2025

IL CAPITALE CULTURALE
Studies on the Value of Cultural Heritage

eum

Rivista fondata da Massimo Montella

Il capitale culturale
Studies on the Value of Cultural Heritage
n. 31, 2025

ISSN 2039-2362 (online)

Registrazione al Roc n. 735551 del 14/12/2010

Web http://riviste.unimc.it/index.php/cap-cult, email: icc@unimc.it

Editore / Publisher eum edizioni università di macerata, Corso della Repubblica 51 – 62100 Macerata, tel. (39) 733 258 6081, fax (39) 733 258 6086, http://eum.unimc.it, info.ceum@unimc.it

Layout editor Oltrepagina srl

Progetto grafico / Graphics +crocevia / studio grafico

Rivista accreditata AIDEA
Rivista riconosciuta CUNSTA
Rivista riconosciuta SISMED
Rivista indicizzata WOS
Rivista indicizzata SCOPUS
Rivista indicizzata DOAJ
Inclusa in ERIH-PLUS

Yaman M., Fire Risk Analysis with Risk Matrix Method in Historical Wooden Mosques as Cultural Heritage
«Il capitale culturale», n. 31, 2025, pp. 393-414
ISSN 2039-2362 (online); DOI: 10.13138/2039-2362/3525

Fire Risk Analysis with Risk Matrix Method in Historical Wooden Mosques as Cultural Heritage

Muammer Yaman*

Abstract

Historically, the tradition of using regional materials varied across different geographies. In northern Anatolia, buildings were predominantly constructed using wooden. Preserving wooden structures as cultural heritage is crucial, necessitating strategies against fire risks. This paper aims to assess fire risks in historical wooden buildings and develop recommendations for risk mitigations. To this end, Göğceli Mosque was selected to maintain its original properties amidst a declining number of historical wooden mosques. In-situ observations and risk matrix methods were employed to identify fire risks, while total evacuation time was calculated by simulation environment. Findings highlighted fire hazards such as exposed electrical equipment and fire loads, alongside challenges in exit route alternatives, increasing evacuation times. Through the risk matrix, it is emphasized that there are unacceptable fire risks in the case study. Strategies to mitigate identified risks were developed, emphasizing the applicability of performance-based solutions through risk analysis methods.

Storicamente, la tradizione di utilizzare materiali regionali variava a seconda delle diverse geografie. Nell'Anatolia settentrionale, gli edifici erano prevalentemente costruiti

* Ondokuz Mayis University, Faculty of Architecture, Department of Architecture, OMÜ Güzel Sanatlar Kampüsü, 55100 Ilkadım, Samsun, Türkiye, e-mail: muammer.yaman@omu.edu.tr.

in legno. Preservare le strutture in legno come patrimonio culturale è cruciale e richiede strategie contro i rischi di incendio. Il contributo mira a valutare i rischi di incendio negli edifici storici in legno e sviluppa raccomandazioni per la mitigazione dei rischi. A tal fine, è stata scelta la Moschea Göğceli in quanto conserva le sue caratteristiche originarie nonostante il numero decrescente di moschee storiche in legno. Sono state condotte osservazioni *in situ* e metodi basati su matrici di rischio per identificare i rischi di incendio, mentre il tempo totale di evacuazione è stato calcolato tramite simulazione. I risultati hanno evidenziato pericoli di incendio tra cui le attrezzature elettriche esposte ed elevati carichi di incendio, insieme a difficoltà nella individuazione di vie alternative di fuga, aumentando i tempi di evacuazione. Attraverso la matrice di rischio, si sono evidenziati rischi di incendio inaccettabili rispetto al caso in esame. Sono state sviluppate strategie per mitigare i rischi identificati, sottolineando l'applicabilità di soluzioni basate sulle prestazioni attraverso metodi di analisi del rischio.

1. *Introduction*

The tradition of building wooden structures is a very prevalent design approach in the Black Sea Region. As a result of architecture's use of a regional element as a building material, the region is seen as a representation of the relationship between forest, tree, and wooden structure. The shaping of the architecture of the region, which is rich in forest assets, has also emerged with this approach[1]. Moreover, the closed economic system, the sloping terrain of the region, and the lack of transportation facilities also prioritized the use of region building materials[2]. When the historical building stock is analyzed, civil architecture samples of a certain period especially religious buildings (mosques) were built entirely with wooden materials. Structural systems emerged with the çantı technique, which was created by stacking wooden elements on top of each other[3]. The çantı technique is the overlapping (without nails) of tree logs at the corner points by passing through certain processes[4]. The çantı construction system is a building tradition with unlimited freedom of movement in terms of demountability and portability. The applied technique provides the culture of the society to be shaped within the framework of certain needs and the emergence of tangible and intangible practices defined as verbal/auditory/visual. This situation is great importance for the preservation of tangible and intangible cultural heritage and historical building tradition in the preservation of historical wooden mosques.

[1] Can 2004; Nefes, Gün 2019.
[2] Sözen, Eruzun 1992.
[3] Mısırlı 2022; Yücel 2022.
[4] Tayla 2007.

Typologically, "çantı without nails mosques", whose walls are also made of wooden in the class of wooden mosques, are found in Ordu, Samsun, Trabzon, Rize, Artvin, Düzce, Izmit, Sakarya and their districts and their surroundings in the Black Sea Region[5]. Ayverdi, one of the first researchers on çantı mosques, discussed the mosques in the Western Black Sea region under the title of "*Candı Mosques*" and stated that these works gradually disappeared because they did not see the value they deserved[6]. Outside Türkiye, it is known that similar çantı mosques have been built in the Adjara region of Georgia[7]. Although there are many mosques built with the "çantı technique", one of the wooden construction systems seen extensively in the Black Sea Region, they are among the immovable cultural assets that are in danger of disappearing rapidly[8]. Sensitivity to environmental and climatic conditions such as temperature and humidity changes, light, fungus, insect attacks, wear and tear, fire, earthquake or other natural disasters and destructive actions of humans for the material properties of historically important wooden mosques cause serious damage to the cultural heritage of the northern Anatolian region. This susceptibility brings disaster-related strategies to the forefront in conservation strategies for wooden cultural heritage[9]. It should be provided that the wooden mosques in the region are preserved and their today use continues with the necessary restoration processes.

