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EFFECTIVENESS OF FIRE SAFETY IMPLEMENTATION IN HERITAGE BUILDINGS

Nurin Ezzati Mohd Fadzil¹, Mohd Azian Zaidi^{1*}

¹Department of Built Environment Studies and Technology, College of Built Environment, Universiti Teknologi MARA, Perak Branch, 32610, Seri Iskandar, Perak, Malaysia

2021459944@student.uitm.edu.my, *mohda763@uitm.edu.my

ABSTRACT

This study investigates the implementation of fire safety in heritage buildings. It describes the contributory factors to the lack of fire safety implementation in historic buildings. A quantitative method has been selected to aid in identifying the factors, namely by obtaining responses to a survey questionnaire. In the literature review phase, seven factors were identified as initial contributors to the lack of fire safety implementation in heritage buildings. These factors were the low level of fire safety management systems, methods used to improve fire safety in historic buildings, fire safety systems, cost, fire safety awareness, facilities manager factors, and fire safety implementation. Eight variables were identified and tested using a survey questionnaire. These variables were maintenance of the fire protection system, cost-effective consumption, installation of fire-fighting system type, standard of management, housekeeping and maintenance, fire risk, method to improve fire safety, understanding about fire safety, and knowledge about fire hazards in historic buildings. The results of the analysis found that one factor recorded a mean value below 3.50, indicating that the factor is not statistically significant, thus only seven factors were identified as crucial for improving the implementation of fire safety in historic buildings when the mean value was greater than 3.50.

Keywords: *fire safety implementation, heritage building, regulation, effectiveness of fire safety, fire safety framework*

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INTRODUCTION

Researchers came up with the concept of a fire triangle to gain greater knowledge of the causes that contribute to flames, as well as the measures by which they can be prevented or extinguished (OSHA, 2008). Since a majority of fires are caused by reckless or dangerous behaviour, arson, equipment failure or acts of nature, fire prevention has been one of the most important operations carried out by fire departments for more than 85 years. In order to reduce the likelihood of a fire occurring, it is necessary to create and enforce fire codes, as well as provide public fire safety education programmes, carry out property inspections, and conduct investigations into the causes of fires (Della-Giustina, 2014). The evidence obtained from the investigations into these terrible events demonstrates that the misuse of buildings, poor maintenance, and faulty fire protection design were the primary causes of the hazard in many of these fires (Ming Lo, 1999). The threat posed by fires in buildings has been met with a variety of responses from society, including the establishment of fire departments, the provision of insurance, the establishment of building regulations, the dissemination of information regarding the dangers posed by fires, the implementation of controls regarding the use of materials and products in buildings, and the construction of buildings that are resistant to the effects of fires (Zamrodah, 2016).

LITERATURE REVIEW

Background

The process of implementing fire safety in the built environment has typically been one that is required to adhere to a great deal of regulation. Protecting people from the dangers of fire is one of the main aims of the mission. The laws of physics are rarely invoked, and instead, their implementation is generally associated with code compliance. Although fire safety is directly related to the laws of physics and the management of human behaviour in a high-risk situation, these laws of physics are rarely invoked. When it comes to historical buildings, the structure itself has a contextual significance that, in most cases, is not taken into consideration by building rules. There are components of the building that cannot be altered in any way without causing the overall value of the structure to suffer. In addition, the structure may hold essentially valuable objects, regardless of whether such objects are physically integrated into the fabric of the building. It is possible that the usage of several of these objects, as well as the objects themselves, might constitute a risk. Because of these characteristics, historic buildings present a challenge because it may not be acceptable to make modifications to these buildings to install modern fire protection

features, and it is frequently impossible to manage risks in a manner that is consistent with the assumptions made in fire codes (Torero, 2019).

Fire Safety Objective

The basic objective of fire protection is to reduce the risk of death, injury, loss of property, and harm to the environment to levels deemed acceptable in the event of an uncontrolled fire. The priority given to protecting people's lives versus protecting their belongings varies by country, as does the type of building being protected and the people who live within it. More recently, there has been a movement within national codes to prioritise the protection of people's lives over the preservation of property. Some rules operate with the presumption that repairing fire damage to a building is the responsibility of the building's owner or insurer. The provisions of these codes are designed only to ensure the safety of other people's lives and property. Even if a building complies with the minimum requirements of a building code, many fire protection features, such as automatic sprinkler systems, provide both life safety and property protection. This property protection becomes important if the owner is unaware of the extent to which a fire will likely damage the building and its contents (Buchanan & Abu, 2017).

