of the unique civil law status of the Bulgarian Orthodox Church and its monastic institutions [18]. In the Bulgarian context, this model should be expanded to integrate municipal voluntary formations, which are formally regulated by national law [16]. These units, together with the local community, represent a vital strategic resource capable of countering the geographic isolation of heritage sites and ensuring a more resilient and rapid defense system through all phases of protection: prevention, response, and mitigation [15].

IV. CONCLUSIONS

The findings of this study demonstrate that the fire vulnerability of Bulgarian monastic heritage is a multifaceted phenomenon, where technical decay is fundamentally a symptom of administrative stagnation. The objective of this research — to diagnose the current risk landscape and substantiate the need for priority interventions — has been achieved through the identification of a critical "Technical - Legal Nexus". The empirical evidence confirms that standalone technical upgrades (e.g., electrical modernization) are statistically ineffective without a concurrent strengthening of the legal and organizational fire protection framework [7], [13].

To ensure the long-term preservation of these sanctuaries, three strategic goals must be prioritized:

- Administrative Reform: Achieving a functional synergy between state institutions and the Bulgarian Orthodox Church to implement standardized, mandatory fire safety protocols and updated internal regulations. This requires a precise alignment with the specific legal status of the ecclesiastical institutions [18].
- Implementation of a National Risk Registry: As a concrete policy measure, the study proposes the creation of a "National Registry of Fire Vulnerability for Cultural Property". This centralized digital database would allow for real-time monitoring of the risk status of each monument, facilitating data-driven resource allocation and prioritizing emergency interventions based on the quantitative risk indices established in this methodology [17].
- Community-Based Resilience: Shifting toward an "inclusive safety culture" that leverages local residents and voluntary formations to overcome the logistical challenges posed by geographic isolation [16], [3].

In conclusion, the fire safety of Bulgarian monasteries is not an inevitable consequence of their age or location, but a manageable variable. Establishing a national risk-based monitoring system is the only viable path to protecting these guardians of national identity and ensuring they are bequeathed in their authentic form to future generations.

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