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Risk Management: The effect of FIST on perceived safety in crowded large space buildings

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Abstract: Facilities management within large buildings used by large crowds must involve effective risk management as a key component. Poor risk management within large space buildings such as sport stadiums, concert halls, and religious buildings have resulted in crowd disasters in various venues across the world. Fruin suggested that Force, Information, Space and Time (FIST) are the main factors that influence the occurrence of crowd disaster. Within the built environment, safety is considered in two main parts: objective safety (normative and substantive) and subjective safety (perceived). This paper theorised that poor perceived safety alone could result into crowd disaster, and by using the FIST model, it investigates the relationship between the four critical FIST factors and perceived safety in large buildings. The research chose to use the Holy Mosque in Makkah as a case study, a building where large crowd always use on continuous basis all year round with its peak occupancy usually reached during the Hajj (an annual pilgrimage to Makkah that is undertaken by Muslims from all over the world). The Holy Mosque is a large building of 356,800 square metres with a maximum capacity of two million users (pilgrims). Data was collected using iPad devices via a group-administered questionnaire distributed to 1,940 pilgrims of 62 different nationalities. The results were analysed using SPSS for descriptive analysis and AMOS 22 for Confirmatory Factor Analysis (CFA) and Structural Equation Modelling (SEM). The fitness of the model was tested and the unidimensionality, convergent validity, discriminant validity, and reliability were assessed. The findings clearly confirmed that there is a significant relationship between the FIST factors and perceived safety in large buildings. These findings will assist facilities managers by making them aware of the users' safety perception and the factors that make them feel unsafe.

Keywords: Facilities management, risk management, perceived safety, crowd safety, crowd disaster, structural equation modeling.

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1. Introduction

Safety in built environment is made of objective safety and subjective safety (perceived safety) (Sorensen & Mosslemi, 2009). In organizational context, objective safety is measured as the actual number or risk of incidents or injuries occurred in an organization. Whilst subjective safety is intangible and it refers to the feeling or perception of being safe or unsafe within a specified period. Numerous studies have been undertaken on objective safety in the built environment (Sagun et al., 2013; Wieringa et al., 2016; Sagun et al., 2008), but there has been a lack of research on the subjective safety (perceived safety) particularly in large space buildings where large numbers of users attend at the same time for an event or congregation.

Research has concluded that safety is the inverse of risk-the lower risk the higher is the safety (Moller et al., 2006). It means safety can be achieved through mitigating a risk to a tolerable level by using risk management approaches. Dickie (1995) confirmed that poor risk management in large space buildings during an event have led to many crowd disasters across the world. Booty (2009) stated that each large space building used by large number of people (crowd) is normally surrounded by diverse types and levels of risk requiring an effective management. Leopkey and Parent (2009) defined risk management as a proactive approach to eliminate threats to an organization through anticipating, identifying, assessing and mitigating the possible risks. The British Institute of Facilities Management (BIFM, 2014) have classified Risk Management (RM) as one of the 24 key components of Facilities Management (FM). FM covers all aspects of planning, managing space, designing, environmental control, health and safety and support services (Alexander, 1996). It significantly contributes to the delivery of strategic and operational objectives on a day-to-day basis (Nazali et al., 2009). When events are held in large space buildings, Ali et al. (2011) highlighted that facilities managers must be involved before, during and after the event to reduce risk and enhance safety. Chotipanich (2004) mentioned that organizations that own large space assets for public use often make the strategy to reduce risks as a top priority to enable them gain advantage over their competitors.

It is therefore conclusive that FM of large space buildings used by large number of people (crowd) must involve an effective risk management as a key component. In current practice, emphasis is placed on addressing objective safety. Fruin (1993) has studied this issue and established some of the key factors that influence objective crowd safety that he referred to as crowd disaster. As mentioned earlier, there is a lack of understanding of the same issue as it relates to subjective safety. This study therefore has adopted the factors used by Fruin to investigate whether they affect subjective safety in large space buildings. The factors are referred to by the acronym FIST: Force, Information, Space, and Time. The paper argued that there is a strong relationship between FIST and perceived safety in large space buildings by studying the extent to which perceived Force, perceived poor Information, perceived insufficient Space, and perceived poor Time management influence perceived safety. For the research to investigate this hypothesis, the Holy Mosque in Makkah, Saudi Arabia has been chosen as a sample large space building for the research project.

2. The Holy Mosque as a Large Building

Hajj is a religious event which includes large number of pilgrims with diverse cultures, ages, genders, nationalities and languages. It is one of the five pillars of Islam and an obligation for Muslims whom are capable financially and physically to perform Hajj at least once in their lifetime (Khan, 2012; Alsolami et al., 2016). Annually around two million pilgrims, visit Makkah (also called Mecca) to perform the Hajj, at the same place and time in a period ranging between 4 to 6 days. This has been considered one of the largest gatherings in the world (Alnabulsi & Drury, 2014), and the number of people who wish to perform Hajj is increasing yearly. The rituals of the pilgrimage are mainly concentrated in four holy places: Holy Mosque, Mina, Muzdalifah and Arafat. These are situated at different parts of the city and its neighbourhood (Ascoura2013). The pilgrims arrive to Mecca on the 8th Dhul-Hijjah Arabic calendar when the Hajj starts and they leave after completing their rituals by the end of Hajj on the 13th Dhul-Hijjah. The first holy place the pilgrims visit when they arrive is the Holy Mosque to perform Tawaf and Saee. Tawaf is a movement of the pilgrims around the Kaaba (circumvention), which is situated in the centre of the Holy Mosque. In Tawaf, pilgrims move around the Kaaba seven times in an anticlockwise direction. While in the Saee, pilgrims walk seven rounds between two points in the Holy Mosque called Safa and Marwah, where each round is around 0.5 km in distance (Khan, 2012). On completion of the welcome Tawaf and Saee at the Holy Mosque, the pilgrims then travel to Mina to camp for a night. They then start moving from Mina to Arafat, where they camp again until sunset. They then move to another location called Muzdalifah, to camp until midnight. After that they move to Jamaraat Bridge to perform another ritual before they return to the Holy Mosque for another Tawaf and Saee. It is usually at this event that the Holy Mosque is full to its maximum capacity.

