

FIRE RISK ANALYSIS AND FIRE SAFETY DESIGN IN HISTORICAL SOCIOCULTURAL BUILDINGS

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Abstract

While historical buildings play an important role in transferring the socio-cultural values of the period to future generations, fires cause the destruction of cultural sustainability.

Aim: The aim of the study is to determine the risks encountered in historical buildings and to determine the measures that can be taken.

Method: The checklist method prepared in accordance with the fire regulations in Turkey and the risk analysis method defined in NFPA 101 A were used together. In this study, fire risk analysis was evaluated on a sample historical theater building in Turkey.

Results: When the risk-reducing factors are evaluated according to NFPA101A and BYKHY; the locations and characteristics of the floor and vertical shafts in the BYKHY are ignored and not associated with fire risks. In the NFPA101A fire safety assessment system, only the access roads to the building are excluded from the risk analysis.

Conclusion: In order to reduce the risks in fire safety, the originality of the building should be left in the second place and the sources of ignition and flammable coatings should be located far away and the change of function to the spaces that pose a risk should be limited.

Keywords: Assembly building; Fire Regulation; Escape routes; Escape width; Fire safety.

1. INTRODUCTION

Assembly buildings are often multifunctional buildings with high human density where various activities take place. The variable user density and diverse activities within this building group indicate the necessity for additional precautions. [1]

In assembly buildings, users often exhibit a profile of not recognizing spatial organization and being unaware of exit locations and stairs. This situation leads to chaos during a fire due to panic and physical constraints [2]. If a fire occurs, particularly in concealed spaces, locating the exit becomes difficult, increasing the evacuation risk, especially in assembly

buildings with high user loads [3]. Therefore, fire safety measures in these areas are crucial [4]. To prevent such scenarios, directional signs should be more prominent compared to other building groups, fire escape plans should be diversified and present in most spaces, and the direction towards escape stairs should be made more noticeable, possibly with illuminated signs, and the evacuation time should be extended by using fire-resistant materials [4].

As a result of uncontrollable fires such as the 64 AD Rome, 1657 Tokyo, 1871 Chicago, 1922 Izmir and 1966 London fires, many settlements have been destroyed and traces of the culture and life of the period have been erased along with the destroyed

buildings. The protection of historical cities and imaginary buildings against fire plays an important role in ensuring the sustainability of the cultural traces of that period and transferring these values to generations [5]. Over time, life, social and cultural values change and buildings undergo change and transformation to keep pace with this change. The preservation of historical buildings is only possible by continuing their function and bringing the buildings to the city and society[6]. For this reason, it is inevitable to change the function and transformation of historical buildings without spoiling their cultural identity. This transformation and re-functionalisation also brings fire risks[7]. While the addition of spaces with high fire risk increases the risk of ignition, the transformation into socio-cultural buildings increases the user load and reveals the risk of evacuation. Fire poses risks at the building, city and human scale, causing damage to each parameter[8].

Determining the location of escape routes and stairs in historical buildings, calculating corridor widths, compartment design, determining the access routes of fire brigade teams to the building, material selection and natural ventilation for smoke evacuation, smoke curtains, chamber and smoke insulation applied to control smoke spread are among the passive safety measures. The subsequent expansion of the existing building may often be impossible as making changes to the spaces will damage the originality of the project. Replacing the finishing and cladding elements with flammable materials can often cause the historical identity of the building to change. For this reason, the fire resistance of the materials can be increased by painting with transparent paints that can increase the flammability classes of the materials, and no changes can be made to the materials that do not allow this. Active fire safety measures are systems that are activated depending on another energy source added to the building and at the same time increase the effect of passive fire safety measures. When analysed in this context, it is necessary to create shafts by breaking the slab for smoke evacuation systems added to historical buildings. Active security systems, unlike passive systems, require an energy source. For this reason, it is necessary to intervene in the slabs for the installations needed for all warning detection and smoke control systems. In addition, it is inevitable that the application of automatic extinguishing systems, the application of detectors and the cables are visible from the outside. These situations are generally not considered appropriate by the Cultural Heritage Conservation Board. The final

decision can only be made after the opinions are taken by the Foundation for the Protection of Historical Cultural Assets. Directional signs, emergency lighting only facilitate users to reach the escape routes. Since these systems are applications made without much intervention to the structure, it is not thought that they will cause any problems.

In historical buildings, the implementation of active-passive systems to prevent destructive effects of fire often leads to the loss of the original value of the building due to the interventions made, imposing challenges both in terms of application, craftsmanship, and financially on the user. Meeting the required financial burdens or obtaining additional revenue and profit by giving different functions to the building, creating public spaces will require more sensitivity and financial obligations in the fire protection of historical buildings. Especially in buildings that undergo functional changes later on, difficulties can also be encountered during the implementation of measures [9]. In such cases, fire protection systems that are neglected and disregarded due to such reasons may cause greater damage to the building during a fire later on. The main materials forming the building increase the risk of fire and its severity if it occurs [10]. Attention should be paid to wooden houses, which were once widely used in our architectural culture, due to their weak resistance to fire, and the highest level of precautions should be taken. Insulation should be increased in sections such as electrical lines, power source boxes to provide sufficient time even in case of fire outbreak [11]. However, precautionary measures taken for fire safety should not compromise the historical values, and precautions should be taken to ensure that changes and additions made do not lead to the loss of these values. The process should be organized, documents should be kept, research should be conducted for economic decisions, and reports should be prepared for the next step. This process can be achieved through fire safety management. Fire safety management in historical buildings consists of four stages: risk assessment, documentation, low-cost measures, and advanced measures [12].

In historical buildings, conducting risk assessments and implementing fire safety measures play a crucial role in preventing damage from fire and ensuring the transfer of our historical and cultural heritage to future generations without loss [13]. The fire risk management process is primarily about controlling and preventing the spread of fire. Responsibilities for these situations can vary from country to country. Five fun-

damental interconnected steps have been developed to complete the fire risk management process [14]. These steps include identifying fire hazards, determining at-risk individuals, evaluating, recording, planning, informing, teaching, and training, reviewing, and monitoring risk management. Fire risk assessment methods determine whether the fire safety measures taken in a building are adequate and the associated fire risk is assessed using fire risk assessment methods. To predict fire risks, the system should be identified, fire scenarios should be developed, and measures should be taken accordingly. There are many methods for calculating fire risks [15].

Many historical buildings change their functions in order to maintain their cultural identity and respond to the changing needs of today's society, thus ensuring their sustainability in a robust manner. The high number of users in socio-cultural buildings will lead to many casualties as well as structural cultural destruction in a fire that may occur. Although a possible fire is a disaster that can cause the complete destruction of the building, there are no regulations and guidelines for the fire protection of historical buildings that have undergone a change of function in national and international regulations. There is a big gap in the literature on this subject. In this study; it is aimed to determine the fire risks in historical socio-cultural buildings and to prepare a guide by determining the measures to be taken. In the selection of risk analysis methods, it is necessary to make analyses by choosing the most appropriate method for the structure and its function. For this purpose, in order to provide reliable and permanent solutions, more than one method should be selected together and analyses should be made and necessary precautions should be taken.

In the analyses of existing structures, the check-list method and the method of determining safety parameters according to NFPA 101 A [19] can be easily applied because it is easy to make and has a control and recycling mechanism in reducing risks. The evaluation system specified in NFPA 101 A provides us with a numerical measurement of the values of fire controls, escape safety suitability, and at the same time whether a general fire safety is provided. Within the scope of NFPA 101 A, according to the main materials of the building, fire resistance properties, suitability of escape routes and shafts, in which parts the sprinkler system is applied, the characteristics of the fire alarm, the presence of smoke detection, the fire resistance times of the interior coatings, the presence of smoke control, corridor lengths in relation to

the number of exits, the number of escape routes, the characteristics of the compartment, the frequency of training and exercises. According to the number of storeys of the building, mandatory safety requirement values are obtained depending on whether it is an old or existing building. The obtained individual assessment figures and the mandatory safety requirement values are obtained to show us whether the fire controls, the suitability of escape safety and at the same time whether a general fire safety is provided. These evaluations made in the capacity of NFPA 101 A reveal which safety requirement is missing and needs to be completed. In addition to these analysis systems in historical buildings, benefit-loss analyses by evaluating the interventions to be made to the building are among the methods that will provide priority in terms of the measures to be taken and the damage and touches to be given to the identity of the historical building.