Effectiveness of Fire Safety Implementation

The term "effectiveness" should be understood to refer to the interplay between two other concepts: efficacy and reliability. Provided that effectiveness is defined as the degree to which a working system accomplishes an aim, it should come as no surprise that the efficacy of a system may vary depending on the purpose. For instance, the effectiveness of a fire safety system (such as sprinklers, smoke or heat detectors, or fire-resistant barriers) is measured by its ability to prevent deaths from occurring. Its efficacy is:

- 100% if there were no fatalities whenever it was present and operated.
- Between 0 and 100% if the rate of fatalities whenever it was present and operated was reduced compared to otherwise identical situations with that system not present.
- 0% if the fatality rate remained the same whether it was present or not.
- Negative if the fatality rate increased in fires when it was present and operating.

Therefore, the effectiveness of anything as a combination of its efficacy and its reliability is dependent on the aim being considered, and as a result, it is not necessarily the same for each purpose. This definition of effectiveness reveals a widespread (and often unacknowledged) assumption, namely that effectiveness and reliability are interchangeable terms. On the other hand, it is self-evident that despite a system's high degree of reliability, it may nevertheless fail to meet the requirements of a given aim (Thomas, 2016).

The Obstacles in the Implementation of Fire Safety

Awareness

According to Roslan and Said (2017), the lack of understanding about fire safety among building owners and members of the public is the primary cause of fire disasters that occur in historic buildings. Awareness is very important to control the fire hazard or conduct an evaluation of the fire risk in order to create better knowledge and awareness among the people working in the building.

Cost

It is necessary to perform maintenance or inspection of a building's fire protection system to guarantee that it is in excellent operating condition. Despite this, maintenance is one of the components that incur the greatest cost in the process of providing fire prevention measures. It also demands cost-effective consumption (Ishmah et al., 2021).

Fire Safety System

The installation of fire-fighting water systems has the potential to rescue a building from destruction; nevertheless, in some situations, the activation of these systems in an uncontrollable way might inflict more damage than the fire itself. On October 1, 2019, the Missouri State Historical Society in Columbia, Missouri, lost certain historical documents due to a failing sprinkler head, which resulted in a damp cabinet and the historical documents becoming wet (Ishmah et al., 2021).

Issues Faced by Facility Managers in the Implementation of Fire Safety in Heritage Buildings

To begin, most of them have a considerably increased risk of fire given that their pre-existing buildings and contents are especially susceptible to being consumed by fire. In most cases, the dangers that are present during fires involving historic structures are caused by the building itself, the contents of the building, the nature of the fire situation, the purpose of the building, and environmental factors to consider. The second difficulty is the method used to improve fire safety in historic buildings. The owner of a historic building bears most of the responsibility for ensuring that the structure is fire-safe. However, modernising fire safety measures in historic structures might potentially bring about conflict between the requirements of the fire safety standards and the building's historical importance, and this is especially likely to occur if the building's primary function has been altered (adaptive re-use). For instance, when it is necessary to build more stairs as a method of escape as well as install fire precaution hardware such as exit warnings, emergency lights, and fire detection systems, complications may often develop. It should be noted that, in situations where the need for fire protection and the need to minimise intrusion into historic structures are in conflict with one another, a logical and systematic approach to the assessment

of fire safety requirements is required in order to reveal alternative methods of achieving adequate, appropriate, and cost-effective protection. (Salleh, 2012).

Current Fire Safety Implementation in Heritage Building

Roslan and Said (2017) provided an overview of some of the selected research that had been carried out on the fire safety management system for heritage buildings in Malaysia. This research demonstrated that the level of fire safety management system at heritage buildings in Malaysia is still low. The implementation of the fire safety equipment is still insufficient or inappropriate, and it does not meet the criteria established by the legislation. Starting from the conservation process that was done to the buildings, the fire safety system in the heritage buildings has not been changed very much. However, some of the fire safety systems are not suitable for the new function of the buildings after they have been through an adaptive reuse process.