One of the biggest problems of wooden mosques today is the fire factor. The low flammability class of structural and non-structural elements of mosques, spatial reinforcements (*minber, mihrab,* etc.), decorative elements, and finishing materials (carpets, curtains, etc.) increases the risk of fire[10]. Along with these risks, the fire spreads rapidly within the wooden mosque and the fire resistance time of the structural elements is very short due to the structural system technique. Additionally, the high number of occupants during worship in mosques of historical importance and the low mobility of occupants due to age create a risk within the scope of evacuation conditions[11]. A comprehensive fire risk assessment should be carried out in çantı mosques built with wooden and necessary strategies should be created to eliminate possible risks.

Fire risk assessment is the process of evaluating the fire risks or levels of fire safety provided to occupants and property in a performance-based fire safety design. Fire safety includes the use of fire safety strategies to control the growth of fire and the spread of smoke and to speed up the evacuation of

[5] Bayhan 2014; Furtuna, Ulusoy Binan 2021.
[6] Ayverdi 1989.
[7] Seçkin 2016; Seçkin 2018.
[8] Nefes *et al.* 2015; Yavuz 2009.
[9] ICOMOS 2017.
[10] Yaman, Kurtay 2021.
[11] Newman *et al.* 2020.

occupants and the response of the fire departments[12]. However, none of the fire safety strategies is fully effective. A fire that occurs for any reason can affect the entire building and pose a threat to occupants[13]. In this context, the purpose of fire risks is to highlight the strategies that can be taken at a specific level for occupants and property in fire safety design. A comprehensive risk assessment takes into account all possible undesirable fire scenarios and their consequences. It includes the correlation of expected fire events with the success or failure of several fire safety strategies.

The fire risk assessment process consists of five steps; identifying fire hazards in the building (i), identifying people at risk (ii), assessing whether existing fire safety arrangements are satisfactory or need to be improved, recording the findings (iii), preparing an emergency action plan, conducting information and training activities (iv), and regularly checking the assessments (v)[14]. As a result of the architectural properties and identities of historical wooden mosques, fire risk assessments should be carried out[15]. Occupant evacuation analysis (planning and simulation) in risk assessments is critical for the development of performance-based solutions in fire safety. In research on historical and contemporary mosque typologies, it is necessary to analyze the occupant profile and spatial configuration, analyze occupant behavior, and determine the risks in total evacuation time according to the occupant loads and exit capacities[16]. Preparation of evacuation models based on developing technology, simulation, building information modeling, and artificial intelligence methodologies and their use in fire risk analyses offer an effective fire safety strategy[17]. This study aims to create a set of process methods for fire risk assessment of historical wooden mosques. A fire risk assessment of the historical wooden mosque in Anatolia was conducted with the risk matrix method from qualitative fire risk assessments. With the process management, recommendations were created to reduce the fire risks threatening the wooden mosques of the region. A proposed model for fire safety strategies in historical and contemporary mosques with different planning typologies together with historical wooden mosques has been created.

[12] Moshashaei, Alizadeh 2016.
[13] Yung 2008.
[14] Dobbernack 2003.
[15] Chorlton, Gales 2019; Satir, Toprakli 2021.
[16] Alfakhry, Yahya 2022; Alighadr, Fallahi 2016; Toprakli, Satir 2024; Yaman, Kurtay 2021.
[17] Almatared *et al*. 2024, Ternero *et al*. 2024.

2. *Materials and Method*

To identify the responses of historical wooden buildings to structural fires and to manage the risk assessment process, a case study was conducted. Göğceli Mosque, the oldest known wooden mosque in Anatolia, was taken as a case study and examined. A fire risk assessment was created and an in-situ observation (checklists, photographs, interviews, linear measurements, and observations) was carried out in the historical wooden mosque. The case study was conducted for each accessible area of the building. To accompany the data from the checklist, photographs were also taken as physical evidence of the identified fire risk issues. Linear measurements were taken to record the dimensions of building components relevant to fire safety. Interviews were also conducted with the mosque's officers (*imam* and *muezzin*) to obtain information on the planning of fire safety strategies in the historical wooden mosque. Additionally, problems were identified using the risk matrix method and risk mitigation strategies were suggested. In-situ observations and investigations were carried out on 2024.02.07.

A fire escape plan for Göğceli Mosque was prepared to conduct detailed research of the historical building within the scope of fire risk assessments; exit distances were calculated. Additionally, a fire evacuation simulation was made according to the most intense use situation of Göğceli Mosque. The evacuation simulation of the case study was carried out through the Pathfinder Thunderhead computer program (Pathfinder 2024.01.0605). Pathfinder Thunderhead is an evacuation assessment simulation tool that is simple to use, good to visualize, and easy to implement. Pathfinder uses Agent Based Modeling (ABM). This approach allows simulation of the behavior and interactions of evacuees and modeling of the behavior of large groups[18]. The smoke detectors in the enclosed space operate directly during a fire and provide information to the occupants. Additionally, the spatial organization being a centrally-planned mosque strengthens communication and interaction among occupants. This enables the fire to be detected more quickly and easily, and also allows for a quicker response time. Therefore, the pre-evacuation time has been excluded from the scope of the evacuation analysis. The impact of smoke on occupants during evacuation involves different calculations and analyses, which are not within the scope of this paper. The evacuation simulation was carried out in a scenario where, during any fire, all occupants directly moved to escape and participated in the evacuation process. All methods and processes applied in the research were prepared through diagrams (fig. 1).

[18] Pathfinder 2024.

2.1. Case study

Göğceli Mosque, designed entirely with wooden materials, is located in a historical cemetery east of the Yesilırmak River in Hasanbahce of Carsamba District of Samsun Province. Examination of samples taken from different parts of the oak trees in the building yielded a date of 1206 (dendrochronology) and the cloister (*revak*) was repaired in 1335[19]. However, the fact that the wooden materials of the building are spolia (*spoils*) and that there is no inscription indicates that the construction date of the historical mosque cannot be known with certainty. The mosque was built as a masonry structure with wooden panels made of sliced oak wood with a thickness of approximately 15-18 cm. The wooden panels are connected to each other in the corner areas with the *kurtboğazı geçme (çatma başı)* technique. The three-pitched roof of the building, which has a largely flattened geometry, is covered with tiles. Since the building is made of wooden, it was raised from the ground by means of 60-70 cm logs. Göğceli Mosque has a very large plan layout with dimensions of 17,44*21,55 cm (375.832 m^2). The mosque consists of the narthex (*son cemaat mahali*) located on the north facade, the Harim (12,60*13,70) and a single row of cloisters surrounding these two spaces from the east, west and north[20].