- There are no regulation articles for ensuring fire safety in historical buildings that have undergone a change of function.
- The regulations for existing buildings are insufficient to ensure the fire safety of historical buildings and buildings that have undergone a change of function.
- It is impossible to make arrangements for escape routes in these buildings.
- All interventions to be made to historical buildings will disrupt the authenticity of the building.
- Permission and approval should be obtained from the relevant institutions before the interventions.
- Functions with high fire risk should not be transformed to reduce the risks.
- Fire risks encountered in historic buildings are uncertain.
- The priority ranking of the fire risks encountered in historical buildings in the prevention phase is not known.

2. PROBLEMS ENCOUNTERED IN TAKING FIRE SAFETY MEASURES APPLIED LATER IN HISTORICAL BUILDINGS

Historical buildings carry a contextual value with the architectural traces of the period in which they were built, the materials used in their construction and their belongings such as paintings, artistic objects, religious objects. As can be seen in examples such as candles in the church, fabrics in the textile museum, etc.,

many of the values owned prevent the building from being preserved and continued to be used. This situation constitutes an obstacle to the measures to be taken for the fire resistance of the historical building such as fire-resistant stairs, sprinkler system, smoke detectors. A separate regulation has been established in some countries such as England and America against fire hazards in historical buildings due to this situation. The purpose of these regulations is based on the need to achieve an adequate level of safety in a building with many modification restrictions and where common tools and equipment for fire protection have become unacceptable [17]. Measures to be taken, determination of escape routes and widths, determination of fire brigade teams' access routes to the building and emergency gathering areas, placement of hydrants and extinguishing systems, selection of materials limiting fire spread, smoke control, ventilation, smoke detection, alarm and or taking these measures in an existing building can be done in accordance with standard regulations. However, many problems are encountered at this stage due to the identity of historical buildings. Especially when the function is changed, fire risks may also increase. The difficulties encountered can be grouped as historical preservation, façade-aesthetic understanding and infrastructure capacity status.

• **Challenges in historical preservation:**

While ensuring fire safety, especially the need to change the existing coatings due to the fact that they are effective in the spread of fire, the expansion of corridors and stairs due to the insufficient width of the escape routes, and the arrangements to be made in case of the need for additional fire escapes may disrupt the originality of the building. In this case, it should be tried to produce solutions together without losing its value by applying the least change to the materials of the building.

• **Difficulties in facade – aesthetic understanding:**

Fire escapes added to the facade due to the insufficient number of escape stairs may cause the identity of the historic facade to deteriorate. In addition, the closure of the openings on the facade due to the fire escape stairs negatively affects the character of the facade. In addition, the flammable coatings on the facade cause the flames to move along the entire facade, and their replacement would significantly damage the character of that period.

• **Difficulties encountered in the implementation of active systems:**

Active systems are systems that require an independent energy source that can be added to the building later. This is why they can also be installed in buildings during the use phase. However, in order to realize these applications, there is a need for installation. The installations can pass through the open or can be arranged by demolishing walls and floors. The important thing is that it is done with minimal intervention to the structure.

3. MATERIALS AND METHODS

Every building carries a fire risk. The important thing is to keep these risks within tolerable limits. Fire safety is achieved by conducting fire risk assessments for each building and identifying risk-reducing measures as the main objective. Different risk assessment methods can be used for existing buildings and those to be newly designed. During the research process, data can be collected through both quantitative and qualitative research methods to conduct analyses [16]. Mixed methods research is a more detailed and outcome-focused approach where quantitative and qualitative data are collected, integrated with each other, and then results are derived using the advantages of integration. Accordingly, in line with the goals and process determined in the study, literature review, interview technique, checklist method, and quantitative risk analysis method defined in NFPA, “Fire Safety Assessment System with risk analysis” methods were used together.

The checklist method involves conducting a fire risk analysis based on observation. By preparing a fire safety determination form based on the “Regulation on the Protection of Buildings from Fire” in Turkey, the aspects of the building that do not comply with the regulations were identified, and recommendations were made to reduce the risks.

Check-list table consists of 10 sections and 40 sub-items and 19 pages. Since the prepared checklist table is very long, it is shortened and given in Table 1 (Fire Risk Analysis According to BYKHY) and the values are indicated on the table by examining the historical theatre building. The fire safety analyses of the theatre building examined in the article were made under these headings with the checklist method and the results are given in Table 1.

- In the first part; general data about the building,
- In the second part; the articles of the regulation

- related to the decisions including the layout and site plan of the building,
- In the third part; compartments, floors, walls, facades and roofs,
 - In the fourth section, the planning of escape routes,
 - In the fifth section; the number, capacity and distance of escape routes and their components (doors, corridors, stairs, ramps, lighting and signage)
 - In the sixth chapter; fire detection and alarm systems,
 - In the seventh chapter; fire extinguishing requirements,
 - In the eighth chapter; smoke control requirements,
 - In the ninth chapter; special requirements for buildings for assembly purposes
 - The tenth chapter includes special requirements for historic buildings.

Table 1.
Fire Risk Analysis According to BYKHY (checklist) (Created by the author based on study data)

Precaution Taken	Adequate	Not Adequate	Precaution Taken	Adequate	Not Adequate
Building location, access	+		Non-slip material		+
Fire compartment		+	Railing balustrade	+	
At least half of the exits to be within the compartment		+	RAMPS		
Floorings	+		Accessibility	+	
Suspended ceiling	+		Non-slip material	+	
Installation insulation		+	Gradient	+	
Facade insulation	+		Landing	+	
Facade characteristics		+	ACTIVE SYSTEMS		
Roof covering	+		Detection system		+
ESCAPE ROUTES			Warning system	+	
Uninterrupted escape route	+		Extinguishing system		+
Easily accessible		+	Periodic maintenance and testing		+
Number, capacity, and distance of escape routes			Fixed hose and fire cabinet	+	
Escape distance		+	Water intake installation	+	
Escape route widths		+	Hydrant	+	
Exit widths	+		Hydrant distance		+
DOORS			Number of portable extinguishing devices	+	
Door widths		+	Smoke control system		
Opening direction		+	HVAC installation		+
Fire resistance feature		+	Staircase shaft pressurization		+
Self-closing		+	Width of circulation areas in theater halls	+	
ESCAPE ROUTE COMPONENTS			Emergency lighting on steps in case of power failure		+
Inner escape route width	+		Number of seat rows	+	
Selection of fire-resistant materials	+		Seat widths	+	
STAIRS			Wall coverings	+	
Number of stairs		+	Plumbing works	+	
Do half of them open outward?		+	Fire safety landing		+
Distance to exit		+	Fire protection of stairs		+
Number of steps		+	Panic device on escape doors along the escape route	+	
Landing width	+		Preservation of original materials in renovations of historical buildings		+
Headroom height		+			
Fire safety landing		+			

Table 2.
Fire Safety Evaluation System with Risk Analysis Table (Referenced from NFPA 101)

