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Investigation on evacuation scenarios according to occupant profile in mosques through different fire regulations

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Abstract

Structural fires cause excessive life and property loss. The reduction of life and property loss in fire, risk management is achieved by evacuation scenarios and occupant profile in proper and real manner. Assembly buildings should be considered and evaluated as areas of intensive use, especially for evacuation scenarios and occupant profile. Within the scope of the study, the occupant profile for mosques as an assembly building with independent exits created with single space was analysed, fire safety risks were identified and evacuation scenarios were determined. The occupant profile and evacuation scenarios are crossed and evacuation risk combinations are created for mosques. Within the context of evacuation risk combinations, the building occupant load was calculated according to the occupant load coefficients of the fire regulations of Turkey, USA, UK, New Zealand, Singapore and Australia via the Canik Central Mosque sample. Building occupant loads were calculated according to regulations and evacuation times were calculated through Pathfinder simulation program. It was found that there were large differences between the resulting evacuation times. The study concluded that differences in occupant load coefficients found in fire regulation greatly affected evacuation times. In mosques whose floors have independent exits, especially the upper floor (mahfil) is the determinant of evacuation times. The need to design alternative exits where two exits are not sufficient for the mahfil has been determined. As the transition to performance-based fire regulation systems has accelerated, it has been determined that occupant load coefficients are an important parameter in calculating evacuation times for mosques.

Keywords
Evacuation time, Evacuation scenario, Occupant load, Assembly buildings, Fire regulations.

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1. Introduction

Structure fires pose a great threat to the life safety of occupants. Fires cause great casualties in buildings due to the high occupant density and the presence of large amounts of combustible materials in the environment. It is necessary to eliminate the possible threats and fire causing factors and to create fire safety precautions in buildings (Sun & Turkan, 2020). According to the International Association of Fire and Rescue Services (CTIF) 2019 World Fire Statistics Report, thousands of people die due to structure fires (Table 1). The statistical results, which we encounter with large numbers in different countries, reveal the necessity of researches on fire safety precautions.

Turkey is located in the 500-1000 range (the result of a fire casualties in 2016). The fires that occur are far above casualties. Istanbul, where most of the population in Turkey, revealed the structure fire statistics confirm this situation. When the structure fire statistics for Metropole Istanbul have been examined, fires increase the risk factor even further. Although they have decreased in number from the various periods to the present, fires continue to be a major threat to human life (Istanbul Fire Department Report, 2020). Building fire safety precautions and effective evacuation planning in buildings where occupant density is high are effective in reducing the number of injuries/deaths.

The creation of fire safety precautions in buildings is assured by fire regulations. The recent fires and results revealed the need to reconsider and evaluate the fire regulation during the building design and construction process. There are passive and active fire safety precautions created within the framework of fire regulations. Passive fire safety precautions cover the principles set up during the design process and require integration with the architectural project. It includes fire safety precautions that must be taken at the context of the settlement, building, building elements and building materials. Design of escape routes, identification of occupant profile and creation of evacuation scenarios are sub-topics of passive fire safety precautions. Active fire safety precautions constitute the whole of mechanical systems that contribute to passive fire safety precautions in the architectural project. It provides the most appropriate and effective solutions to support passive fire safety precautions by setting them up at the design process such as adding them to the existing project later. Smoke detection and warning systems, emergency guidance systems, smoke control and automatic extinguishing systems are the sub-topics of active fire safety precautions (Demirel et al., 2017; Rahardjo & Prihanton, 2020). In the architectural design process, it is important to create passive and active fire safety precautions together within the framework of fire safety precautions. However, in the architectural design process expected from the designer (architect), the passive fire safety precautions are designed to be at the highest level and in all possible evacuation scenarios, it is aimed to provide appropriate evacuation conditions and evacuation time.

Today, although the fire regulation requirements of the countries have been created over a certain period of

Table 1. *Distribution of casualties caused by fire (2016).*

Deaths from Fire (2016)	Surveyed Countries
10 000 - 50 000	China, India
7 000 - 10 000	Russia, Nigeria
3 000 - 7000	USA, Pakistan, Congo
2000 - 3000	Sudan, Côte d'Ivoire, South Africa, Uganda, Tanzania
1000 - 2000	Ghana, Burkina Faso, Chad, Japan, Angola, Niger, Myanmar, Kenya, Somalia, Mozambique, Cameroon, Brazil, Yemen, Iran, Bangladesh, Ukraine, Indonesia, Egypt
500 -1000	Poland, Sri Lanka, Benin, Mexico, Malawi, Guinea, Iraq, Belarus Haiti, Saudi Arabia, Algeria, Turkey, Zimbabwe, South Sudan, Zambia, Burundi, Madagascar, Philippines, Mali, Thailand
400 - 500	Germany, Vietnam, Kazakhstan, Nepal, Sierra Leone, Uzbekistan, Afghanistan, Rwanda, Morocco, Senegal, Peru,
300 - 400	DPR of Korea, Republic of Korea, United Kingdom, Togo, Chile, Cambodia, France, Argentina, Romania

