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A Simulation Study to Suggest an Emergency Exits in Mosul's Mosques in Case of Emergency

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ABSTRACT

Nearly every mosque in Mosul has one or two gates that are essentially arranged on one wall opposing the Qibla wall. The worshipers would be unable to flee if an explosion or arson at the wall of those gates causes the gates to close, either from the inside or the outside. As a result, evacuation would be challenging or impossible. International architectural codes do not contain any specific requirements for fire safety precautions in mosques. However, the mosque prayer hall is essentially an assembly hall that frequently hosts huge crowds of attendees during prayer times. International building regulations stipulate that these assembly buildings must have multiple emergency exits. This study clarifies the issue and offers solutions by designing alterative emergency exits on the side walls or the Qibla wall, which would allow worshipers to leave the mosque prayer hall in an emergency while still meeting the time requirements established by well-known international codes, as well as the standards for fire safety precautions and means of escape. The simulation was realized on the software tool called Pathfinder.

1. INTRODUCTION

The design and selection of emergency exits are a crucial issue in mosque construction, because the prayer hall appears to be an architectural space created for numerous floor-seated occupants. When architects attempt to place the entrances to the main prayer hall, they are constrained by mosque architectural requirements in general: they must take into account the outward movement of the worshipers and the manner they enter the main prayer hall. By convention, the entrances on either side of the Qibla wall should be placed at the farthest point from the Qibla, aiming to assure the seclusion of the main prayer hall, particularly in mosques where the location of the prayer area varies depending on the season [1].

Many studies have utilized different software to evaluate the evacuation from mosques, in the light of the specific typology of mosques in different countries. The previous studies generally fall into three categories:

1. Estimating the evacuation time based on where the mosque's exits are currently located, with the possibility of closing or blocking part of them in an emergency. The majority of these mosques were historic [2, 3].
2. Recommending more emergency exits for the current scenario to improve the evacuation procedure and determine the appropriate evacuation time. All these mosques were newly built [4, 5].
3. Selecting the best emergency exit configuration in a virtual representation of a typical mosque by testing many exit numbers and positions using evacuation software [6].

The entrances (exits) of Mosul mosques are typically at the center of the wall opposite the Qibla and are typically opened in the opposite direction of escape—into the interior.

This study relies on the Pathfinder software to identify an alternative emergency exit in Mosul mosques for evacuating worshippers in an emergency, while taking the evacuation time as a criterion.

2. EVACUATION TIME AND EXITS WIDTH

The evacuation time is the amount of time it takes for a person to go from any area of the building that is occupied to a location of safety. Generally speaking, depending on the type of construction, evacuation times of 2-3 minutes are utilized in the design of escape means from buildings. In fact, studies that found that people should have 2-3 minutes to escape from the building in a stressful situation before panic sets in. It is always preferable to remove people before they become panic [7].

In pertinent building codes, the unit exit width is recommended to be 533mm. This is based on the assumption that 40 persons per minute in a single file can discharge through a 533mm-wide exit, or 100 persons in a single file in 2.5 minutes. This falls in the previously discussed range of evacuation time. The width across the shoulders of a typical adult male is taken to be 533mm. However, in reality, such a width is unacceptable and even dangerous because any impediment, no matter how minor, has the potential to be fatal. Therefore, a minimum width of 765 mm is used to achieve a 40 person per minute discharge rate [7].

Therefore, every alternative emergency exit suggested in this study, whether it is on the Qibla wall or the sidewalls, will have approximately either one unit of exit width (76.5 cm) or two units of exit width, i.e., 153 cm.

3. OBJECTIVE

In the event of any emergency leading to the closing of the main gates, the research intends to examine the feasibility of creating emergency exits for the prayer hall. This is accomplished by simulating the process of evacuating the congregation during prayers from the hall to a location of safety, while limiting the ideal evacuation time to 2.5 minutes.

This study suggests an alternative emergency exit on both side walls of the main prayer hall to the selected sample (which contains different mosques sizes and capacities). This helps to determine the best condition for each mosque to evacuate all prayers within the appropriate time, taking into account the previously mentioned evacuation time.

These alternate exits adhere to the requirements for emergency exits in other structures and architectural settings. These exits use self-closing, fire-rated doors that can only be opened from the inside and are not always in use. It is not possible to use them to enter the mosque prayer hall because doing so would cut through the rows of worshipers.

4. METHODOLOGY

This study recommend three emergency exits on each of the side-walls of the Qibla and the Qibla wall. It is assumed that the main wall opposite the Qibla, which contains the main gates to the mosque prayer hall, will be exposed to an emergency, resulting in the closure of all of its gates.

