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CRITICAL FACTORS THAT INFLUENCE THE CHOICE OF FIRE SAFETY SYSTEMS IN GHANA

[1] Baabereyir Bertino Richard 1st, [2] Tetteh Otchie Philip 2nd, [3] Ohene Michael 3rd , [4]Asubey Yakubu 4th

[1]Lecturer1st, [2] Lecturer2nd, [3] Lecturer3rd, [4] Lecturer4th
[1]

[1]Department of Technical Education1st , Sefwi Wiawso, Ghana

[1] Sefwi Wiawso College of Education

Abstract: Recently, fire outbreaks in the country have generated many discussions on rumours relating to politics, sabotage or religious differences among others, yet little is done to reduce this high incidence of fire outbreaks. One quandary identified is that, there is no uniform standard for building safety design, and ambiguous acceptance criteria used by building designers enthralling them to design what they think it is vital to them, hence, ignoring regulations and standards as their bench mark. The study adopted a quantitative descriptive approach, and questionnaires items tested by principal architects and chief service engineers, totalling one –hundred and thirty-four (134) of which 95 for architects and 39 for services engineers with good standing firms, belonging to registered professional bodies across the country. SPSS Version 21.6 package was used in two forms of statistical analysis undertaken: descriptive statistics such as frequency, and percentages were used to summarize information from respondents, and factor analysis using the enabled the critical influential factors identified from literature, regulations and international standards under ten components as 1) Holistic Design variables, 2) Relevance design considerations variables, 3) Fire safety objectives variables 4) Performance based code variables, 5) Fire detection, alarm Systems and suppression systems variables, 6) Active Fire Protection variables, 7) Building Fire Safety consideration variables, 8) Fire Emergency Power Design variables, 9) Built-in' Fire Protection or 'Passive Fire Protection' (PFP) variables, and 10). Fire risk activities variables. Kish (1965) formula was used for calculating minimum sample size for the study. The results of this study would enable fire safety designers Ghana to be successful in its quest to incorporate these identified influential factors in their designs. The study seeks to find out critical influential factors related to design of building fire safety that contribute to BSI's in Ghana: purposeful of given initial screening evaluation for fire safety and health performance throughout the entire design process.

Keywords: Critical, Factors, Influences, Choice, Fire, Safety, Systems, Ghana

1. Introduction

Fire guts are unabated phenomena in human endeavour, and as such our public needs information on fire safety risk relating to their living environments, concerning extreme fire guts in our public buildings. However, these buildings serve as monumental pillars to the state such as Ministry of Information, the loading gantry of Tema Oil Refinery, offices of the Electoral Commission, Central Medical Store and the Ridge residence of former President Rawlings, but few to mention [1] (Addai, Tulashie, Annan, & Yeboah, 2018). One quandary identified is that no a uniform standards have been made for building fire safety at the design level, and no unambiguous acceptance criteria for building in serviceable condition, impelling designers to design what they think rather then, using regulations and standards as their bench mark (Sagun, Anumba, & Bouchlaghem, 2024). As the objectives and provisions of these Acts were based on several different perspectives, the required level of fire safety was not always achieved because there was no or insufficient coordination between the different fire safety requirements that were based on the various regulations (Hagen, & Witloks, 2014, 2020). A fire protection concept highlights basic areas that require special attention for fire protection measures and facilities, divided into such themes as town and country planning, architecture, technical systems, furnishings, internal organisation and use and deployment of the fire service (Hagen, & Witloks, 2014; 2024). Hence, comprehensive ways, and concept must be developed to determine performance indicators (Factors) and relevant criteria for fire safety designs in buildings, focusing on prevention of fire safety and health associated problems (Rusydie, & Ahmadon, 2016).