The Harim is entered through a single door in the center of the north facade. Inside the Harim, there are two rows of pillars in groups of three arranged parallel to the mihrab wall (*qibla wall*). These pillars are distributed in a balanced manner within the Harim. The two pillars in the middle of the groups of three are placed on the door-mihrab axis. The pillars generally have a polygonal cross-section (approximately 22-30 cm in diameter) and it is understood that most of them were renewed over time[21]. The dimensions of the wooden panels used on the facades of Göğceli Mosque are quite large, and with these large panels, spacious Harim was created using the masonry technique. This unique approach is one of the elements that make the architecture of the mosque unique. The Harim is illuminated by two windows on the east and west facades. The windows located close to the mihrab wall are slightly smaller. Additionally, a total of six ventilation holes were opened on the mihrab wall in the form of crenellations arranged in two rows, one above the other (lower row windows are measured 30*35 cm externally and 23*27 cm internally). The ones close to the ground were covered with iron cages. However, the light from four windows was insufficient to illuminate this large building. Therefore, the Harim has a half-light or half-dark atmosphere.

[19] Kuniholm 1991; Kuniholm 1995.
[20] Can 2013; Nemlioğlu 2001.
[21] Can 2013; Bayraktar 2009.

Located to the north of the Harim, the narthex (*son cemaat mahali*) has a width of 6,60 m. Its roof is supported by three pillars placed in the center of the space[22]. The pillars are placed in a triangular arrangement, one in front on the mihrab-door axis and the other two at the back. However, today, a support pillar has been added as a result of the axial rotation of the mosque with the effect of live and dead loads. The narthex is surrounded by three facades like the Harim and is surrounded by walls built in masonry style with wooden panels. There is a single door from the center of the entrance cloister on the north facade to the narthex. The Harim is reached through a second door placed on the same axis. Both doors are single and are not original doors. The east and west facades of the narthex and the large openings resembling windows on both sides of the entrance door are covered with wooden cages with amulets. These details give a unique character to the architectural design of the historical building.

The Harim and the narthex are surrounded by a single row of cloisters on the north, east, and west facades. Especially the entrance cloister on the north facade offers an unusual and different arrangement. This cloister is supported by a total of eight pillars and the pillars are placed in the form of a convex arc on the facade. The width at the corners of the cloister is 1,80 m, while the width in the center is 2,43 m. The cloisters on the east and west facades are formed with ten pillars arranged at equal intervals. The width of the side cloisters is 2,42 m. The cloister on the eastern side was later divided at a point close to the center at the level of the northern wall of the Harim, and the part of the cloister extending along the Harim was converted into a women's mahfil by closing the exterior facade. A single door was used for the partition[23]. The cloisters were covered by extending the roof cover of the main building with the same slope. Due to this design, when viewed from a distance, the mosque has a very flattened appearance as if it has collapsed to the ground. According to some remains and statements of region people, the outer side of the cloisters was surrounded by 1 m high wooden railings[24]. These details add a unique touch to the architecture of the mosque (fig. 2).

Göğceli Mosque is a historical building that preserves its functional originality except for the *mimbar (pulpit)* platform. The mihrab has remained original and the plan scheme has preserved its originality. The facade layout, geometry ratios and roof design are original. The section separating the women's mahfil of the cloisters contains a built-in addition. The foundation, walls, pillars, floors and ceiling systems comply with the original construction technique. The building maintains its physical originality through repairs and its

[22] Can 2013.
[23] Danışman 1988; Nemlioğlu 2001.
[24] Nemlioğlu 2001.

structural stability is considered good[25]. It was used as a case study because it is the oldest wooden mosque in Anatolia and has tangible and intangible cultural heritage characteristics[26].

2.2. Fire risk assessments

Fire risk assessment is a performance-based approach to what can harm occupants due to fire in buildings[27]. It helps determine the likelihood of a fire occurring and the fire hazards it poses to people using the building. Its purpose is to determine whether existing fire strategies are sufficient and reasonable relative to the overall risks presented or whether they need to be reduced through control strategies. There are qualitative, quantitative, semi-quantitative likelihood, semi-quantitative consequence, and cost-benefit fire risk assessments[28]. Qualitative fire risk assessment is based on subjective assessments not only of the likelihood of a fire hazard or fire scenario occurring but also of the outcome of such a fire hazard or fire scenario. In qualitative fire risk assessments, there are no numerical values for probability or outcome that can be used to derive the product[29]. In the research, the risk matrix method, one of the qualitative fire risk assessments, was used due to the lack of necessary statistical data and records and the lack of historical fire documents related to wooden mosques.

Risk matrix method is the evaluations obtained by crossing the probability of a fire scenario with the outcome of this scenario. The risk matrix has probability (typically frequency) on axis and consequences on the other axis. Both frequency and consequences are divided into subcategories. The frequencies and consequences that govern risk are threshold levels for decision-making purposes and are independent of the fire safety strategies and properties that govern the risk of individual scenarios[30] (tab. 1). The risk matrix was adapted the NFPA 551 Guide for the Evaluation of Fire Risk Assessments. NFPA 551 guidelines have been adopted for the frequencies and consequences used in risk analysis[31]. Frequencies (probability levels) range from frequent ($p > 0{,}1$), probable ($p > 0{,}001$), occasional probable ($p > 10\text{-}6$), remote ($p < 10\text{-}6$), and improbable ($p \sim 0{,}0$). The risk of each scenario included in the risk assessment is determined by taking into account the fire safety strategies and applicable

[25] Furtuna, Ulusoy Binan 2021.
[26] Tunçay, Yavuz 2023.
[27] Watts, Kaplan 2001.
[28] NFPA 551 2022; Wu, Guo 2018.
[29] Yung 2008.
[30] Akashah *et al.* 2017; Watts 1991.
[31] NFPA 551, Annex A – Explanatory Material 2022.

properties. Such systems and properties provide the level of safety expressed by the corresponding risk compared to the risk levels in the matrix for tolerability and acceptability decisions[32].

	Consequence (Severity)				
Frequency (Probability)	Negligible	Marginal	Major	Critical	Catastrophic
Frequent	Acceptable	Further evaluation	Unacceptable	Unacceptable	Unacceptable
Probable	Acceptable	Further evaluation	Unacceptable	Unacceptable	Unacceptable
Occasional	Acceptable	Acceptable	Further evaluation	Unacceptable	Unacceptable
Remote	Acceptable	Acceptable	Acceptable	Further evaluation	Further evaluation
Improbable	Acceptable	Acceptable	Acceptable	Acceptable	Further evaluation

Table 1. Risk matrix in fire risk assessment (Risk matrix adapted from NFPA 551 Guide for the Evaluation of Fire Risk Assessments)

In the research, fire risk analyzes were examined in five steps. In the steps examined, a detailed analysis was applied as a result of in-situ observations.