Security parameter	Parameter value							
1. Construction	Non combustible material					Combustible material		
NFPA220/building construction type/height	Type 1(442 or 332) Type 2	Type 2(111)		Type 2(000)	Type3 211 200	Type4 (2HH)	Type5	
1-2 floor	0	0		0	0 -1	0	0 -1	
3 floor	2	2		-6	0 -6	0	0 -12	
4-5 floor ≤22,8m	2	2		-10	0 -12	0	-3 -12	
>5 floor 22,8m	2	2		NV	0 NV	0	-6 NV	
>22,8m <45,72m	2	-1		NV	0 NV	0	NV NV	
45,72	2	NV		NV	0 NV	0	NV NV	
2. Classification of risks	Unprotected escape route			separate from escape routes		complete		
	2 missing	1 missing		2 missing		1 missing	0	
	-7	-4		-4		0		
3. Vertical shaft	Open (or incomplete protection)				Close			
	5 or more floor	4 floor		3 floor	2 floor	<30 min.	30 min. -1 hour	>1 hour ^g
	-10	-7		-4	-2	-2	-1	0
4. Sprinkler	None	Corridor		except corridors and lobbies			Whole building	
				Standart		Speed	Standard	Speed
	0	0		4		6	10	12
5. Fire alarm	None			without notification			notification	
				Without voice command		With voice command	Without voice command	With voice command
	0(-2)k			1(0)k(-1)p			2(0)p	2(1)k(-1)p
6. Smoke detection	None			Corridor		Rooms	Whole building	
	0			1		2	4	
7. Entrance Exit	No exit corridor			Alternative exit corridor>15,24m				
	> 22,8m ≤ 30,4m	> 15,24(6,09)h ≤ 22,86		> 60,96m ≤121,92m		≥ 60,96mc	≤ 15,24 m 30,48	≤ 15,24m
	-2	-1		-1		0	1	3
10. Escape rote	One	Multiple rote					Direct exit	
		inadequate		adequate		Smoke resistant area		
	-6(0)i	-2		0		3	5	
11. Corridor/separate room (compartment)	allocated exits and protection level							Compartment
	incomplete	Smoke resistance		≥ 1/2 hour c			≥ 1 hour c	
		No smoke resistant door	smoke resistant door	No smoke resistant door		smoke resistant door	smoke resistant door	
	-6/0	0	1(2)f	1		2(3)f	3(4)f	3
12. Training and drills	Number of drills conducted in 1 year							
	0			1-2			>2	
	-2(-3) ^m			0(1) ⁿ			1(2) ⁿ	

Fire Safety Assessment System with risk analysis involves numerical risk analysis based on parameters in NFPA 101-Life Safety Code[18], evaluating factors that increase hazards, and bringing alternative solu-

tion proposals to reduce risks to a tolerable level. The fire risks of the building were determined using the NFPA 101A safety parameters table in Table 2. In order to perform risk analysis in NFPA regulations

for mixed-function buildings, risk analysis tables have been created in which risky situations are determined and graded. Risk assessment was carried out with the help of these tables in order to determine which parameter increases the risks in the theatre building selected in the study and which measures will reduce these risks if these measures are taken.

Fire risk parameters (specified in NFPA 101)[19] are applied and evaluated separately for all risky spaces in the building. In determining the safety parameters for the selected spaces, the table in Table 2 is taken as basis in terms of the physical and design criteria of the user and the space; the construction of the building, the floor of the examined space, the escape distances and number, the quality and compartment features, the presence of vertical shafts opening to the space, detection, alarm, extinguishing systems, smoke control, the properties of interior coatings, the width and number of doors and corridors, and the evaluations of the exercises applied. In the analysed sample building, the parameter value of the feature met for each item was selected and the fire risk of each item was calculated by summing.

The selected values are written into three separate columns, and individual assessment figures are obtained by summing up the values in each column. Mandatory safety requirement values have been obtained based on the number of floors the building has, depending on whether it is an old or existing building. The obtained individual assessment figures and mandatory safety requirement values have been processed to determine whether fire controls, evacuation safety, and overall fire safety are adequate

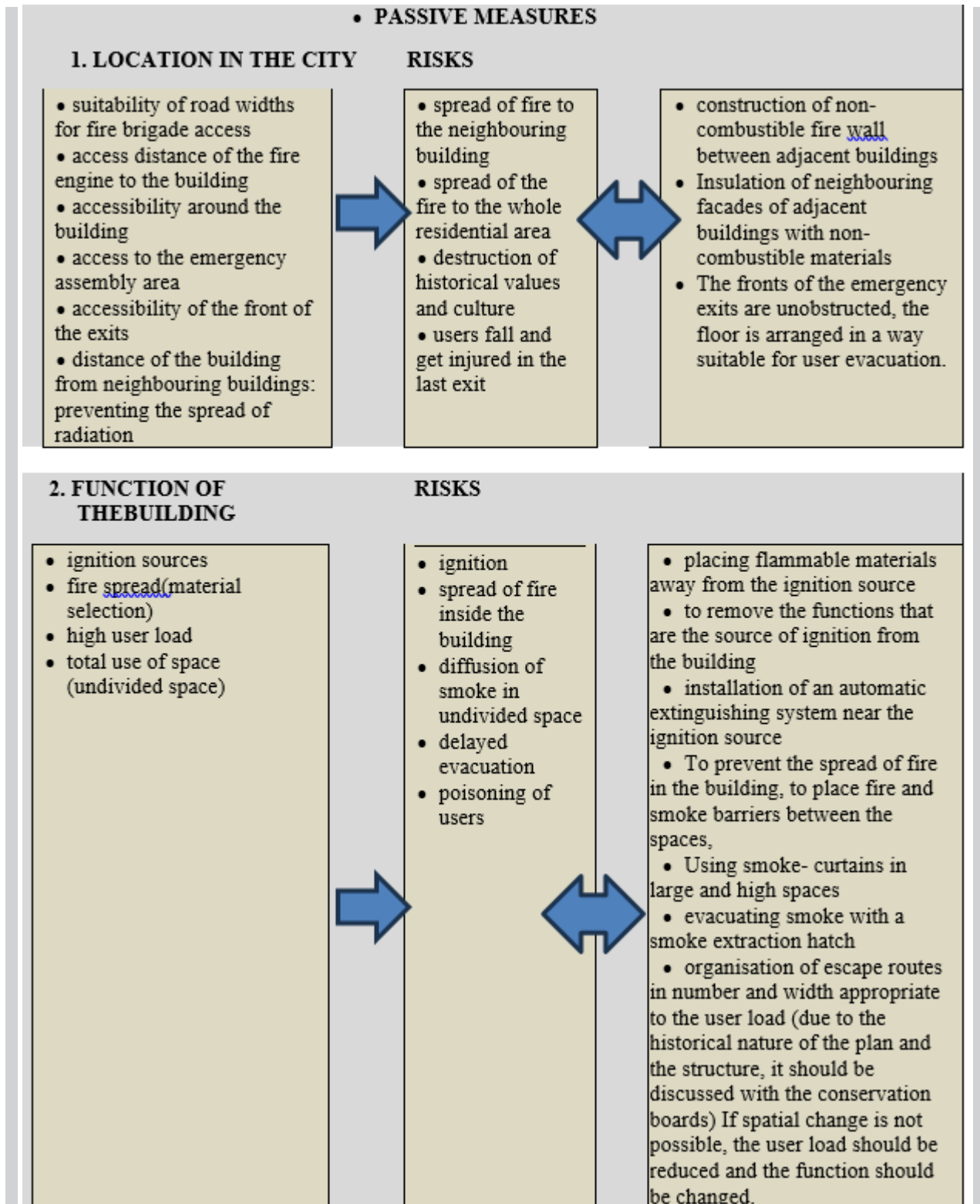
These tables reveal which safety requirements are lacking and need to be fulfilled. Data such as plan organization, building features, building materials used, escape routes, vertical openings, smoke detection and sprinkler systems, entrances and exits, characteristics of escape routes, compartments, and emergency programs are entered into the table to obtain corresponding values in the final stage, determining fire safety requirements. If the results fall below the established limits, necessary adjustments are made for the measures falling below the limit, and the risk assessment is repeated based on the new measures. If the total value cannot be reduced below the limit, further measures are taken in other areas, and the risk analysis continues until the total risk value falls below the limits.