(Source: World Fire Statictics Report, 2019) time (occupant access to the safe area), various differences have been observed in building evacuation times. It is important to create building specific evacuation risk combinations by occupant based evacuation scenarios in buildings (Hadjisophocleous & Bénichou, 2000). For this purpose, the transition from prescriptive-based systems to performance-based systems is accelerated in fire regulations in developed countries in the field of fire safety and project specific-occupant based evacuation scenarios are created within the framework of building fire risk assessments (Hall & Watts, 2008; Meacham, 2010). Some prominent countries such as the United States of America, the United Kingdom, Canada, Sweden, New Zealand and Australia are at an advanced phase in the development and application of performance-based fire regulation systems. Evacuation scenarios, fire and smoke models are developed in the creation of performance-based fire safety precautions (Tavares & Galea, 2009).

Turkey's Regulation on Fire Protection (TRFP) as part of structure fire safety precautions in Turkey came into force in 2002 and has undergone several revisions to its current use (TRFP, 2015). It is clearly stated that the rules contained in the regulation are binding and that their provisions are decisive, except for the specific building groups (in the areas of metro, marina, heliport, tunnel, stadium, airport and similar use areas, in case there are not sufficient provisions in the regulation). In this case TRFP, prepared as a prescriptive-regulation; limits the use, adoption and dissemination of performance-based approaches to a certain extent.

In occupant based evacuation scenarios within the framework of passive fire safety precautions, it is important to define the building occupant profile and develop evacuation scenarios. The evacuation time of occupants in the building during the fire is largely positively correlated with building occupant load. When the building occupant evacuates the building within the appropriate time under normal conditions, this time increases greatly depending on the situation of escape and panic as the occupant density increases. The impact of occupant load on evacuation time poses a major threat, especially in assembly buildings. It should be aimed to address the risks such as intensive use in assembly buildings, involving different age groups, occupant's recognition of the building and performance concentration requirements, and to create performance-based fire safety precautions specific to the project. (Kucera & Strakosova, 2013).

When the fire regulations are examined, as a comprehensive class for assembly buildings cover places of worship, eating and drinking facilities, entertainment venues, museums, exhibition halls, gymnasiums, conference and concert halls, terminals, including airports and ports. Within the scope of fire regulations, mosques are evaluated in the category of assembly buildings. When searching at the Turkish mosque building stock, a lot of mosques have been built within the borders of Turkey recently and are still being built. There are no regulations that contain occupant based evacuation scenarios for performance-based fire safety precautions. Given the intensive use of mosques, it is necessary to determine the occupant profile and to design evacuation scenarios. It is necessary to examine the occupant profile for mosques, especially with the occupant load coefficients determined in the fire regulations of countries. It is very important that the occupant load in the building is analysed correctly and transferred as input to the project in order to create performance-based fire safety precautions.

2. Methodology of the study

Passive fire safety precautions for mosques as an assembly building have been addressed and occupant based evacuation scenarios have been emphasized. Within the scope of the study, occupant profiles for mosques were determined and evacuation scenarios deemed necessary within the framework of fire safety were determined. Two main components, identified as occupant profile and evacuation scenarios, were crossed and evacuation risk combinations were created. In order to calculate the evacuation times of the evacuation risk combinations, a mosque project within the borders of Turkey with independent exits in building has been discussed. Evacuation times were determined using the Pathfinder Simulation Program within the framework of fire regulations for the Canik Central Mosque, which is considered as a sample (Pathfinder, 2012: Pathfinder, 2017).

In determining of the occupant load, Turkey-Turkey's Regulation on Fire Protection (TRFP, 2015), United States of America-NFPA Life Safety Code 101 (NFPA 101, 2018), United Kingdom-BS 9999 Fire Safety in the Design, Management and Use of Buildings, Code of Practice (BS 9999, 2017), New Zealand-Acceptable Solutions and Verification Methods (NZBC, 2017), Singapore- Code of Practice for Fire Precautions in Buildings (SCDF, 2018) and Australia-National Construction Code Volume 1 (NCC, 2019) fire regulations, standards and codes have been reviewed. In the framework of the mosque, which is considered as a case study, evacuation times were determined and evaluations have been made depending on the occupant load coefficients found in the fire regulations. Comparing the evacuation times in evacuation risk combinations, it was determined that major differences were observed, and the differences were due to the occupant load coefficient taken from fire regulations. Assessments on evacuation times have been made in the creation of performance-based fire safety precautions for mosques. Proposals have been developed about the planning of the evacuation of mosques with independent exits in buildings created with the design of single space.

3. Risk assessments for fire safety precautions in mosques

Mosques are places of worship arising from the orientation of the general form decision to the Qibla. In the period from the past to the present, mosques are used as wide volumes where different functions are performed for worship, education and gathering (Rasdi & Utaberta, 2010). As an intensive use area, mosques gather different age groups in single space. The single space planned is called harim. In today's mosque planning, the harim is followed by a gallery floor connected with the side walls and back walls. This gallery floor is defined as mahfil. Considering the burden of the occupant depending on the mosque planning, it is inevitable that an environment of chaos will occur in a possible fire. Especially for mosques, there is a high rate of accumulation at the exit after worship and the occupants cause clutter at the exit doors.