1. For the entire elected sample, an emergency exit with a width of one unit, or 76.5 cm, was deployed on a side wall of the Qibla. In this scenario, with the main gates closed, the computer simulation program Pathfinder calculates the evacuation time.
2. A second hypothetical emergency exit with the same width was designed on the second wall, facing the first wall. This time, while the first and second hypothetical emergency exits are open, the simulation program determines the amount of time needed to evacuate, with the main gates closed.
3. A third hypothetical emergency exit was opened on the Qibla wall. In this case, the evacuation time was simulated by closing the main gates with the three emergency exits open.

The above three cases were simulated again, but with two units of exit width (153 cm) for each design. In total, six different evacuation scenarios were considered and discussed for each mosque in the sample.

This study proposes emergency exits to evacuate the worshipers from each mosque in the sample in the event that the existing main gates were forced to close and taking into account the 2.5 minute evacuation criterion. In this way, the authors highlighted the best case based on the estimated evacuation times from each case. In other words, the study aims to determine the number of exits needed in Mosul city for mosques of various sizes.

5. CASE STUDY

A straightforward statistical pilot analysis of Mosul mosques revealed that, according to their locations, they may be categorized into three groups:

1. Small (floor space: around 100m^2);
2. Medium (floor space: around 200m^2);
3. Large (floor space: around 300m^2).

It was previously found that these mosques were new construction (i.e., they were built according to current engineering specifications). The research sample was chosen to include one mosque from each of the following three groups (Table 1).

Table 1. Research sample

Mosque name	Snapshot from outside	Place or neighborhood	Area in m^2	classification
Noor Almustafa		Alwahda	92	small
Alwahab		Alnoor	198	medium
Alnuaiemi		Arbajia	295	large

Table 2. Occupant load of the research sample

Mosque name	Occupant load (persons)
Noor Almustafa	92
Alwahab	198
Alnuaiemi	295

The occupant load should be calculated for figuring out when to evacuate any facility in order to evaluate various evacuation scenarios. The total number of individuals who could potentially occupy all or a portion of a building at any given moment is known as the occupancy load [8]. As a result, the building's occupant load is determined using the occupant load factor established by the regulations of the international fire regulation. This factor is a measurement of square meters per person based on utilization [8]. In fire regulations, occupant load is calculated based on the total number of occupants.

The majority, if not all, construction codes lack specific restrictions on emergency exits for mosques, and the international fire regulations fail to provide adequate occupant load factors for mosque prayer halls. Additionally, the emergency escape requirements for moques present unique difficulties, particularly when defining the number, width, and layout of exits. mosques are typically categorized as assembly buildings when it comes to fire regulations [5]. The occupant load in the building must be analyzed correctly to simulate the evacuation scenarios efficiently.

The occupant load factors for both purpose groups and mosques are not specified in the provisions of the Iraqi Code of Practice for Fire Protection in Buildings (646) [9].

The mosque prayer hall is assigned the assembly group C classification by the UAE Fire and Life Safety, and its occupant load factor is set to 0.9 m^2/person [8].

The occupant load factor in the assembly group is assessed to be 1 m^2/person under the Saudi Fire Protection Code (SBC 801) [10].

The 1 m^2/person occupant load factor is adopted by most major nations' fire regulations and codes, including the UK [11-13].

This criterion (1m^2/person) is allocated for each prayer in the mosque prayer hall, far from the fire protection provisions and evacuation, by mosque design standards in the majority of Islamic countries that serve small neighborhoods [1, 14], same as the case in this study. The evacuation times for the aforementioned three size groups were simulated in various scenarios, using the (1m^2/person) occupant load factor (Table 2).

6. DATA ANALYSIS AND DISCUSSION

The simulation results showed an apparent affinity in the evacuation time between the case of two exits with one unit of exit width, i.e., 76.5cm, with that in the case of one exit with two units of exit width, i.e., 153 cm. This result is well expected based on the calculation of evacuation time (Tables 3-5).