- Fire hazards: Fire hazard assessment is a crucial part of the process, as it identifies potential fire sources and the types of fires they could cause.
- Person at risk: A risk analysis should be conducted to determine the profiles and behaviors of occupants in fire safety strategies. Factors such as the occupant loads, their distribution, mobility, level of awareness, and education level play a significant role. The behavior of occupants during a fire and their ability to evacuate should be examined.
- Evaluation, act and regulation principles: This step requires reviewing the existing safety measures to ensure they are effective under current conditions and meet regulatory standards. This process helps verify that the safety protocols in place are adequate for protecting individuals and managing potential risks.
- Records, planning and training: In this step, for risk analysis, records of fire incidents and plans should be kept, fire safety planning should be made, occupants must be informed and occupants must be trained.
- Reviews and revise: It must be ensured that the fire risk assessment is up

[32] Santana *et al*. 2007.

to date and valid. You should revisit your fire-risk assessment if you suspect it is no longer valid, for instance, after a near miss or whenever there is a significant change in the risk level on your premises. Regular reviews are essential to ensure the assessment remains accurate and effective.

3. *Results and Discussion*

Fire risk analyzes were carried out as a result of the investigations and in-situ observations made on the case study. In the risk analyses, risks were identified, evaluated with a risk matrix and risk mitigation strategies were suggested. In the risk matrix, definitions were made according to the colors (red-yellow-green) used to value the impact between the frequencies and consequences of possible risks. For these identifications, strategies should be created to improve unacceptable risks (tab. 2).

Fire Risk Analysis	*Risk*	*Risk Mitigation Strategies*
Fire Hazards		
Heat Sources (Portable Heater, Electrical Equipment, Cigarettes, Lighters, etc.)		Perform regular inspections of equipment conditions. Maintain equipment within their recommended operating range. Create a smoke-free area at a certain distance around the building.
Fire Source		No sources of fire in and around the building.
Fire Load (High Amount of Flammable Material)		Applying impregnation to structural wooden elements and components. Use of fire-resistant material (carpet, furniture etc.) in interior spaces.
Uninterrupted Oxygen in the Fire Triangle (Openings-Doors-Windows-Leaks)		Since the building is a centrally-planned mosque and has a direct relationship with the external environment. Doors, windows, and leaks between wooden elements were explained.
Risk of Arson		Security procedures may limit the likelihood of this hazard.
People at Risk		
Density of Occupant (Occupant Load)		Avoid keeping occupants indoors above the capacity of the building.
Occupant's Age Being Older/Younger		The average age of the occupants is older; but it was not perceived as a threat.
Limitation of Mobility		Position individuals with limited mobility close to escape. Identify occupants who can assist them during evacuation.
Lack of Familiarity		Create evacuation plan diagrams and exit signs at certain intervals in the centrally-planned mosque building

Fire Risk Analysis	*Risk*	*Risk Mitigation Strategies*
Evaluate, Act and Regulation Principles		
Fire Spread		
Low Fire Resistance Class of Materials		Apply impregnation to structural wooden elements and components. Control wooden elements according to structural requirements. (restoration process)
Low Fire Resistance of Building Elements		Apply impregnation to structural wooden elements and components. Control wooden elements according to structural requirements. (restoration process)
Lack of Compartment (Fire and Smoke Zone)		There is no compartment planning due to the centrally-planned mosque design.
Unprotected Openings in the Building (Atriums, Shafts, etc.)		Take passive fire stopping precautions in cable crossings. Add fireproof materials between wooden that do not come into contact with each other.
Fire Prevention		
Restriction of Fire Department Access		Organization of a more comfortable fire department access road. Creation of easy maneuvering areas for the fire truck.
Lack of Indoor Extinguishing Possibility		Keep portable extinguishers at different points. Check their expiration dates.
Lack of Outdoor Extinguishing Possibility		Create uninterrupted water resources with the hydrant system.
Availability of Detection-Warning Systems		Position smoke detectors at the highest point in the space.
Fire Escape		
High Escape Route Distances		High escape route distances. Existing one-way escape distances are higher than necessary.
Lack of Alternative Escape Routes (Different Alternatives)		No alternative exit route. Evaluation of exit alternatives from windows during fire.
Detection of Escape Route Obstacles		There are no obstacles in the escape route.
Inappropriate Exit Doors (Opening Direction, Unlocking Status and Clear Opening, Material)		The opening direction of the exit door is to the inside (in the Harim). Insufficient exit door width increases evacuation time. The exit door was made of wooden materials.
Insufficiency of Escape Directions		Visibility of exit in a centrally-planned mosque layout.
High Total Evacuation Time (Comparative Analysis of Evacuation Simulation Based on Current Statistics)		Create alternative escape routes. (Windows may be an alternative for the escape route.) Limit occupant load to a certain capacity in the Harim.

Fire Risk Analysis	*Risk*	*Risk Mitigation Strategies*
Record, Plan and Train		
Prepare a Fire Action Plan		An integrated fire action plan should be created with mosque officers (imam and muezzin) and occupants.
Training of Officials-Occupants		Provide fire safety training for mosque officials and occupants. Conduct fire drills periodically. Preparation of emergency evacuation plans, and fire master plans
Distribution of Tasks During Fire		Distribution of tasks for mosque officials and occupants. (extinguishing, rescue, first aid, etc.)
Review & Revise		
Fire Incidents for the Building and Its Surroundings	N/A	It could not be detected in the records, statistics, or risk analysis.
Additional Designs to the Building Affecting Fire Risks		Imam room was added. However, it is envisaged that it will be removed in the restoration projects prepared for the historical building.

Table 2. Fire risk analysis and mitigation strategies of case study (by author)

According to fire risk analyses, the amount of fuel in the environment poses a great danger in terms of fire outbreak[33]. The presence of electrical equipment (HVAC and lighting devices) exposed electrical equipment and the absence of a smoking area around it pose a threat in the historical building examined within the scope of the case study (fig. 3). The absence of fire source areas (kitchen, boiler rooms, etc.) in the historical building was considered as a risk-reducing factor. The construction of the mosque is made of wooden and the presence of carpets poses a risk of fire spread. Uninterrupted oxygen in the fire triangle during a fire is not possible for the centrally-planned mosque layout of the historical building. Therefore, it was not evaluated within the scope of risk. There are ten windows of different sizes and a door in the Harim. The fact that the windows and the door are usually closed for security reasons interrupts the oxygen. Leaks between the wooden elements may cause oxygen to be continuous and the fire to continue. However, lightning can also be a threat to fire in historical buildings[34]. It was determined that there was no lightning rod near the examined historical wooden mosque. Additionally, since the risk of arson is a threat to religious buildings, necessary strategies must be taken[35].

