Journal of Engineering, Project, and Production Management
2020, 10(3), 170-178

# Health and Safety in Crowded Large Size Buildings: The Effect of Perceived Safety on User Behaviour in the Holy Mosque

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Engineering and Project Management
Best Paper of EPPM 2019 Conference
Received January 7, 2020; received revisions January 27, 2020; February 14, 2020; accepted February 27, 2020
Available online March 18, 2020

**Abstract:** Crowded large space buildings are today becoming highly desirable facilities for communities, towns, and cities. Due to stricter health, safety requirements, and environmental effects, such buildings are of greater interest for research. The buildings are used for a variety of functions, including sporting, entertainment, and religious events. The Holy Mosque in Makkah Saudi Arabia is an excellent example of a crowded large space building with a maximum capacity reaching up to 2 million users, especially at the Hajj and Ramadan periods. Quite often, designer and facility managers of crowded large space buildings pay keen attention to normative and substantive (objective) safety, but research shows that perceived (subjective) safety which should also be important, is clear overlooked. To prove the significance of perceived safety, a theory has been adopted, which states that a reduction in perceived safety (PS) will negatively affect the user behaviour (UB) resulting in the occurrence of a disaster in crowded large size buildings. Initial research undertaken by the authors have identified 10 key factors affecting subjective safety in crowded large space buildings, this stage of the study is an empirical study to aimed at establishing how significant each factor affects PS and the effect of perceived safety on the UB in such types of buildings. The Holy Mosque was used as a case study. The research adopted the quantitative research methodology by collecting primary data using a group-administered questionnaire in electronic devices such as iPad from more than 1,940 Hajj pilgrims coming from 62 countries. This was analysed by SPSS and AMOS 22 for confirmatory factor analysis (CFA) and structural equation modeling (SEM) to test the interrelationships between the 10 identified factors and PS or between PS and UB through several hypotheses. The research has demonstrated that there is a significant influence on PS by most of the established factors and that PS has a significant influence on the behaviour of pilgrims in the Holy Mosque.

**Keywords**: Subjective safety, perceived safety, user behaviour, crowded large space buildings.


DOI 10.2478/jeppm-2020-0019

## 1. Introduction

Every city or big town has a number of large space buildings that are used by a large number of people for a variety of functions such as sporting, shopping, religious, social and other entertainment events. During the design and facilities management stages of such buildings, experts normally pay great attention to health and safety. Research has established that keen attention is given to the normative and substantive aspects of safety, but perceived aspects of safety is often overlooked due to lack of appropriate understanding. The global aim of the study reported in this paper is to provide a better understanding of the variables of perceived safety and how they affect the behaviour of users of crowded large space buildings. The paper is aimed at establishing the significance of each variable on perceived safety, and relationships between each of the factors of perceived safety and user behaviour. As a case study, the empirical study chose and used the Holy Mosque in the city of Makkah in Saudi Arabia.

## 2. Literature Review

Large space buildings are buildings that have functional spaces in which the indoor volume or the space is such that its condition (temperature, relative humidity, air quality, etc) is nonhomogeneous e.g. lecture theatres, event halls, and atriums. Crowded large space buildings are massive buildings, that are occupied or used by a gathering of a large number of people in the same place and time for a certain common purpose e.g. stadiums, exhibition centres, entertainment event centres, religious

buildings, airports. The Holy Mosque at Makkah in Saudi Arabia is arguably the biggest crowded large space building in the world, accommodating up to two million people at its peak occupancy. The Holy Mosque, also called Al-Masjid Al-Haram by the Muslims, was created about 4000 years ago when Prophet Ibrahim (Abraham) built the Kaaba (Ka 'bah). The Mosque became well established at the time of Prophet Mohammed when the Hajj pilgrimage was prescribed to all Muslims. At that time the Holy Mosque was made up of a circular plaza of about 2,100 square metres. The Hajj is an annual pilgrimage to the city of Makkah by Muslims lasting 4-6 days that involves rituals in four holy places: The Holy Mosque, the Arafat, the Muzdalifah, and the Mina. At the Holy Mosque, pilgrims perform the Tawaf (anticlockwise circumvallating movement of pilgrims in the Holy Mosque around the Kaaba repeated seven times) and the Saee (walking to and fro between two locations seven times). This visit to the Holy Mosque is done on the 2nd day immediately after the first visit to Jamarat (ritual site situated at Mina).

