Volume 9, Issue 8, August – 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG511

Critical Factors Influencing the Choice of Fire Safety Systems Design in Ghanain Public Buildings

Baabereyir Bertino Richard[1]; Ohene Michael[2]; Tetteh Otchie Philip[3]
[1]Department of Technical Education, Sefwi Wiawso College of Education, Western-North, Ghana & Box 94
[2]Department of Technical Education, Sefwi Wiawso College of Education, Western-North, Ghana, & Box 94
[3]Department of Technical Education, Sefwi Wiawso College of Education, Western-North, Ghana. & Box 94

Abstract:- Recently, a day passed without fire outbreaks in Ghana 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 benchmark. 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. The sampling frame was deduced from 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, due to its highly concentrated architectural and service engineering firms. Kish (1965) formula was used for calculating minimum sample size for the study. SPSS Version 21.6 package was used to produce the statistical analysis tools for the study. Descriptive statistics such as frequency and percentages were used to summarize the data gathered from respondents. However, the influential critical factors identified from the literature, regulations, and international standards codes are grouped under ten components as follows;- 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. The results of this study would enable fire safety designers in 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, Influence, Choice, Fire Safety Systems, Design, Public Buildings, Ghana*

I. INTRODUCTION

Building is expressly designed with harmonizing amenities to minimize possible vulnerabilities crisis for workers, laborers, and, persons in the structure can be expatriate suitably and safely. The structure is peril when likelihood is disillusionment to imperil lives, apparatus, and resources in it. Such devastation or prostration in the event of a vulnerability can endanger the protection of inhabitants causing substantial monetary losses (Huffman, 2013; Thevega, 2022). Therefore, structures are made to endure movements from copious expected dangers to safeguard lives and structural protection from fire during its lifespan and other dangers befall in structures. Fire peril in structures is express as possible accident or deliberate fire to lurk lives, structures, and belongings protection in an edifice (Masril et al., 2022). Notwithstanding fast global growth transversely the world fire risk in structures have experienced noteworthy alteration base of sternness, flexibility which have develop a rising anxiety in current ages. Since twenty years ago, (2002-2024), fire occurrences have triggered over one million bereavements from over eighty millions outburst (Brushlinsky et al., 2017), and with yearly forfeiture of worldwide fire risk resulting for about one percent of the world's GDP (Bulletin, 2014) (nearly US$857.9bn [G.D.P., 2018]). Typically, 3.8 million fires instigated 44,300 deaths yearly in industrialized and unindustrialized nations transversely the world (Brushlinsky et al., 2017). Current writings points to the statistic that, between the year 2010-2024, the highest fire outburst is over (600,000-1,500,000 per year), with bereavements (1,000-10,000 yearly) globally befallen in the industrialized nations such as USA, Britain, Russia etc. (Brushlinsky et al., 2016). Meanwhile, unindustrialized nations such as Ghana, Niger, Togo, etc. are affected with high amount of fire fates (10,000-25,000 approximately annually) and bereavements of (100,000-600,000 yearly) (Brushlinsky et al., 2016). Consequently, to alleviate such antagonistic fire risk impacts, it is imperative essential to offer fire protection in structures to avert occurrence of fire and control its evolution, and impact of fortuitous fires whereas combating it to minimum required mark (Menzemer, 2023). Presently, fire protection in structures is providing by ensuing requirements endorsed by structural cyphers and criteria of practices. Whereas provisions and policies for safeguarding fire protection in

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG511

structures differ from another of practicing to other, and most of them are grounded on prescriptive-based method which is derivative of analogous fire protection ideologies (Thevega, et al., 2022). In prescriptive-based methodologies, fire protection in structures are providing by means of amalgamation of active and passive fire fortification methods. Active fire fortification classifications (sprinklers, heat and smoke detectors etc.) are intended to perceive and regulate early phase fire ignition and importantly from life-safety viewpoint (Kodur, 2019). However, passive-fire fortification methods (building and non-building constituents) are intended to safeguard building l permanency through fire coverage and to control fire blowout. Their core goalmouth is to permit sufficient period for firefighting and salvage actions, and to minimalize financial sufferers.