The capacity of the historical building was determined as approximately 332 occupants in the person risks from the fire risk analysis. The total occu-

[33] Akashah *et al*. 2016.
[34] Huang *et al*. 2009.
[35] Akyön, Özcan 2017.

pant load in the historical wooden mosque is based on the NFPA 101 Life Safety Code and Türkiye's Regulation on Fire Protection occupant load coefficient (1,5 m^2/person)[36]. The wooden mosque cannot accommodate more occupants during worship. However, the number of occupants, which is not perceived as a major threat to the historical mosque, should be evaluated together with the age and mobility of the occupants[37]. It was found that the risks of the number of occupants and the age of the occupants were rated on a medium scale. However, the fact that occupants are generally elderly individuals limits their mobility. In the case study, it was determined that elderly individuals recognize the building and have high awareness.

The fact that the mosque is a centrally-planned mosque within the scope of evaluation and regulation principles from fire risk analysis does not make it possible to create compartments. However, it has been determined that building materials and building elements cannot provide the necessary performance within the scope of fire risks as a result of the past centuries. Especially the deterioration and structural collapse of wooden elements in contact with the exterior proves the magnitude of this risk. The fact that the cables are exposed and allowed to circulate throughout the building without taking precautions in the openings inside the building poses a threat in terms of fire. The historical building has fire department access in case of a possible fire. However, the roads accessing the building should be widened in this context and a more comfortable maneuvering area should be created. There are portable fire extinguishers indoors. However, there is no hydrant system outside, there are fountains to supply water. There is fire detection (smoke detectors) and warning systems in the historical building. Smoke detectors were installed where the roof meets the wall, rather than at the highest point. This placement could reduce their effectiveness due to the way smoke spreads. During a fire, smoke alarm systems may not be fully efficient, relying more heavily on occupants visually detecting fires rather than being alerted promptly by the detectors. Due to the lack of alternative escape routes for escape distances, one-way exit (common path) distances (approximately 27 m) were examined and found to be high distances for a historical building without automatic sprinkler systems (fig. 4)[38]. No obstacles were encountered on the escape route. However, it is thought that opening the exterior escape doors to the interior may pose a risk for congestions during escape. Since it is a direct circulation door, it is not locked. It was determined that exit signs for the escape were insufficient in the wooden historical mosque. However, providing exits through the door used for common entrance reduces the need for guidance.

[36] NFPA 101 2024; TRFP 2007; Yaman, Kurtay 2021.
[37] Kobes *et al.* 2010.
[38] TRFP 2007 Appendix-5/B; Appendix-14.

Evacuation analysis was performed at full occupancy capacity of the occupants of the historical wooden mosque. In the evacuation analysis, it was assumed that the occupants consisted of elderly individuals as the riskiest group and the speeds were taken as 1,05-1,2 m/s for men and 1,04-1 m/s for women[39]. Simultaneous total evacuation time during fire evacuation was analyzed. In the evacuation simulation, the occupants in the mosque are considered randomly distributed. The total evacuation time of the occupants (332 people) was 176,3 s (approximately 3 min). Congestion represents a recurrent condition over simulation time at Exit Door-1 and Exit Door-2. A scene from the evacuation simulation is presented where the flow rate at Exit Door-1 is minimal during the congestion period (fig. 5). Depending on the number of occupants in the historical wooden mosque, the total evacuation time was too high for buildings of similar building class. Yaman and Kurtay found that a much higher number of occupants (1131 people) evacuated in about 3 m depending on different scenarios[40]. Azkur and Oral determined a total evacuation time of 10 m 48 s with a high number of occupants (2849 people) in a mosque[41]. Toprakli and Satir determined the total evacuation time between 8 m 20 s (Süleymaniye Mosque; 4799 people) and 2 m 46 s (Kılıc Ali Pasa Mosque; 1141 people) depending on the high occupant's number in their evacuation analysis in various historical mosques[42]. The fact that the exit doors from the Harim and the narthex (*son cemaat mahali*) as the main space are non-alternative and narrow (*bootleneck*) caused congestions at these points. In the women's mahfil, it was determined that the total number of occupants was completely evacuated within the first 60th s.

Preparing a fire action plan within the scope of records, planning, and training principles from risk analysis was deemed necessary. Strategies that can be applied before a fire and interventions that can be done during a fire should be created. The action plan can also be a pioneering work for creating a regional fire master plan. It is deemed necessary to provide training to officials-occupants (the historical wooden mosque has a fixed occupant potential) within the scope of the fire action plan. In training, task distribution during a fire should be defined and individual responsibilities regarding fire risks should be defined. Within the scope of risk analysis investigations, no previous fires in the building and its surroundings could be detected. It is necessary to keep fire statistics of the cemetery where the historical wooden mosque is located and the residential area around it. The imam's room, which was built later in the building, does not pose a fire risk. However, it should not be forgotten that the building should be evaluated through the restoration process.

[39] Fitzpatrick *et al*. 2006; Yeo, He 2009.
[40] Yaman, Kurtay 2021.
[41] Azkur, Oral 2022.
[42] Toprakli, Satir 2024.

The method for fire risk assessments in historical wooden buildings designed in the research was examined on a case study. The method consists of a literature review, in-situ observations, evacuation analysis, risk matrix, and mitigation strategies for wooden mosques. Through this method, sophisticated fire risk assessments of historical mosques (the four-iwan and the centrally-planned mosque) are provided. It emphasizes that there are unacceptable fire risks in the case study of wooden mosques and that risk mitigation strategies should be explained. It should be recognized that fire risk assessments can be adapted and applied to different building typologies.