The Holy Mosque is a large space building which can accommodate around two million worshipers at the same time. It includes indoor (covered) and outdoor (open) type spaces that makes it more complex to effectively manage and control. The Holy Mosque is considered one of the largest mosque in the world. Throughout the Kingdom of Saudi Arabia history, numerous expansion projects have been carried out. The first major expansion began in 1956 and lasted for ten years to complete. This expansion was done by King Saud when the area of the Holy Mosque was about 28,000 square meters with capacity of 50,000 worshipers. Since then the area of the Holy Mosque has been expanded to accommodate the number of the worshipers who are increasing yearly. The current area of the Holy Mosque has reached up to 356,800 square meters and still increasing (Alnabulsi & Drury, 2014).

Fig. 1. Holy Mosque in Makkah

Figure 1 shows the aerial view of the Holy Mosque with the Kaabah situated centrally and the Safa (at the top) and Marwah (bottom right) points are connected by clearly visible long straight lines.

Several incidents have occurred during the Hajj that caused the loss of hundreds of lives (Miller, 2015; BBC, 2015). Still (2000) identified the safety limit for crowd density as 40 people in 10 square meters for a moving crowd and 47 for standing areas. The level of the density at the Holy Mosque in its full capacity reaches 6-8 people per square meter, which is considered extremely high because having such density has the potential for the occurrence of crowd disaster. This research is primarily focusing on preventing these incidents in the Holy Mosque. The safety of the users at risk is the priority at this stage to reduce the risks in the future. Hajj authorities are investing a lot of resources in crowd management and crowd control and continuously modifying and adjusting the physical environment of the Holy Mosque based on objective safety considerations.

This study is focused on the risk perception rather than other emotions. Other studies such as Barhamain (1997) investigated the level of satisfaction of users based on their experience with regards to the facilities and services provided during the Hajj event. It was found that six critical factors of facilities and services have an apparent influence on the users' perceptions. The findings emphasised that the security and safety in crowded large space buildings are ranked the highest required factors. This research is providing data for additional issues that must be considered in order to ensure a safe physical environment and crowd protection measures based on subjective safety. The research is not about modelling the movement of the crowd or the physical space, it is about the perception of the pilgrim and how can that perception affect the safety in the environment.

3. The Conceptual Model

This study investigates the relationship between the four FIST factors with perceived safety. It chose the Fruin (1993) theoretical framework to propose a simple model made up of four hypotheses for the research inquiry. Imenda (2014) defined a theoretical framework as "the application of a theory, or a set of concepts drawn from one and the same theory, to offer an explanation of an event, or shed some light on a particular phenomenon or research problem".

According to Fruin (1993) the FIST elements were derived from personal experiences, analysis of major crowd incidents and traffic flow principles. The FIST model has been established to demonstrate that the crowd characteristics, prevent and mitigate the crowd disasters through developing efficient guidelines. Indeed, it was developed based on the real conditions and objective safety. The proposed conceptual model used in this research replaces the tangible items used by Fruin with perceived situation and its effect on perceived safety. The conceptual model is shown in Figure 2, which includes one dependent variable (perceived safety) and four independent variables (perceived force, perceived poor information, perceived insufficient space, perceived poor real time management).

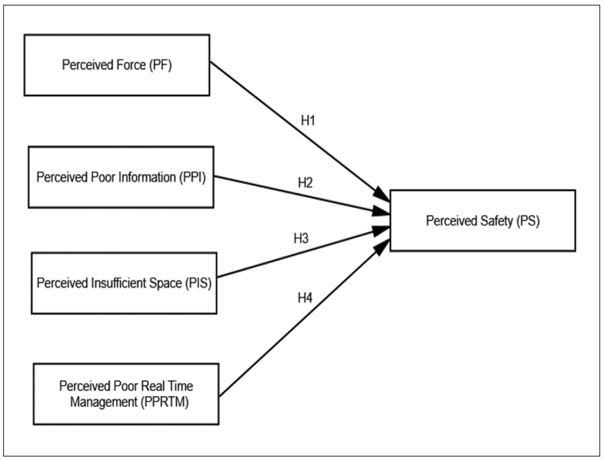

Fig. 2. The conceptual framework

In the conceptual model, the relationships between the independent variables and the dependent variable could be influenced by factors that may originate from two main sources, i.e.: the Environmental envelope; and the User. The environmental envelope surrounding the relationships include the characteristics of the environment, physical condition and space layout or configuration. In the Facilities Management (FM) point of view, the planning through implementation to the controlling functions are conducted through the environmental envelope. The FM is able to change the characteristics and/or the physical conditions and/or the space configuration by using the 24 components of FM to implement appropriate systems for Hard and Soft Services in response to the perception or requirements of the user to achieve the optimum fit. The factors that could influence the relationships between the variables (independent versus dependent) that originate from the User include: the Personal (e.g. experience, education, sex, age, religion); Physical (e.g. fitness, mobility); Psychological (e.g. phobia, depression, anxiety); and Physiological (e.g. blood pressure, heart condition, sight, hearing). As part of the authors' global study, only the personal factors have been considered, which means that the research has assumed that the physical, psychological and physiological factors are frozen or static.

In this study, the perceived safety is defined as the feeling (or perception) of an **unsafe situation** at an event over a specified period. Based upon this definition and the defined context stated, the dependent and independent variables will be empirically and statistically measured. The following sub-sections will provide detail definitions of the dependent variable (perceived safety) and the four independent variables (perceived force, perceived poor information, perceived insufficient space, perceived poor real time management) leading to the development of the four hypotheses H1, H2, H3 and H4.