II. LITERATURE

Fire guts are unabated phenomena in human endeavour, and as such, our public needs info on fire-safety peril relating to their immediate surroundings, concerning extreme fire guts in our public buildings. Studies in Ghana and Nigeria signposted that, the commonest reasons for fire occurrences in multistory structures are electrical faults (Nimlyat, 2017; Baabereyir, 2018; Ayakwa, 2022). However, these buildings serve as monumental pillars to the state such as Tema Oil Refinery, Electoral Commission Office, Kumasi central Stores (Kejietia Market), Central Medical Store, Mokola Market, Appiate Township but few to mention (Addai, Tulashie, Annan, & Yeboah, 2016). One quandary recognized is non- uniform requirement for structural fire provision at the policy making stage. Besides, it has diverse acceptable standards for structures in-serviceable conditions, which compels countless engineers for designing what they ponder as vital to them: ignoring regulations and standards as their benchmark (Sagun, Anumba, & Bouchlaghem, 2013; Ebenehi et al, 2017). As the ideas and requirements of these Acts were grounded on numerous diverse viewpoints, the prerequisite mark of fire-safety is not permanently accomplished since there is no or inadequate harmonisation amongst the dissimilar fire-safety regulations which is grounded on the several standards [3] (Hagen & Witloks, 2014). A fire-protection theory highpoints rudimentary areas that necessitate exceptional consideration for fire-protection procedures and amenities, separated into such leitmotifs as town and country planners, architecture, technical-systems, furnishings, internal decorations and uses, and the use of the fire facility (Hagen &Witloks, 2014). Hereafter, all-inclusive ways, and concepts should be developed to accesses the performance indicators (Factors) and relevant standards for fire -safety design in buildings, aiming at preventive fire-safety and health associated problems (Rusydie, & Ahmadon, 2016). However, there is a need for all-inclusive consideration of structure elements purposely for given the early structural protection evaluation and healthy performance through designing to realization of actual project. Vast amounts of researches have been devoted for identifying design target or goals aiming at eradicating design impart on fire prevention. Ramly, Ahmad and Ishak (2006) found that, 47% of fire safety flaws were instigated by architectural flaws, 17% of designing elements, 15% from production, 18% from wastage of structure, 15% of weak- upkeep, while 5% from vandalizing. 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. The results veto that, design flaws are preventable when palpable attention is gear toward its needed considerations enshrined in international building codes, and its related documents. Further, regardless of this, process of designing is crucial in the implementation of fire safety holistically, bringing all design ensnares on board with all stakeholders. Again, available studies pointy that, structural designs are integral in fire-safety provisions (Maluk et al., 2017). More so, Buchanan and Abu, (2017) stressed that, needless fire perils in structures could be reduced considerably when designers use their skills rather than case corrective activities. They also identified that, the unclear procedures need enforcing will for creating awareness of fire safety necessities 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 and ASTM E119-18 (2018).

III. RESEARCH METHODOLOGY

The study adopted quantitative research deductive approach in relation to theory and concerned with the design measurement and sampling (Amponsah, 2010; Babbie, 2010). This design was chosen because, the study sought to explore the contribution of designers to building fire safety in Ghana.

A. 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.

➢ *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 conurbations are selected due to having over 60 percent Ghana's major construction sites and experts as well as more operatives such as architects and service engineers needed for the survey, (Akomah, Boakye & Fugar, 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).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG511

- *Sampling Techniques*

Purposive random sampling 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, 2012, p. 113). Determine the sample size, Kish (1965) formula which is mostly applied for engineering studies, such as Assaf et al., (2021), Abdul-Hadi (1999), among others. 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.

Fifty percent (50%) was used to cater for non-repose rate for the study to beef -up a low responses that looms the generality and validity of the study's findings (Lahndt, 1999b, Enshassi et al., 2010). 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.

IV. DATA COLLECTION TECHNIQUES

The ultimate questionnaire deduced from 25 scholarly research papers; of which some were ICC: International Building Codes, Standards, Regulations, and Architect's Handbook of Professional Practice. In all, 34 fire safety design 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 (certify practitioners) belonging to registered professional bodies. Opinion of specialists was sought for validity of the enquiry items. Pilot–testing of the items was dealt with in two phases. Phase one dealt with implementation the pilot questionnaire, and phase two was for follow-up responses aim at scrutinizing the items for clarity (Willar, 2012). The data is evaluated using by Statistical Package for Social Sciences (SPSS) version 21.6, and thirty-four (34) identifiable fire safety critical factors examined by randomly selected practitioners (95 Architects, and 39 Service Engineers) of Ghanaian relevance extracted. The surveys was self-sent to the respondents for completion (Danso, 2017).