However, it needs a comprehensive understanding of building factors purposeful of given the initial screening to evaluate building safety and health performance through designing to realization of actual project. Vast amounts of researches have been dedicated to the identification of architectural performance and ways to eliminate architectural defects on fire safety. Ramly, Ahmad and Ishak (2016; 2022) found that, 47% of fire safety defects were caused by design defects, 17% from materials, and 15% from construction, 18% from misuses of facilities, 15% from poor maintenance and 5% from vandalism. Their work implied that, the designers' in-depth knowledge and understanding in fire safety engineering and their good performance standard could reduce constructional defeats significantly with reference to acceptable regulations, standards and good performance criteria. Again, Isa, Najihah, Thuraiya and Nur (2024) is also of the view that, the majority of the defects identified are related to poor architectural works, followed by poor electrical works and civil and structural defects. These findings suggest that defects are preventable, if palpable holistic design factors are enshrined in international building codes, and its regulations, well as bringing all design ensnares on board with all stakeholders. Again there is much literature pointed out that, building design play an important role in building safety. More so, Al-Hamoud and Khan (2014 as cited in Masril, Deddy, Rosil, & Muhammmad, 2024) stressed that, unnecessary hazards in buildings design can be reduce much more easily at the drawing board rather than case after the corrective action. They identified that if there are clear rules that are enforced, designers will be aware of safety requirements in the design process.

Hence, the aim of this study is to find out whether Ghanaian designers really incorporate in their designs with fire safety critical factors, and the objective for this study is to examine critical influential factors relating to design of building fire safety respect to BSI.S.

3. Research Methodology

A quantitative strategy is adopted in this research due to the fact that, quantitative research follows a deductive approach in relation to theory and is concerned with the design measurement and sampling focuses on relationship between dependent variables and independent variables (Babbie, 2010; Amponsah, 2010, p. 149). It is objectivity in nature, where hard and reliable data are often collected, and emphasizes on its quantification and its bias is minimised through using objective instruments such as standardised questionnaires, observation schedules, and interview guides to collect data (Borg & Gall, 1996; Maree, 2007; Amponsah, 2010, p. 149). The quantitative design was chosen because the study sought to examine critical influential factors that contribution to the choice of designers relating to building fire safety in Ghana.

3.1. Population and Sampling Frame

The population of the study is Registered Architectural Consultancy Firms with good standing and Accredited Service Engineering firms in Ghana. Their total number for the population is one hundred and seventy (170) for architectural firms and thirty-four (34) for Service engineers firms across the country.

3.1.1. Sampling Frame

This is simply the list of currently Registered Architectural Consultancy Firms with good standing in the building construction industries in Ghana and the list of Service Engineering firms in Ghana Association of incorporated Engineers in two cities namely, Kumasi, and Accra in Ghana. These two metropolises were selected because they are the major Metropolises in Ghana where most architectural and service engineering firms are highly concentrated (Akomah, Boakye & Fugar, 2010; 2023). The merit of sampling frame for research is that, "no human interference is found in the selection of the sample and in the end, be representative of the population" (Curwin & Slater, 2008, p. 52). Not found

3.1.2. Sampling Techniques

Simple random was used to select the Architects and service engineers for the study, because the target population has similar characteristics and haven equal chance in the selection process (Arthur, 2020, p. 113). Determine the sample size, Kish (1965) formula that gives a scientific procedure for calculating minimum sample size, was applied for this study. Aziz (2013); Enshassi (2010); Ametepey, Gyadu- Asiedu & Assah- Kissiedu, 2018, among others have used this equation in their studies. The sample size deduced from Kish (1965) is shown as calculated below:-

$n = \frac{n'}{\left\{1+\left(\frac{n'}{N}\right)\right\}}$ Where

n = Sample Size from finite population

N = Total Population

n´ = Sample Size from infinite population calculated from; $n' = S^2 / V^2$, Where

V = Standard error of sample population equal to 0.05 for the confidence level

95%, t = 1.96

S^2 = Standard error variance of population elements,

$S^2 = P(1 - P)$; Maximum at P = 0.5.