3.1 Perceived Safety (PS)

Perceived safety refers to the feeling (or perception) of an unsafe situation that exist during an event. Studies in urban design have shown that perceived safety can be affected by the characteristic of the environment, physical condition, and configuration of spaces (Mehta, 2013). As people feel unsafe in such an environment for some reason, they panic and often attempt to escape from the real or perceived danger by acting abnormally and/or chaotic pushing and shoving (Challenger et al., 2009b). This may raise the user's perception of risk of trampling or stampede. Similarly, the physical condition of the facility with regard to risk of falls, slips and trips can affect the user's perception of safety. Again, someone new to an environment may find it safe because they may not be familiar with specific cues of the context. For example, being aware of any structural or mechanical or electrical damage to existing facilities or the potentiality of occurrence of such damage may raise the perception of risk of facilities failure or damage. In crowding studies, it has been highlighted that the perceived safety is closely tied to perceived crowding (Graefe et al., 1984; Dawson & Watson, 2000; Tseng et al., 2009). Perceived crowding is defined as "the psychological counterpart to population density" (Kim et al., 2016). The perceived safety is negatively affected by the perceptions of crowding - and research has shown that when perception of crowding increase, people sense of safety decline (Tseng et al., 2009) that may negatively go to the level of perceiving the risk of fatality. These perceptions can vary with age, sex, culture, and familiarity with the environment (Mehta, 2013; Yang & Wyckoff, 2010), for example: women and older people have diverse sense of safety compared with others.

3.2 Perceived Force (PF)

Perceived force is the feeling or perception of force by an individual within a crowd which may originate by either seeing, hearing or feeling. There are several consequences that may result from the perceived force which have been termed as indictors (items) by this study. Force in the crowd is usually created from the interior of the crowd and has two main forms: the self-driven force; and the leaning force that comes from the weights of the bodies (Zhen et al., 2008). It can reach to high level such that it cannot be easily controlled or resisted due to high pressure of the crowd (Still, 2016; Fruin, 1993). It is argued by Zhen et al. (2008) that the force among people is a significant factor that leads to casualties. (Silvers, 2008; Still, 2016; Fruin, 1993; Yokota, 2005) stated that most of the deadliest event disasters involved large crowds, with most of the injuries and fatalities originating from crowd compression and the subsequent loss of footing or inability to move. Fruin (1993) pointed out that "horizontal forces sufficient to cause compressive asphyxia would be more dynamic as people push off against each other to obtain breathing space". He confirmed that news media have reported that compressive asphyxia is the main reason of deaths not the trampling. Berlonghi, 1995 argued that when people in a crowd are being swept along with movement and compressed, it can lead to serious injuries and fatalities from suffocation. Krausz & Bauckhage (2012) claimed that most of the people who die from suffocation die because of the enormous pressure on their chests (up to 4500 N (1000 lbs.)), which Zhen et al. (2008) referred to as the most sensitive part of the body to a crushing force. Forces among people in a crowd are generally created when the density is higher than a certain level, and a disaster can occur when the crowd density reaches a critical density.

Helbing & Mukerji (2012) have mentioned that it is not only the density that crushes people, but also the crowd dynamic (particularly when the density becomes high); and the physical interaction among people that transfers forces from one body to others. Critical crowd density is when the floor space of standing person reaches to around 1.5 square feet. According to Fruin (1993) crowds become a fluid mass when it reaches 7 persons per square metre, and describing the psychological pressures of crowds while they are moving at maximum density is difficult. As the density increases, individuals may lose control over their direction of movement and become part of the crowd. At this point the crowd density equals the plan area of the human body.

From the above literature review, the established indicators (items) could be summarised as breathing difficulties, crowd pushing, movement difficulty, crowd pressure, uncontrollable pushing, and suffocation. The literature review has clearly demonstrated that 'Force' is a critical factor to crowd safety. This study will test the effect of perceived force on perceived safety in the Holy Mosque during the Hajj, therefore the following hypothesis has been formulated:

H1: Perceived force has a significant influence on perceived safety.

3.3 Perceived Poor Information (PPI)

Before attending an event, an individual may consider a wide range of information with regards to the venue and the type of crowd. This information could include the nature of the group, experience with similar groups, familiarity with the venue, crowd behaviour, signage and means of communication between those managing the crowd and the crowd. Fruin (1993) pointed out that the information includes the means of communication, sights and sounds influencing the perceptions of the group, public address, signs, ticketing, actions and training of personale. Sime (1999) argued that poor communication before or during an event is characterized as one of the causes of crowd disaster. Obtaining real time information about the situation of the crowd in large assembly spaces including crowd actions, reactions, real or perceived is therefore essential. Experts have underlined that communication and real-time information are key factors in preventing crowd disasters. It is a good practice to set up a communications centre and a centralized crowd management system. Information communicated to – or withheld from – the crowd can influence their perceived safety. The Cabinet Office (2009) guidance states that "communicating with the crowd is essential in maintaining order and managing behavior". Based on the above literature review, the following indicators (items) for perceived poor information could identified: health and safety information, communication, availability of all types of signs, signs visibility, and warning signs. It also means that the following hypothesis could be formulated:

H2: Perceived poor information has a significant influence on perceived safety.

3.4 Perceived Insufficient Space (PIS)

Space in built facilities includes physical facilities, seating area, corridors, stairs, escalators, standing area and lifts. Architects and engineers will typically pay attention to local building codes but may often disregard for people's movement and perception of safety. It has been shown that when the venue does not have enough space to accommodate the crowd and the capacity becoming high, say seven people per one square meter, the human psychology will usually undergo a change. It is also argued by experts that when people attempt to escape from a possible disaster they rush to an exit ignoring alternative exits made available. Although this research has frozen the factors that could influence the user other than the personal factors, Fruin (1993) has indicated that it is hard to describe the psychological and physiological pressure within a high-density crowd because individuals may lose their control. Several studies have shown that crowd density can influence the perceived safety and behavior (Westover, 1981; Oakes & North, 2008; Alnabulsi & Drury, 2014). Others have shown that human bodies within crowded space are surrounded by heat and thermal insulation to the extent that some people may be weakened and faint (Chukwuma & Kingsley, 2014). Research has also shown that it is not only the space availability that is the issue, but its ineffective or poor use. This is often caused by the failure of crowd control system which may result into human stampede (Chukwuma & Kingsley, 2014). Therefore, it could be concluded that ineffective or poor use of space is also one of the key risk factors that could lead to crowd disaster (Still, 2000).