4. *Conclusion*

The solution for fire safety in historical wooden mosques requires a performance assessment that explicitly demonstrates that the fire safety objectives have been achieved. In the case of historical wooden mosques, fire safety assessments include life safety, but also include adequate protection of cultural heritage. Many historical wooden mosques have properties that make them inherently safe, even if not fully compliant with current codes and regulation. For this purpose, the research was conducted on a sample of historical wooden mosques to conduct a fire risk assessment and eliminate potential risks. The research covers the testing of the methodology and process management developed in the research with a case study. With the methodology and process management, the fire risks that threaten the historical wooden mosques of the region are analyzed and the necessary recommendations are presented to reduce them. A comprehensive qualitative research was carried out on the elimination of fire hazards, minimizing the possible threats to the occupant profile during the fire, resolving fire escape and evacuation scenarios quickly and effectively, preparing emergency action plans and training, and periodic inspections of fire-related records. The research presents a comprehensive fire risk analysis management for historical wooden mosques in the Black Sea region. Although the research focuses on historical wooden mosques, it also provides a method that can be used for the four-iwan and centrally-planned mosque in terms of space organization. The method and process created in the research can also be applied on historical and contemporary mosque. The research envisages producing performance-based solutions in fire safety-oriented approaches for cultural heritage and constituting an important resource for architects, engineers, fire safety, and restoration experts. In future research, it is recommended to conduct fire risk assessments by using fire and smoke simulations in historical buildings and to develop rational and valid holistic risk mitigation strategies through artificial intelligence, machine learning, and building information modeling.

Acknowledgements

The author would like to thank the Samsun Regional Directorate of Foundations and Republic of Türkiye Directorate General of Foundations for their permission and help during the research.

References

Akashah F.W., Baaki T.K., Lee S.P. (2017), *Fire risk assessment of low cost high rise residential buildings in Kuala Lumpur: A case study*, «Journal of Design and Built Environment», special issue: Livable Built Environment, 17, pp. 124-139.

Akashah F.W., Wan-Teh W.S.N., Baaki T.K. (2016), *Fire risk assessment of historic buildings in Malacca World Heritage Site*, «The Malaysian Surveyor», 51, 4, pp. 30-38.

Akyön F.V., Özcan, S. (2017), *Evaluation of fire risks in mosques*, International Exhibition and Symposium on Fire and Safety, TUYAK, Istanbul, Türkiye.

Alfakhry A.A., Yahya L.M. (2022), *A simulation study to suggest an emergency exits in Mosul's mosques in case of emergency*, «International Journal of Safety and Security Engineering», 12, 5, pp. 569-575.

Alighadr S., Fallahi A. (2016), *DEM evaluation of evacuation behavior: a case study of "The Mosque of ASMU"*, «Journal of Seismology and Earthquake Engineering», 18, 1, pp. 47-58.

Almatared M., Liu H., Abudayyeh O., Hakim O., Sulaiman M. (2024), *Digital-twin-based fire safety management framework for smart buildings*, «Buildings», 14, 4.

Ayverdi E.H. (1989), *Osmanlı mimarisinin ilk devri (Ertuğrul, Osman, Orhan Gaziler, Hüdavendigar ve Yıldırım Beyazıt 630-805 (1230-1402) I*, Istanbul: Istanbul Fetih Cemiyeti Yayınları.

Azkur H.S., Oral M. (2022), *Evacuation problem in mosque buildings, the case of Konya Hacıveyiszade Mosque*, «Journal of Architectural Sciences and Applications», 7, 1, pp. 235-247.

Bayhan A.A. (2014), *Ordu/Perşembe'den iki ahşap çantı cami örneği*, «TÜBA-KED Türkiye Bilimler Akademisi Kültür Envanteri Dergisi», 12, pp. 99-107.

Bayraktar M.S. (2009), *Samsun'da Anadolu Selçuklu ve Ilhanlı Döneminden kalan tarihi yapılar*, «Uluslararası Sosyal Araştırmalar Dergisi», 7, 2, pp. 85-118.

Can Y. (2004), *Samsun yöresinde bulunan ahşap camiler*, Istanbul: Etüt Yayınları, Türkiye.

Can Y. (2013), *Samsun'da bulunan iki önemli ahşap eser* Gökçeli ve Bekdemir Camileri, in *Samsun Araştırmaları III. Kitap Mimari ve Kültürel Miras, Ejsane, Dil, Sanat, Edebiyat ve Siyaset*, C. Yılmaz (Ed.), Samsun: Erol Offset, pp. 23-42.

Chorlton B., Gales J. (2019), *Fire performance of cultural heritage and contemporary timbers*, «Engineering Structures», 201, 109739.

Çarşamba Municipality (2018), *Tarihi Göğceli Camii (Çivisiz Camii)*. <https://www.carsamba.bel.tr/icerik/tarihi-gogceli-camii>, 18.02.2024.

Danışman G. (1988), *Samsun yöresi ahşap mimarisinin gelenekselliği-Bafra İkiztepe arkeolojik verilerinin ışığında* Çarşamba Gökçeli Camii›nin incelenmesi, IX Türk Tarih Kongresi Bildirileri, Ankara, n. 1, pp. 135-144.

Dobbernack R. (2003), *Fire Risk Assessment Methods*, Final Report of Workgroup 6 – Fire Risk Evaluation to European Cultural Heritage – FIRE-TECH.

Fitzpatrick K., Brewer M.A., Turner S. (2006), *Another look at pedestrian walking speed*, «Transportation Research Record: Journal of the Transportation Research Board», 1982, 1, pp. 21-29.

Furtuna Ç. (2018), *Samsun-Çarşamba'da* çantı tekniğinde inşa edilmiş ahşap camilerin belgelenmesi ve vernaküler mimari miras bağlamında incelenmesi, Mimar Sinan Güzel Sanatlar Üniversitesi Fen Bilimleri Enstitüsü Mimarlık Anabilim Dalı Yüksek Lisans Tezi, Istanbul: Master's Thesis.

Furtuna Ç., Ulusoy Binan D. (2021), *Samsun-Çarşamba'da çantı tekniği'nde inşa edilmiş ahşap camilerin korunmalarına yönelik belgeleme ve değerlendirme yaklaşımı*, «TÜBA-KED Türkiye Bilimler Akademisi Kültür Envanteri Dergisi», 23, pp. 11-36.

Huang D., Li L., Zhang H., Shi L., Xu C., Li Y., Yang H. (2009), *Recent progresses in research of fire protection on historic buildings*, «Journal of Applied Fire Science», 19, 1, pp. 63-81.

ICOMOS (2017), *Ahşap Mimari Mirasın Korunması Için Ilkeleri*, ICOMOS, Uluslararası Anıtlar ve Sitler Konseyi Türkiye Milli Komitesi. <http://www.icomos.org.tr/Dosyalar/ICOMOSTR_tr0633313001536913605.pdf, 20.11.2024>.

Kobes M., Helsloot I., Vries B., Post J.G. (2010), *Building safety and human behaviour in fire: A literature review*, «Fire Safety Journal», 45, pp. 1-11.