The sample size of the Architectural and service engineers firms with good standing can be calculated from the afore mentioned equations as follows;

$n' = \frac{S^2}{V^2} =$

$S^2 = P(1- P)$

$S^2 = 0.5(1- 0.5)$

$S^2 = 0.5 \times 0.5$

$S^2 = P(1-P)$

Where P = 0.5

$S^2 = 0.5(1- 0.5)$

$S^2 = 0.25$

To find V^2, let V=0.05 level of confidence.

$V^2 = (0.05)^2$

$V^2 = 0.0025$

$$\therefore\ n' = \frac{S^2}{V^2} = \frac{0.25}{0.0025}$$

$n' = \underline{100}$

n (Architectural Firms with good standing) = $\frac{100}{\left\{1+\left(\frac{100}{170}\right)\right\}}$ = 63 Firms across Ghana.

Service Engineering firms with good standing = $\frac{100}{\left\{1+\left(\frac{100}{34}\right)\right\}}$ = 26 Firms across Ghana.

A non-response rate of 50% was assumed to overcome a low response that could threaten the generalization and validity of the study's findings (Lahndt, 1999, Enshassi et al., 2010, Ametepey, Gyadu- Asiedu & Assah-

Kissiedu, 2018). Therefore, the total minimum number of questionnaires for the study, which stands at eighty-nine, has increased to One Hundred and thirty-four (134) firms for both respondents.

4. Data Collection Techniques and Questionnaire Development and Administration

The final questionnaire was based on a draft questionnaire deduced from 25 scholarly research papers; of which some were ICC: International Building Codes, Standards and Regulations and Architect's Handbook of Professional Practice. In all, 34 fire safety designing factors were found, developed and tested. The questionnaires were in a form of multiple choice and likert scale items tested by principal architects and chief service engineers with good standing firms, belonging to registered professional bodies. Opinion of experts was sought on the validity of question items. Also, pilot –testing of the questionnaires was conducted in two phases. The first phase involved completing the pilot questionnaire, and the second phase involved the conduct of a follow-up feedback interview in relation to pilot survey respondents' thoughts. The pilot respondents were asked whether they understood the instructions for completing the questionnaire, and whether the wording and place to mark responses to each question were clear. Another issue, which was addressed, was the average time required to complete the questionnaire, as it was acknowledged that if it would take a long time for respondents to complete, they might be reluctant to participate and this would have negative impact on collection numbers and nature of responses (Willar, 2012; 2020). The data were analysed using the Statistical Package for Social Sciences (SPSS) version 21.6 The final questionnaire was divided into two sections; A, and B). The first part sought the demographic background of respondents whereas the second part consisted of thirty-four (34) identified fire safety critical factors (likert scale), that are to be examined by randomly selected practitioners (95 Architects, and 39 Service Engineers) on the relevance of these factors in Ghanaian context. The questionnaires were personally delivered to the selected engineering firms who were in turn requested to deliver them to the most experienced or qualified architects and service engineers for completion (Danso, 2018).

5. Reliability of Measurement Scales

The overall value of Cronbach's alpha for independent variables is 0.928. This means that all the Cronbach's alpha values of the measurement used exceeded the cut-off threshold of 0.7 (Hair et al., 1998; 2006). Impliedly, the amount of shared variance, or covariance, among the items making up an instrument to the overall variance have high internal consistency, and therefore considered adequately, (Oladapo (2007); Idrus and Newman (2022)..

6. Data Analysis

Statistical package for social scientist (SPSS. 21.6) was used to analyse the data retrieved from the survey, since the research is of quantitative in nature. Two forms of statistical analysis were undertaken: descriptive statistics such as frequency, standard deviations and percentages were used to summarize information from respondents. Also, Principal Component Analysis and inferential statistics such as t-test was used herein to determine architects, and service engineers' perceptions on the identified fire safety critical factors in Ghanaian context.