- *Reliability of Measurement Scales*

The items had Cronbach's alpha of 0.928, thereby satisfying reliability scale, with least cut-off threshold of 0.7 (Hair et al., 1998; 2006). Impliedly, the items had high internal consistency (homogeneity), and with good response rate of above 30% enough in construction research (Danson, 2017; Baabereyir, 2018)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG511

- *Data Analysis*

Statistical package for social scientist (SPSS. 21.6) was used to analyse the data retrieved from the survey. Two forms of statistical analysis were undertaken: Descriptive and Principal Component Analysis were used herein to determine architects, and service engineers' perceptions on the identified fire safety critical factors in Ghanaian context.

- *Results of the Response*

134 questionnaires were deployed for the study of which 93 were accomplished and reimbursed, and 86 of it used for the study, while 8 were not well filled. The response rate was 69. 5 percent, thereby accepted for engineering survey (Lahndt, 1999b; Hoonakker, 2010 Baabereyir, 2018).

- *Demographic Characteristics of the Respondents*

The respondents' demographics is crucial to any study, playing noteworthy function in the respondents' opinions around theme(s) being responded for. Ferguson and Mulwafu (2012), state that, socio-economic experiences of society stimuluses their acuities and impactful their lives to acquire the outcome validity of fallouts acquired and developed a thoughtful contextual of respondents regards to their education and skills. Fifty-three (53) representing (61.6%) were male respondents and 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, matured experienced people were used for this survey., Twelve (12) representing 14.0 percent of the respondents had Bachelor's degree, 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. This means that, the study employed highly-qualified personnel's. Again, majority of respondents (82) representing (94.1 percent) exceeds 10 years working experience. In conclusion, it reflects companies' features and work ethos viewpoint of using high experience personnel in the industry. Seventy-five (75) representing 87.2% were architects and eleven (11) representing 12.8% were service engineers. These responses suggest that, majority of the operatives in Ghanaian building industry were architects.

- *Factor Analysis of Critical Factors to Consider in Designing for Fire Safety*

Assess the critical factors to consider in designing for Fire Safety in Ghana Factor analysis was used. The thirty-four items attained had Cronbach alpha (α) value of 0.928, thus had adequacy for the reliability scale. Further, the communalities of 34 factors had 1.00, and extraction ranges of 0.643 - 0.867, thereby demonstrating its suitability for factor-analysis. Further reduction were made communalized the 34 significant factors into patterns to empire elucidate the critical factors' consideration in designing for Fire Safety in Ghana. In regard, Principal Component Analysis (Varimax Rotation and Kaizer Normalisation; Kaiser-Meyer-Olkin (KMO) and Bartlett Sphericity Test measurement were accomplished to chequered the inter-correlation degrees among the items for suitability of factor analysis. It was to determine factors' empirical significance. Eigenvalue 1.0 criterion factor retention was done to suggest that, factors accounting for variances above 1.0, must be involved in the extraction. Also, linear combinations of observed variables method were performed for the extracted factors. The first component accounts for the biggest amount of variance and the second accounts for the next largest amount of variance with uncorrelated among or between them and so no and so forth.

Table 1, below revealed that, Component 1 had overall variance of 10.659, which accounts for 31.349 % of the 34 factors' variances. Component 2 had 3.399 variances, accounting for 9.998% of the overall variance for 34 factors and Component 3 had 2.061 variance, accounting for 6.062% variance for 34 factors. Component 4 had 1.777 variance, accounting for 5.228% for 34 factors, while Component 5 had 1.6822 variance, accounting for 4.946% for 34 factors. Furthermore, the Component 6 had 1.484 variance, accounting for 4.363% for 34 factors whereas Component 7 had 1.346 variance, accounting for 3.959% for 34 factors. Yet again, Component 8 had 1.329 variance, accounting for 3.909% for 34 factors while Component 9 had 1.329, accounting for 3.909% for 34 factors. Meanwhile, the Component 10 had 1.329 accounting for 3.909% for 34 factors. All the ten components established 76.429% variance for the 34 factors.