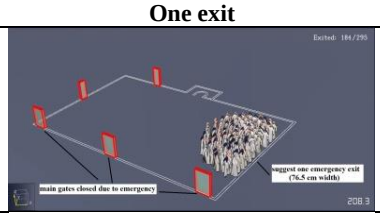
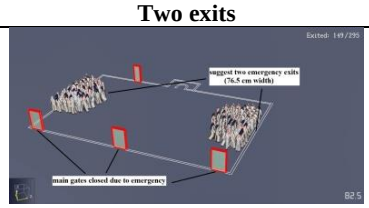
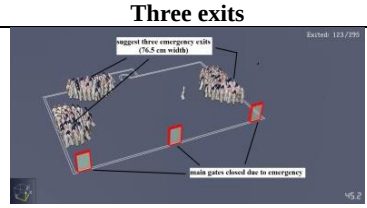
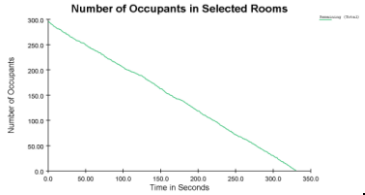
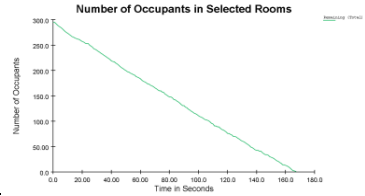
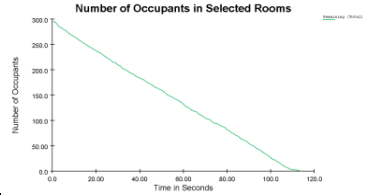
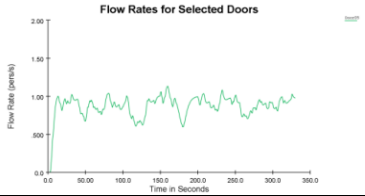
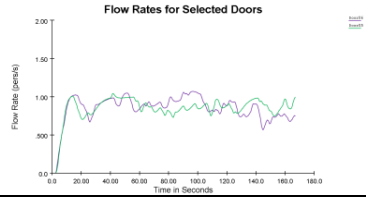
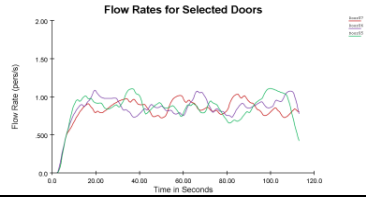
The flow rate through the hypothetical exits was nearly identical in all cases. But there was a quick discharge and quick escape, up to the first 15 seconds, as indicated by the steep curve. This seems obvious in the case where there is just one hypothetical emergency exit. The flow rate stabilized after it oscillated about one person per second through exits with one unit of exit width and two people per second through exits with two units of exit width. This is the regular rate designed for exits with these exit widths.

By doubling the exit width (from one to two units of exit width), the evacuation time decreased to about 50%. By doubling the number of exits (of the same width), the evacuation time also decreased to about 50%. However, adding the third exit to the main prayer hall reduced the evacuation time to about 30% of the time when there were two exits (of the same width) (Figures 1-3).

The results show that small mosques like Noor Almustafa may just require one emergency exit with a single unit of exit width to minimize the time needed for evacuation (2.5 min.).

Two emergency exits with one unit of exit width or one exit with two units of exit width may be required for mosques of medium capacity (Alwahab) to ensure effective evacuation.

Table 3. Alnuaiemi mosque under different simulation scenarios

Alnuaiemi Mosque (one unit of exit width 76.5 cm)			
	One exit	**Two exits**	**Three exits**
Pathfinder simulation snapshot			
Number of occupants evacuated per unit time			
Flow rate through exits			

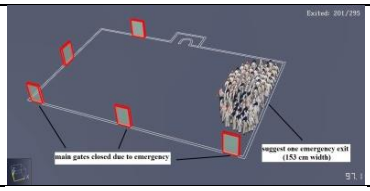
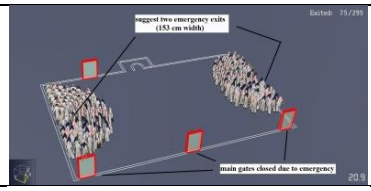
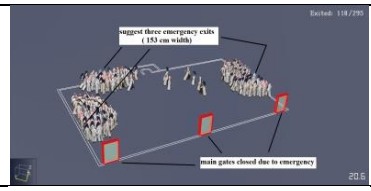
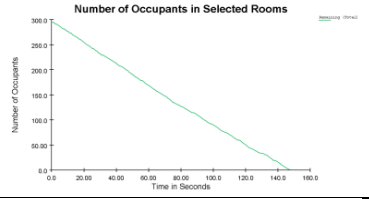
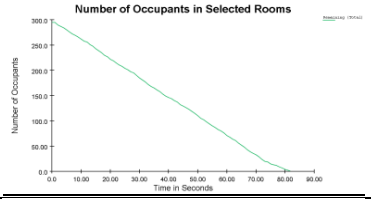
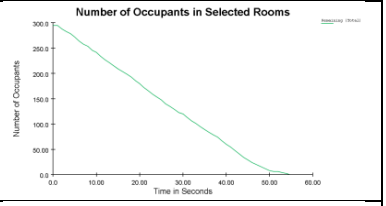
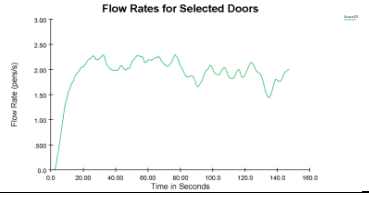
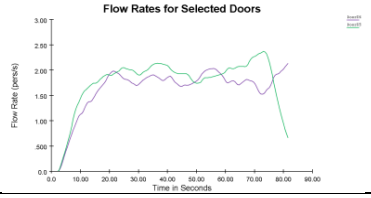
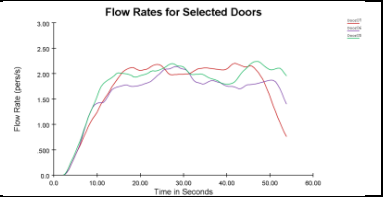
Alnuaiemi Mosque (Two units of exit width 153 cm)			
	One exit	**Two exits**	**Three exits**
Pathfinder simulation snapshot			
Number of occupants evacuated per unit time			
Flow rate through exits			