The most important factor in the emergence of the fire in mosques is arson. As a worship building, fires occur in mosques with the effects of various gains and ideologies. Arson has become the main problem, especially in mosque fires that occur in different countries (Akyön & Özcan, 2017). According to Anadolu Agency data, Denmark in 2020, the US state of Connecticut in 2019, Germany in 2019, the US state of Florida in 2017, France in 2016, Canada in 2015, Sweden in 2016, the capital of Sweden, Stockholm in 2014 fires emerged as a result of arson. Turkey borders of arson in the period up to the present from the past caused many mosques have emerged with fire (Anadolu Agency, 2020). A lot of people were injured and died as a result of mosque arson. Fires caused by arson, especially in mosques, require the provision of necessary safety precautions and evacuation risk combinations of at appropriate evacuation times.

Mosques are designed and constructed in similar schemes in functional form. However, connections between floors and escape route designs are changing; this situation requires the creation of different evacuation scenarios. In order to determine the evacuation times by designing evacuation scenarios, the relationship between the harim and mahfil floor should be examined (Berksan, 2015). Different evacuation scenarios arise in the mosques designed independently from each other in the planning of harim and mahfil escape routes and mosques designed using interconnected, common entrance/exit. Mosques with different entrances/exits for the harim and mahfil floors give more appropriate evacuation results during evacuation times to prevent accumulation.

The architectural form of the mosque did not change much during the period from the past to the present. Mosques produced from similar forms have valuable examples that can survive to date as an important cultural heritage. Especially in huge mosques with high occupant load, the risks for fire safety precautions increase more. Different fire safety precautions have been adopted in national and international fire regulations, especially for historical buildings. However, it should not be forgotten that mosques are at high risk as an assembly building. It is appropriate to make a different risk assessment for mosques in historical buildings and the suggestions that can be applied should not be against the restoration principles of the historical building.

In the event of a possible fire in mosques, all occupants are exposed to fire and smoke in the same way. In this case, it becomes necessary to evacuate all the occupants in the building within the same period. Within the framework of national and international fire regulations, it is appropriate to carry out simultaneous-full evacuation planning in mosques as an assembly building in case of emergency (Chow, 2007). This situation arises from the fact that the architectural form of the mosque has been created with single space building. Fire risk assessments determined in mosque planning are as follows:

- The fact that there is a single space design in interior planning facilitates the alternative of escape route design. Having alternative escapes to each other facilitates risk management, and this contributes to shortening the evacuation time. At the same time, the evacuation time takes place more quickly with the effectiveness of fire detection, warning and guidance systems. However, single space causes fire and smoke to spread rapidly indoors. This situation makes it difficult for compartment and horizontal evacuation possibilities in buildings.
- With the adoption of traditional construction technique in mosques, main entrance doors are generally opened towards the interior. This situation creates an accumulation in the last exit doors during the fire and causes the evacuation time to be extended (Topraklı et al., 2019). In this study, the opening direction of all doors was excluded in determining the evacuation times.
- The use of carpets in the interior changes the occupants' behaviour at the last exit in the fire evacuation. Occupants may tend to take their shoes. This situation causes the evacuation time to be extended (Nassar & Bayyoumi, 2012). In this study, the tendency to take shoes was excluded in determining the evacuation times.
- Mosques should generally be handled over the neighbourhood or settlement. It is thought that the mosque occupants are generally from the close environment and fixed individuals. Due to religious and historical aspects or settlement, some important mosques are preferred for all city users or tourists. In the light of these data, the familiarity of the mosque changes. However, in mosques produced with single space design, the familiarity factor is not considered as a determinant in the evacuation time.
- Considering the occupant load in the mosques, the use of elderly/disabled individuals is in the majority that needs attention. Individuals with limited mobility (elderly/disabled) cause prolonged evacuation time. On special days and nights, the use of the mahfil floor in the mosques is realized by women. In these cases, it is important to define and evaluate a different occupant profile in mosques.
- Structural elements, architectural components and interior design used in mosques should be examined within the scope of fire safety precautions risk assessment. In historical mosques, the construction of a wood structure system, the number and position of vertical structure system elements in the mosque, the fire reaction of floor and wall finish materials should be investigated and their effect of occupant behaviour should be known during the evacuation process.