As the number of pilgrims increased, the second caliph Umar bin Al-Khattab expanded the Holy Mosque to 3,600 square metres completed in the year 638 (Bukhari. S, 2013). This tread of expansion continued until year 919 bringing the total area to 29,127 square metres. Although the mosque experienced numerous restorations and refurbishments, it remains the same size for over 1,200 years. On 5th April 1956, King Saud bin 'Abdul Aziz commenced a major expansion project both horizontally and vertically, becoming a two-storey massive edifice. This redevelopment continued during the time of King Faisal bin 'Abdul Aziz until when it was completed in 1975 bringing the total area to 160,000 square metres. With the global technological advancement in the communication, logistics and aviation sectors and the increase in the number of Muslims around the world, the number of pilgrims continued to rise. Consequently, the expansion of the Holy Mosque continued with King Fahd Bin 'Abdul Aziz adding 57,000 square metres in 1993 and introducing major improvements by installing escalators to convey worshippers to the second floor and the roof-top (Bukhari. S, 2013). The expansion of the Holy Mosque has continued to date, bringing its current size to 356,800 square metres and increasing. The peak occupancy period is often during the annual Hajj pilgrimage. The rituals performed by pilgrims in the Holy Mosque requires them to be often on the move (circulating the Kaaba and walking between two locations called the Al-Safa and Marwah), except when congregational prayers are done that normally last only for about 5 minutes each time.

Several disasters have occurred which have been reported by numerous researchers such as Gad-el-Hak (2008) and Miller (2015). Such incidents have caused the loss of thousands of lives, especially during the Hajj period. Researchers such as Still (2000) has established the safety crowd density limit as 40 persons in every 10 metres square for a crowd that is moving and 47 for a stationary crowd. However, Alnabulsi and Drury (2014) have established that crowd density in the Holy Mosque often reaches 6–8 persons per meter square, which is almost doubled the safety limit. Such a crowd density in any confined space is regarded as extremely high risk with the potential of the occurrence of a crowd disaster. The highest density in the Holy Mosque is often reached during the Hajj, especially on the second day. Berlonghi (1995) classified this type of crowd as "a dense or suffocating crowd" which he defined as a crowd in which the physical environment is rapidly decreasing because of high density as people get swept along with movement and compression. He argued that such a crowd could result in injuries and even fatalities.

In the development and the use of crowded large space buildings, health and safety are always on the top, or the most important factor for designers and facilities managers. In various venues across the world, either poor design or management of health and safety risks in such buildings are often the most cause of crowd disasters, which is known to have been exacerbated by the behaviour of the users. Researchers like Sagun et al (2008) have shown that the fundamental principle of safety in the built environment is ensuring the safety of occupants during both normal uses and in an emergency. For the Holy Mosque, the Hajj Authorities have invested heavily in infrastructure and are using strategies and systems to help mitigate the Health and Safety risks using objective safety considerations based on global best practices. The emphasis on objective safety is a good thing, but it is also important that subjective safety (perceived) is equally considered and therefore cannot be overlooked. Dickie (1995) provided evidence, when he studied some major past crowd disasters in Sunderland in 1883 (183 deaths), in London 1943 (173 deaths), in 1946 in Bolton (with 33 deaths), in 1971 at Glasgow with 66 deaths and in Sheffield in 1989 (96 deaths), that a flaw of hazard and poor risk management during the event were major factors or reasons for these disasters, and that issues associated with the perception of the crowd and their actions or behaviour could not be eliminated from the reasons leading to the disastrous outcomes.

As reported by Miller (2015), BBC (2015), and Challenger et al (2009), notable stampedes and other failures have occurred at various Hajj events that resulted in the many injuries and death of thousands of pilgrims. Although none of these notable disasters has occurred directly in the Holy Mosque, having our knowledge of past crowd disasters at events, the level of crowd density, and the increasing number of pilgrims it is sufficient evidence that the potentiality of occurrence of a crowd disaster is extremely high. This reveals the essential need of having a better understanding of the relationships between perceived safety and behaviour of users (the pilgrims) in the Holy Mosque.

Previous publication by Alkhadim et al (2018) have identified 10 critical factors of perceived safety in crowded large space buildings, namely:

i. Perceived force (PF),

ii. Perceived poor information (PPI),

iii. Perceived insufficient space (PIS),

iv. Perceived poor real time management (PPRTM),

v. Perceived risk of stampede (PRS),

vi. Perceived risk of riot (PRR),

vii. Perceived risk of structural failure (PRSF),

viii. Perceived risk of terrorist attack (PRTA),

ix. Perceived risk of explosion (PRE),

x. Perceived risk of natural disaster (PRND).

Their work adapted the first model developed by Fruin (1993), the six dimensions and Loci model developed by Chukwuma and Kingsley (2014) to identify the 10 subjective safety factors. Alkhadim et al (2018a) reported a detailed confirmatory factor analysis of these factors together with PS, UB and tested the theoretical pattern of the variables and their loading on a developed construct to show how well they match reality.

Based on the studies by Fruin (1993), Chukwuma and Kingsley (2014), Alkhadim et al (2018), and Alkhadim et al (2018a) a conceptual SCSM has been developed to enable the investigation of the interrelationships between the 12 variables. The SCSM model is depicted in Fig. 1. As shown in the SCSM model, there are 3 sets of hypotheses. The first set of ten hypotheses (H1a to H10a) is to test the respective direct effect of each critical factor on PS. The second set is the hypothesis H11 which will test the direct effect of perceived safety on UB, and the third set of ten other hypotheses (H1b to H10b) is aimed at testing the indirect effect of each critical factor on UB respectively. The primary aim of this paper is to investigate either the direct and indirect effects of the critical factors on PS and UB respectively or the direct effect of PS on UB. This has been achieved through the tests of the 21 hypotheses in the conceptual model.