Table 4. Alwahab mosque under different simulation scenarios

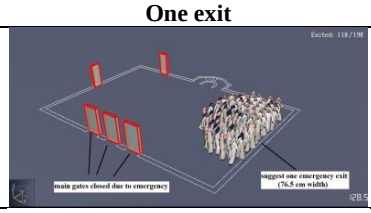
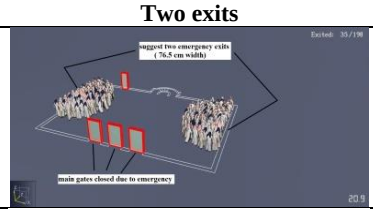
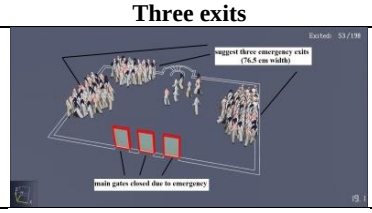
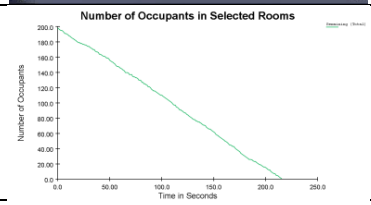
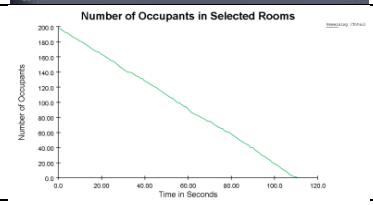
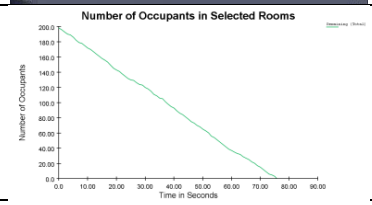
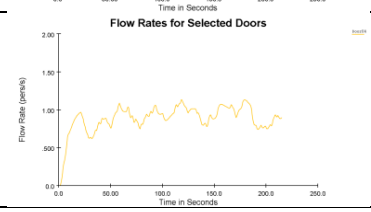
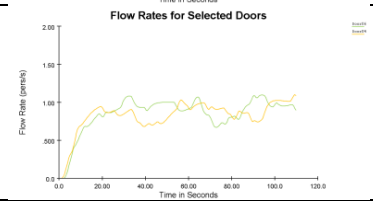
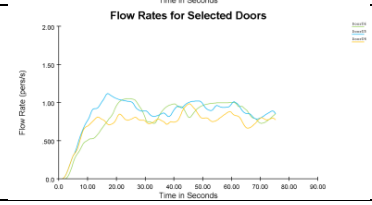
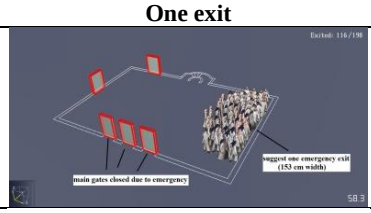
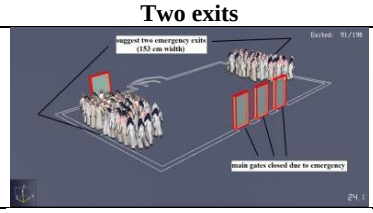
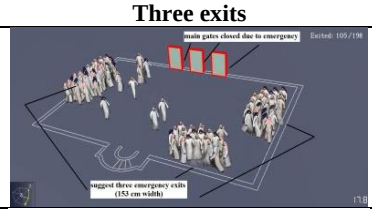
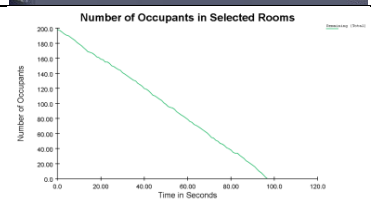
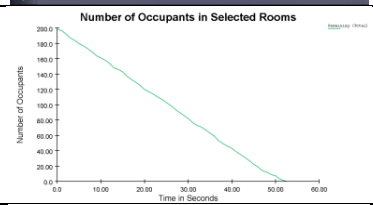
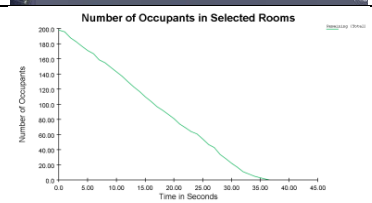
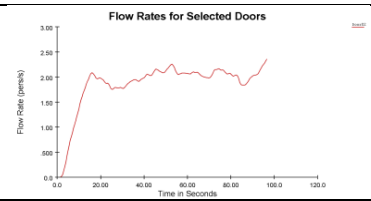
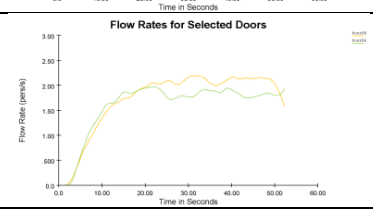
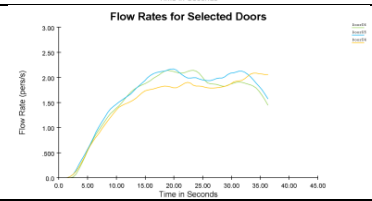
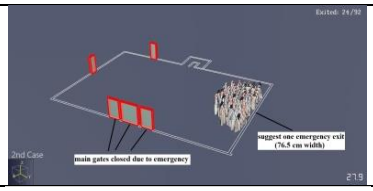
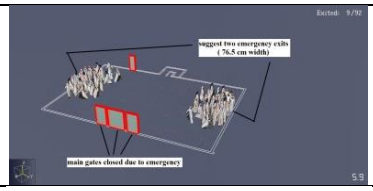
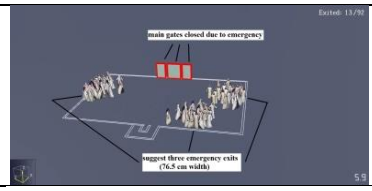
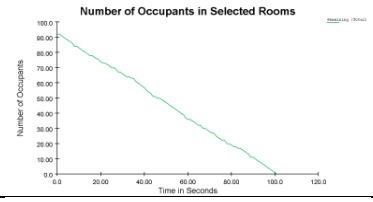