Table 2. *Occupant load coefficients for mosques within the fire regulations.*

Types of Building	Turkey (TRFP) m²/person	United States of America (NFPA) m²/person		United Kingdom (BS 9999) m²/person		New Zealand (NZBC) m²/person	Singapore (SCDF) m²/person	Australia (NCC) m²/person
Mosque (Places of Religious Worship)	Assembly Buildings[1]	Assembly Buildings		Standing Areas		Risk Group CA	Place of Public Resort	Assembly Buildings
		Concentrated Use[2]	Less Concentrated Use[2]	Normal	High	Area Without Seating or Aisles	Prayer Hall/ Gallery	Church / Multi-Purpose Hall
	1,5	0,65 net	1,5 net	1[3]	0,5[3]	1	1,5	1

[1] it has been recognized as multi-purpose hall / seminar hall.
[2] without fixed seatings
[3] typical and higher or lower factors might be more appropriate depending on the circumstances of the intended use and nature of the occupants

- Active fire safety precautions in mosques affect evacuation time. Fire/smoke detection and warning systems, emergency lighting-routing systems, smoke control systems, automatic fire extinguishing systems, such as the presence of an effective evacuation planning fire safety precautions allows.

Mosques have been evaluated in different ways as occupant load in national and international fire regulations. In the framework of fire regulations, specific designations for mosques are not detailed. In the fire regulations, passive and active fire safety precautions for mosques are given under the title of assembly buildings. There are requirements for fire safety precautions according to building height and plan square meters as an assembly building. In the fire regulations, occupant load coefficients that can be taken from the assembly buildings are investigated and are given in Table 2.

When national and international fire regulations are examined, it is important to determine the occupant load depending on the building class. However, in the fire regulation, occupant load coefficients for mosques are not generally included. There are also assessments such as seatless settlement/standing areas/more or less intensive use within the scope of assembly buildings. The occupant load of mosques is calculated in different ways depending on the occupant load coefficients within the framework of the evaluations and this results in the acceptance of the occupants in mosques to be evacuated with different evacuation times. In fire risk assessment, it is especially important to realize fair evacuation scenarios in order to minimize and eliminate loss of life and property.

4. Creation of evacuation risk combinations in mosques

In fire evacuation planning, it is especially important to identify fire risks within the scope of passive fire safety precautions, to calculate the occupant load of the building and to create evacuation scenarios. In determining evacuation times, the occupant profile and the occupant density in the building should be determined and design different evacuation scenarios. For this purpose, occupant profiles and evacuation scenarios should be created for mosques within the scope of the study.

Occupant profile in mosques is considered as a community of people offering a wide range for different age groups. This community also includes many older people and individuals with reduced mobility. However, in the comparison of the occupant load coefficients presented by the fire regulations, there are no refinements within the framework of individuals with limited mobility. In fire regulations, the number of occupants is taken as the basis for the determination of occupant load. Within the framework of these data, two main occupant profiles were identified in evacuation scenarios for mosques:

- The harim and mahfil is composed of middle age male occupant profile (P1),
- The harim is composed of middle age male occupant profile; the mahfil is composed of middle age female occupant profile (P2).

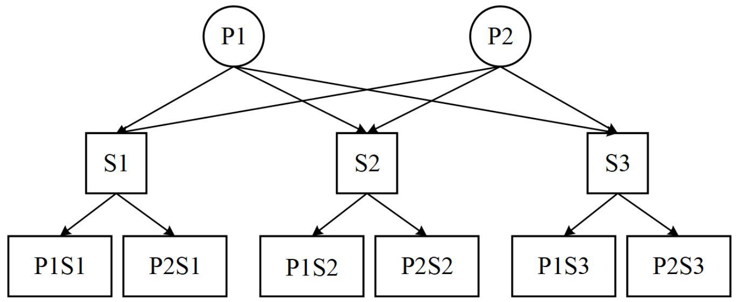

Figure 1. *Creation of evacuation risk combinations.*

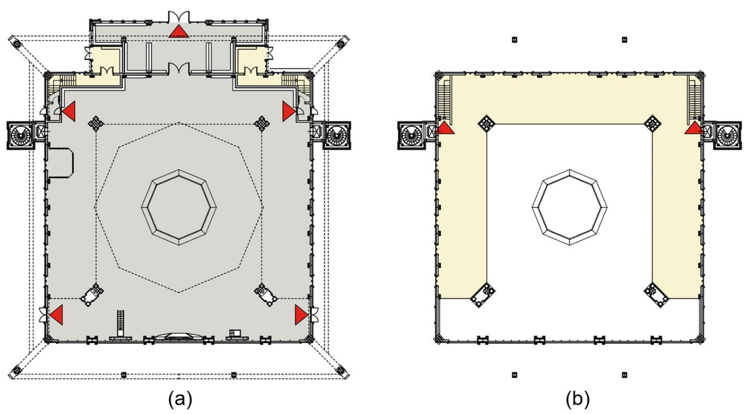

Figure 2. *Location of emergency exits in mosque plans, (a) harim; (b) mahfil.*

The creation of evacuation scenarios in mosques should be created within the framework of fire safety precautions risk determinations. Possible risks should be identified and occupant behaviour should be known and appropriate evacuation times should be calculated within this framework. Three different evacuation scenarios were discussed in the simultaneous-full evacuation assessment:

- Evacuation scenario (S1) under unobstructed and normal conditions,
- Evacuation scenario (S2) in case the harim main exit door is blocked,
- Evacuation scenario (S3) if any of the mahfil exit doors is blocked.