## 3. Research Methodology

Following in-depth literature-based research and numerous visits to the Holy Mosque at different times, the study was able to establish the items for each variable to guide the development of the questionnaire. The primary data was collected using a group-administered questionnaire in electronic devises (such as iPads) from more than 2000 Hajj pilgrims coming from 62 countries based on a stratified sampling technique. After initial data screening, the 1,940 received questionnaires from pilgrims were accepted. The generated data were analysed with SPSS and AMOS 22 for descriptive analysis, CFA, and SEM. The CFA analyses established the 12 latent constructs while the assessment of the model clearly indicates solid evidence of unidimensionality, convergent validity, discriminant validity, and reliability. It, therefore, justified for further analysis to be undertaken. Out of 58 items, 38 items were found with acceptable factor loading greater than 0.60. As mentioned earlier, the details of the descriptive and CFA analyses have been reported in Alkhadim et al (2018a).

There are two main reasons why SEM was used as a statistical technique, namely: because the study is about establishing the relationship between the PS and UB, there are latent variables involved, and it is not possible to measure these variables directly. Secondly, it is a powerful tool for testing the model fit to the data and measurement error (unreliability) for each variable of the constructs. This capability of SEM has also been confirmed by Choi (2013).

## 4. Structural Equation Modeling

The research has developed a structural model as shown in Fig. 2, which presents the interrelationship among the 12 variables and the 38 items. It consists of 10 unobserved exogenous constructs (PF, PPIPIS, PPRTM, PRS, PRR, PRSF, PRTA, PRE and PRND) and two unobserved endogenous constructs (PS and UB).

Awang (2015) and Hu and Bentler (1999) found that a model that achieves fit indexes values of Comparative Fit Index (CFI) $\geq$ 0.90, Standardised Root Mean Square Residual (SRMR) $\leq$ 0.08, and the Root Mean Square Error of Approximation (RMSEA) $\leq$ 0.06 should be considered an acceptable model fit. Considering these fit indexes, the model illustrated in Fig. 2 is therefore considered a good fit because the CFI is 0.979, SRMR is 0.032, and RMSEA is established as 0.043. Consequently, it is acceptable for the model to be used for further analysis in testing the 21 different hypotheses identified in Fig. 1.