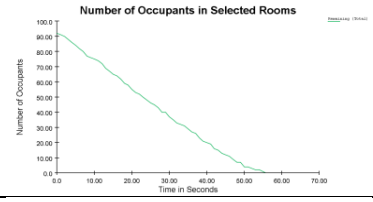
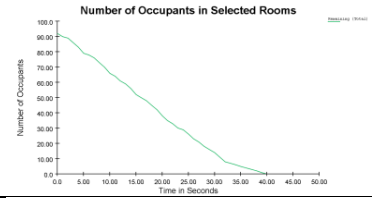
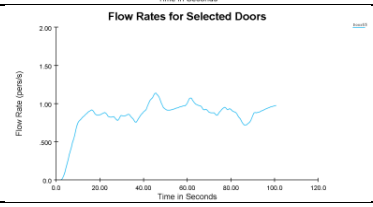
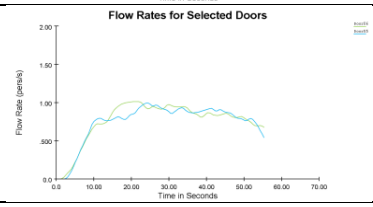
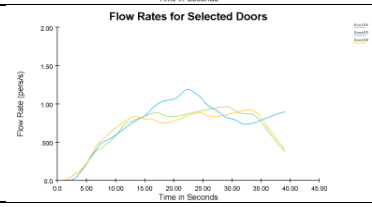
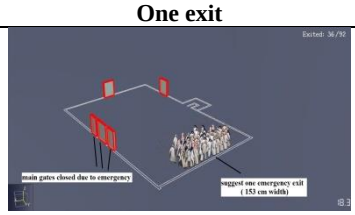
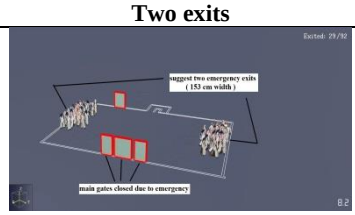
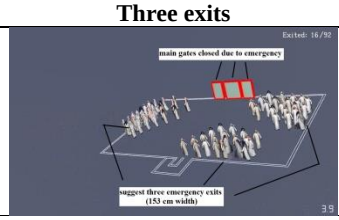
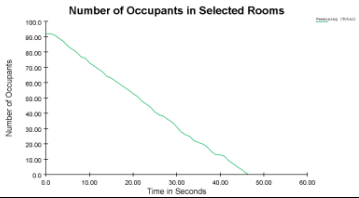
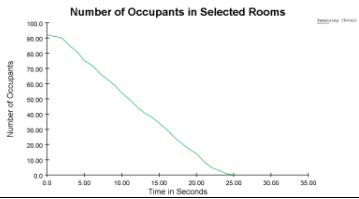
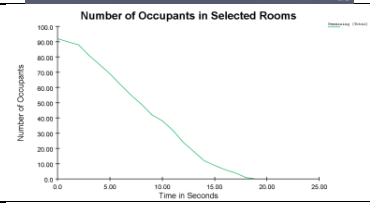
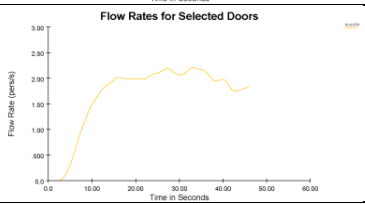
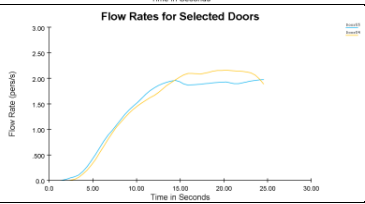
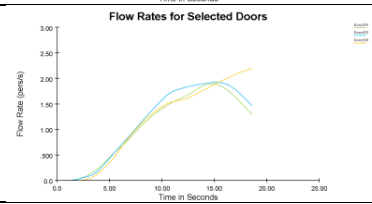
Alwahab Mosque (one unit of exit width 76.5 cm)			
	One exit	**Two exits**	**Three exits**
Pathfinder simulation snapshot			
Number of occupants evacuated per unit time			
Flow rate through exits			
Alwahab Mosque (Two units of exit width 153 cm)			
	One exit	**Two exits**	**Three exits**
Pathfinder simulation snapshot			
Number of occupants evacuated per unit time			
Flow rate through exits			

