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An Investigation of Building Occupants Behaviour during Fire Alarm

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ABSTRACT

The safety of building occupants during fire emergencies depends mainly on the occupant's behavior in the fire event. Therefore, this study investigates the behavior of high–rise building occupants in Nigeria when they hear the sound of fire alarm under fire drill. The study adopted a survey research design. The population for this study consists of 349 low and high-rise building occupants across six north-central state of Nigeria. A research question was used to direct the study. A structured questionnaire was used to collect data from the respondents which was duly validated by an expert in the field of fire safety. Cronbach Alpha reliability technique was used to determine the internal consistency of the questionnaire items at 0.90. Data collected were analysed through confirmatory factor analysis (CFA) using Statistical Package for Social Sciences (SPSS) and Analysis of Moment of Statistics (Amos). After a preliminary analysis (descriptive), data from respondents were found suitable for presence in confirmatory factor analysis (CFA), The CFA was performed, and results of the analysis support the one-factor model of occupants behavior in building when they hear the sound of the alarm during a building fire can enhance early evacuation and safety of lives and properties. The study found that occupants required nine actions to be taken when they hear the sound of fire alarm under investigation. However, the study recommended that fire training; total compliance with the relevant fire safety regulations, fire drill, fire communication, and effective fire safety management should be organized for the high or low-rise building occupants to enhance their knowledge of fire safety in a building.

Keywords: Behaviour; fire alarm; fire safety; high rise buildings; fire situation

INTRODUCTION

High-rise building all over the world is gaining more attention by day; as a result of its increased demand due to recent development in technology, with the aim of economized land usage, increase in urban population, and accommodating several occupants in a small space (Srinivasa 2015). However, this has caused high-rise and low-rise buildings in Nigeria's significant cities like Lagos, Abuja, and Port Harcourt as a priority due to the high cost of land for development.

Several nations of the world have adopted the choice of high-rise buildings to enhance more land for development. However, according to (Ibrahim 2007), land shortage within the metropolis was minimized by the economic system of land use through the construction of low and high-rise buildings on the main area within the city. Similarly, (Tang, B.-S. 2002) also cited that in the nation like Japan, Singapore, and Hong Kong, shortage of developable land in city areas have resulted in vertical living as the most useful system for people.

Nigeria Building construction industry has not performed as expected in the part of fire safety in the building, the current condition of fire safety in buildings in Nigeria and low-rise could be because of insufficient or non-functional legislation concerning fire disaster, such as fire safety act and none enacted National Building Code. Although, fire safety act adopted by several states in Nigeria can be traced from the pre-colonial era which

requires total review to conform with the latest technology and modern building style (Lawan 2011).

However, numerous researchers criticizing high-rise living in various perspectives have raised several suggestions (TIPPS 2013)observed that high-rise buildings occupants are exposed to fear of fire ignition in which usually causing depression, stress, anxiety, and lowering interest in the daily activity carried out in buildings. Concerning the fire risk in buildings, (Al-Kodmany 2018), the authors emphasized that the risk is a bit low in low rise buildings as compared to high-rise buildings that have numerous floors, which create a significant effect, demanding that a large number of persons traveling through vertical distances on the staircase. (Kobes, M. 2008). Further observed that fire disasters in the building have a significant effect on the building, and it is at a higher risk in high-rise buildings (Lawan, M. 2011). Thus, capable of creating a variation in floors, those results in natural movement within the buildings.

However, (Ekaterini T.D. & Keramidas 2019) observed that the effect of fire in high rise buildings is related to the types of materials, which may lead to extensive fire and smoke during the fire outbreak. Nevertheless, (Groner 2016) declared that most of the building occupants are often not aware of the fire safety measures and facilities within the building. Glauberman (2018) revealed that occupants of high-rise buildings are unsure about the effectiveness of firefighting measures.

PURPOSE OF THE STUDY

To investigate the behaviors of an office building occupants during a fire alarm and determine the construct validity of the model-based on confirmatory factor analysis (CFA).

RESEARCH QUESTIONS

The following research question was established to guide the study:

1. What action will an office building's occupants take when they hear the fire alarm?

2. How valid are the occupant's actions when they hear fire alarm toward enhancing earlier evacuation from building fire based on the CFA model

HIGH – RISE BUILDING

High-rise buildings have been seen from a different perspective, by various researches. The buildings are mainly defined according to the height or numbers of stories. However, according to Tall Buildings and Urban Habitat, high-rise are buildings whose height centers different situations in the design, building, and use than those that exist in traditional buildings of a particular region and period "there is no particular definition for high rise building that is generally accepted (Ericson Ronci 2013). Although, several researchers, scholar, and professional bodies tried to view high-rise building differently (Mir M.A. 2012).