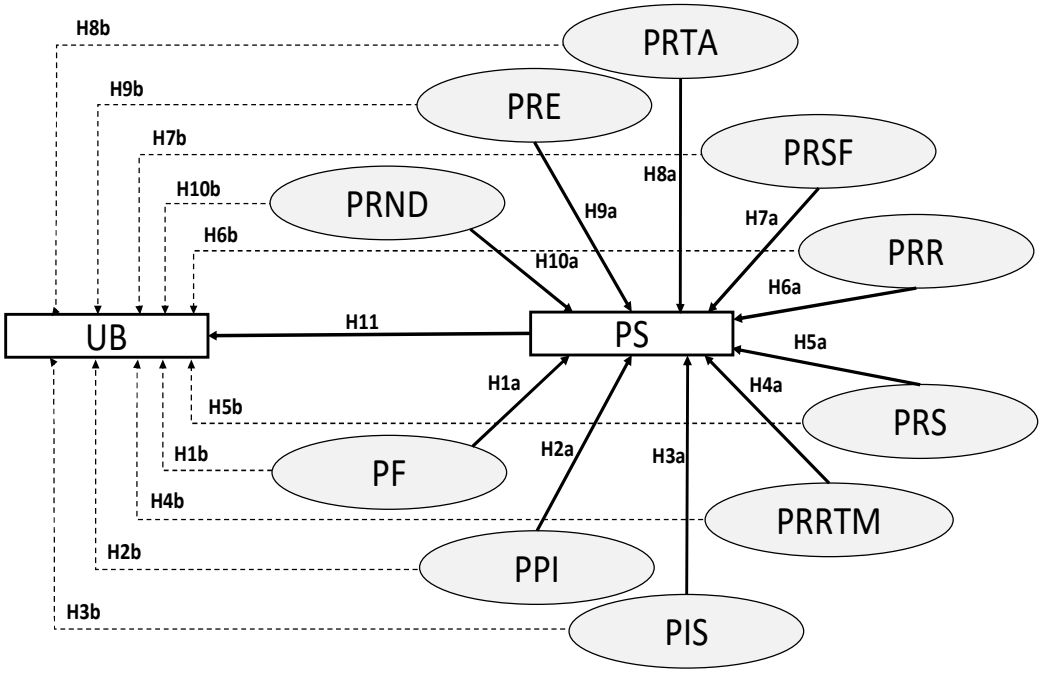


**Fig. 1.** The subjective crowd safety model (SCSM)

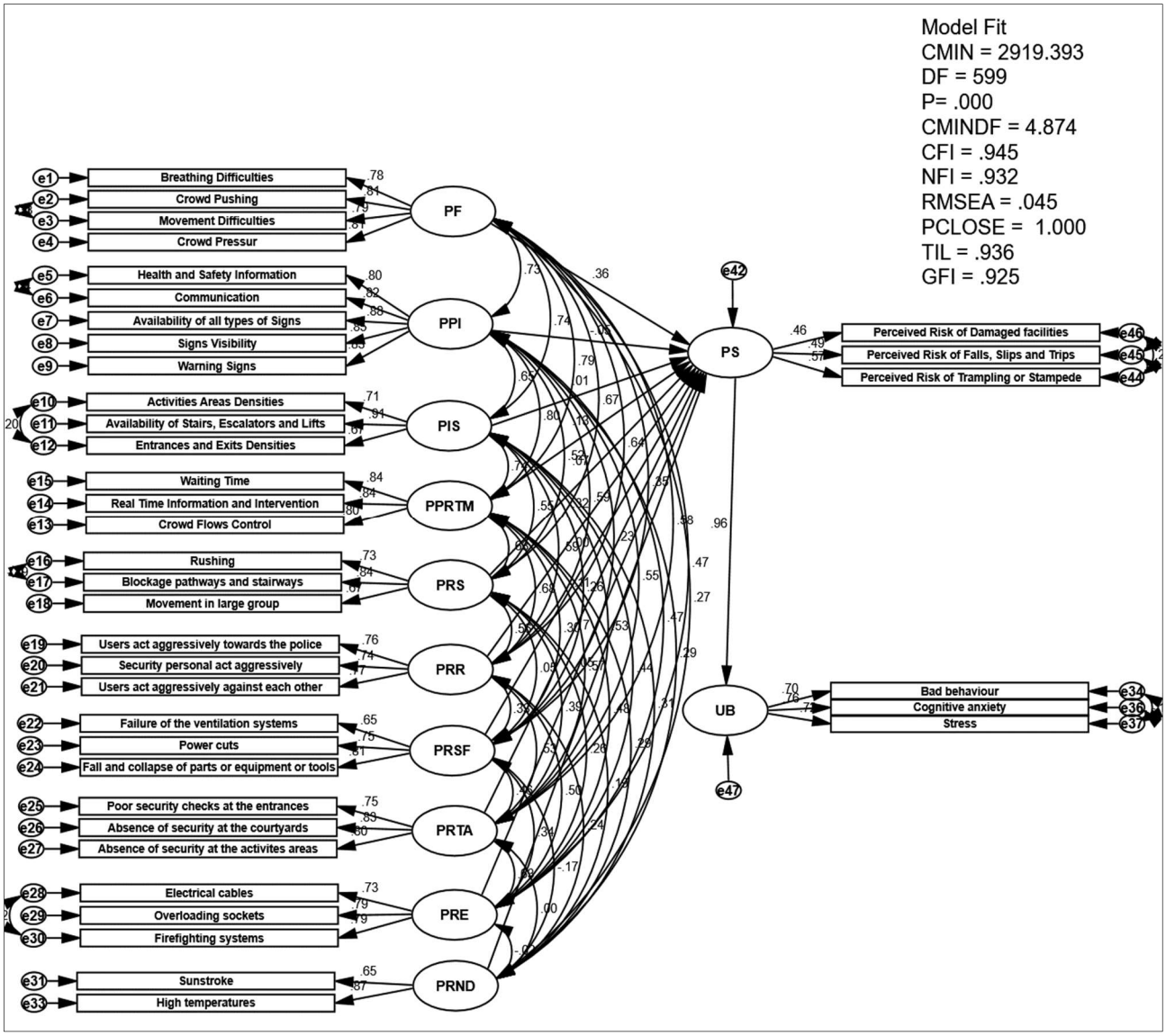


**Fig. 2.** The proposed structural model

## 5. Testing Direct Effects

From the further analysis, the outcome regarding direct effect of the critical factors on PS and direct effect of PS on UB are summarised in Table 1 which shows each path and its estimates for path coefficient weight, standard errors, coefficient regression composite reliability, and p-value as well as the remark or statement of significance for each path. It simply presents the effect of each of the exogenous constructs on the endogenous construct respectively.

The findings showed that the independent variables significantly affect PS, except the following three critical factors: PPI - with a p-value equals to 0.207; PIS having a p-value of 0.882; and PRSF (p=0.925). This means that the following hypotheses have been rejected: H2a, H3a, and H7a.

Again, in Table 1, the result of hypothesis H2a, in which PPI has a direct significant effect on PS, indicates that the path coefficient has a negative value of -0.026 with a p-value less than 0.207. This implies that the relationship is insignificant, therefore PPI does not have a significant influence on PS. This shows that for a one-unit increase in the PPI, its effect on PS will decrease by a measure of 0.207 units. Although Stokes (2015) and Challenger et al (2009) found that the crowd communication is essential in maintaining order and the behaviour of people in the crowd, this finding can be justified by claiming that listening to any announcement is least in the pilgrims' priority, because they are normally deep in their spiritual thoughts and deeds. Observation has revealed that the public address system in the Holy Mosque is only used for recitation of Quranic verses and for calling for prayers; it never used for announcements or crowd control.