From the above literature review, the indicators (items) for PIS could be summarised as: density in activities areas; availability and distribution of stairs, escalators and lifts; densities at entrances and exits; densities at walkways; and other spaces available. Similarly, the following hypothesis has been formulated:

H3: Perceived insufficient space has a significant influence on perceived safety

3.5 Perceived Poor Real Time Management (PPRTM)

Fruin (1993), argued that real time information and intervention is a key factor for preventing crowd disasters. Time plays an important role in an event, for instance the density of the crowds before the event is much less compared to the rapid egress and heavy crowd densities leaving an event. Research has shown that failure of detecting the crowd behavior at the right time can lead to injuries and fatalities (Lloyd et al., 2017). Crowd management literature have made it clear that it is a requirement to ensure the flow of the pedestrian does not exceed the capacity of the spaces through which they are flowing or the capacities of the space in which they are congregating. The crowd congregation could be as people wait at entrances, exits and/or stairways and lifts/escalators, or as they arrive at the final event location. There is evidence to suggest that lack of consideration is sometimes given to how crowd flow and density. Literature has shown that crowd flows and its density can be successfully managed by controlling timings (Cabinet Office, 2009). Based upon the literature review, the indicators (items) are summarised as: crowd flows control; real time information and intervention; waiting time; waiting time at entrance; and control systems. Hence, the hypothesis is formulated as follows:

H4: Perceived poor real time management has a significant influence on perceived safety.

4. Research Method

A questionnaire can be administered in two different ways: self-administered questionnaire and group administered questionnaire (Zohrabi, 2013). Self-administered questionnaires are usually completed by the respondents. This type of questionnaire can be administered electronically using the internet, phone, intranet, or by sending the questionnaires through post or email to the respondents who then return later after completion. Alternatively, they can be delivered by hand to each respondent and collected later (Saunders et al., 2009). This procedure has some major defects as the respondents often don't return the questionnaire or may face unclear or vague questions while the researcher is unavailable to clarify them. Also, the researcher does not have any idea how the respondents answered the questions. While the group administered questionnaire "is administered to the groups of individuals all at one time and place …" (ibid). This method is often preferred than the self-administered approach because it has a higher rate of return and the researcher retains the opportunity to be able to clarify to the respondents any misunderstanding that may arise (Zohrabi 2013).

For this study therefore, the primary data was obtained using group-administered questionnaire. The group administered questionnaire is chosen instead of the self-administered approach because of the following: the respondents (pilgrims from all over world) have limited time at Makkah; there is the need to achieve a high rate of return to meet the unit sampling targets; the respondents speak different languages and thus may seek clarification if any misunderstanding arises.

The questionnaire encompassed six sections: section one is background information; sections two to five are designed to measure the user (pilgrim) perception with reference to the independent variables (perceived force, perceived poor information, perceived insufficient space, perceived poor real-time management), section six refers to the dependent variable (perceived safety).

The items included in the questionnaire were adapted from literature reviewed including but not limited to Berlonghi, 1995; Alnabulsi & Drury, 2014; Fruin, 1993; Chukwuma & Kingsley, 2014; Kemp & Moore, 2010; Rahmat et al., 2011; Illiyas et al., 2013. All the identified indicators (items) have been included in the questionnaire to achieve the aim of the study. Each of the items was measured on a 5-point Likert scale (using 1= strongly disagree through to 5 = strongly agree.

A pilot study was carried out in Makkah in 2016 before the Hajj began in order to evaluate the validity and reliability of the questions and instructions. It aimed to check the clarity of instructions and the items of the questionnaire, to determine the time needed to complete the questionnaire, to ensure the statements were clear and easy (not difficult or complex) to understand and to gain any other useful comments that could add value to the questionnaire.

The population sampling for this study targeted all the pilgrims (local and foreigners coming specifically for the Hajj) during Hajj within the zone of Makkah. A total population size of 1,942,946 pilgrims was determined based on the report provided by Ministry of Hajj and General Authority for Statistics. 1,940 participants were surveyed with an estimated confidence level of 95% and a 2% margin of error during the Hajj 2016 (1437 Arabic Calendar).

The data collection involved investment of effort, resources and support that was kindly provided by the Hajj and Umrah Research Institute. The Research Institute provided manpower (postgraduate students to collect the data), iPads, an iOS programmer, and guaranteed access to pilgrims and to the Mosque and its environment. The questionnaire statements were programmed into iPad devices and linked to the central database located in an office at the Hajj and Umrah Research Institute.

The study focused on the Tawaf, which is the most critical and crowded period for pilgrims in the Holy Mosque during the Hajj. The level of density could reach 6-8 people per square metre. Due to high density, the data could only be collected around the Holy Mosque immediately after the pilgrims have performed their Tawaf. Collecting the data in the crowd at the Holy Mosque was technically impossible due to the high density of the crowd and the impracticality of stopping people in the middle of their worship. In some cases, the data collection was also carried out post-Tawaf in other locations including the camps and accommodation where the pilgrims were staying. The data collection began from the 10th Dhul-Hijjah until the end of the Dhul-Hijjah month (period of 20 days).

Twelve reliable postgraduate students of the Umm Al Qura University Makkah were selected as helpers to collect the data. Several criteria were in place for selecting the right students to collect the data including the following:

1. Have at least two years of experience in collecting field data during Hajj event;

2. Be recommended by the Hajj and Umrah Research Institute;

3. Be a student who is studying (postgraduate courses) at Umm Al-Qura University in Makkah;

4. Be able to speak a minimum of two languages (i.e. Arabic and another selected language such as Hurdu, Hausa, Indonesian, Malay, English, French or Mandarin);

5. Be able to explain the questions to the pilgrims (who may not be able to read or write);

6. Be able-bodied (in order to safely go around Makkah in large crowd during the Hajj);

7. Be computer literate and be able to use an iPad.

The process started by programming the questionnaire statements into iPad devices and linked them to the database center at the Hajj and Umrah Research Institute as shown in Picture 1 to ensure the quality of the collected data and to track the postgraduate students in an effort to minimise bias. There were some restrictions, having everything been monitored (location, time, date) by the centre, in terms of where the helpers go and what they do.