Table 5. Noor Almustafa mosque under different simulation scenarios

Noor Almustafa Mosque (one unit of exit width 76.5 cm)			
	One exit	**Two exits**	**Three exits**
Pathfinder simulation snapshot			
Number of occupants evacuated per unit time			
Flow rate through exits			
Noor Almustafa Mosque (two units of exit width 153 cm)			
	One exit	**Two exits**	**Three exits**
Pathfinder simulation snapshot			
Number of occupants evacuated per unit time			
Flow rate through exits			

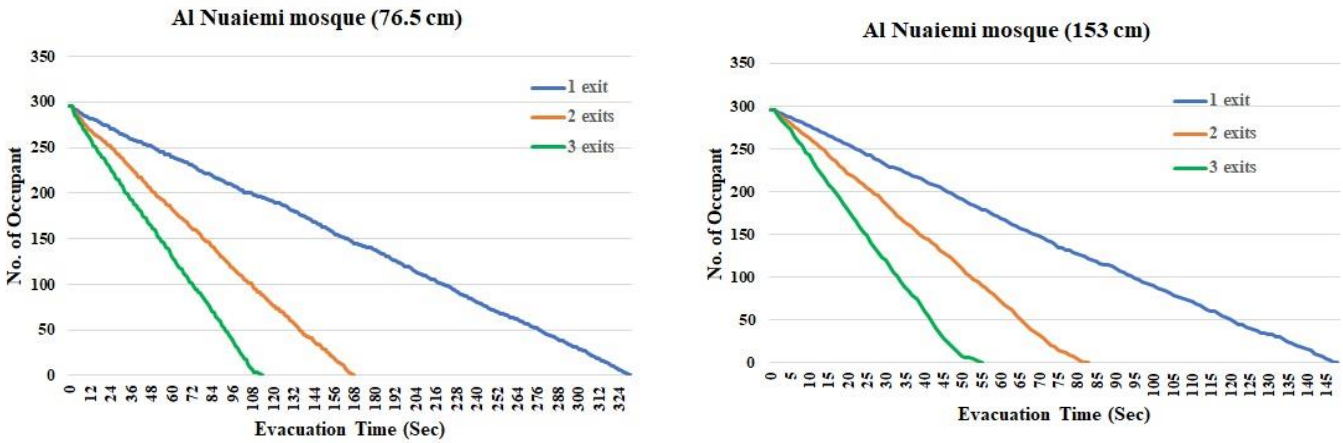


Figure 1. Variation in evacuation time with the number of exits (Alnuaiemi mosque)