For hypothesis H3a (i.e. PIS has a direct significant effect on PS), the established path coefficient of PIS to PS is 0.003 ($p<0.882$). Again, this is not statistically significant and can, therefore, be concluded that PIS does not have a significant direct influence on PS. This again is a surprising outcome since the literature review seems to indicate that space or PIS should be a significant factor due to the excessive congestion in the Holy Mosque, which has exceeded the recommended limits of crowd density. Although these results differ from published studies by Oakes and North (2008), Westover (1981),

**Table 1.** The significant effect among the constructs

| Constructs | | | Estimate β | S.E. | C.R. | p | Result |
|---|---|---|---|---|---|---|---|
| PS | <--- | PF | 0.229 | 0.031 | 7.507 | *** | Significant |
| PS | <--- | PPI | -0.026 | 0.021 | -1.263 | 0.207 | Not Significant |
| PS | <--- | PIS | 0.003 | 0.019 | 0.148 | 0.882 | Not Significant |
| PS | <--- | PPRTM | 0.076 | 0.03 | 2.543 | 0.011 | Significant |
| PS | <--- | PRS | 0.035 | 0.017 | 2.068 | 0.039 | Significant |
| PS | <--- | PRR | 0.19 | 0.021 | 8.976 | *** | Significant |
| PS | <--- | PRSF | -0.002 | 0.019 | -0.095 | 0.925 | Not Significant |
| PS | <--- | PRTA | 0.073 | 0.021 | 3.442 | *** | Significant |
| PS | <--- | PRE | 0.116 | 0.02 | 5.847 | *** | Significant |
| PS | <--- | PRND | 0.048 | 0.022 | 2.161 | 0.031 | Significant |
| UB | <--- | PS | 1.259 | 0.059 | 21.489 | *** | Significant |

other studies by Alnabulsi and Drury (2014), Kim et al (2016) that have both agreed with the finding. They argued that the crowd (pilgrims) must have been high in what they term "social identification" (i.e. Muslims). In that situation, the persons in a crowd act as one because they share a common social identity which increases cohesion and in-turn increases socialising within the crowd and positive feelings.

The testing of hypothesis H7a (i.e. PRSF has a direct significant effect on PS), the results revealed β= -0.002 and p<0.925. This is interpreted to mean that the hypothesis is not supported. Its, therefore, implies that PRSF has no significant direct effect on PS. Even though there was an incidence of a construction crane collapse in 2015 that resulted in fatalities, the rejection of H7a is expected because pilgrims consider the building to be a holy place built with good care using structurally sound building elements. The fact that there are no structural swaying or movements as the pilgrims conduct their rituals or deeds in the mosque, it reinforces their confidence.

Regarding Table 1, it can be deduced that each of the following hypotheses is supported. For hypothesis H1a (PF has a direct significant effect on PS), the path coefficient between PF and PS is significant with β = 0.229 (p<0.001). This suggests that for a unit increase in PF, its effect on PS increases by 0.229 units. It means that PF has a significant direct effect on PS. PF is created by hearing, feeling, sensing and/or seeing the effect of the force as the pilgrims perform their rituals in and around the Holy Mosque. Both Still (2016) and Berlonghi (1995) have established that when density exceeds a certain level, crowd force will increase and may result in a disaster.

The test of hypothesis H4a (i.e. PPRTM has a direct significant effect on PS) has revealed β = 0.076 and p<0.011. It means that PPRTM has a significant direct influence on pilgrims' perception of safety. Similarly, for hypothesis H5a (PRS has a significant influence on PS), the results showed β = 0.035, p<0.039, therefore, PRS has a significant direct effect on the pilgrims' perception of safety. Again, for hypothesis H6a (PRR has a significant influence on PS), the values of β = 0.19 and p<0.001 confirm that PRR has a significant direct effect on the pilgrims' perception of safety. This signifies the importance of avoiding any form of the riot in and around the Holy Mosque and the need to ensure effective implementation of real-time management. Interestingly, both PPRTM and PRR are more significant than the risk of a stampede. It seems to suggest that managers need to make explicit their efforts in timely crowd management (crowd stop & start, re-directions & diversions, entry & exit controls) and orderliness of procession because it tends to make the pilgrims feel safer even if it makes their processions to take longer.

The analysis of hypothesis H8a (PRTA has a direct significant effect on PS) gave the values of β = 0.073 and p-value <0.001. The results clearly support the hypothesis that the pilgrims' perceived risk of the occurrence of a terrorist attack has a significant direct influence on his or her perception of safety. The analysis of hypothesis H9a (PRE has a significant effect on PS) also revealed β = 0.116 and p<0.001. It means that the occurrence of any form of explosion (or explosive sound) has a significant effect on the perception of safety. Also for hypothesis H10a (PRND has a significant effect on PS), the value of β = 0.048 and value of p < 0.031. It confirms that the effect of natural disasters has a direct effect on pilgrims' perception of safety.