METHODOLOGY

Several methods are applied to achieve the objectives of this research. Among the methods are by obtaining as much information as required about the factors contributing to the effectiveness of the fire safety implementation for heritage building, understanding the issues faced by the facility manager in the implementation of fire safety for the heritage building and proposing the framework model for the fire safety improvement.

Background to Research Design

There will be many stages to the investigation in order to reach the goals of the research project. The first stage is to study the literature in order to learn more about possible fire threats and fire safety in general. After the first stage is done, the second stage is conducting a questionnaire survey. In the third stage, all of the information gathered would be put together and analysed. As the last step, the studied data would be presented, and a report would be written with conclusions and suggestions for the future.

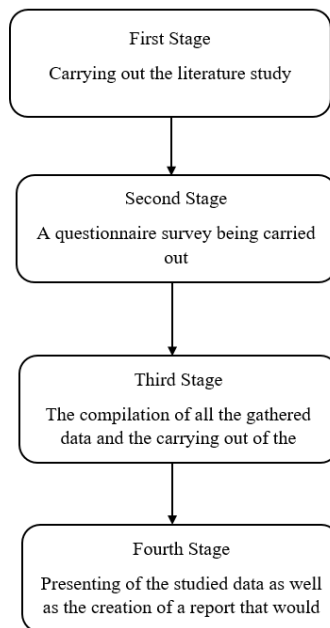


Figure 1: Research Methodology Framework

Stage of Research

In order to accomplish the aims and objectives of the study, the research methodology will need to be carried out in several stages. This research seeks to identify the factors contributing to the effectiveness of the fire safety implementation for heritage building and the issues faced by facility managers in implementing the same, as well as to propose the framework model for the fire safety improvement. Elaboration on the several stages are as set out below:

- Stage 1: Literature Review

It is necessary to conduct a literature review in order to get a crystal-clear perspective on the relevant areas of the study and to gain the ability to identify a genuine problem that has previously been addressed by other researchers. Readings from primary sources, such as academic journals, conference papers, articles, and instructional books, as well as readings taken from the internet and database browsers, are used to compile the results of the literature review.

- Stage 2: Data Collection (Survey Questionnaire)

This data collection will be done using the quantitative data collection method. It will require the distribution of a questionnaire to the selected facility

managers and tourists of the selected case study. For this research purpose, all the questions in the questionnaire have been designed to fulfil and achieve the third objective of this research, which is to propose the framework model for fire safety improvement.

- **Stage 3: Analysis Data**

The results of the study will be determined by analysis of the data obtained from the questionnaires that formed part of the survey. The information and data acquired will be examined and processed in order to determine how well they relate to the goals of the study. Upon the completion of the information analysis, the results of the findings will be presented in a manner that is easy to comprehend, making use of bar charts, pie charts, and tables.

- **Stage 4: Conclusion and Recommendations**

Following completion of the data analysis in Stage 3, which will be followed by Stage 4, the conclusion and recommendations will be presented. A conclusion will be drawn in the last stage of this study, and it will be based on the overall stages that have been completed in this study, hence it will cover the whole of the research, starting with the introduction and continuing all the way through to the conclusion.

Justification for this Research

Before entering the data collection stage through the distribution of a survey questionnaire, the identification of several elements as justification is needed to fulfil this research purpose. By referring to the literature review of obstacles faced in the implementation of fire safety, there were two problems mentioned by professional researchers, namely:

- Pre-existing heritage buildings and their contents are especially susceptible to being consumed by fire.
- The method used to improve fire safety in historic buildings

Justification is needed for this research to identify the sub-factors on those two problems faced by the facility managers, and also for the purpose of achieving the objectives of this research.

Quantitative Data Analysis Method

Quantitative data analysis can be defined as the process of analysing data that is number-based or data that can easily be converted into numbers, whereas data analysis is simply the process of finding useful information by evaluating data. In order to achieve its purpose of analysing the data gathered via numeric variables and statistics, it is predicated by numerically and statistically characterising and interpreting the things that it examines. Quantitative data analysis methods often include the use of algorithms, mathematical analytical tools, and software in order to glean insights from the data and provide answers to queries like "how many," "how frequently," and "how much." Data for quantitative data analysis is frequently collected via methods like surveys, questionnaires, polls, etc.

RESULTS AND ANALYSIS

Development of Conceptual Framework

Based on the data obtained from the literature review, three primary groups of factors were developed in order to investigate the relationship between the specific variables and to develop a framework for the fire safety efficacy of heritage buildings.