General information about the historical theatre building where the field study was carried out: The cultural center analysed for fire risk is built as a community center in the early years of the Republic of Turkey in the 1930s [13]. In 1939, it was transformed into a cultural center with a cinema hall, classrooms, meeting rooms, ballrooms, and a library on the ground floor. The meeting and ballrooms functioned as the foyer of the cinema hall due to their positioning in the plan. A gymnasium was planned on the basement floor, sloping downward with the terrain on the front façade and at ground level on the rear facade. A gymnasium and shelter were designed on the basement floor for use. According to the project description report of the project, designed as a community center in 1938 and winning the first prize in the architectural design competition, while the ground floors housed the city's heavily used and heart-like spaces, the administrative section was on the first floor, and the guesthouse reserved for special guests such as Atatürk and state dignitaries was on the second floor [20]. The building has a total of five entrances, which are crucial for fire evacuation. Two entrances were designed for accessing the cinema hall on the basement floor for goods entry and accessing the gymnasium. On the ground floor, the community center entrance is on the right side, and the party entrance is on the left side. The other entrance is the courtyard entrance designed for access to the conference hall, which is reached from the terrace along a long axis around the columns in the courtyard. Due to its location on sloping terrain, the building's facades have different perceptions of the floors. Three floors are observed on the south facade, and five floors are observed on the north facade. The building is a community center with a rectangular plan measuring 55x42 m and a courtyard of 20x16 m. Unlike the load-bearing systems used at the time of construction, the building was built with reinforced concrete. Different heights of windows were used on the rear facade. Two of the building's five exits are provided from this facade's basement floor. The building has undergone changes in plan and function over time. Currently, the building serves four different functions: Bursa Regional State Symphony Orchestra Directorate, Bursa State Classical Turkish Music Choir Directorate, State Theatre Directorate, and State Fine Arts Gallery. While three units use common escape routes within the same building, the State Fine Arts Gallery has its own independent section and an independent escape route.

4. FINDINGS AND EVALUATION

In the first stage, fire risks were assessed according to Nfpa safety parameters and checklist method pre-

pared in accordance with the articles of BYKHY and final recommendations were made. The findings and recommendations were evaluated in terms of



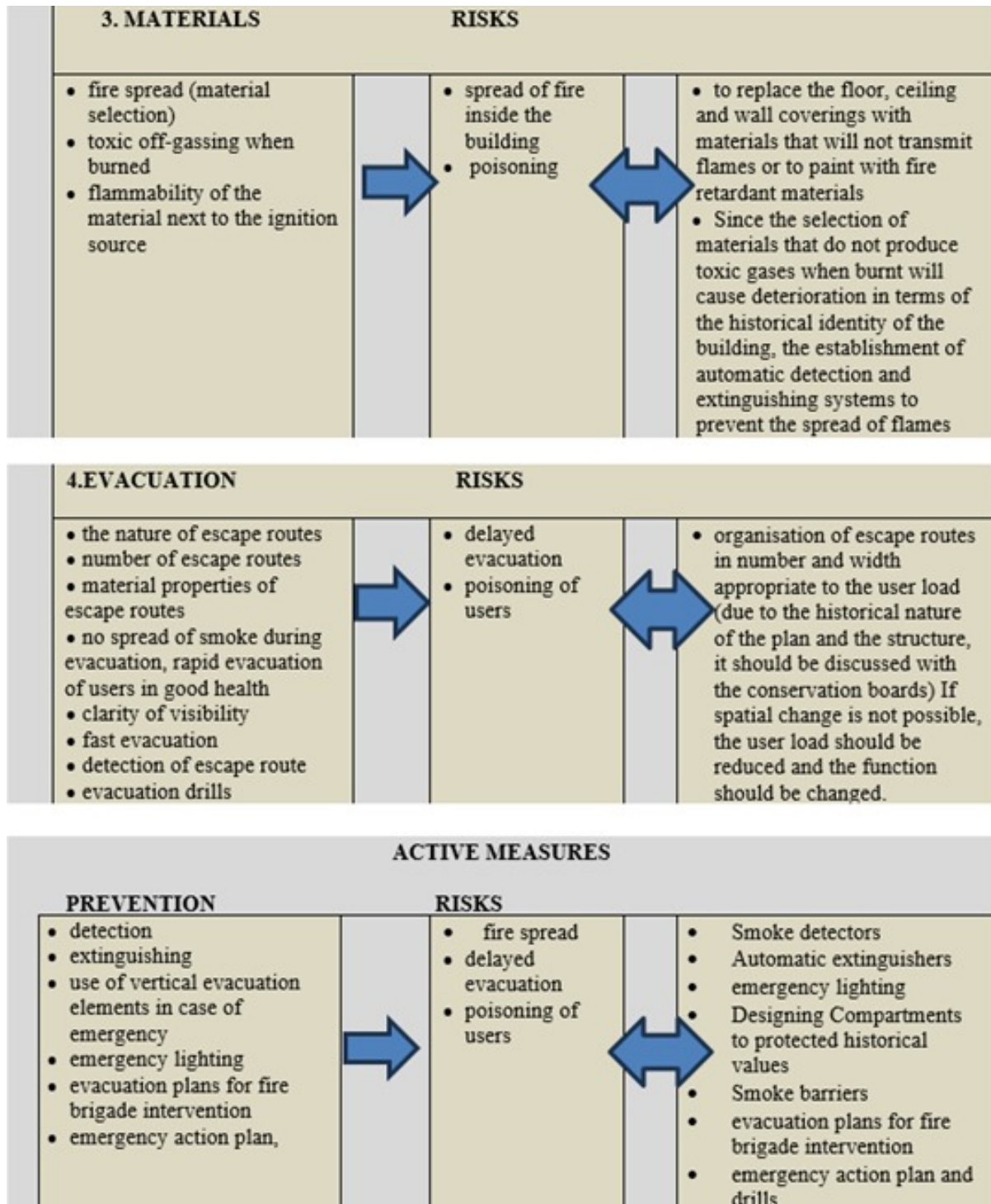


Figure 1.
Fire risk assessment stage (Created by the author based on study data)

intervention to historical buildings and cultural sustainability. The checklist method prepared in accordance with the provisions of the BYKHY is a preliminary study to determine the current fire safety status of the examined building. Which of the fire safety mea-

asures in the building are in compliance with the fire regulations and which points need to be taken have been determined by this method and the data has also formed a basis for the NFPA 101 fire risk analysis method. The determinations made are summarised in

Table 1. In this table, if those measures have been taken in the building against the items related to fire regulations, the adequate column has been marked if those measures have been taken, and the inadequate column has been marked if no measures have been taken.

The theatre building, which underwent major renovations in 2010, experienced minor changes over time [21]. The single-story building housing the artist entrance on Feraizade Street was demolished and replaced with a parking lot. The second basement floor entrance to the main building was closed by filling it with gas concrete (Fig. 2). The health center located on the ground floor of the theatre was also completely closed. Internal dividers were demolished, and a foyer, café, cloakroom, and meeting-reading room were planned for the artists, and the spaces were divided with internal walls. These areas are only for the use of artists. The staircase leading to the basement in the Health Center was cancelled. The area allocated for the Health Center on the basement floor was included in the carpentry workshop and started to be used as a warehouse. A floor was made in the stairwell created due to the staircase, and it started to be used as a cloakroom. A tube passage was created on the ground floor to connect the artist entrance with the backstage wings. The tube passage was entirely made of steel carriers and metal panels.

The risk analyses were evaluated according to the applied method, using the checklist method prepared in accordance with the provisions of BYKHY and evaluated according to NFPA safety parameters, and result recommendations were made. The findings and recommendations were evaluated in terms of intervention in historical buildings and cultural sustainability. The risks identified in line with the examinations are given in Fig. 1. These risks are grouped in detail under the headings of the building's location

in the city, function, material evacuation, precautions and intervention.

According to the results obtained from the “fire safety assessment system” of the theatre building, it has been observed that Dede Efendi Hall, the State Theatre Directorate on the 1st basement-ground – 2nd floors, the main hall, and the spaces on the 1st floor meet all the criteria for fire control, evacuation needs, and overall fire safety, containing tolerable risks. However, it has been determined that the State Fine Arts Gallery on the ground floor and the Choir and State Symphony Orchestra Directorate on the 2nd floor, along with the theatre committee section, do not meet any of the criteria, thus being categorized as high-risk areas (Table 4). While the fire safety assessment system is effective in identifying risks in the spaces, it cannot provide a detailed analysis for reducing these risks. Therefore, in units where risks are identified as high, a more detailed analysis should be conducted using the checklists prepared according to BYKHY 18 to establish a fire-safe building design. This method provides an opportunity for a more detailed examination.