The National Fire Protection Association (NFPA 2000) defined high-rise building as a building with a minimum of 23-meter height from the ground floor to the highest floor level. While, another defines high-rise building as a structure that extends higher than the maximum reach of available firefighting equipment, and it is between 23-meter height. Another definition adopted by Attia and Evred is that a building regarded as high-rise building is any structure that exceeds 36-meter height or more than 12 stories (Ebenechi & NM 2017).

Therefore, these are an indication that the definition of a high-rise building is bounded between height and numbers of story, which may be a result of several factors such as standard and code legislation. However, it can be argued that any building that is likely to be more affected by lateral forces such as wind and earthquake is a high-rise building.

FIRE SAFETY IN HIGH- RISE BUILDING

The primary purpose of fire safety in a building is to protect humans and property against death, injuries, and destruction (Ebenehi, I.Y. 2017). Furthermore, the researchers explained that fire safety can occur under two significant aspects, which are passive and active. Passive protection measures in the building can be referred to as inbuilt measure installed in a building during construction to prevent the occurring of fire and enhance quick evacuation of an occupant in a building that is on fire while the active protection is a measure installed at the post-construction stage of the building to fight fire when it occurs. In a similar perspective, Kobe et al. (2010) defined fire disaster prevention, limitation, the frustration of the spread of flame, heat, smoke, and ultimately elimination of fire to enhance successful evacuation of occupants in a building that is on fire. Qureshi 2007).

There have been several pieces of research on fire safety within high-rise buildings. (Enrico R. 2013) observed that human behavior in a building could influence

fire behavior in high-rise buildings and fire characteristics. The building feature that influences fire behavior is such a complicated component of building material used for both internal and external finishes and escape route..(Chow 2001)have researched into building characteristics for 50 high –rise buildings where fire disaster occurred. The focus of the authors was various, smoke in the stairs, vertical spread (Xing, Z. 2012), and structural damages (BitternCe & Cecilia A. 2013). The authors concluded that performance-based design is critical to ensure fire safety in high-rise buildings.

HUMAN BEHAVIORS IN BUILDING FIRE

The numerous researches in human behaviors in fire conducted by different researchers in a building could not give definite answers to how humans behave when an emergency occurs. Meanwhile, in the 1950s (Bryan 2002) several study efforts have been describing it. For example, (Kobes 2010) correct human behavior as the activities that building occupants take built upon their perception of the condition, their purpose to performance, and the thoughts involved before the actions are carried out. (Yatim 2009) revealed that occupants' response to a particular condition depends on knowledge of the occupants, i.e., what they have done before in a similar condition. Kobe et al. (2010) acknowledged numerous traits of human behavior in evacuation:

FIRE ALARM AND ITS CHALLENGES IN BUILDING

Proulx (1998), on evacuation drill low-rise residential buildings, conducted a research where each of the building is 6-7 story high, estimated to have 100 rooms and 200 occupants. The evacuation questionnaire survey of the research revealed that 25% of the occupants said they do not hear the fire alarm from their apartments.

However, it is also revealed that audibility issues experienced in an apartment where the fire alarm application was situated in the endless corridors. Despite that, the alarm signal was louder in the B-corridors; the signal was not audible inside the house units, particularly in the room situated far away from the corridor (Proulx 2000).

According to Bryan (2000), the researcher revealed that, when an occupants notice a fire cue, they attempt to confirm how serious the situation is. It is an indication that quick evacuation may not be achieved due to the delay of warning to the occupants across the entire building, because of insufficient sound pressure level of the alarm gong, and this device should be operated manually.

Fire alarm functions can be integrated by several components such as fire detectors, annunciator panels, and manual call points, besides, alarm function, fire alarm, and detection systems can also actuate other fire safety measures in the building (IRC1984)

An effective fire alarm could also comprise visual signal devices known as a visual alarm to warn the building users that is situated far from the alarm bell and in crowded areas. However, oral communication is possible to be integrated into the fire alarm system by connecting loudspeakers located at strategic points of a building to the central control.

Furthermore, the audio alarm signal operation is timely, in which it can be stopped while the loudspeakers are in use. Several studies have highlighted the primary objectives of fire alarm systems in buildings. However, the primary purpose of fire alarm highlighted by Proulx (2000) are warning occupants in case of a fire and prompt immediate action, initiate evacuation movement, and permit adequate time of escape. One of the most common fire alarm system in the building is an alarm gong.

However, an alarm does not depend on electrical energy. Instead of depending on the power supply, the gong is driven manually with its weight and consequently provides mobility to the user to inform the occupants during a fire emergency, and it is relatively less expensive when compared with the other fire alarm system.