7. Results of the Response

A total of 134 questionnaires were administered out of which 93 were completed and returned. However, 86 questionnaires were used for this study, since the remaining 8 questionnaires were not well filled. The response rate was 69.4 percent, which is good for a construction research survey (Lahndt, 1999b; Hoonakker, 2010; & Danso, 2018).

8. Demographic Characteristics of the Respondents

This section presents the demographics of respondents. It includes gender, age, academic qualification, working experience and type of work by the respondents. The demographics of the respondents was essential to the study since they play significant roles in the development of people's perceptions about a particular issue as well as how they respond to issues. According to Ferguson and Mulwafu (2012) and Baabereyir (2014), the socio-economic backgrounds of people influences their perceptions and the effect of development programmes on their lives and ascertain the validity of the results obtained and to develop an understanding of the background respondents with respect to their qualifications and experiences. Fifty-three (53) representing (61.6%) of the total respondents were males while their female counterparts were 33 representing (38.4%). Majority (67 representing 89.5%) were 40-years and above. There is no record for respondents above 65 years. Impliedly, the respondents were matured. When asked about their educational qualifications, twelve (12) representing 14.0 percent had Bachelors, fifty-six (56) representing 65.1 percent had Post Diploma certificate and eighteen (18) representing 20.9 percent had Master degree and above. Impliedly, majority of the respondents representing (86%) were Post Graduate Diploma and Master's holders and can be said to employ highly qualified personnel. Responses on work experience suggested that majority of the survey respondents (eighty one (82) representing 94.1 percent) had more than 10 years working experience. The responses of the respondents can be said to reflect their firms' characteristics and work culture in view of the greater working experience they possessed. Seventy-five (75) of the respondents representing 87.2 percent were architects and eleven (11) representing 12.8 percent were service engineers. These responses suggest that, majority of the operatives in Ghanaian building industry were architects.

9. Factor Analysis of Critical Factors to Consider in Designing for Fire Safety

Factor analysis was used to assess the critical factors to consider in designing for Fire Safety in Ghana. The thirty-four items obtained a Cronbach alpha (α) value of 0.928 thereby satisfying the reliability scale. All the 34 factors had communalities of 1.00, and extraction range of 0.643 - 0.867, thereby indicating their appropriateness for the factor analysis. The 34 significant factors were further reduced to common factor patterns. This was done to empirically explain the critical factors to consider in designing for Fire Safety in Ghana. In doing this, principal component analysis with Varimax rotation and Kaizer Normalisation as well as Kaiser-Meyer-Olkin (KMO) and Bartlett test of sphericity measure were performed to check for degree of inter-correlation among the items and the appropriateness of factor analysis and to determine which factors have empirical significance. Factor retention was by the eigenvalue 1.0 criterion, suggesting that only factors that account for variances greater than one should be included in the factor extraction. The principal component analysis (**Table 1.1**), where linear combinations of observed variables are formed, was the method used to extract the factors. The first principal component is the combination that accounts for the largest amount of variance and the second principal component accounts for the next largest amount of variance and is uncorrelated with the first and so no and so forth. From the **Table 1.1**, it is revealed that, Component 1 has total variance of 10.659, which accounts for 31.349 % of the total variance of the 34 factors. Component 2 has total variance of 3.399 accounting for 9.998% of the total variance of the 34 factors and Component 3 has a total variance of 2.061 accounting for 6.062 of the total variance of the 34 factors. Component 4 has total variance of 1.777 accounting for 5.228% of the total variance of the 34 factors, while Component 5 has total variance of 1.6822 accounting for 4.946% of the total variance of the 34 factors. Furthermore, the Component 6 has total variance of 1.484 accounting for 4.363% of the total variance of the 34 factors whereas Component 7 has total variance of 1.346 accounting for 3.959% of the total variance of the 34 factors. Yet again, Component 8 has total variance of 1.329 accounting for 3.909% of the total variance of the 34 factors while Component 9 has total variance of 1.329 accounting for 3.909% of the total variance of the 34 factors. Meanwhile, the Component 10 has total variance of 1.329 accounting for 3.909% of the total variance of the 34 factors. These ten components constitute 76.429% of the total variance of the 34 factors.