Avoiding bias is necessary for obtaining accurate results, the research therefore took several steps to avoid bias. Firstly, the questionnaire was framed using straightforward questions and avoided uncommon words and complex sentences. It ensured that all questions are short, not leading questions, and clear. Interval questions were used instead of Yes/No to make it more accurate and effective. Also, the research kept the time period short by collecting the data immediately after the event (Tawaf) because the respondents are more likely to recall the recent event. Moreover, the selected postgraduate students (helpers) underwent a thorough and rigourous training program (see Picture 1) in order to ensure that there is no bias of the helpers. The training included a detailed understanding of the aim of the research and the purpose of the data collection. The questions were explained categorically and interpreted in the language that they have to read to the respondents. They were limited to the statement of questions in order to prevent their own bias so were isolated and restricted. Lastly, they were reminded of the security and ethical issues and the importance and benefits of obtaining quality data.

After collecting the primary data by using the group administered approach, the Structural Equation Modelling (SEM) has been used as a statistical test. SEM was chosen as statistical technique for several purposes: Firstly, this study attempts to establish the interrelationship between the FIST and perceived safety which encounter latent variables that cannot be measured directly. Secondly, SEM is powerful tool that is able to test the model fit to the data and at the same time take into account the measurement error (unreliability) for each latent variable of the constructs being estimated (Choi, 2013).

The data was analysed using the Statistical Packages for the Social Sciences (SPSS) and Analysis of Moment Structure (AMOS) for the Descriptive Analysis and Structural Equation Modeling (SEM) respectively.

5. Results

Before undertaking the SEM analysis, it was ensured that the collected data is clean and normally distributed. Kaiser-Meyer-Olkin (KMO) and Bartlett's Test is also required to check whether the data is appropriate to continue with a confirmatory factor analysis procedure (Raston et al., 2010). KMO and Bartlett's Test of Sphericity as shown in Table 1 indicates that all values of independent and dependant variables have achieved the measure of Sampling Adequacy greater than the minimum level of 0.60 with a significant p-value $p<0.05$.

Picture 1: Process of collecting the data centre and tracking system

measurement items that have acceptable factor loading for the latent construct which is 0.60 and above (Hu & Bentler, 1999; Awang, 2015).

5.1. Confirmatory Factor Analysis (CFA)

When undertaking a CFA, it is necessary to assess the unidimensionality, convergent and discriminant validity, as well as reliability (Awang, 2015). The CFA needs to be performed for all latent constructs prior to modelling the interrelationship in SEM. The unidimensionality should be made first before assessing the convergent and discriminant validity, and reliability. Unidimensionality refers to the

Figure 3 presents the structural model, which resulted from some modifications been made based on Modification Indices (MI) in order to achieve a model fitness. Several items have been deleted (for example uncontrollable pushing, suffocation, walkway densities etc.) one at a time and others have been covarying the errors terms with the purpose of achieving the minimum fitness index.

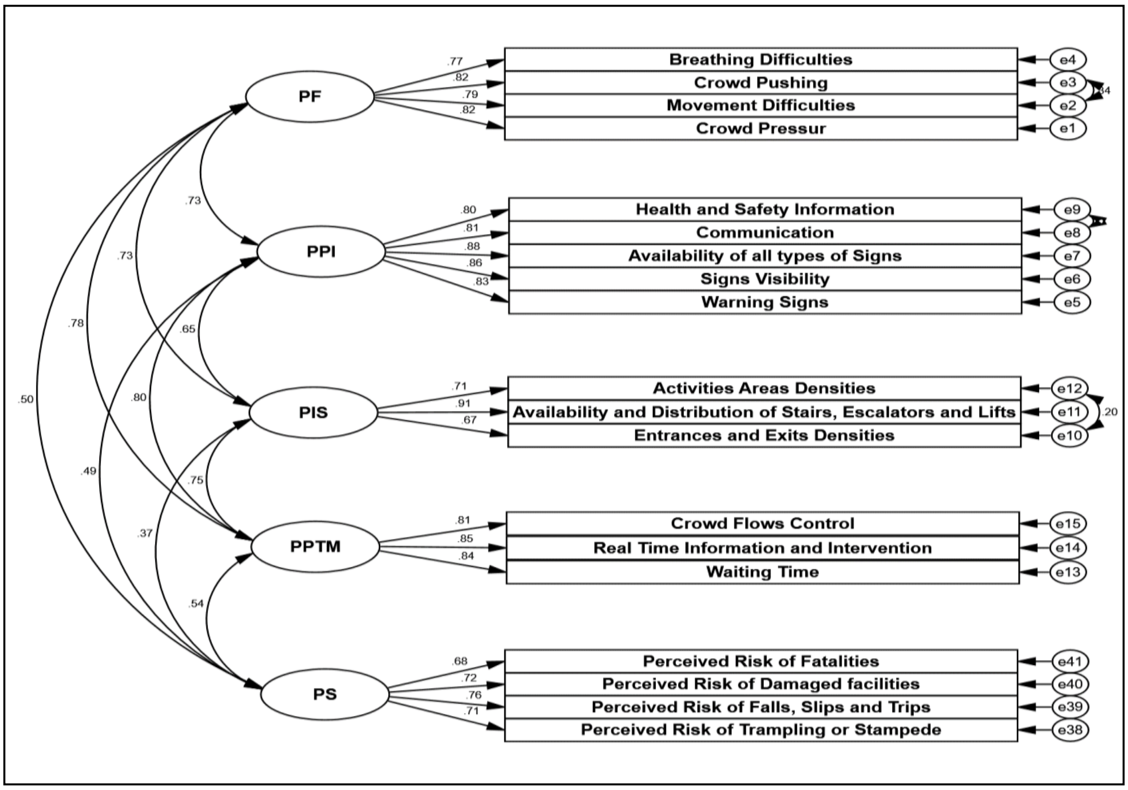

Fig. 3 The Path Diagram on the Confirmatory Factor Analysis for all variables

Table 1. KMO and Bartlett's Test.

Variables	Kaiser-Meyer-Olkin Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
		Approx. Chi-Square	DF	p-value
PF	.894	7652.203	15	.000
PPI	.889	7666.568	10	.000
PIS	.838	5139.037	10	.000
PPTM	.847	5154.857	10	.000
PS	.866	5234.356	28	.000

Note: DF = Degree of Freedom

Table 2. Descriptive analysis and Factor loading for items.