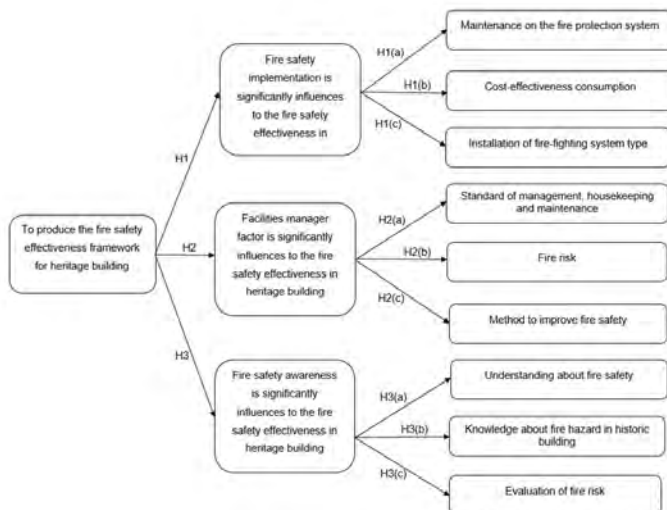


Figure 2: Conceptual Framework

Quantitative Method

Aims of Survey Questionnaire Forms

The distribution of survey questionnaires forms is intended to ascertain the average mean index for each variable evaluated by respondents, and to produce a fire safety effectiveness framework for historic buildings.

Distribution of Questionnaire's Procedures

To collect a complete description of the respondents' background and analyse all the collected data, the questionnaire was divided into three sections: A, B, and C. Section A of the survey asked respondents for their demographic information. For sections B and C, when testing the variables obtained from the objectives, facility management will be asked questions regarding the significance of these variables in developing the fire safety effectiveness framework for historic buildings.

Section A: Demographic Information

Section B: Effectiveness of Fire Safety Implementation and Issues Faced by Facility Manager

Section C: Awareness of Fire Safety in Heritage Buildings

A Google Form was used to disseminate the questionnaires to respondents working in the facility management department of historic buildings. The methods of questionnaire distribution were determined by contacting and asking the respondents via phone on the best way to send them the questionnaire.

DISCUSSION AND ANALYSIS

To accomplish this objective, the data obtained from the results and findings of the questionnaire are tabulated in the table of the average mean score index for the significant factor. It presented again three elements of primary factors, each with its own identified significant factor. The variables that are initially rated as moderately effective are deemed not to be the determining factor in generating the fire safety effectiveness framework for historic buildings.

Table 1: Identification of Moderately Effective Factors

IMPORTANT FACTOR		MEAN
Main Factor 1	Maintenance on the Fire Protection System	3.16

Fire Safety Implementation is Significantly Influences to the Fire Safety Effectiveness in Heritage Building	Cost-Effectiveness Consumption	3.53
	Installation of Fire Fighting System Type	3.65
Main Factor 2 Facilities Manager Factor is Significantly Influences to the Fire Safety Effectiveness in Heritage Building	Standard of Management, Housekeeping and Maintenance	3.74
	Fire Risk	3.77
	Method to Improve Fire Safety	3.88
Main Factor 3 Fire Safety Awareness is Significantly Influences to the Fire Safety Effectiveness in Heritage Building	Understanding About Fire Safety	4.00
	Knowledge About Fire Hazard in Historic Building	4.14

Maintenance of the fire protection system is highlighted in green in the table above because it has a substantial impact on the fire safety efficacy of heritage buildings. The identified element highlighted in green is not deemed crucial to produce a fire safety effectiveness framework for historic buildings.