Nonetheless, according to table 1.2 below, the first component had "The design process as a whole (0.843)", "Doors and Purpose-designed (0.783)", "Passive barriers (0.765)", "Redundancy of firefighting (0.739)", "Fire safety provisions (0.723)", "Consideration should be wide range of initiating events (0.703)", "Considering and identifying hazards (0.640)", "Built-in fire protection (0.583). Moreover, "Three main areas (0.575)", and "Consideration should be given to accidental (0.516)", are showing the most critical fire safety design factors in Ghana. In the second component had four critical factors, which are "The relevant considerations (0.752)", "System required managing fire impacts (0.698)", "Smoke Management System provision (0.693)",and "Procedural barriers (0.588)',presented in order of critical priority, while the third component revealed "Considering design purpose (0.734)", and "Emergency and Standby Power provision (0.647)".The fourth component indicated these factors presented in order of consideration as follows: -Fire safety design should be checked (0.838)", "Egress system provision (0.610)", and "Materials for constructing Fire Compartmentation (0.580)". In addition, the fifth component revealed "Fire suppression System provision (0.747)", "Fire Alarm System provision (0.697)", "Fire extinguishing system of various types (0.678)". The sixth component suggested these critical factors, "Detection and Alarm System alerting rapid response (0.852)", "Smoke Control Panel designed to limit spread Fire (0.556)", and "Consideration of automation (0.506) being the least among the group. Once again, the seventh component indicated "A building is considered safe (0.820)", and "Consideration should be given to the level (0.550)". Last but not the least, the eighth up to the tenth components have one critical factor each as presented as "In designing emergency power for fire (0.834)", "Passive fire resistance provisions (0.833)', and "The activities that go into building associated (0.896)", respectively. The principal component analysis showed from the list of communalities that none of the factors was below 0.5 hence all the items were involved in the analysis. Factor analysis enabled the 34 critical factors to be placed under ten (10) components as follows:

Component 1: Holistic Design

The influence of the design process as a whole has been well recognized (Isa, 2011; Kecklund, Andree, Bengtson, Willander, & Sire, 2020). This will help to access fire safety as holistic approach involving fire engineers in the initial design process. This component identified doors and purpose-designed, passive barriers, redundancy of firefighting, fire safety provisions, consideration for wide range of initiating events, considering and identifying hazards, built-in fire protection, three main areas of design and accidental consideration as major critical factors to the choice of fire safety systems in Ghana.

Component 2: Relevance design considerations

The relevance design considerations giving to fire safety has well documented (Rusydie, & Ahmadon, 2016; Ramly, Ahmad, & Ishak (2016;2022).It will give way for comprehensive concepts, standards and regulations development to determine performance indicators (Factors) and relevant criteria for fire safety designs in buildings, focusing on prevention of fire safety and health associated problems. This component identified, relevant design considerations, system required for managing fire impacts, smoke management system provision and procedural barriers as critical design factors.

Component 3: **Fire safety objectives**

The effect of fire safety objectives as design factor is well-documented (ICC: International Building code 2007; Hong Kong fire code for Practice, 2019, p. 5; Rashid, Ifeanyi (2020) as cited in Akadiri, Chinyio, & Olomolaiye, 2013). The key areas for fire design considerations should include developing goals, objectives, criteria and acceptance targets, and assessing the fire risk leading to failures of fire systems. This component identified, purpose of design, and emergency standby power provision.