Although there is no record of any major terrorist attack or explosion occurring in the Holy Mosque, the results suggest that pilgrims see the threat of terrorism or an explosion as a critical risk factor. There are three key items in this risk factor that made the pilgrims feel unsafe: poor checking of pilgrims at all entrances, absence of security guards at the courtyards and entrances, and visible absence of security personnel especially at the locations of major ritual activities. The works of Araña and León (2008) and Kozak et al (2007) support these findings when they found the perceived threat of

terrorism directly influences the decision that persons make and the action they take. Having the 2016 Hajj during the hot season, it is also expected that the effect of natural disasters on subjective safety should be significant because the PRND factor includes items such as sunstroke, lack of shaded areas, and lack of alternatives to reduce high temperatures. The work of Lowe et al (2011) has found that high temperatures may cause an increase in aggressive behaviour, cramps, exhaustion, dehydration, and heatstroke.

The most important hypothesis is hypothesis H11 (i.e. PS has a significant direct influence on UB). The test results showed the value of β=1.259 and the p-value <0.001. This is statistically significant and it suggests that PS has a very high impact on the behaviour of pilgrims in the Holy Mosque. The works of Challenger et al (2009) and Machielse (2015) support this outcome when they confirmed that the sense of safety will normally influence how people behave in a crowded space. Similarly, the work of Zhuang and Wu (2012) is also consistent with this outcome when they found that the influence of subjective safety is significant in the study of the behaviour of the crowd and improve safety.

To summarise the findings, seven out of eleven hypotheses have been supported (H1a, H4a, H5a, H6a, H8a, H9a, H10a, and H11). The three rejected hypotheses are H2a, H3a, and H7a. H2a is rejected having a value of p=0.207, which could be interpreted that the information provided to pilgrims before and during the Hajj is appropriate and sufficient such that PPI has no significant effect on the pilgrims feeling unsafe. H3a has a value of p=0.882 and therefore rejected also, which could also be interpreted to mean that space in the Holy Mosque or the crowd density has no effect on the pilgrims' feeling unsafe. H7a is rejected (p=0.925), which means that the perception of a structural or mechanical collapse does not affect the pilgrims' feeling unsafe.

## 6. Testing Indirect Effects (Mediation)

As part of the research, the mediation effect (indirect effect) on the relationship between the independent and its dependent variables in the model has been examined. Gaskin (2016) and Gaskin and Lim (2016) defines mediation as the effect of one variable on another is transmitted (at least in part) via a third or intervening variable. It is simply the product of at least two paths that can be traced computationally from one variable to another. It means that for the research to analyse the mediation effect, it is required to recognize both the direct and indirect effects. The direct effect is that from an independent variable that goes directly to the dependent variable; while the indirect effect is simply that from independent to the dependent variable but through a mediator variable that can be either partial mediator or a full mediator.

To assess the indirect effect (i.e. mediation effects), the study used the resampling producer "bootstrapping". According to Awang (2015), this test is required by researchers to confirm the effects of mediation or for testing the indirect effect between variables. The tests were carried out using the Maximum Likelihood Bootstrapping resamples procedure in AMOS 22 with bootstrap samples of 2,000 and 95% bias-corrected confidence intervals.

**Table 2.** Mediation effect between factors and UB

| Parameter | β | Maximum likelihood | | | Bootstrap | | | | | Type of Mediation |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Lower | Upper | p | SE | SE-SE | Mean | Bias | SE-Bias | |
| **PF → PS → UB** | .289 | .204 | .386 | .001 | .046 | .001 | .289 | .001 | .001 | Partial Mediation |
| **PPI → PS → UB** | -.033 | -.098 | .028 | .301 | .032 | .000 | -.034 | -.001 | .001 | No Mediation |
| **PIS → PS → UB** | .004 | -.057 | .061 | .910 | .030 | .000 | .003 | -.001 | .001 | No Mediation |
| **PPRTM → PS → UB** | .096 | .012 | .192 | .027 | .046 | .001 | .096 | .001 | .001 | Partial Mediation |
| **PRS → PS → UB** | .044 | -.003 | .091 | .065 | .024 | .000 | .043 | .000 | .001 | No Mediation |
| **PRR → PS → UB** | .239 | .183 | .304 | .001 | .030 | .000 | .240 | .001 | .001 | Partial Mediation |
| **PRSF → PS → UB** | -.002 | -.049 | .047 | .947 | .025 | .000 | -.003 | -.001 | .001 | No Mediation |
| **PRTA → PS → UB** | .092 | .030 | .150 | .005 | .030 | .000 | .092 | .000 | .001 | Partial Mediation |
| **PRE → PS → UB** | .146 | .094 | .200 | .001 | .027 | .000 | .146 | .000 | .001 | Partial Mediation |
| **PRND → PS → UB** | .060 | .001 | .124 | .048 | .032 | .000 | .061 | .000 | .001 | Partial Mediation |

The results of the analyses are summarised in Table 2, where the values for the parameter estimate for the regression weight, upper and lower limit of confidence intervals, p-value, standard errors (SE), standard error estimate for the standard error (SE-SE), mean parameter estimate (mean), the bias for the parameter estimate (bias), and the standard error (SE-bias) are provided, including the type of the mediation for PS mediating the relationship between each of the 10 critical risk factors and UB. The results in Table 2 have revealed that the bootstrap estimate for the mediation effect was not biased.