No.	Items	N	Minimum	Maximum	Mean	SD	Factors				
							PF	PPI	PIS	PPRTM	PS
1	Breathing Difficulties	1940	1	5	3.5015	1.23073	0.77				
2	Crowd Pushing	1940	1	5	3.4521	1.33477	0.82				
3	Movement Difficulties	1940	1	5	3.3979	1.32396	0.79				
4	Crowd Pressure	1940	1	5	3.5000	1.31461	0.82				
5	H&S Information	1940	1	5	3.4093	1.41404		0.80			
6	Communication	1940	1	5	3.2351	1.31889		0.81			
7	Availability sign types	1940	1	5	3.2845	1.36955		0.88			
8	Signs Visibility	1940	1	5	3.1866	1.37435		0.86			
9	Warning Signs	1940	1	5	3.2613	1.36759		0.83			
10	Activities Areas Densities	1940	1	5	3.5608	1.17780			0.71		
11	Availability and Distribution Stairs, Escalators and Lifts	1940	1	5	3.3448	1.32230			0.91		
12	Entrances and Exits Densities	1940	1	5	3.4485	1.25580			0.67		
13	Crowd Flows Control	1940	1	5	3.2809	1.29742				0.81	
14	Real Time Information and Intervention	1940	1	5	3.2521	1.29818				0.85	
15	Waiting Time	1940	1	5	3.2763	1.30297				0.84	
16	Perceived Risk of Fatalities	1940	1	5	2.6371	1.08592					0.68
17	Perceived Risk of Damaged facilities	1940	1	5	2.6789	1.15595					0.72
18	Perceived Risk of Falls, Slips and Trips	1940	1	5	2.7680	1.14354					0.76
19	Perceived Risk of Trampling or Stampede	1940	1	5	2.9675	1.17147					0.71

The shortlisted items are shown in Table 2, which outlines the factor loading for each indicator (item) that have achieved the minimum fitness index. Table 2 also provides the descriptive statistics showing the number, minimum, maximum, mean and standard deviation for each item.

5.1.1. Convergent Validity

To establish convergent validity, the model fit must be adequate, and the average variance extracted (AVE) must exceed 0.50 (Hair *et al.*, 2010). Table 3 provides the result of the model fit measures. Hu & Bentler (1999) recommend a comparative fit index (CFI) ≥ 0.95, standardized root mean square residual (SRMR) ≤ 0.08, and root mean square error of approximation (RMSEA) ≤ 0.06 for acceptable model fit. The values included in Table 3 indicate that the model is fit and all measures of CFI = 0.979, SRMR = 0.032, and RMSEA = 0.043 have achieved the required level. Also, the results of AVE for all constructs as illustrated in Table 5 have achieved the standard minimum required level of 0.50.

Table 3. Fit Indices.

Measure	Estimate	Threshold	Interpretation
CFI	0.979	>0.95	Good fit
SRMR	0.032	<0.08	Good fit
RMSEA	0.043	<0.06	Good fit

5.1.2. Discriminant Validity

To establish discriminant validity three criteria must be met (Gaskin, 2016a; Hair et al., 2010). Fornell-Larcker test needs to be undertaken where the square root of AVE for each construct must be greater than any inter-construct correlations (Fornell & Larcker, 1981). All constructs for this study have met this criterion. The square root of the AVE of the construct is greater than its estimates of correlation as presented in Table 4.

Other two criteria for discriminant validity that must also be met are the Maximum Shared Squared Variance (MSV) and Average Shared Squared Variance (ASV). Hair *et al.*, 2010 recommend that MSV and ASV must be less than the results of AVE (MSV<AVE, ASV< AVE). The results of ASV and MSV as detailed in Table 5 indicate that our measurement model is valid

Table 4. Discriminant Validity Fornell-Larcker test.

Constructs	1	2	3	4	5
PF	**0.800**				
PPI	0.729	**0.836**			
PIS	0.734	0.651	**0.773**		
PPRTM	0.782	0.798	0.748	**0.831**	
PS	0.495	0.486	0.366	0.538	**0.717**

5.1.3. Reliability and Construct Validity

Table 5 presents the results of the reliability and construct validity test. Two reliability tests have been undertaken for this study: composite reliability (CR) and Cronbach's alpha. We preferred to use both tests to guarantee the reliability of the data before conducting any further analysis. CR is more accurate than Cronbach's alpha because it does not assume that the loadings or error terms of the items are equal (Chin *et al.*, 2003). The CR test has met the standard minimum threshold of 0.60.

The model also confirms that all Cronbach's Alpha values for the construct as given in Table 5 are above the recommended value of 0.70 (Gaskin, 2016; Peterson & Peterson, 1994). This indicates the acceptability of internal consistency and confirms that all the items used in the model are technically free from errors (Hair et al., 2010).

Overall, the result of the assessment of the measurement model shows solid evidence of unidimensionality, convergent validity, discriminant validity, and reliability. It clearly shows that the items on each construct of the study are reliable and recommended, which confirms that the model has got enough measurement properties hence it can proceed with Structural Equation Modeling.

Table 5. Reliability and construct validity.

Constructs	CR >0.6	AVE >0.5	Cronbach's > 0.7	MSV	ASV	Convergent validity CR>AVE AVE>0.50	Discriminant validity MSV<AVE ASV< AVE
PF	0.877	0.640	0.886	0.611	0.48	Yes	Yes
PPI	0.920	0.698	0.922	0.636	0.46	Yes	Yes
PIS	0.814	0.598	0.824	0.560	0.41	Yes	Yes
PPRTM	0.870	0.691	0.866	0.636	0.52	Yes	Yes
PS	0.808	0.514	0.804	0.289	0.23	Yes	Yes