Component 4: Performance based code

The impact of fire safety influential factor on the performance-based code has been well documented (Yung, 2008; Nystedt, 2011, p. 9; Guidance Document for ASFP Innovation Project, 1999; National Fire Protection Association (2020b). In this case, very building or structure shall be constructed in such a way that, materials, and their fittings and furnishings shall be regarded to their use and situation. It should also afford satisfactory safety with respect to egress and evacuation of persons and provision of acceptable safety against damage to property and the environment. The structure presented by Yung is related to the development of the fire in the building and it uses principles of "defence in depth" to show the relationship between various safety measures. Defence in depth is originally a military term where the defender seeks to delay rather than prevent the advance of an attacker. The regulations on fire safety use the principle as fire prevention does not focus all the resources only on the prevention of a fire; instead, it also requires the deployment of escape routes, compartmentation, detection, extinguishers etc. In practice, defence in depth is strongly related to redundancy, i.e. a system that keeps working when a component fails. This helps to reduce the risk that a single failure of a safety feature could cause a consequences considered to be too severe. However, the performance- based code serves as a guide to designers to compliance with fire safety regulations in accordance with pre-accepted solutions or by means of analysis and calculations, which document that, safety against fire, is satisfactory. This is very important in fire design, since it blocks fire and smoke spreads in the apartment and enhanced fire evacuation process. This component identified, checking fire safety design, egress system provision, and materials for fire compartmentation.

Component 5: Fire detection, and suppression systems

The effect on the influential fire safety factor on Fire detection, alarm Systems and suppression systems has been well-documented, (Grill, 2003, p.1; Roberts, 2003; Society of Fire Safety Engineers, 2022). Fire detection and alarm systems are intended to provide early warning notification of fire events within the buildings in which the systems are installed to occupants as well as fire events for both on- and off-site emergency response personnel. They also provide control over fire safety functions for fans and dampers to reduce smoke spread, recall and shutdown elevators and control fire door. The output functions include occupant notification, emergency response notification, fire safety functions and annunciation of input device type and location. Occupant notification can occur throughout the building or within selected zones as required for building evacuation concepts. Emergency response notification can be transmitted directly to the Fire Department, but typically occurs through a third party or by onsite personnel responsible for monitoring the fire detection and alarm system. Further, fire/smoke damper and fire door closure is often used to compartmentalize buildings areas to limit the spread of smoke and fire. This component identified the provision of: fire suppression system, fire alarm system, and fire extinguishing system of various types.

Component 6: Active Fire Protection

The influential fire safety factor on an active fire protection is well-documented, (Society of Fire Safety Engineers, 2012, p. 86; 2022). An active fire protection is a fire prevention guide which requires special energisation or a command signal to operate. In designing, all the Active fire systems need to be actuated by a signal. This component identified, fire detection and alarm system for rapid response, smoke control panel design, and consideration of automation.

Component 7: Building Fire Safety consideration

The influential fire safety factor on building fire safety consideration is well- documented, (NKB, 1994; BIS BS, 476:20; 2001; SFPE, 2019; & CAENZ, 2018), provide information on the fire safety design process. However, these guides focus on design using fire engineering principles (i.e. an analytical approach) and there is a need for an overall description of the design process showing the relationship between the prescriptive and the analytical design approach for fire safety design process, starting with the qualitative design review and the initial risk screening which should be conducted no matter which principal design method (prescriptive or analytical) that is selected at a later stage. The initial risk screening could vary in extent depending on the complexity of the building and it intended use. The initial risk screening is conducted by collecting relevant information on e.g. architectural design and occupant characteristics, as well as on specific fire hazards. This component identified, building safety consideration, and considering fire safety at all levels of design process.

Component 8: Designing Emergency Power for Fire.