Within the scope of the study, the occupant profile and evacuation scenarios determined for the mosques were matched by crossing and evacuation risk combinations were created (Figure 1). P1 and P2 selected as different occupant profiles; S1, S2, S3 selected as different evacuation scenarios created for mosques are crossed. The resulting evacuation risk combinations; evacuation scenarios were created for each occupant profile. Evacuation risk combinations created are coded as evacuation scenarios (PXSX) depending on the occupant profile. Evacuation times for each risk combination created were calculated separately through the computer simulation program.

Canik Central Mosque in Samsun province of Turkey was taken as a case study to evaluate the evacuation risk combinations in mosques. In the mosque case, harim and mahfil floors are designed independently of each other in the planning of escape routes. The basement floor used as a car park is located in the mosque design project. However, it has been excluded from the scope of the study due to its lack of relationship with the upper floors and its occupant load is very low. In the planning concept of the mosque, the setting of a single space has been preferred. On the harim floor, 5 different emergency exits (two on the side walls and one on the back wall) are designed in such a way as to be alternative to each other. On the mahfil floor, 2 different emergency exits are designed to be alternatives to each other (Figure 2). However, it is thought that having a one-way escape distance of 25 m on the floor could prolong the fire evacuation time during a possible fire. As part of the project, there are two elevators next to the minarets. However, elevators were not considered appropriate to use within the framework of fire safety precautions and was disabled and not used in mosque evacuation planning.

Within the framework of the national and international fire regulations, mosque, which is considered as a case study, the occupant load was calculated depending on the occupant load coefficients (Table 3). Within the scope of the study, four different occupant loads determined by fire regulations were calculated. Four different occupant load groups have been identified as the Turkey, Singapore and United States (Less Concentrated) (1); United Kingdom (Normal) and New Zealand (2); USA (Concentrated) (3); United Kingdom (High) (4). Mosque occupant load determinations indicate that the occupant load profiles of the countries differ widely in fire regulations. This situation affects the total evacuation times in the sample mosque, causing passive and active fire safety precautions to be designed in different ways.

5. Result and evaluation

Occupant based evacuation risk scenarios were identified in the creation of passive fire safety precautions in mosques. For the mosque, the occupant loads were calculated according to the occupant load coefficients of the fire regulations of Turkey, United States of America, United Kingdom, New Zealand, Singapore and Australia. Sample mosque evacuation times according to the occupant load calculated for each regulation were determined through the Pathfinder simulation program (Table 4). The evacuation times of evacuation risk combinations created in the mosque, which are considered as a sample in the Pathfinder computer simulation program, are simulated. In the determination of evacuation times, the sample building was completely emptied. In evacuation process, especially evacuation of the mahfil floor has been determinant in evacuation times. The Pathfinder computer simulation program uses Steering Mode behaviour for occupants. Steering mode analyses complex occupant behaviours with natural motion algorithms (Pathfinder, 2017). With the mode used, the occupants of the building are properly delivered to the emergency exit and controlled transitions are provided for the occupants at the exits in case of density. In the simulation program occupant profiles, the speed of male occupants is 1,19 m/s and the speed of female occupants is 1 m/s. Uniform occupant placements were made as the position of the occupants for worship in mosques.

Evacuation times according to occupant load were calculated based on fire regulations of evacuation risk combinations created within the framework of occupant profile and evacuation scenarios for mosques, and fire regulations were compared in this context. Four different occupant loads were identified in the fire regulations examined in the scope of the study and evacuation times were evaluated with these occupant load. Within the framework of the fire regulations examined, the occupant load coefficients of Turkey, the United States (Less Concentrated Use) and Singapore were treated as 1,5 m2/person and evacuation times were determined to be equal. Similarly, in the United Kingdom (Normal), New Zealand and Australian Country fire regulations, occupant load coefficients were treated as 1 m2/person and evacuation times were found to be equal. When the fire regulations are examined, the maximum occupant load coefficients that can be determined for mosques are the United States (Concentrated Use, 0,65 m2/person) and the United Kingdom (High, 0,5 m2/person). Within the framework of two different occupant load coefficients, evacuation times have been achieved to be the longest (Figure 3).

Table 3. *Occupant load of the mosque selected as a sample according to the fire regulations.*

Occupant Load / Net Area (m^2)	Turkey (TRFP)	United States of America (NFPA)		UK (BS 9999)		New Zealand (NZBC)	Singapore (SCDF)	Australia (NCC)
		Concentrated Use	Less Concentrated Use	Normal	High	Area Without Seating or Aisles	Prayer Hall/ Gallery	Church / Multi-Purpose Hall
Harim / 1152 m^2	768	1772	768	1152	2304	1152	768	1152
Mahfil / 545 m^2	363	838	363	545	1090	545	363	545
Total / 1697 m^2	1131	2610	1131	1697	3394	1697	1131	1697