METHODOLOGY

To achieve the primary objective of this study, the researcher adopted a survey research design, in the view of Ali, the survey is a descriptive study that uses a sample of the examined document, describing and clarifying what is missing on the present status of occurrences being examined. The population study consists of 349 office-building occupants from six north-central state of Nigeria. Two study questions were developed to guide the research. A structured questionnaire was used to gather data from the respondents, which was duly authenticated by fire safety experts. Cronbach's alpha reliability method was used to determine the inner consistency of the questionnaire items at 0.91. Data collected were analyzed through confirmatory factor analysis (CFA) using statistical package for social science (SPSS) and analysis moment of statistics (AMOS).

The survey study design is appropriate for this study since data were collected through a questionnaire on the action of office-building occupants when they hear the fire alarm in the building.

RESULTS

Table 1 mean score with standard deviation and observations on the action occupants will take when they hear the sound of fire alarm in a fire situation in office buildings in Nigeria. The initial CFA of occupant's action when they hear the fire alarm in the event of a fire is presented below. The CAF did not adapt to the standard for goodness model fit due to RMSEA, which stood at 172, conflicting to the specified threshold of .080 or less. The values obtained are Chi-Square = 304,497, DF=27, Ratio= 11.278, P=000, CFI=.915, IFI=.915, TLI=.907 and RMSEA=.172.

The CFA model for occupant's action when hear alarm comprises nine variables. The result in Figure 2 approves the prominent factor loadings within the satisfactory threshold but displays the misfit of the model with an RMSEA value of 1.72, which shows there is a need for Chi-square perfection. In order to achieve this, the modification indices (MI) values as presented in Table 1 were well checked and was established that the measurement errors of e4 and e9 to be 55.402, e1 and e6 to be 45.642, e5 and e9 to be 37.960, e3 and e8 to be 28.605, e2 and e7 to be 32.341, e7 and e9 to be 21.001, e3 and e7 to be 20.627, e4 and e8 to be 17.402. They were considered greater than the maximum requirement of less than 15.00. Hence, the items, which with the redundancy modified by deleted items 3, 2, and 9 respectively and item 1, 6, 4 and 8 were covariance, and the model fits were attained.

The modified CFA for occupants' actions when they hear the fire alarm in a building was presented in Figure 2. The covariance of items SAR1 and SAR6, as well as SAR SAR4 and SAR8, and items 2, 3, and 9 were deleted. The modification indices criteria was enhanced. Therefore, the obtained values are Chi-Square=14.690, DF=7, Ration=2.099, P=.040, CFI=.996, IFI=.996, TLI=.991, and NFI=.992, RMSEA=.056. Hence, the model is considered suitable.

DISCUSSION OF FINDINGS

The findings of this study presented the behavior of office building occupants in Nigeria when they hear the sound of the fire alarm during the event of a building fire; influence the occupant's early evacuation from building during a fire emergency. The findings in Table 1 revealed that the data collected are valid and mean value, standard error of the mean, and standard deviation were shown in Table 1.

Confirmatory factor analysis (CFA) used in this study is a statistical method used to approve the factor structure

TABLE 1. Showing the modification indices for confirmatory factor analysis of building occupant behavior in the alarm.

			M.I.	Par Change
e8	<-->	e9	4.436	-.020
e7	<-->	e9	21.001	-.044
e6	<-->	e7	4.210	-.019
e5	<-->	e9	37.960	.054
e4	<-->	e9	55.402	.068
e4	<-->	e8	17.402	.038
e4	<-->	e7	6.821	-.025
e4	<-->	e6	10.436	-.028
e3	<-->	e9	4.824	-.023
e3	<-->	e8	28.605	.057
e3	<-->	e7	20.672	.049
e3	<-->	e5	7.820	-.028
e3	<-->	e4	5.893	-.025
e2	<-->	e9	9.440	-.025
e2	<-->	e7	32.241	.048
e2	<-->	e6	11.872	.027
e2	<-->	e4	12.156	-.028
e1	<-->	e8	5.044	-.021
e1	<-->	e6	45.642	.060