When fire risk analyses are conducted according to regulations from two consecutive different countries and considering factors that reduce risks according to NFPA 101 A and BYKHY [23], it's observed that certain aspects are overlooked or differently addressed. For instance, in BYKHY [23], the locations and characteristics of the floors and vertical shafts are disregarded and not associated with fire risks. Similarly, NFPA 101A excludes the risk analysis of access routes to the building. However, the checklists prepared according to BYKHY [23], are much more detailed and explanatory compared to NFPA 101A. While every risk can be examined down to the lowest level in BYKHY [23], numerical evaluations are conducted in the fire safety assessment system, but they

Table 4.
Fire Risk Assessment Dependent on Spaces (Created by the author based on study data)

Spaces	Fire Compt	Evacuation Safety	Overall Fire Safety
2 nd basement floor State Theatre Directorate			
2 nd basement floor Choir Directorate			
Dede Efendi Theatre Hall			
1 st basement floor State Theatre Directorate			
1 st basement floor Choir Directorate			
Ground floor State Theatre Directorate			
Ground floor Fine Arts Gallery			
Main Hall (Theatre Hall)			
1 st floor			
2 nd floor State Theatre Directorate			
2 nd floor theatre committee section			
2 nd floor Choir and Symph. Orch. Directorate			

do not delve into details.

In the fire risk parameter tables, an additional examination was conducted separately from the evaluations made for all floors of the theatre halls, which provides numerical measurements regarding whether fire safety and evacuation safety are provided and whether overall fire safety is ensured. Using the fire risk parameter method specified in NFPA 101 A, calculations were made based on the values in Table 2, and results regarding the adequacy of fire control, sufficiency of exit requirements, and general fire safety of the assessed venue were obtained. According to the fire risk assessment conducted by NFPA 101 A, from the spaces identified as having risks, the absence of fire protection in the State Fine Arts Gallery and the distant positioning of some spaces from exits increase the risks by reducing evacuation safety. Additional escape stairs are deemed necessary to reduce evacuation safety risks due to inappropriate escape distances from the farthest points. The addition of stairs, especially those added to the facade of historical buildings, not only compromises the identity of the building but also contradicts NFPA 101 due to only one escape staircase serving the offices in the chorus and State Symphony Orchestra.

Directorate on the 2nd floor of the theatre committee section. To comply with regulations, additional fire stairs need to be designed. However, due to the prohibition of such a significant intervention that would disrupt the function of the historical building, the use of the building has been restricted. Among alternative solutions that reduce risks are completely closing these areas to users or providing a second escape with an additional staircase located close to the areas. Following the implementation of these recommendations, subsequent risk analyses showed that overall fire safety values exceeded limits and the risk table turned green in terms of evacuation safety and general safety. However, the fire control section still remained risky, indicating that the design of evacuation routes alone is insufficient in reducing risks.

In general, when risk analysis is evaluated, it is observed that active systems and material selections do not adequately ensure safety in situations where fire control is not established, and under the same conditions, if evacuation routes are appropriately designed, the general safety criteria are inadequate. It is seen that when evacuation route design is combined with active safety measures and material selections applied in a way that reduces risks, fire safety can be established in the building. During the fire risk

analysis related to fire control, the values specified in Table 2 are calculated according to the formula = vertical openings /2 + fire alarm/2, + smoke detection/2 + interior finishes/2 + corridor separation/2. The obtained value was examined to determine whether it was within acceptable limits. According to individual safety assessment results, the compartment risk situation is indicated as S1. The value of Sa is taken as 2 for the existing buildings for general safety. In this case, if $S1 - Sa > 0$, tolerable evacuation safety is ensured. However, in the examined building, since $S1 - Sa > -5$ for the ground floor State Fine Arts Gallery, 2nd floor chorus and State Symphony Orchestra Directorate, and 2nd floor theatre committee section, evacuation safety cannot be ensured. Additionally, since $S2 - 2b > -12$ for the 1st basement floor State Theatre Directorate, ground floor State Fine Arts Gallery (Figure 3), 2nd floor chorus and State Symphony Orchestra Directorate, and 2nd floor theatre committee section, it was determined that general fire safety and fire control were not ensured.

In the evaluation of evacuation safety, the characteristics of interior finishes, the construction material of the building, smoke control in fire control, evacuation distances, exit widths, and exercises do not have a direct impact on risk analysis. It is observed that even if evacuation safety is provided in cases where fire control is not established, general fire safety is not ensured. In this case, it is seen that by taking active fire safety measures evaluated in fire safety into account, fire safety in the building can be ensured.

As a result of the fire risk analysis of the Theatre Building according to BYKHY; non-compliance with regulations and necessary arrangements resulting from risk analysis, access and access routes to the building, evacuation route requirements and distances, emergency direction signs and lighting systems, fire risks in show halls, and measures to be taken in historical buildings have been evaluated.

Access and access routes to the building: According to BYKHY Article 22, access to the building is ensured in such a way that the fire department does not exceed a horizontal distance of 45 m as shown in Figure 2. According to BYKHY, the distances of hydrants to buildings show compliance between 5 and 15 meters.

Evacuation route requirements and distances: Fire stairs are not protected against fire and do not have a fire safety vestibule. As the Theatre Building is a historical building, since the provisions of BYKHY are stated in the historical building section as "In cases

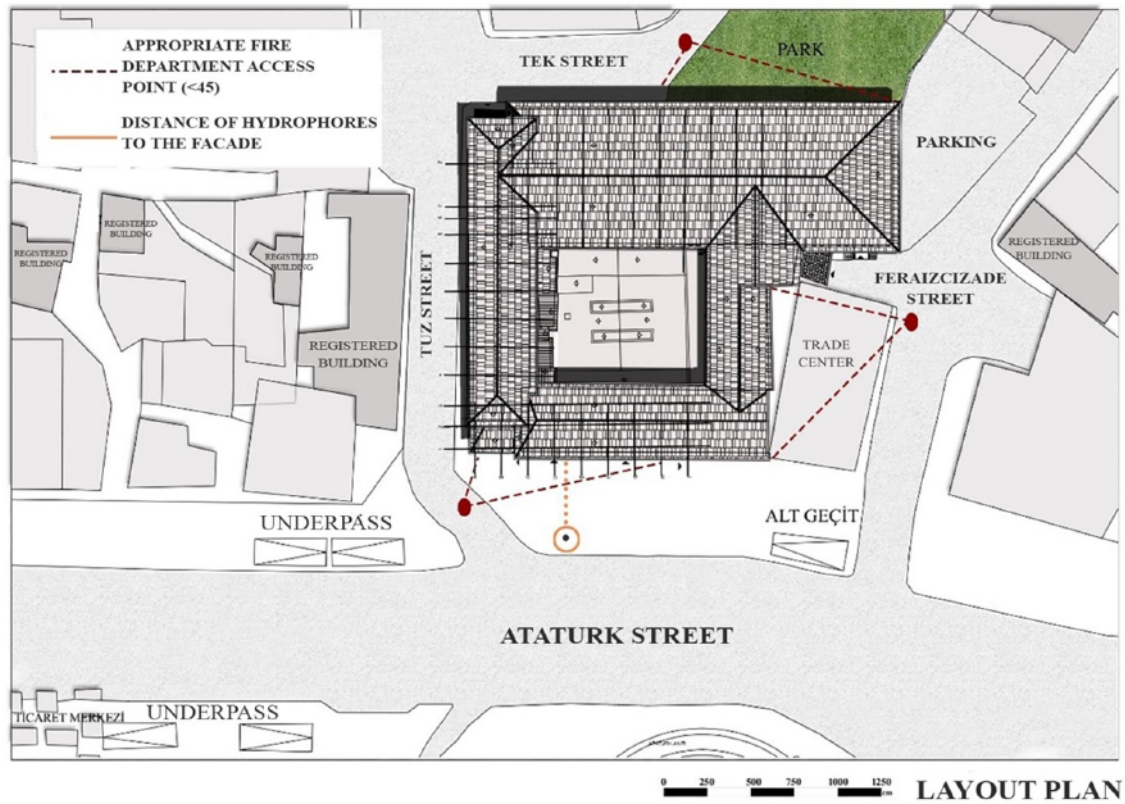


Figure 2.
Examination of the Layout of the Theatre Building According to BYKHY Articles. (Created by the author)

where historical buildings do not have the possibility of change in terms of physical and visual aspects, the existing staircase is accepted as a fire staircase and escape”, no fire safety vestibule has been created. Fire prevention measures required for stairs have been ignored to preserve the aesthetics of the historical building. In this case, a middle ground needs to be found between the fire risk posed by user density and the aesthetic values of the historical building.