Table 4. *Evacuation times of evacuation risk combinations.*

Evacuation Risk Combinations	Turkey (TRFP)	United States of America (NFPA)		UK (BS 9999)		New Zealand (NZBC)	Singapore (SCDF)	Australia (NCC)
		Concentrated Use	Less Concentrated Use	Normal	High	Area Without Seating or Aisles	Prayer Hall / Gallery	Church / Multi-Purpose Hall
P1S1	3 m 12 s	7 m 18 s	3 m 12 s	4 m 50 s	9 m 15 s	4 m 50 s	3 m 12 s	4 m 50 s
P2S1	3 m 57 s	8 m 38 s	3 m 57 s	5 m 45 s	11 m 2 s	5 m 45 s	3 m 57 s	5 m 45 s
P1S2	3 m 12 s	7 m 18 s	3 m 12 s	4 m 50 s	9 m 15 s	4 m 50 s	3 m 12 s	4 m 50 s
P2S2	3 m 57 s	8 m 38 s	3 m 57 s	5 m 45 s	11 m 2 s	5 m 45 s	3 m 57 s	5 m 45 s
P1S3	6 m 16 s	14 m 26 s	6 m 16 s	9 m 28 s	18 m 33 s	9 m 28 s	6 m 16 s	9 m 28 s
P2S3	7 m 36 s	17 m 5 s	7 m 36 s	11 m 10 s	22 m 3 s	11 m 10 s	7 m 36 s	11 m 10 s

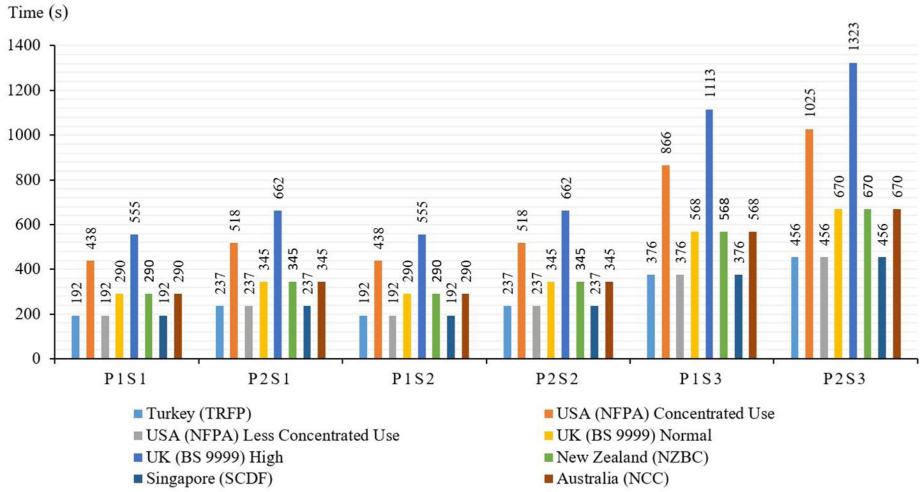

Figure 3. *Comparison of evacuation times within the framework of fire regulations.*

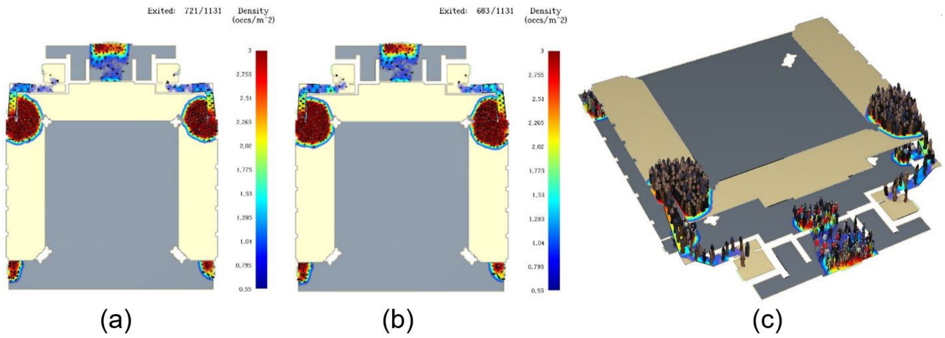

Figure 4. *Evacuation risk combinations on Turkey fire regulation (2 minute), (a) P1S1 (721/1131 person); (b,c) P2S1 (683/1131 person).*

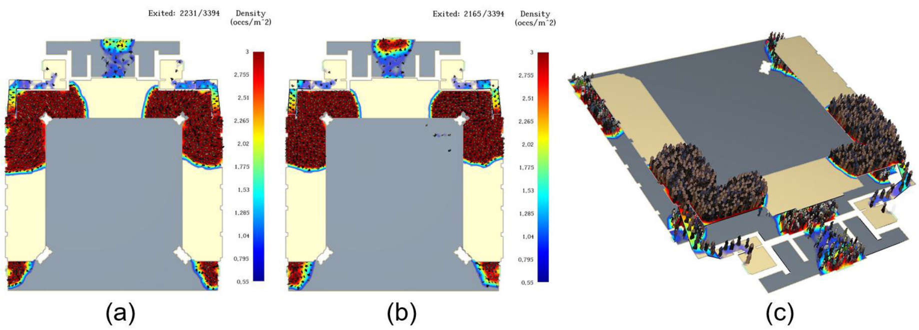

Figure 5. *Evacuation risk combinations on United Kingdom (High) fire regulation (3 minute), (a) P1S1 (2231/3394 person); (b,c) P2S1 (2165/3394 person).*