Table 2: Identification of Very Effective Factors

IMPORTANT FACTOR		MEAN
Main Factor 1 Fire Safety Implementation is Significantly Influences to the Fire Safety Effectiveness in Heritage Building	Maintenance of the Fire Protection System	3.16
	Cost-Effectiveness Consumption	3.53
	Installation of Fire Fighting System Type	3.65
Main Factor 2 Facilities Manager Factor is Significantly Influences to the Fire Safety Effectiveness in Heritage Building	Standard of Management, Housekeeping and Maintenance	3.74
	Fire Risk	3.77
	Method to Improve Fire Safety	3.88

Main Factor 3 Fire Safety Awareness is Significantly Influences to the Fire Safety Effectiveness in Heritage Building	Understanding About Fire Safety	4.00
	Knowledge About Fire Hazard in Historic Building	4.14

The elements of cost-effectiveness consumption and installation of firefighting system types are highlighted in red in the table above because they have a significant impact on fire safety efficacy in heritage buildings. In addition, the elements of standard of management, housekeeping and maintenance, fire risk, and methods to enhance fire safety are also highlighted in red to indicate that these are factors which substantially influences the fire safety efficacy in heritage buildings. The same holds true for basic fire safety awareness, which has a significant impact on the fire safety effectiveness in historic buildings, as well as comprehension of fire safety and knowledge of fire hazards. All of the elements highlighted in red under "important factor" are deemed crucial and should be proposed as the best potential factors for developing the fire safety efficacy framework for historic buildings.

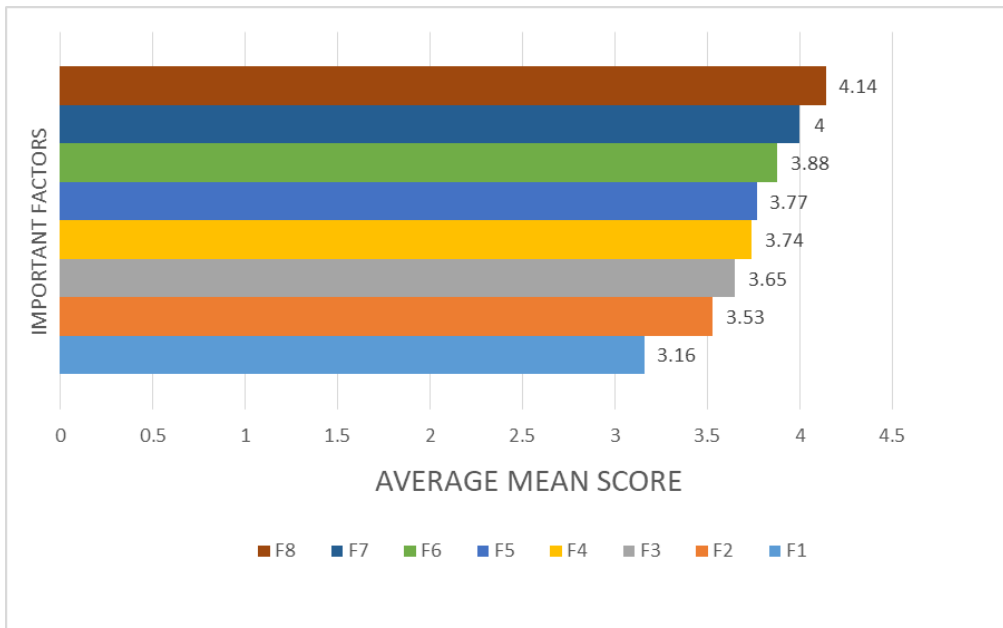


Figure 3: Determination of Best Possible Factors

The figure above presents the graph for the overall elements in determining the best possible factor to produce the fire safety effectiveness framework for heritage

buildings, based on the average mean score index of 3.50 and above. By referring to the bar chart in Figure 4.8, there are several important factors reaching a reading of more than 3.50 average mean score index that have already been marked with a red line in the bar chart. Therefore, cost-effectiveness consumption (F2), installation of fire-fighting system type (F3), standard of management, housekeeping and maintenance (F4), fire risk (F5), method to improve fire safety (F6), understanding about fire safety (F7) and knowledge about fire hazard in historic building (F8) recorded average mean index readings of more than 3.50 and thus determined as the best possible factors to produce the fire safety effectiveness framework for heritage buildings.