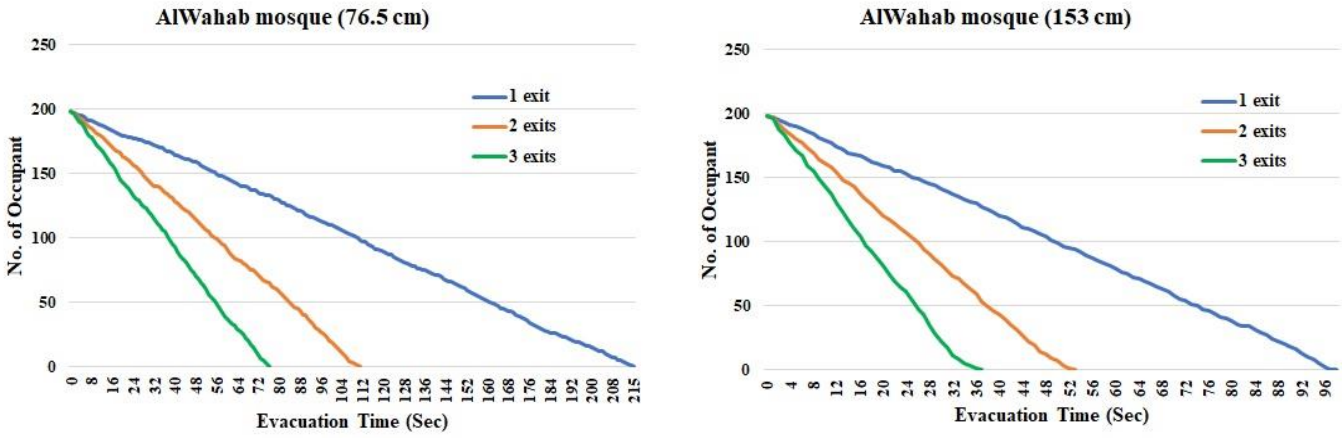


Figure 2. Variation in evacuation time with the number of exits (Alwahab mosque)

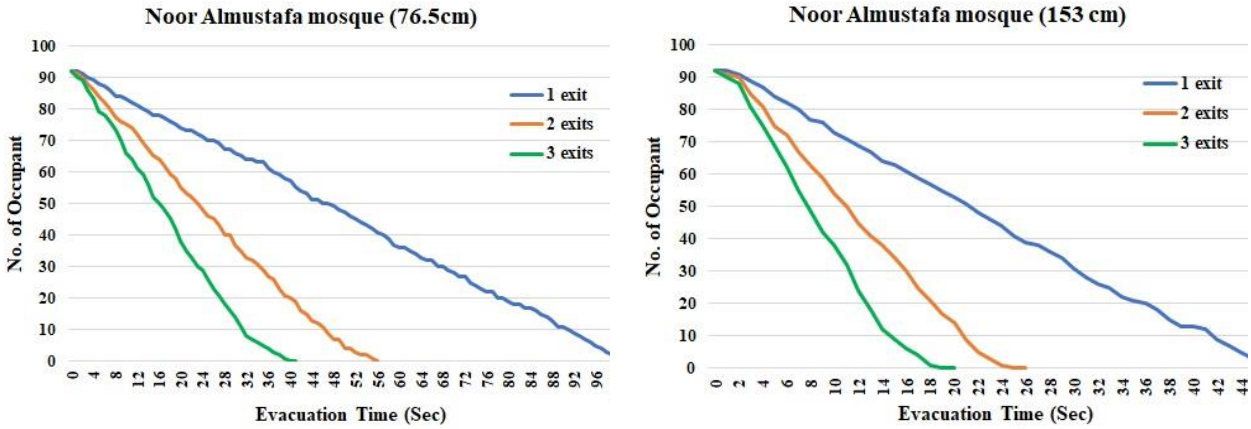


Figure 3. Variation in evacuation time with the number of exits (Noor Almustafa mosque)