The variable profile of the occupant profile greatly changes the evacuation time. The fact that female occupants move more slowly than male occupants supports this situation. If the occupant load is low in the evaluation to be made based on the occupant profile in determining the evacuation time, less difference; If the occupant load is high, more difference arises. As a result of this situation, the presence of female occupants in evacuation risk combinations increases the total evacuation time due to their speed of movement. Comparisons of P1S1-P2S1 evacuation risk combinations in Turkey, one of the lowest number of occupant loads, and in the United Kingdom (High) fire regulations, which determine the most number of occupant loads, reveal the result of different occupant profiles (Figure 4 - Figure 5).

When the evacuation times obtained from evacuation risk combinations are examined, evacuation scenarios can be evaluated. Within the scope of the national and international fire regulations

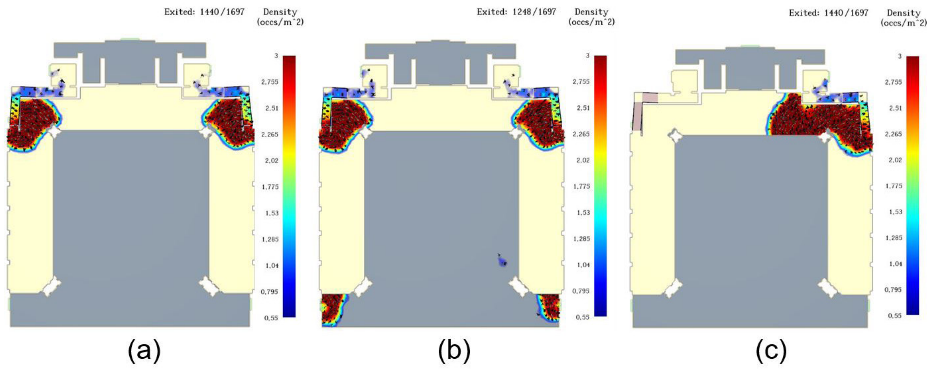

Figure 6. *Evacuation risk combinations on New Zealand fire regulation, (a) P1S1 (1440/1697 person) (2,5 minute); (b) P1S2 (1248/1697 person) (2,5 minute); (c) P1S3 (1440/1697 person) (5 minute).*

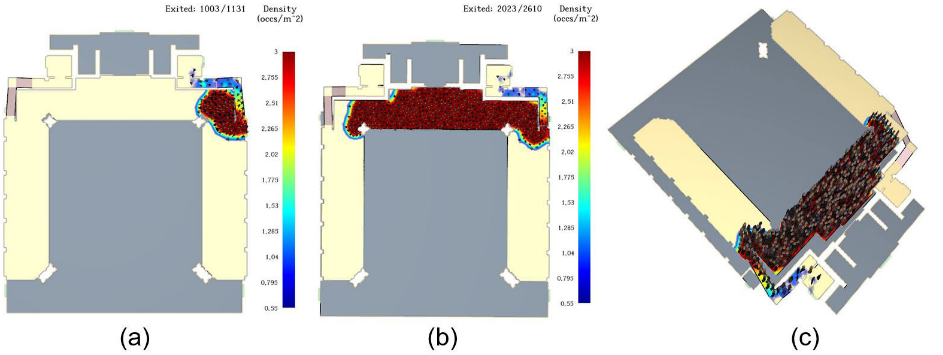

Figure 7. *Evacuation risk combinations on United States (Less Concentrated) fire regulation (5 minute), (a) P2S3 (1003/1131 person); Evacuation risk combinations on United States (Concentrated) fire regulation (5 minute), (b,c) P2S3 (2023/2610 person).*

examined, 5 emergency exits on the harim provide an effective fire evacuation. Regardless of the occupant profile, blocking the riskiest exit (main entrance door) does not prevent the evacuation from happening quickly and in a short time and does not affect the total evacuation time. However, in the event that one of the emergency exits on the mahfil floor is blocked, the evacuation time reaches 2 times of the unobstructed evacuation time and greatly increases the fire safety risks. The New Zealand fire regulation P1S1-P1S2-P1S3 evacuation risk combinations are an example of this situation, as is the case with the fire regulations of all countries examined (Figure 6). As a result of this situation, it is important to design and construct alternative exits, increase exit widths, create unobstructed exits and evaluate these approaches in the context of evacuation risk scenarios, especially for the mahfil floor in rooms created with single space design. In addition, the vertical structure systems elements placed on the stair line in the sample mosque, which was handled within the scope of the study, narrowed the escape distances and caused the evacuation time to be extended.