Kuniholm P.I. (1991), *A 1503 – Year cronology for the Bronze and Iran Ages 1990-1991 progress report of the Aegean Dendrochronology Project*, VII. Arkeometri Sonuçları Toplantısı, Çanakkale, Türkiye, pp. 121-130.

Kuniholm P.I. (1995), *Aegean Dendrochronology Project: 1993-1994*, XI. Arkeometri Sonuçları Toplantısı, Ankara, Türkiye, pp. 121-130.

Mısırlı A. (2022), *Zonguldak/Çaycuma'da çanti tekniğinde inşa edilmiş bir cami: Akçahatipler Köyü Cami*, «TÜBA-KED Türkiye Bilimler Akademisi Kültür Envanteri Dergisi», 26, pp. 55-70.

Moshashaei P., Alizadeh S.S. (2016), *Fire risk assessment: A systematic review of the methodology and functional areas*, «Iranian Journal of Health, Safety & Environment», 4, 1, pp. 654-669.

Nefes G., Gün, R. (2019), *Samsun/Yakakent'te çantı tekniğinde inşa edilen geleneksel köy camileri*, «Uluslararası Sosyal Araştırmalar Dergisi», 12, 68, pp. 595-605.
Nefes G., Gün R., Çakır A. (2015), *Samsun/Bafra İlçesi'nde çantı tekniğinde inşa edilmiş bir grup ahşap camii*, «Dinbilimleri Akademik Araştırma Dergisi», 15, 2, pp. 291-317.
Nemlioğlu C. (2001), *Göçeli (Gökçeli) Cami*, I. Uluslararası Selçuklu Kültür ve Medeniyeti Kongresi, III, Cilt, Konya, Türkiye.
Newman J.P., Minguez B.G., Kawakami K., Akieda Y.I. (2020), *Resilient Cultural Heritage: Learning from the Japanese Experience (English)*, Washington, DC: World Bank Group.
NFPA 551 (2022), *NFPA 551 Guide for the Evaluation of Fire Risk Assessments*, USA: National Fire Protection Association (NFPA).
NFPA 101 (2024), *NFPA 101 Life Safety Code*, USA: National Fire Protection Association (NFPA).
Pathfinder (2024), *Pathfinder user manual*, Version: 2024-1, Thunderhead Engineering.
Santana M.L.A., Rodrigues J.P., Leça Coelho A., Charreau G.L. (2007), *Fire risk assessment of historical areas: The case of Montemor-o-Ve*lho, «WIT Transactions on Engineering Sciences, The Art of Resisting Extreme Natural Forces», 58, pp. 81-90.
Satir M.S., Toprakli A.Y. (2021), *Qualitative and quantitative analysis of fire evacuation risks of 18 historical mosques in Ankara-Altındağ region*, «Journal of the Faculty of Engineering and Architecture of Gazi University», 36, 3, pp. 1613-1629.
Seçkin S. (2016), *Decorative features in the Ottoman Structure in Georgia Adjara*, «Methodological Aproaches to Social Sciences», 8, 2, pp. 45-58.
Seçkin S. (2018), *Gürcistan/Acara Keda bölgesi'ndeki Osmanlı Dönemi camileri*, «Turkish Studies Social Sciences», 13, 18, pp. 1133-1169.
Sözen M., Eruzun C. (1992), *Anadolu'da Ev ve Insan*, Istanbul: Emlak Bankası.
Tayla H. (2007), *Geleneksel Türk Mimarisinde Yapı Sistem ve Elemanları 1*, Istanbul: Cilt.
Ternero R., Fuertes G., Alfaro M., Vargas M., Sabattin J., Gutierrez S., Duran C. (2024), *Artificial intelligence methodologies for building evacuation plan modeling*, «Journal of Building Engineering», 96, 110408.
Toprakli A.Y., Satir M.S. (2024), *Assessing evacuation risks in prominent historical mosques: An integrated quantitative and qualitative approach via the HM-ERI framework*, «International Journal of Disaster Risk Reduction», 113, 104866.
TRFP (2007), *Türkiye's Regulation on Fire Protection*, Ankara, Türkiye: Council of Ministers.
Tunçay H., Yavuz E. (2023), *Gelenekten Geleceğe Ahşap Camiler*, Ankara: Tunçay Yayıncılık, Birinci Baskı, pp. 102-105.

Watts J.M. (1991), *Criteria for fire risk ranking*, Fire Safety Science – Proceedings of the Third International Symposium, n. 3, pp. 457-466.
Watts J.M., Kaplan M.E. (2001), *Fire risk index for historic buildings*, «Fire Technology Journal», 37, pp. 167-180.
Wu L., Guo S. (2018), *Comparison and analysis of building fire risk assessment methods*, 3rd International Conference on System Reliability and Safety (ICSRS), Barcelona, Spain: IEEE.
Yaman M., Kurtay C. (2021), *Investigation on evacuation scenarios according to occupant profile in mosques through different fire regulations*, «A|Z ITU Journal of the Faculty of Architecture», 18, 2, pp. 477-489.
Yavuz M. (2009), *Çaykara ve Dernekpazarı'nda Geleneksel Köy Camileri*, Ankara: Türkiye Diyanet Vakfi Yayınları.
Yeo S.K., He Y. (2009), *Commuter characteristics in mass rapid transit stations in Singapore*, «Fire Safety Journal», 44, 2, pp. 183-191.
Yung D. (2008), *Principles of Fire Risk Assessment in Buildings*, London: Wiley, pp. 5-16.
Yücel G. (2022), *Risk altındaki kültürel miras: Karadeniz Bölgesi'ndeki geleneksel ahşap yığma (çantı) camiler için değerlendirme*, «Kent Akademisi», 15, 2, pp. 481-505.