The influential fire safety factor on emergency power design has been established, (Asiedu, 2012, p. 40; Society of Fire Protection Engineers -SFPE, 2019). The emergency and standby power is necessary for the continuous operation of essential life safety systems. The integrity of the emergency and standby power systems will need to be evaluated as part of the overall building fire strategy. Electrical systems are crucial for normal operation and life safety. As part of electrical design systems, the reliability of utility power should be investigated. The reliability of utility power can be evaluated through historical data available from the power company. When this data is not available, it is more difficult to estimate power reliability, and as such, allowance should be taken into account. Furthermore, evaluating the reliability of the utility power needs to consider both total power outages and the quality of power being delivered, as this may affect the equipment as well. Further, areas where utility power is considered unreliable, enhancements to on-site electrical supply systems should be considered. In fact, using the same equipment for both the augmentation of normal power and emergency power needs to be considered if in case of fire outbreak it can still efficiently workable. It may be practical to increase the level of power generation to take into account the dual use of such equipment. For example, if on-site generators are used to provide normal power and emergency power, these systems may need to be enhanced to increase their reliability during emergency conditions. The quality of on-site generated power affects the reliability of the power usage for fighting fires in facilities. Often, power coming from generators is sufficient to run critical systems for limited periods, but these generators may not be designed to run equipment continuously. This component has identified, designing emergency power for fire.

Component 9: Passive Fire Protection' (PFP)

The influential fire safety factor on passive fire protection has been-documented, (Guidance Document for ASFP Innovation Project, 1999; Gautami, Prajapati, & Khurana, 2020). The passive fire protection do not need any special energisation or command signal to operate, (although some systems such as dampers and certain types of doors may be designed to operate from such methods or remotes). The PFP is vital to the stability and integrity of a building or structure in case of fire. It is the overall terminology used to describe the inherent reaction to fire performance and/or the comparative period of resistance to fire. PFP with proven fire performance properties is built into the structure to provide stability and separate the building into areas of manageable risk e.g. concrete, brickwork, and steelwork treated with intumescent paint or boxed/profiled specialist board materials etc. (Brushlinsky, Ahrens, Sokolov, & Wagner, 2017). These are designed to restrict the growth and spread of fire allowing the occupants to escape or the fire fighters to do their job. Therefore, the recommendations for fire resistance are expressed in terms of time and the ability of dividing elements such as walls or floors to contain fire and/or maintain insulation values. This component identified, passive fire resistance provisions.

Component 10: Fire risk activities

The influential fire safety factor on risk fire activities in buildings has been-documented (Sampson, 2010; Chen, & Reniers, 2020). The causes of fire activities include cooking (e.g., kerosene stoves, electric cookers, gas cookers, coal pots), lighting devices (e.g., candles lanterns), cigarettes, and lighted mosquito coils, improper electrical fittings, use of substandard electrical materials, defective generators, power fluctuations resulting from frequent power outages, and illegal tapping from the national grid, overloading of electrical appliances on the same fuse, and improper electrical installation and old wiring systems in homes and workplaces are some of the possible causes of fire outbreaks in Ghana. More so, Paul- Stollard, and Abrahams (2020), in designing to reduce the ignition risk the architect has to do two things: first, to design out the predicted ignition hazards or sources; and secondly, to enable the building to be managed in such a way that the risk of ignition is eliminated. Regards to this, research should focus on developing new fire resistant materials and harnessing emerging technological advances for mitigation of fire hazard in the developing countries such as Ghana. Olawoyin (2018) argued that nanotechnology, can be the future of developing fire resistant materials if it is tested and applied properly. However, there are several knowledge gaps in this field that need to be addressed. However, the actual design against the risk and the design to permit management against the risk must be seen together. The first necessity for the designer is an understanding of the most likely ignition risks in the particular building type under consideration: it is essential to know your enemy if it is going to be defeated. This component identified, fire risk activities in buildings.

Table 1.1 Shows the total variance critical factors for design of fire safety in buildings in Ghana by principal component analysis extracted up to component 15 of 45