Escape route coverings play a significant role in transmitting flames. While non-combustible A1FL class mosaics made of terrazzo, a combination of concrete and marble pieces, are used as floor coverings for escape stairs serving the directorates, flame-resistant BFL laminate parquet is used for the stairs serving the directorates and theatre halls in the north direction. Compliance with regulations is ensured in the selection of floor coverings according to BYKHY requirements for at least flame-resistant materials. However, considering the requirement in the regulations that assembly-purpose buildings must have fire resistance (resistance) durations according to the fire resistance (resistance) durations of building use classes in BYKHY, the use of

laminate parquet does not comply with these values. Doors, not subjected to a specific fire regulation at the time of construction, often lack features such as smoke tightness, self-opening capability, and being made of fire-resistant materials. Doors often have shortcomings such as their opening directions being opposite to escape directions, smoke leaks, and failure to self-open. The internal escape corridor door serving the accessory storage rooms and laundry rooms on the 2nd basement floor does not have a self-closing mechanism due to being an intermediary to reach the exit door. Additionally, the door serving the Dede Efendi Hall through the lobby opens in the opposite direction, which may prevent it from opening during a fire due to the formation of user congestion in front of the door. It is important to keep movement unrestricted on the escape route during evacuation, thus the floor should be resolved at the same level as shown in Figure 3 with escape routes. Attention should be paid to door thresholds on external exit doors. Since thresholds are not compliant with the regulations, levels should be equalized and thresholds should be removed. External exit doors should have a landing in front of them to

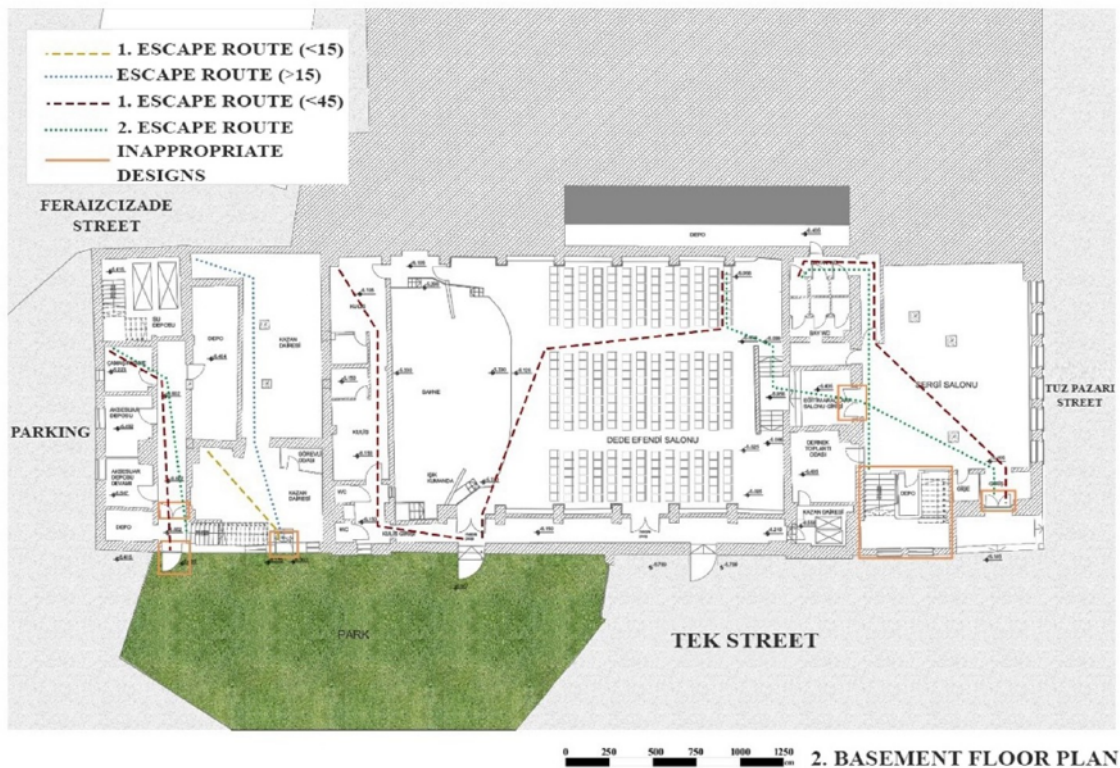


Figure 3.

Analysis of Escape Routes in the Existing Second Basement Floor Plan (yellow line; single escape distance suitable according to BYKHY, blue line; unsuitable escape distances, maroon line; suitable double escape distance, green line; alternative escape, orange line; represents unsuitable designs). (Created by the author)

prevent hindrance to escape during evacuation, and access to the outside should be provided with a gradual transition to the outside level.

The areas with the highest user load are the theatre halls. Due to having at least two exit doors, the Main Hall and Dede Efendi Hall comply with the regulations. However, in the Feraizcizade Hall with a user load of 65, the presence of a single exit necessitates the need for a second exit. Therefore, a new exit alternative should be created or the number of users should be kept below 50. This situation also emerged as a factor reducing risks in the fire risk assessment system.

Emergency direction signs and lighting systems: It is important during a fire for users to see their escape route and reach safe areas outside the building. Especially in buildings with high user density such as socio-cultural buildings, emergency lighting is required for floors with a user load of more than 200 and self-contained fixtures are required due to being in seismic zone 1. Emergency lighting can burn for 120 minutes as it receives electricity from the existing

generator in the building. In this sense, compliance with the regulations is ensured. In terms of direction, the absence of signs on some doors can confuse users during evacuation and cause delays. Therefore, more directional signs should be used, and signs indicating that certain doors and directions should not be entered should be placed. Decisions regarding the impact of these interventions on the historical building should be made in consultation with members of the Board for the Protection of Cultural and Natural Assets and architects.

In the project, examinations were carried out based on BYKHY articles, non-compliant practices were identified, and new proposals compliant with the regulations were developed. Evaluations of the current situation in the project were examined in Figures 3-4-5-6-7. The project was based on BYKHY Articles to be examined.

The compliance of the existing theatre building with the articles of the regulation on fire protection of buildings was examined. The second floor plan was revised (Figure 7). Escape distances are values that

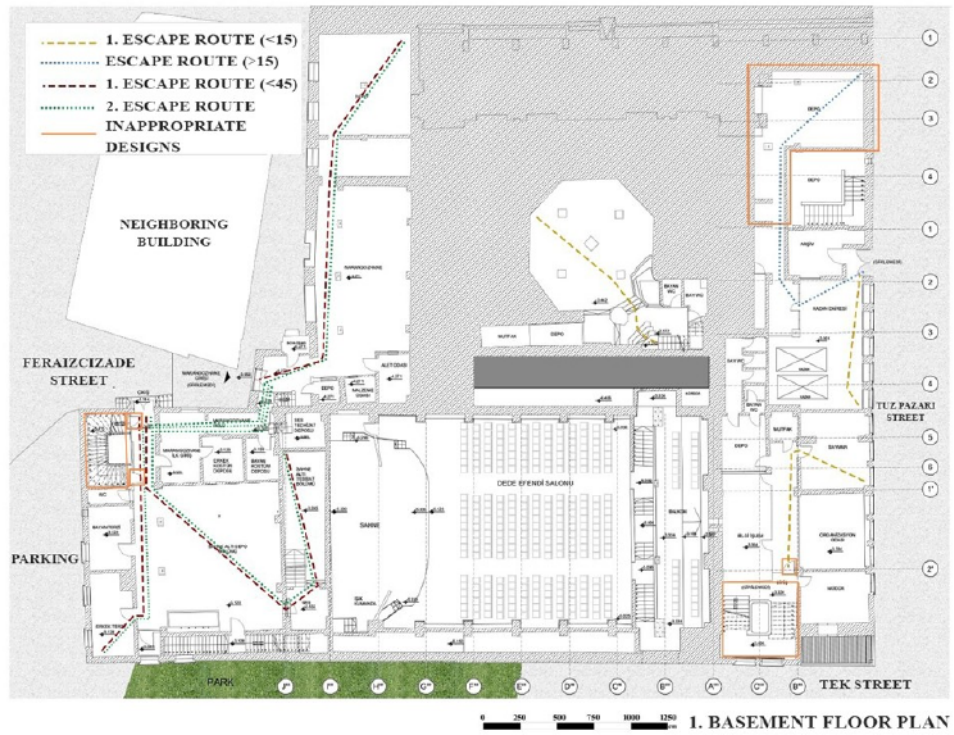


Figure 4.
Analysis of Escape Routes in the First Basement Floor Plan. (Created by the author)