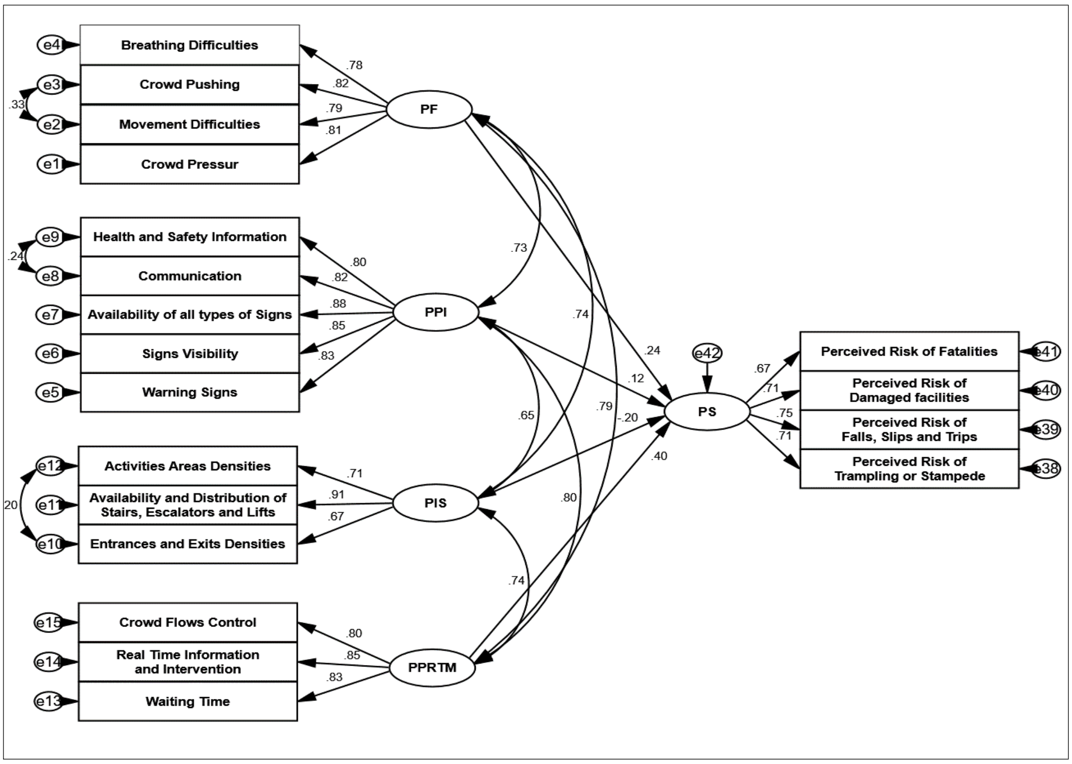

Fig. 4 Regression Path Coefficient for the Structural Model

5.2. Structural Equation Modeling (SEM)

The structural model as shown in Figure 4 presents the interrelationship among the variables. It consists of 4 unobserved exogenous constructs (perceived force, perceived poor information, perceived insufficient space, and perceived poor real time management) and one unobserved endogenous constructs (perceived safety). Based on the fit indexes, the model is a good fit and all measures of comparative fit index (CFI) = 0.979, standardized root mean square residual (SRMR) = 0.032, and root mean square error of approximation (RMSEA) = 0.043 have achieved the required level. (Hu & Bentler, 1999; Awang, 2015) recommend a CFI ≥ 0.90, SRMR ≤ 0.08, and RMSEA ≤ 0.06 for acceptable model fit. Consequently, the model is accepted for further analysis and testing of the hypotheses.

AMOS 22 for Structural Equation Modeling software has been used to run the model, and the regression weight for each of the four hypotheses (H1, H2, H3 and H4) have been obtained and shown in Table 6. The table shows the path for the construct and its coefficient as well as the significance for that particular path. It presents the effect of each exogenous construct on the respective endogenous construct. The results reveal that all the independent variables have significant effect on perceived safety. The path coefficient of perceived force to perceived safety is 0.189. This value indicates that for every one-unit increase in the perceived force, its effect on perceived safety would increase by 0.189 units. The impact of perceived poor information on perceived safety is 0.088. In contrast, perceived insufficient space has a negative impact on perceived safety by -0.193. The perceived safety is also affected by perceived poor real time management by 0.305. More importantly, the results revealed that there is a significant effect (P<0.001) of all constructs on perceived safety.

Table 6. Regression Weight for path coefficient and it's Significant.

Path Construct relationship	Estimate	P	Hypothesis
H1: Perceived force -> Perceived safety	.189	***	Supported
H2: Perceived poor information.> Perceived safety	.088	.010**	Supported
H3: Perceived insufficient Space -> Perceived safety	-.193	***	Supported
H4: Perceived poor real time management -> Perceived safety	.305	***	Supported

Note: = *p < 0.05, ** p < 0.01, ***p < 0.001

6. Discussion

The findings clearly supported our hypothesis and the proposed model as detailed in Figure 2. It has been confirmed that the perception of the users (pilgrims) about safety in large space buildings are strongly affected by four main perceived FIST factors: perceived force, perceived poor information, perceived insufficient space and perceived poor real time management.

The analyses have revealed that the perceived force has a positive impact on perceived safety by 0.189. This means that the more users perceive force the more they feel unsafe. Four indicators have been identified that measure the perceived force including breathing difficulties, crowd pushing, difficulty in movement, and crowd pressure. Once the user experience or feel any of these indicators, it will make them feel unsafe.

Perceived poor information also has a positive effect on perceived safety but to a lesser degree than the effect of perceived force. The regression weight of the effect of perceived poor information on perceived safety is 0.088, which is considered the lowest effect on perceived safety amongst the FIST factors.

The results have found that the perceived poor real-time management factor has the highest impact on perceived safety by 0.305. Three main items affected the users' perception: 'loss of crowd control', 'poor real-time information and intervention', and 'waiting time to use the facilities was unacceptable'. Berlonghi (1995), argued that those who are managing the crowd must be able to expect an appropriate intervention and timely response to prevent the disasters.