Appendix

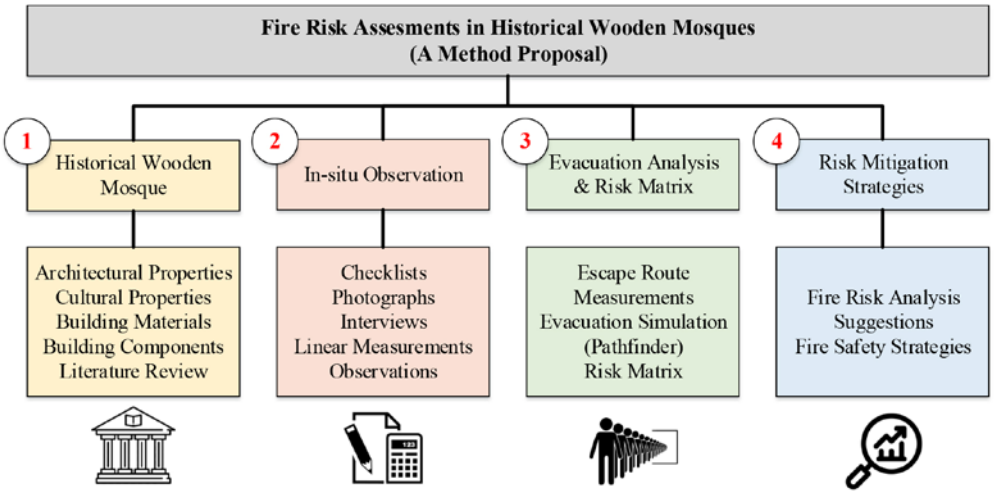

Fig. 1. Method and process of the research (by author)

Fig. 2. Göğceli Mosque plan and exits (a) (Furtuna, 2018, adapted), Outdoor environment (b) (adapted from the official accounts of Çarşamba Municipality) and Harim (c) (by author)

Fig. 3. Electrical equipment in case of fire hazards (by author)

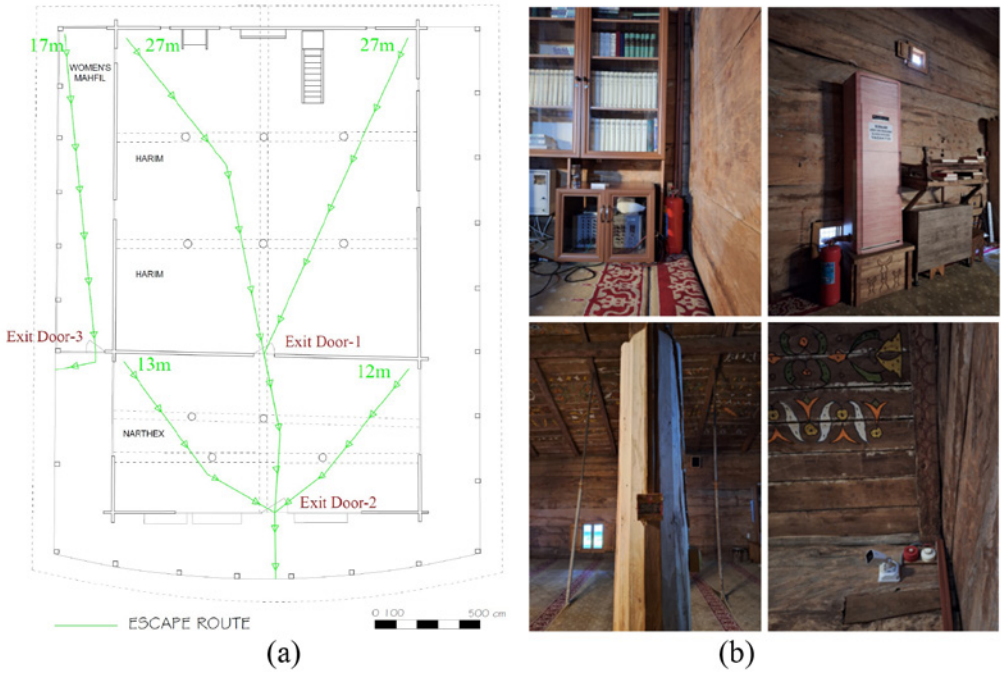

Fig. 4. Escape distances in the plan of a historical wooden mosque (a) and portable fire extinguishers and fire warning-alarm and smoke detection systems (by author)

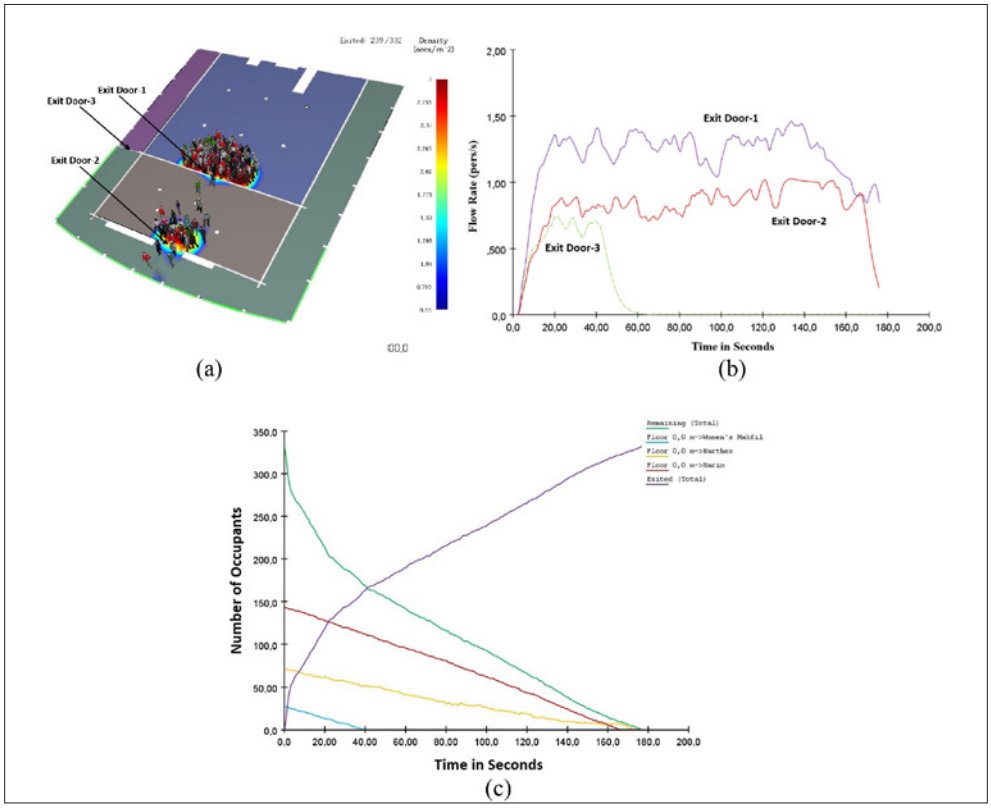

Fig. 5. Congestions at 100th s (a), flow rates at exit doors (b) and room evacuation and total evacuation time (c) (by author)

JOURNAL OF THE DIVISION OF CULTURAL HERITAGE
Department of Education, Cultural Heritage and Tourism
University of Macerata

http://riviste.unimc.it/index.php/cap-cult/index

eum edizioni università di macerata

ISSN 2039-2362