The United States and the United Kingdom fire regulations (BS 9999, 2017) have created different risk groups for mosques within the scope of assembly buildings and occupant load coefficients are presented as an alternative. According to the United States of America fire regulation (NFPA 101, 2018), finding Concentrated Use / Less Concentrated Use occupant load coefficients is an appropriate sample for this situation (Figure 7). According to the risk scenarios determined by the designer within the framework of fire safety precautions, finding alternative approaches is very important in terms of obtaining the most realistic and detailed results.

Within the framework of national and international fire regulations, major differences were detected in evacuation times calculated according to the occupant load coefficients. As a result of the calculations on the project of the mosque sample, a difference of 18 m 51 s was determined according to the fire regulation data (the shortest time was 3 m 12 s/1131 occupants the longest time was 22 m 3 s/3394 occupants). The resulting evacuation time difference represents a very risky time in terms of fire safety. Considering the rate of fire spread and the reaction time of smoke on the human, it is important to design the occupant profile and evacuation times for mosques in a way that will be the most appropriate, and to evaluate the regulation that gives the maximum occupant loads and use it within the scope of the project. According to the occupant load coefficients in the fire regulations of Turkey and Singapore, which determine the minimum occupant load within the framework of the fire regulations examined, evacuation times of evacuation risk combinations occur in very short periods of time. The United States and United Kingdom fire regulations, which determine the highest occupant load and provide alternative approaches within the framework of the fire regulations examined, have been found more appropriate in terms of precautions to be taken against fire safety risks. Increasing the occupant load also increases passive and active fire safety precautions. In this case, reducing the occupant load coefficient in the fire regulation is planned as a factor to increase the occupant load and supports the performance-based fire safety precautions that can be taken within the scope of the architectural project for mosques. The purpose of building evacuation planning is to enable the most occupants to evacuate the building as soon as possible.

6. Conclusion

Structure fires cause excessive loss of life and property. Fire safety precautions should be provided in assembly buildings where the occupants are concentrated, especially passive fire safety precautions should be created. It must be ensured that fire evacuation conditions, which form the basis of passive fire safety precautions are created correctly and truthfully. The 100% occupancy rate for mosques as an assembly building for in a short time makes it necessary to provide fire safety design and provide performance-based solutions in terms of risks that may arise. It is important to analyse the occupant profile specific to mosques and create evacuation scenarios. Possible fire scenarios and occupant behaviour and realistic alternative solutions should be developed.

Occupant profile and evacuation scenarios components and evacuation risk combinations for mosques need to be established within the framework of fire regulations. Different occupant load coefficients in national and international fire regulations for mosques lead to different evacuation times due to variable evacuation risk combinations. When the fire regulations were examined, considerable differences were found in evacuation times due to evacuation risk combinations. Although there are different concentrations in different evacuation times for mosques, it is very important criterion to identify the riskiest and to develop precautions to stay on the safe side. Individuals with limited mobility that are excluded from the scope of the study are also more at risk when considered within the scope of the occupant profile. Setting up alternative exits, treating occupant load as the most critical level determined in the fire regulations, increasing the number of exits and expanding the exits results in optimum evacuation times obtained from evacuation risk combinations.

The fact that the riskiest door for the harim floor is blocked in evacuation scenarios built within the framework of national and international fire regulations did not affect the evacuation time by finding alternative escapes. However, the fact that any of the exits constructed as an alternative to the mahfil floor is blocked has doubled the evacuation time. It was determined that evacuation of the mahfil of the mosque has higher risks in the planning of the mosque, which was created with single space design and has independent exits on the floors, and insufficient exits extend the evacuation time too much even though the occupant load is low. Attention should be paid not to narrow the escape distance when positioning vertical structure elements in escape corridors and stairs. In the United

States and the United Kingdom fire regulations within the framework of fire regulation systems, different occupant load coefficients have been found to be alternative, in terms of risk assessment. Turkey and Singapore in terms of occupant load factor for the mosque fire investigated in fire regulations and evacuation time regulation have been identified as low risk in terms of comparison with other countries to put forward regulation. In the transition period of fire regulation to performance-based systems, it was put forth that it is necessary to establish detailed information mechanisms for occupant load coefficients, especially through occupant based evacuation scenarios and evacuation times. Fire regulations should be created for real use and considering building performance requirements. It should be noted that fire regulations create minimum limit conditions and that the designer (architect) can increase precautions to remain on the safe side in creating fire safety precautions, based on evacuation risk combinations. Within the framework of passive fire safety precautions, stricter precautions are required for occupant load coefficients. What is decisive in the study is that the fire regulations, which provide the most occupant profile according to occupant load coefficients, are on the safe side. It is important to control escape routes in mosques that are in the high risk group as assembly buildings, to analyse fire and smoke propagation, and to investigate fire safety precautions that can be taken in historical mosques.

As a result of the study, it has been concluded that the occupant load coefficient greatly affects the evacuation time for mosques that are built with single space and have independent exits. The necessity of occupant based evacuation scenarios has been demonstrated in creating performance-based fire safety. It is recommended that the fire regulations of the countries are handled within this framework and the occupant load coefficients for mosque design are determined, and the fire regulation is detailed and developed within the scope of the fire safety.

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