Total Variance Explained

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	10.659	31.349	31.349	10.659	31.349	31.349	6.698	19.701	19.701
2	3.399	9.998	41.346	3.399	9.998	41.346	3.537	10.402	30.103
3	2.061	6.062	47.409	2.061	6.062	47.409	2.358	6.935	37.038
4	1.777	5.228	52.637	1.777	5.228	52.637	2.203	6.480	43.518
5	1.682	4.946	57.583	1.682	4.946	57.583	2.189	6.438	49.956
6	1.484	4.363	61.946	1.484	4.363	61.946	2.156	6.342	56.298
7	1.346	3.959	65.906	1.346	3.959	65.906	1.999	5.879	62.177
8	1.329	3.909	69.814	1.329	3.909	69.814	1.873	5.509	67.686
9	1.247	3.668	73.482	1.247	3.668	73.482	1.625	4.779	72.465
10	1.002	2.947	76.429	1.002	2.947	76.429	1.348	3.964	76.429
11	0.888	2.611	79.040						
12	0.844	2.482	81.522						
13	0.777	2.285	83.807						
14	0.651	1.916	85.723						
15	0.613	1.802	87.526						

Extraction Method: Principal Component Analysis.

Table 1.2 Shows the rotated matrix results on the critical factors that influence the choice of fire safety system in Ghanaian public buildings

Rotated Component Matrix

Components	Loadings
Component 1	
The design process as a whole	0.843
Doors and Purpose-designed	0.783
Passive barriers such as fire-related	0.765
Redundancy of firefighting	0.739
Fire safety provisions	0.723
Wide range of initiating events	0.703
Considering and identifying hazards	0.640
Built-in fire protection	0.583
Three main areas	0.575
Accidental considerations	0.516
Component 2	
The relevant considerations	0.752
Fires System management	0.698
Smoke Management system provision	0.693
Procedural barriers	0.588
Component 3	
Design purpose	0.734
Emergency standby power provision	0.647
Component 4	
Checking fire safety design	0.838
Egress system provision	0.610
Fire compartmentation materials	0.580
Component 5	
Fire suppression System provision	0.747
Fire alarm system provision	0.697
Fire extinguishing system provision	0.678
Component 6	
Detection and Alarm system	0.852
Smoke Control Panel design	0.556
Automation consideration	0.506
Component 7	
Building fire safe consideration	0.820
Fire safety consideration at all levels	0.550
Component 8	
Designing emergency power for fire	0.834
Component 9	
Passive fire resistance provisions	0.833
Component 10	
Inflammable activities in buildings	0.896

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.a
a. Rotation converged in 13 iterations.

Conclusion and recommendations

From 34 factors identified from international building codes, regulations, standards and literature as influential factors to the implementation of building fire safety design, factor analysis enabled 30 of them to be placed under ten components: 1) Holistic design factors comprising design process as a whole, doors and purpose-designed, passive barriers such as fire-related, redundancy of firefighting, fire safety provisions, wide range of initiating events, considering and identifying hazards, built-in fire protection, three main areas, and accidental considerations; 2) Relevance design considerations factors comprising relevant considerations, fires system management, smoke management system provision, and procedural barriers; 3) Fire safety objectives factors comprising design purpose, and emergency standby power provision; 4) Performance based code factors comprising checking fire safety design, egress system provision, and fire compartmentation materials; 5) Fire detection, and suppression systems factors comprising fire suppression system provision, fire alarm system provision, and fire extinguishing system provision; 6) Active fire protection factors comprising detection and Alarm system, smoke control panel design, and automation consideration; 7) Building fire safety consideration factors comprising building fire safe consideration, and considering fire safety at all levels; 8) Emergency fire power design factor comprises designing emergency power for fire; 9) Passive fire protection' (PFP) factor comprises passive fire resistance provision; and 10) Fire risk activities factor comprises inflammable activities in buildings. To ensure the successful implementation of building fire safety design sustainable construction, Government with the support of stakeholders in the construction industry should come up with special legislations, codes or standards relating to sustainable construction design practices. Discussions, seminars, training, and workshops on sustainable fire safety designs in buildings and its importance should be initiated by stakeholders in the industry. Government agencies on their part should embark on applicable policies that could provide critical support to make sustainable fire safety construction feasible. The identified factors and measures to overcome sub-standard fire safety construction design should provide an enabling environment for construction practitioners to successfully implement classical fire safety construction and improve construction sustainability for the benefit of society at large.

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