Table 6. Evacuation times of mosques of three different sizes

	The evacuation time in sec.					
	One unit of exit width (76.5 cm)			**Two units of exit width (153 cm)**		
	One exit	Two exits	Three exits	One exit	Two exits	Three exits
Noor Almustafa 92 p.	101 (1.68 min.)	55.8 (0.93 min.)	40 (0.66 min.)	46.5 (0.77 min.)	25 (0.42 min.)	19 (0.32 min.)
Alwahab 198 p.	215.5 (3.6 min.)	110.8 (1.85 min.)	75.8 (1.26 min.)	97 (1.62 min.)	52 (0.87 min.)	36.8 (0.61 min.)
Alnuaiemi 295 p.	330.3 (5.5 min.)	167.3 (2.8 min.)	113.5 (1.9 min.)	147.5 (2.45 min.)	82 (1.4 min.)	54.8 (0.9 min.)

Large mosques with a capacity of 300 prayers (Alnuaiemi) may only require one exit, three exits, or both (with two units of exit width) (Table 6).

7. CONCLUSIONS

1. The issue of building evacuation should be taken into consideration from the very beginning of the design process, especially for assembly buildings where the safety of people is one of the top concerns for design requirements.
2. The research reveals a lack of data regarding the evacuation procedure in Mosul mosques; consequently, the findings are expected to serve as a thorough road map for Mosul mosque designers, particularly when they are attempting to meet the requirements for emergency exits and means of escape.
3. This research presents various design options for the number, width, and configuration of exits to aid in the design process for mosques. This is typically a highly important issue, especially when the mosques are situated on a site with limited access.
4. After the violent events that Iraqi cities have experienced, the Sunni Endowment Department in Iraq, which is in charge of the designs, construction, and supervision of mosques, should require mosque designers to incorporate emergency exits into their plans and to restore the means of escape for existing mosques by incorporating emergency exits appropriate to the mosques' capacities and location.

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REFERENCES

[1] Almuqbil, M.A., Toman, A.R., Alaheedib, A.M., Alshyea, M.F. (2010). Mosque Design Standards. https://mosque-design.com/Allbook.pdf, accessed on Mar. 15, 2022.

[2] Toprakli, Y. (2018). A simulation study on emergency evacuation of slimiye mosque. ASOS Journal, 66(6): 186-198.

[3] Toprakli, Y., Sdihemaiti, S., Agraz, G. (2019). Evaluation of evacuation problem of modern ottoman classical period mosque types. Journal of the Faculty of Engineering and Architecture of Gazi University, 34(4): 2261-2270. https://doi.org/10.17341/gazimmfd.490086

[4] Alighadr, S., Fallahi, A. (2016). DEM evaluation of evacuation behavior: A case study of "The Mosque of ASMU". JSEE Journal, 47-58.

[5] Yaman, M., Kurtay, C. (2021). Investigation on evacuation scenarios according to occupant profile in mosques through different fire regulations. AZ ITU Journal of Faculty of Architecture, 18(2): 477-489. https://doi.org/10.5505/itujfa.2021.47786

[6] Nassar, K., Bayyoumi, A. (2012). A simulation study of the effect of mosque design on egress time. In C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, & A. Uhrmacher (Ed.), Proceedings of the 2012 Winter Simulation Conference, pp. 1230-1237. https://doi.org/10.1109/WSC.2012.6465153

[7] Shields, T.J. (1987). Buildings and Fire. (J. W. Inc., Ed.) New York, U.S.A.: Longman Scientific & Technical.

[8] Directorate General of Civil Defence, M. o. (2017). UAE Fire & Life Safety Code of Practice. UAE: Diwan Arabia.

[9] (C.O.S.Q.C.), C. O. (1996). *Code of Practice for Fire Protection in Buildings No. 646.* Baghdad-Iraq: Ministry of Planning. /chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/http://investbasrah.com/files/Fire-prevention-guide.pdf.

[10] S.B.C.N.C., S.B. (2018). Saudi Fire Protection Code SBC 801A. Saudi Arabia.

[11] BS9999. (2017). Fire Safety in the Design, Management and use of Buildings, Code of Practice. England: The British Standard Instituation.

[12] NCC. (2019). National Cinstruction Code (Vol. Volume 1). Australia: Australian Goverment Agency.

[13] NZBC. (2017). Acceptable Solutions and Verification Methods. Newzealand: Ministry of Business, Innovation & Employment.

[14] Imam, S. (2000). Mosque architecture: Formulation of design criteria and standards in the context of Bangladesh. Bangladish: Bangladesh University of Engineering and Technology.