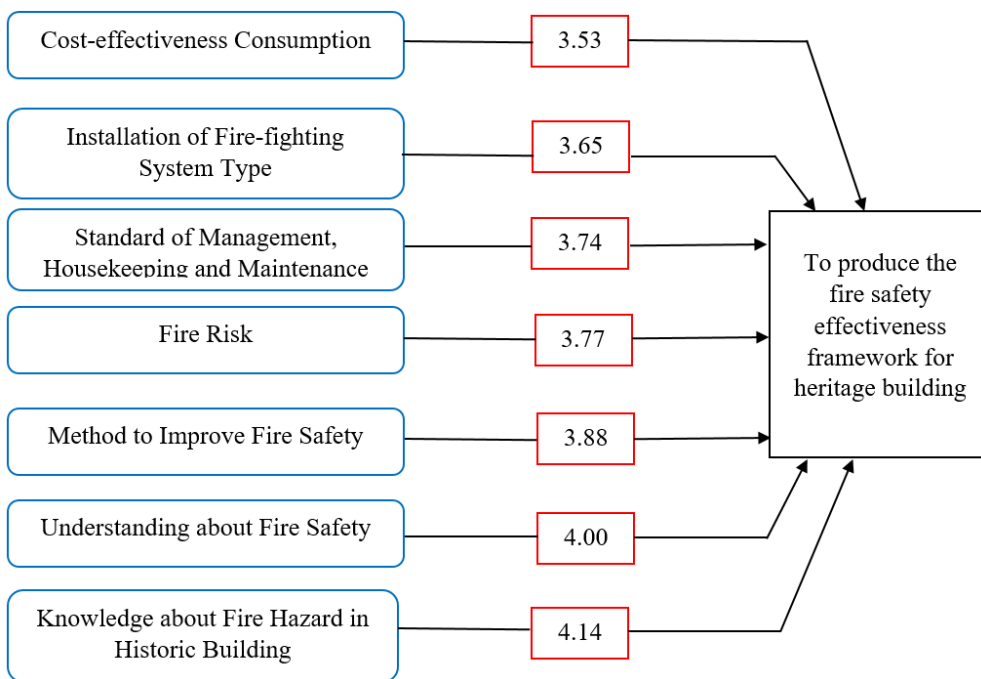


Figure 4: Proposed Framework of Best Possible Factors

In order to achieve the third objective of this study, which is to propose a framework model for the improvement of fire safety, the diagram above sets out the valid factors that have been identified and determined to be the best possible factors for producing the fire safety effectiveness framework for heritage buildings.

Based on the discussion and findings, it can be concluded that survey questionnaires were used to test the variables identified from the objectives. Overall, eight (8) variables were tested and evaluated by the respondents, resulting in the identification

of seven (7) variables as being crucial to the development of the fire safety effectiveness framework for historic buildings.

CONCLUSION

Before conducting this research, an intensive literature review served as the primary study, based on secondary data acquired for this study on the implementation of fire safety measures in historic buildings. From the results of this extensive literature review, it was determined that several factors contribute to the lack of fire safety implementation, with the effectiveness of fire safety implementation receiving the highest rating among issues discussed by professional researchers. Hence, this serves as the justification for this research. In addition, it was determined that one of the factors contributing to the implementation of fire safety in heritage buildings was the presence of challenges.

In the distribution of survey questionnaire forms, all elements that contribute to the efficacy of fire safety implementation in historic buildings have been identified. Variables derived from all objectives were incorporated in the survey questionnaire forms. Out of 80 respondents, 82 provided feedback, and all variables were evaluated. The third objective is to propose a framework model for the enhancement of fire safety by identifying the average mean score index and the most important factor first.

In completing this study on fire safety implementation in heritage buildings, particularly in terms of the factors contributing to the effectiveness of fire safety implementation in heritage buildings, the primary objective of this research will be attained, which is the creation of a framework for fire safety effectiveness in heritage buildings. Several objectives related to the findings were met, demonstrating that this study was successful.

The first and second objectives of this study were accomplished through the distribution of survey questionnaires based on the factors contributing to the effectiveness of fire safety and the challenges faced by facility managers in implementing fire safety. Due to the determination of the average mean index, the distribution of survey questionnaire forms is carried out to determine the optimal factor for achieving the third objective of this study.

After completing every stage in this research, there are a few recommendations that can be made to enhance the implementation of fire safety in historic buildings. Such recommendations include the use of fire-resistant materials that complement the building's original architecture, implementing fire safety measures that support the preservation of the heritage building's distinctive features, studying the building's architectural layout and design to ensure that its fire safety features are compatible

with its historic characteristics, conducting a thorough fire risk assessment of the historic structure, inspecting and maintaining electrical systems on a regular basis to prevent electrical accidents, and lastly to train employees, volunteers, and occupants on fire safety protocols and the significance of preserving historic buildings.

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