In contrast, there is a negative relationship between perceived insufficient space and perceived safety by -0.193. This finding was unexpected and suggests that the more the user perceive space to be insufficient the less they feel unsafe. Normally one would intuitively expect lack of space to result in to the user feeling unsafe. However, this research findings revealed that in events such as this religious event held at the most sacred site in Islam, the level of crowdedness does not lead the users in the Holy Mosque to feel unsafe. These results are consistent with Drury (2007) and Alnabulsi & Drury (2014) where they concluded that the pilgrims were high in social identification as Muslims, meaning that "people act as one in a crowd because they share a social identity. In particular, a strong social identity increases cohesion within the crowd, which, in turn, increases socialising and positive feelings". Alnabulsi & Drury (2014), found that increasing level of crowd density reduces the pilgrim's feeling of being unsafe. The finding in this paper suggests that the negative effect of perceived insufficient space on perceived safety may only apply to dense crowds made up of individuals in unity of purpose with a common social identity – social category membership with high expectations of social support from others in the crowd.

7. Conclusion

This study used Structural Equation Modeling technique to examine each of the relationships between perceived force, perceived poor information, perceived insufficient space, perceived poor real time and perceived safety factors in crowded large space buildings. The paper chose the Holy Mosque used by pilgrims during the Hajj event. It was found that all four perceived FIST factors have significant influence on perceived safety.

The paper initially presents the results of CFA examining five important factors that may cause risk to crowd safety. The theoretical pattern of the variables loading on a developed construct were tested confirming the validity and reliability of the model. After conducting the CFA procedures, 19 items with an acceptable factor loading of at least 0.60 were identified (as detailed in Table 2). The result of the assessment of the measurement model has shown solid evidence of validity and reliability. It also clearly confirms that the items on each construct of the study are reliable and the model has got enough measurement properties.

In crowded large space buildings, this paper has confirmed that building safety risk management system should not only focus on objective safety, it must also include subjective safety. To help integrate subjective safety into the risk management system, the paper has identified 19 key indicators (items) that must be included in the new framework for implementation. These items are listed in Table 2.

The results have shown that all four perceived FIST factors significantly influence perceived safety in a different degree and/or manner. The PPRTM has the largest influence on perceived safety, therefore should be of greater interest to Facilities Managers of large space buildings in order to ensure: that crowd flows in and around the building is well planned and controlled such that unnecessary congregations are avoided; that waiting time at entrances, exits and stairs/lifts are minimised; that an effective and timely crowd behaviour detecting system is set up.

The research findings and methodology are transferable to other types of mass gatherings in large space buildings such as sports events and music events. The practical implications are mainly in planning and management of crowd safety in crowded large space buildings. Currently, management focuses on objective safety and implements it using their own guidance, experiences, and procedures including space planning, managing the spaces, monitoring the crowd, developing crowd simulations modelling etc. The primary purpose of this study is to provide sufficient evidence that would make facilities managers and those who are in charge of managing the events to also consider subjective safety in the management of events in large space buildings. Facilities managers and those who are in charge of managing large events in built environments could use the risk factors and indicators identified in this research to evaluate the crowd risk condition at an event to control crowd behavior and by implication the crowd safety. It has been highlighted that perceived safety is significant in understanding people's behaviour and improving safety (Zhuang and Wu, 2012). After the implementation of the developed safety strategies and systems, it is expected that the facilities managers would collect new data regarding the actual effect of the subjective safety factors with the view of making an improvement to the safety condition in future events at the same venue. Measuring the initial subjective safety (post-implementation) will surely assist the facilities managers by making them aware of the safety perception of the users and the factors that make them feel unsafe. The safety perception could be changed by reviewing the objective safety strategies and systems such as providing more services or information, modifying some elements of the objective safety etc. Subjective safety risk can be minimised by either enhancing or reviewing some of the objective safety elements or by providing more information to the users that let them more relax and feel safer and aware about the health and safety. It is recommended that risk assessment sheet should include a separate new section dealing with subjective safety.

Although perceived safety is a subjective feeling, several factors such as age, education, gender, familiarities to the environment, and other peculiarities of users exert influence. The influence of these variables is investigated in further research because understanding these influences on perceived safety can help managers plan service capacities and usage time frames depending on the respective target group. The findings may also be relevant to emergency responders during an emergency situation. It is recommended that the emergency responders could use the risk indicators to help focus on the real-time information, communication and appropriate intervention with the users, as failure to do so could result in high level of anxiety, feeling unsafe, panic, and ultimately serious incidents such as stampede and trampling. Challenger et al. (2009b) argued that feeling unsafe during an event can drive people to panic from real or perceived risk through acting unusually such as pushing and shoving.

This research has confirmed that the venue cannot be considered fully safe when the subjective safety is overlooked even if all the objective safety precautions and plans are in place before and during the event. The idea is to ensure that the development of the event takes into account both the objective safety and the subjective safety. Numerous studies have been undertaken on objective safety in the built environment (Sagun et al., 2013; Wieringa et al., 2016; Sagun et al., 2008), but there has been a lack of research on the subjective safety (perceived safety) particularly in large space buildings where large numbers of users attend at the same time for an event or congregation. All of the models and frameworks discussed in the literature review were based on objective evaluation, e.g.: FIST was based on the analysis of major incidents, traffic flow principles and reviewing public inquiry reports and to date, these factors have not been tested subjectively.

As mentioned earlier, the subjective safety is intangible, and it refers to the feeling or perception of being safe or unsafe within a specified period. The model used in this research is different from the existing literature as all others were measured in objective perspective. The research have used the models discussed in the literature review to generate the 19 safety indicators that have an impact on the perception of safety.

It would be useful not only to establish the effect of PF, PPI, PIS and PPRTM on PS, but also the effect of each of the identified 15 items of the four groups on each of the 4 items of perceived safety. It is therefore recommended that further research is undertaken to determine if there are statistically significant differences and to what degree by using Structural Equation Modeling.

One other limitation of the research reported in this paper is the lack of consideration of the factors that may influence the user in the physical, psychological and physiological manner. It focused primarily on factors that originate from personal sources. Although the personal factors (age, experience, nationality, and education) have been considered by the research, the paper did not report on the influence of these factors on the relationships between the dependent and independent variables studied. In future research, these could be studied as moderating variables to measure their significance on the relationships between the perceived FIST factors and perceived safety.

The negative effect of perceived insufficient space on perceived safety revealed the fact that the type of crowd that uses the building and/or type of event that is held in the building cannot be overlooked. It is therefore recommended that further research is carried out using other crowd/event types to establish a measure of the difference.

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