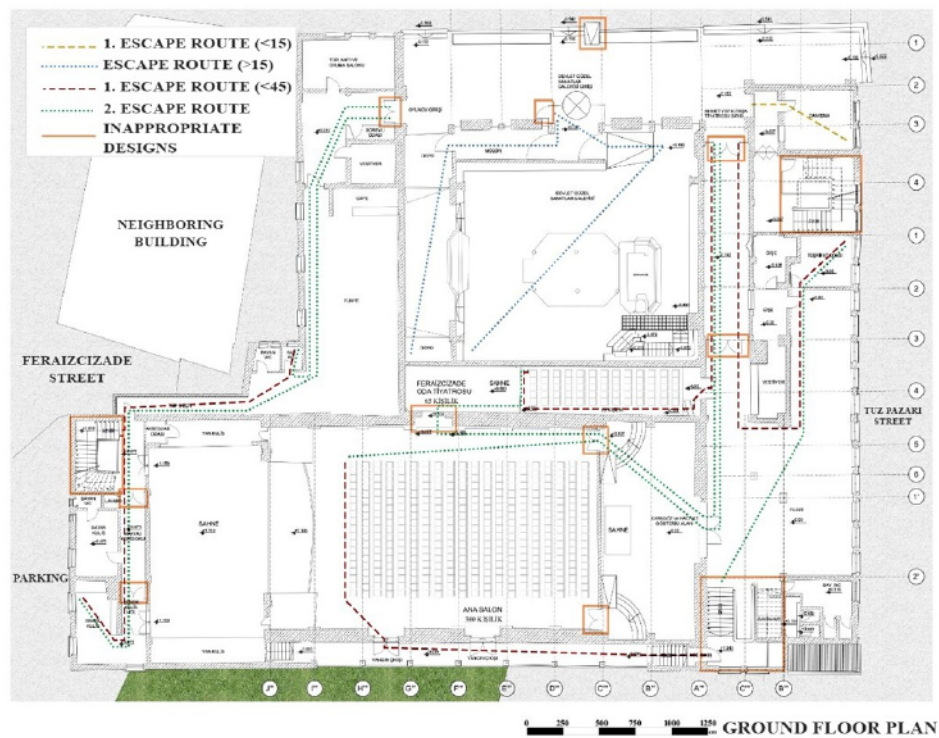


Figure 5.
Analysis of Escape Routes in the Ground Floor Plan (Created by the author)



Figure 6.
Analysis of Escape Routes in the First Floor Plan. (Created by the author)

must be suitable to divide user density in the event of a fire and ensure evacuation in a short time. On this floor, two areas are sections without fire safety because the escape distances exceed the values specified in the regulation.

To ensure compliance with the regulation, these spaces must be completely closed to users, or a second escape must be provided with an additional staircase close to the areas. Fire risks and precautions to be taken in performance halls: The ceiling of the Feraizcizade Hall consists of a suspended ceiling plastered with fire-resistant A1 class spray plaster. The walls have A1 class gypsum plaster and paint. The floor uses B1 class hard-to-ignite laminate flooring. While the materials used comply with the regulation, the use of laminate flooring is not suitable considering the statement in BYKHY that buildings for assembly purposes must be protected for 60 minutes according to the fire resistance periods chosen according to building usage classes. In this 65-seat hall, the row width is assumed to be

compliant with the regulation as it is not listed in the table in the regulation. It is thought that evacuation in the event of a fire will be faster due to the rows being arranged on a flat surface. However, the width of the aisle between the rows is 60-70 cm, and since it is not the same as the corridor width, it does not comply with the regulation. Therefore, the number of rows can be reduced so that the aisle has a minimum width of 110 cm. In the Main Hall, a suspended ceiling made of A1 class coated metal materials has been created. As seen in the walls are covered with composite material containing flame retardant additives, and the floor uses B1 class hard-to-ignite laminate flooring, with non-flammable carpet under the seats. While the materials used comply with the regulation, the use of laminate flooring is not suitable considering the statement in BYKHY that buildings for assembly purposes must be protected for 60 minutes according to the fire resistance periods chosen according to building usage classes. The fact that the widths of the side passages and the

Table 4.
Examination of Fire Safety Measures Specifically for Historical Buildings. (Created by the author)

Fire Risk	Location of the Measure	Measures to be Taken	Intervention on the Historical Building
Inappropriate escape distance	Basement level 1 storage room	A second exit must be created	There is an intervention on the originality of the building. The relevant institution should be consulted.
Exit door width less than the calculated exit width	State Fine Arts Gallery ground floor	The existing door should be replaced with a door that matches the calculated width	Expanding the door opening involves intervention in the originality of the building. The relevant institution should be consulted.
Escape doors opening inward in areas with more than 50 users	Main Hall	The doors should be oriented in the escape direction	Since there is no need to change the existing doors, there will be no alteration.
Single exit in areas with more than 50 users	Feraicizade Hall	The number of seats should be reduced to fewer than 50 users	It is considered that there will be no change in the historical value of the building.
Single escape in areas with more than 50 users	Main Hall balcony on the 1st floor	The number of seats should be reduced by 30 to fewer than 50 users in the area with 80 users	Although there will be a visual change, it is considered that there will be no change in the historical value of the building.
Single escape distance longer than 15 meters	2nd floor	A second escape route should be provided with an additional staircase	It will cause a change in the building. The relevant institution should be consulted.
Lack of sprinkler system	All floors	A sprinkler system should be installed	It will significantly alter the historical appearance. The relevant institution should be consulted.
Inappropriate corridor width in the circulation area	Hall	The number of rows should be reduced so that the circulation area has a minimum width of 110 cm	It is considered that there will be no change in the historical value of the building as a result of reducing the number of seats.
Slippery escape stair treads	Stairs serving the floors	Fluorescent non-slip strips should be applied to the treads	There is an intervention on the originality of the building due to material change. The relevant institution should be consulted.
Flammable material storage area located in open space	Basement level 1 under stage storage area	A compartment should be created, and a smoke detection and extinguishing system should be installed	Since the area will be created outside the building, there is no intervention on the originality of the building.
Escape stair doors not being smoke-proof	Stair doors	The doors should be painted with fire-retardant paint, gaps should be filled with fire-retardant polyurethane foam, and intumescent seals should be used on the doors	It is considered that there will be no intervention on the originality of the building since the doors will be painted with transparent paint.
Presence of thresholds at exit doors	Exit doors on basement level 2 and ground floor	A landing should be created in front of the doors, and a slightly sloped transition should be made to the outside level	There is an intervention on the originality of the facade.
Low fire resistance wooden material covering the theater hall walls	Dede Efendi Hall	The walls should be painted with fire-retardant paint, gaps should be filled with fire-retardant polyurethane foam, and intumescent seals should be used on the doors	It is considered that there will be no aesthetic change in the historical building since the wood will be covered with transparent material.

it is necessary to preserve the old building by supporting it with materials with fire insulation. At this stage, the joint decisions taken as a result of the architects' and engineers' meetings gain importance. The three escape stairs in the building, which do not have fire insulation, can be considered as fire stairs in accordance with the regulations. At the same time, since the stairs are accessed from the corridors, it is not obligatory to build a fire safety hall. However,

since the number of users exceeds 100 on each floor, escape doors should have panic arm mechanisms. There are few doors with these features in the building. Since the change will cause aesthetic concerns, it should be decided after consultation with the relevant people. All interventions to the building have been evaluated in terms of authenticity and reducing fire risks.