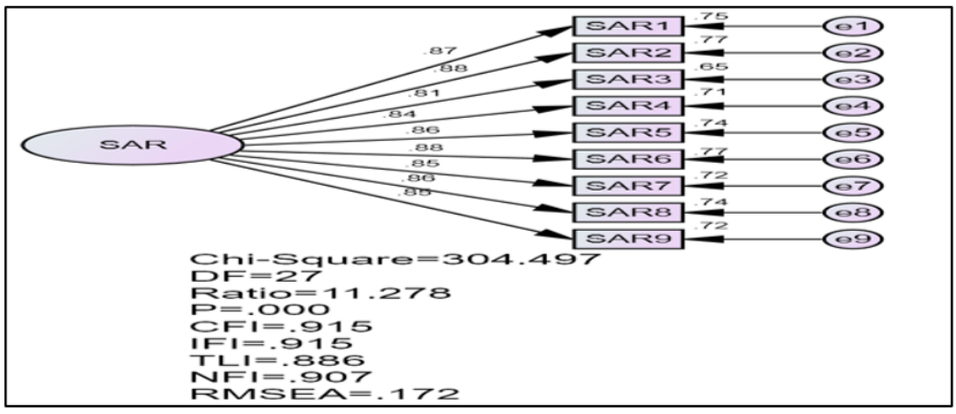

FIGURE 1. Initial confirmatory factor analysis of building occupants behavior in the fire alarm

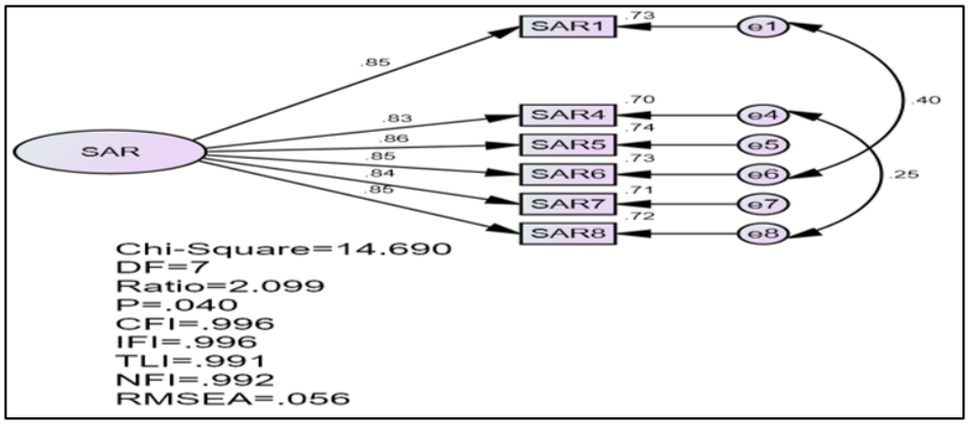

FIGURE 2. Final confirmatory factor analysis of building occupant's behavior in the fire alarm

of a set of apparent variables. It permits the investigator to determine the relationship between observed variables and their critical latent constructs. This study presents both the initial and final CFA models of the constructs. For a model to be considered fit, there are criteria that needs to be met, which include all the factor loading must be equal to or above 0.5. Also, the adjustment indices such as CFI, IFI, TLI should be above 0.90, the ratio of the Chi-square, and the degree of freedom (df) recommendations, which range from as high as 5.0 (Tabachnick 2007) to low as 2.0 (Wheaton 1977) , RMSEA < 0.08. The confirmatory factor analysis (CFA) were conducted to authenticate the findings that shows the items SAR1 (warn others), SAR2 (ignore the fire alarm altogether), SAR3 (help others during the evacuation process) SAR4 (get belongings and leave), SAR5 (leave the building immediately), SAR6 (wait until help comes from others), SAR7 (call the police/fire station), SAR8 (ask neighbors regarding if there is fire), SAR9 (abandon your belongings and leave), were confirmed importance and influence early evacuation of building occupants from a building fire. The final models revealed CFA of occupants behavior when hearing the sound of fire alarm during a building fire, and each item shows a satisfactory factor loading of more than 0.5 as required, and the model displayed satisfactory goodness-of-fit which suggests that the model developed was appropriate to be used to study the behavior of building occupants when they hear the sound of fire alarm during a building fire. The findings of these various authors (Bryan 2002; Kobes 2010).

Proulx (2001), Pires (2005) and Yatim (2009) backing the validation of the findings of behavior study of high-rise building occupants when they hear the fire alarm during a building fire toward enhancing early evacuation of an occupant from a building fire.

CONCLUSION

The study has established that the behaviors of high-rise building occupants in Nigeria when hearing the sound of the fire alarm during a fire influence the occupant's early evacuation from the building fire. There is an urgent need for the management of high-rise buildings in Nigeria to organized and give adequate and timely training for the occupants of high-rise buildings in order to allow them the

necessary skills and knowledge of action to take when they hear the fire alarm in building fires as required by fire safety regulation 2013. However, to ensure early evacuation, the safety of life, and properties in a building fire, fire training, fire drill, total compliance with fire safety regulation, and effective fire safety management.

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DECLARATION OF COMPETING INTEREST

None

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