For interpretation of the results, whenever the figure zero (the null) falls outside the lower and upper limit of the confidence intervals, it means that there is sufficient evidence to reject the null and infers that the indirect effect is significant. However, when zero (the null) falls within the interval, it fails to reject the null which infers that the effect is not significant. Also, whenever the direct effect and the indirect effect are both significant, the mediation type is normally regarded as 'partial mediation'.

The results in Table 2 indicate that the following hypotheses were therefore supported since 'zero' falls outside their respective values of the lower and upper limits of the confidence intervals of the parameter. It also shows that there is partial mediation since both the direct and indirect effects are significant, which therefore suggest that PS mediates the relationship between the various risk factors and UB:

i. The analysis of hypothesis H1b (i.e. PS mediates the relationship between PF and User UB*)* reveals that the indirect effect of PF on UB was statistically significant having the value of β= 0.289, p=0.001 and "zero" falls outside the lower limit of 0.204 and upper limit of 0.386 as the confidence intervals.

ii. For hypothesis H4b (PS mediates the relationship between PPRTM and UB), the results show that the indirect effect of PPRTM on UB was statistically significant (β= 0.096, p=0.027) and zero falls outside the lower limit and upper limit of the confidence intervals (0.012, 0.192).

iii. H6b (i.e. PS mediates the relationship between PRR and UB) - the indirect effect of PRR on UB was statistically significant (β = 0.239, p = 0.001) and zero falls outside the lower limit and upper limit of the confidence intervals of 0.183 and 0.304.

iv. For H8b (i.e. PS mediate the relationship between PRTA and UB) - the indirect effect of PRTA on UB was statistically significant (β = 0.092, p = 0.005), and zero falls outside the lower limit and upper limit values of the confidence intervals (i.e. 0.030, 0.150).

v. Similarly, for hypothesis H9b (PS mediate the relationship between PRE and UB) - the indirect effect of PRE-on UB was statistically significant (β= 0.146, p=0.001) and zero falls outside the lower limit and upper limit of the confidence intervals (i.e. 0.094, 0.200).

vi. Lastly, hypothesis H10b (PS mediate the relationship between PRND and UB) - the indirect effect of PRND on UB was also statistically significant with β = 0.060, p=0.048, and zero falls outside the lower limit and upper limit of the confidence intervals (0.001, 0.124).

However, the other four hypotheses were rejected because the indirect effect is found to be statistically not significant and "zero" falls within the lower and upper limits of the confidence intervals. The results of the analyses evidently show that both the direct and indirect effects are all not significant, therefore, confirm "no mediation" between the respective critical factors and user behaviour. It means PS does not mediate the relationships between each of the four critical factors and user behaviour. The findings for each of the four hypotheses are stated as follows:

i. H2b (PS mediates the relationship between PPI and UB) - the results indicate that there is no any significant indirect effect of PPI on UB having β= -0.033, p=0.301, and zero falls within the lower limit and upper limit of the confidence intervals obtained as -0.098 and 0.028 respectively.

ii. For H3b (PS mediates the relationship between PIS and UB) the results have shown that the indirect effect of PIS on UB was statistically not significant with the values of β= -0.004 and p=0.910. It is also established that zero falls within the lower limit and upper limit of the confidence intervals (-0.057, 0.061).

iii. H5b (PS mediates the relationship between PRS and UB) similarly, the indirect effect of PRS on UB was statistically not significant with values of β= -0.044 and p=0.065. It is also established that the figure zero falls within the lower limit and the upper limit of the confidence intervals (-0.003, 0.091).

iv. H7b (PS mediates the relationship between PRSF and UB) – again, the results suggest that the indirect effect of PRSF on user behavior UB was statistically not significant (β= -0.002, p=0.947) and that the numerical figure zero is within the lower limit and upper limit of the confidence intervals (lower limit = -0.049, upper limit = 0.047).

In summary, the research interpreted the outcomes of the rejected hypotheses as follows: the rejection of H2b means that the awareness of the pilgrims and the information provided to them during Hajj is appropriate and adequate; the rejection of H3b could mean that the space provided in the Holy Mosque does not have any effect on the behaviour of the pilgrims; and also the resulting high crowd density does not have a direct effect on the pilgrims such that they become stressed-up or unnecessarily anxious; The rejection of H5b means that although the risk of stampede influence the pilgrims perception of safety, the perception does not mediate its influence on the behaviour of the pilgrim in the Holy Mosque; and finally the rejection of hypothesis H7a suggests that the likelihood of structural collapse and/or mechanical failure does not affect on the behaviour of the pilgrims in the Holy Mosque.