The biggest problem in historical buildings is that the security measures to be taken in order not to damage the authenticity of the building are ignored. However, in a possible fire, if the precautions are not taken, it is possible that the building and the characteristics of the period it carries and the historical identity of a period may be completely destroyed. For this reason, measures to reduce risks are evaluated in Table 4 together.

5. CONCLUSION

Buildings for meeting purposes with high user density are risky in terms of evacuation due to panic and crowding in case of fire. Preventive measures should be taken at the design stage to prevent fires in such places. In line with the hypotheses proposed at the beginning of the study, the following conclusions were reached.

- There are no comprehensive regulations for fire brigade intervention, structural systems, use of materials, limitation of compartment and smoke spread, escape route requirements and active systems for ensuring fire safety in historic buildings with changed functions. Regulations should be developed on this subject.
- The regulations for existing buildings are inadequate in ensuring the fire safety of historical buildings and buildings that have undergone a change in function, planning of escape routes and interventions on the facade.
- In these buildings, the user load should be limited and reviewed in buildings where it is impossible to make arrangements for escape routes.
- All interventions to be made to historical buildings do not impair the authenticity of the building. Measures can be taken with minimum intervention by making benefit and benefit analyses with permission from the relevant institutions. Due to the lack of regulations and inspections during the construction period of historical buildings, decisions such as corridor widths, number of doors and escape stairs could not be made based on user density. Preserving the cultural values of the period when the building and its community were built can be possible by transforming the building into different functions rather than designing it as a socio-cultural building. As a result of these changes and transformations, ensuring fire safety for new functions is a critical step in the preservation of the building and cultural heritage. In the transformation of an existing building into a socio-cultural building, it is structurally impossible to provide spatial integrations by removing walls and adding exits and stairs to the facade due to the unique nature of the structural features and architectural plans of historical buildings. This creates limitations and risks in terms of fire safety. Especially in theatre halls, it has been observed that the widths of the side corridors, the number of exit doors, fire protection features to facilitate user evacuation, the number of seats and rows, and the widths between rows cannot be designed according to the regulations, thus increasing the evacuation risks in these buildings.
- Permission and approval should be obtained from the relevant institutions before any interventions.
- Functions with high fire risk should not be transformed to reduce the risks. The spaces with high fire risk should be resolved outside the building or measures should be taken to reduce the risk of ignition. This can be achieved by positioning and protecting areas with high fire risk away from meeting areas.
- Fire risks encountered in historical buildings vary according to their function. Risks can be grouped as ignition, spread and evacuation risks.
- In the priority ranking of the fire risks encountered in historical buildings during the prevention phase, it has been observed that taking the fire under control is above the evacuation risk. In this case, ignition should be prevented first and the spread should be prevented by organising extinguishing systems. Most of the deaths in fires are caused by smoke poisoning. Materials used in meeting rooms for acoustic, aesthetic, etc. purposes can cause flames to spread rapidly and release toxic gases. In order to prevent or slow down the spread of smoke and flames, smoke blocking elements should be placed between suspended ceilings, a smoke evacuation system should be installed in conference rooms, and coating materials should be selected from types that do not release toxic gases when burning. It is envisaged that fire-resistant paints will provide fire protection by preserving the original value of the material.
- When ensuring fire safety in these buildings, the goal should be not only structural protection, but also fire protection of the entire residential area. The disasters caused by adverse conditions documented in many historic fires have led to the destruction of many residential areas. Therefore, measures related to settlement decisions are

considered important in reducing the risks. The main measures for fire protection of historic residential areas are to ensure that fire brigades can reach the perimeter of the building, to install hydrant systems and to take measures to prevent the spread of fire to adjacent structures.

RECOMMENDATIONS

The Regulation on Fire Protection of Buildings (BYKHY) is a guiding manual for designing fire-safe structures. However, it is not sufficiently understood by many architects. Especially in ensuring the fire safety of existing structures, there are shortcomings in conducting risk analyses. This issue should be evaluated using risk analysis methods. As a result of the analysis, it is thought that the basic measures to be taken in ensuring the fire safety of historical socio-cultural buildings that have undergone a change in function, listed below, will be a guiding guide in ensuring fire safety.

- Recommendations regarding the intervention of fire brigades: In case there are no road widths around the building located in the congested urban texture where the fire brigade vehicle can extinguish and intervene, a hydrant system connected to the network should be installed; In buildings with inner courtyards and backyards, hydrants should also be placed at these points in order to carry out extinguishing operations from the inner courtyard.
- Recommendations related to the structural system: Due to the load-bearing characteristic of masonry buildings, it is not possible to expand corridors and spaces by demolishing the walls. For this reason, the number of users and exit widths should be considered in the transformation of historical masonry buildings into socio-cultural buildings, otherwise changes of function should not be allowed in these buildings.
- Recommendations on the use of materials: The wooden parts of historical buildings should be painted with fire retardant paints in a way that will not deteriorate the original value of the building and the progress of the flames should be delayed. If permission cannot be obtained from the necessary institutions, the use of ignition sources should not be allowed or a smoke detection and extinguishing system should be placed near the ignition source.
- Recommendations for limiting compartment and smoke spread: The floors with high user density and no direct exit to the outside should be divided into compartments in order to prevent evacuation and flames from advancing (compartment passages should be closed with fire curtains activated in case of fire and their value should be intact). If the original value of the building is deteriorating and permission cannot be obtained from the necessary institutions, the number of users should be reduced and kept under control.

Filling the gaps in the doorways with fire retardant polyurethane foam and using intumescent wicks on the doors in order to delay the spread of smoke in places with high user density

- Recommendations on escape route requirements: To prevent crushing and falls during evacuation in multi-purpose halls, fluorescent anti-slip tape should be applied to the steps or the steps should be illuminated.

Doors should be turned towards the escape direction.

The existing door should be replaced with a door suitable for the calculated width. If the original value of the building is deteriorated by these interventions and permission cannot be obtained from the necessary institutions, the number of users should be limited to the number that will pass through the existing widths.

- Recommendations regarding adjacent buildings: One of the biggest factors that caused many residential areas to burn and consequently disappear in historical fires is the spread of flames to neighbouring buildings in adjacent buildings. If the façade of the building is made of flammable materials, a distance of at least 3 m should be left between the adjacent buildings and the window openings in the building, if these distances cannot be left, the windows should be equipped with smoke-proof wicks and replaced with glass and joinery that maintain their integrity against fire; Building a fire wall between both buildings that rises at least 50 cm above the roof; if there is no protrusion that will delay the jumping of flames at the points where the facade faces meet and if the facades continue on the same surface, it is recommended to use non-combustible Class A material on the surfaces where the neighbouring building meets the historical building.
- Recommendations for active systems: Installation of smoke detection and extinguishing system. Appropriate extinguishing system such as gas extinguishing system should be selected to prevent damage to the original materials used in the building during extinguishing.

Moreover, it has been observed that there is a basic lack of knowledge about fire safety. This situation leads to many difficulties and incorrect applications during the project phase. Fire safety should be taught in undergraduate education and supported with in-service training. Renovation projects should certainly start with fire safety in mind. Since there are no specific laws related to fire, building use permits are given even if the structures are not designed for fire safety. These regulations should be revised, and fire-related provisions should not be limited to regulations. Inspections should be detailed and meticulous. Among most of country, frequent inspections should be conducted in buildings used for gathering purposes, missing and expired materials (e.g., fire extinguishers) should be addressed, signs should be made visible and readable, and damaged products should be replaced. Due to the importance of these factors, inspectors should be competent individuals.

Unfortunately, the study revealed that national and international fire regulations related to historic buildings are inadequate, and there are no regulations, inspection mechanisms, or guidelines for the fire safety of historic buildings undergoing changes and transformations. This article is considered a fundamental guide to fill this significant gap, ensuring fire safety and identifying fire risks in historic socio-cultural buildings that have undergone functional changes.

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