## 7. Conclusion

The paper has discussed the direct and indirect relationships among the variables. It rigorously tested the proposed SEM and helped in establishing the interrelationships among the twelve constructs. The overall key finding is that there is a direct influence of perceived safety on the pilgrims' behaviour in the Holy Mosque. The research provided convincing evidence that perceived safety should not be overlooked in the management of safety because it is a high impact factor on the level of safety (safe condition), especially in crowded large space buildings. It also establishes that

there are seven major critical factors that have a direct influence on the level of the perceived safety of pilgrims as it applies in the Holy Mosque, namely (in the order of significance):

i. Perceived force (PF),

ii. Perceived risk of riot (PRR),

iii. Perceived risk of explosion (PRE),

iv. Perceived poor real-time management (PPRTM),

v. Perceived risk of terrorist attack (PRTA),

vi. Perceived risk of natural disaster (PRND), and

vii. Perceived risk of stampede (PRS).

With the exception of the perceived risk of a stampede, all of the above critical factors also have an indirect effect on user behaviour. Since Raineri (2015) has already established that crowd behaviour is a major factor in crowd disaster, therefore, it is plausible to conclude that anything that significantly influences crowd behaviour could result in an unsafe situation that could lead to a disaster.

The three critical factors that do not have a significant effect on perceived safety are, namely: PPI Perceived Poor Information (p=0.207), PIS Perceived Insufficient Space (p=0.882), and PRSF Perceived risk of Structural Failure (p=0.882).

The paper also discussed the results of the mediation effect (indirect effect) on the relationship between the independent and its dependent variables in the SCSM model. The results have shown six out of ten critical perceived safety factors have significant indirect relationships with user behaviour, namely: PF; PRTM; PRR; PRTA; PRE; and PRND.

The paper suggests that although the expansion of the Holy Mosque as a mitigating strategy would help in objective safety provision, it is however not sufficient to address all the safety challenges. It suggests that Space (PIS), Information (PPI) and Structural failure (PRSF) are not the most critical subjective safety factors for Facilities Managers to worry about. Facilities managers should pay greater attention to creating an orderly procession of pilgrims to prevent perceived force (PF) or risk of riots (PRR), adequate provision of better and reliable hard services to mitigate the risk of explosion (PRE), and provision of better and visible security screening to decrease the risk of terrorist attack (PRTA).

The following recommendations are made to enhance safety at the Holy Mosque:

- All Risk Assessment templates must have an additional section that addresses subjective (perceived) safety. From the research reported in this paper, it is evidently clear that subjective (perceived) safety must be included in all health and safety evaluation and management. It means PS should therefore be added into the general evaluation process of health and safety of crowded space buildings such as the Holy Mosque.

- To enhance the 'feeling safe' of pilgrims as they arrive at the Holy Mosque, it is necessary to have a visible (explicit) system that provides complete coverage and monitoring of all pilgrims. It is important to deploy an effective use of modern technology to control the inflow and outflow of pilgrims (e.g. to count the actual numbers of people that enter and exit the Holy Mosque) at the entrances and exits in order to effectively manage the crowd to avoid extreme high density in the Holy Mosque at all times. The data and information obtained from such a system could also be used to control the rate of arrivals from Mina to the Holy Mosque at peak times during the Hajj to help avoid the pilgrims congregating at entrances as they wait to enter the Mosque.

- In the Holy Mosque, all mechanical and electrical engineering systems and services are primarily managed for the wellbeing of the occupants, but now having perceived safety as one of the core aspects of the management strategy, the maintenance system of all Mechanical and Electrical (M&E) hard services in the facility should now include the avoidance of any type of explosive sound from equipment breakdown. All M&E equipment should be covered or surrounded with sound absorbers to avoid load sounds in the event of exploding.

- Provide a form of security screening system at entrances that can reliably reduce the risk of the terrorist attack and improve the confidence of pilgrims.

- Deploy appropriate strategies to mitigate the unnecessary occurrence of perceived force e.g. to stop pilgrims from moving in the opposite direction of Tawaf; to stop 'large groups' from performing the Tawaf at the ground floor level.

- The research has established that Perceived Risk of Natural Disaster (PRND) has a significant influence on the perception of the safety of users (PS); that PS has a significant direct effect on the behavior of the users (UB); and that PRND has a significant indirect effect on UB. It is therefore very important to pay attention to the items making up the PRND variable. These items include sunstroke and high temperatures. It means that the managers of the Holy Mosque should consider the installation of shades/covers in open areas in order to minimize exposure to heat waves that ultimately impact PRND, PS, and UB with a resulting bad user behavior or even stampede.

**Acknowledgements**

The authors wish to acknowledge the unconditional support provided by the Institute for Hajj and Umrah Research – Umm Al-Qura University in facilitating access to pilgrims and other stakeholders, collection of primary data, and the use of their equipment and facilities.

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