Nonetheless, according to **Table 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 fire fighting (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 communalities above 0.5, hence; all certify for the analysis. Factor analysis allowed the 34 critical factors placed underneath 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, 2012). 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 fire fighting, 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 (2006).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 [30-32] (ICC: International Building code 2007; Hong Kong fire code for Practice, 2011, p. 5; Akadiri, Chinyio, & Olomolaiye, 2012; Çakiroglu, & Gökoglu, 2019). 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, 2017; Guidance Document for ASFP Innovation Project, 1999; National Fire Protection Association 2007). In this case, very building should be built with materials, fittings and furnishings by its specified uses, standards that fit its purposes and situations. It should also, provides suitable protection related to egress and evacuation of occupants and provision of satisfactory protection beside damages to belongings and the milieu. The building offered by Yung is connected to fire ignition in structure and philosophies of "defence in depth" to display causal effect among several protection procedures. The term "Defence in depth" is initiated from military terminologies by which instead of attacking opponent, rather pursue stay to advance the assailant. The protocols on fire-safety have inherit this attitude as fire preventive method, not allocating all its assets for preventive of a fire; instead, it needs to deploy escape routes, compartmentation, detection, extinguishers etc. in fighting fire. In-service, "defence in depth" is powerfully associated to joblessness, i.e. a system that serves as back-up when the main a module fails. It aids to decrease the peril associated with firefighting system(s) that might have caused imports at Spartan levels. However, the performance- based code serves as a guide to designers to compliance with fire safety regulations in agreement through pre-acceptance resolutions or by way of analysing and calculating for codes/ standards that, against fire satisfactory. This is very important in fire design, since it blocking fire and smoking spreading 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, 2012, p. 86; Cost, 2018). Fire detection and alarm systems are envisioned to deliver initial cautionary notice of fire actions inside edifices containing firefighting installations for occupants, fire actions for on- and off-site standby retort staffs. It also, provides for aficionados and kerbs to lessen smoulder spreading, reminiscence and cessation elevators, and regulates fire exit. Their purposes comprise of inhabitant notice, disaster reply notice, fire -safety purposes and annunciation of input device types and location. Inhabitant notice canister befall all over the entire edifice or contained by designated sectors as prerequisite for structure evacuation models. The emergency response notice canister be conveyed right to the Fire office, nevertheless usually arises over a third party or by onsite personnel in charge for checking the fire detection and alarm system. Further, fire/smoke damper and fire door shutter is to classify structures zones for limiting smoke/fire spread. 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; Cost, 2018). 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, 2018; SFPE, 2007; & CAENZ, 2008), give facts on fire-safety designs procedure. Conversely, these monitors designs by means of fire engineering philosophies

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG511

(i.e. an logical slant) which needs inclusive account of designing progression performance connexion both prescriptive and the analytical designs methodology for fire-safety design decisions, through qualitative design evaluation, and early risked valuation conducted with either prescriptive or analytical methods selected at the later stage of design process. The early risk might differ in degree contingent on its complication in edifice and it envisioned use. It can be carryout by amassing pertinent evidence on e.g. architectural design and inhabitant physiognomies respect to precise fire dangers. This component identified, structural fire safety considerations, and consider fire- safety at stages of design procedures.

- *Component 8: Designing Emergency Power for Fire.*

The influential fire safety factor on emergency power design has been established, (Asiedu, 2012). Standby power for buildings is essential to use fire safety systems all round in buildings. The integration of the emergency and standby power systems needs performance evaluation for building fire strategy. Electrical systems are crucial for normal operation and life safety. As part of electrical design systems, the dependability of usefulness power ought to be examined by means of historical statistics accessible from power companies, which practically aid to upsurge and upgrade power cohort into an account of double usage of power source for fire paraphernalia. For instance, using only one generators for normal power and emergency power, systems need to be improved to upsurge its dependability throughout an emergency situations. The superiority of on-site generators for power may affects the dependability of fire- fighting facilities. Generators should be design sufficiently to run crucial fire systems for limited periods, but not for continuously run. 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; Cost, 2018). The passive fire protection needs no exceptional energisation command signal to operate, (although dampers and other types of exits are design to work from such techniques). The PFP is vivacious to the solidity and veracity of a houses on fire. It is the complete techniques use to integrate fire capability resistivity to fire. PFP with confirmed fire resistance possessions should be used in structures to gives stability which separates the edifice into zones of controllable risk e.g. concrete, brickwork, and steelwork treated with intumescent paint or boxed/profiled specialist board materials etc. These are made to confine fire development and blow-out of fire letting the inhabitants to leakage 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; Boateng, 2013). The causes of fire activities in Ghana 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. Paul, & John (2002), in designing to diminish fire eruption risk, the architects have two things to do: firstly, designing predictive fire eruption against risks or its causes; and secondly, to design structures that can eliminate risk of fire eruption. Nevertheless, the genuine design opposes fire dangers and permit management the risk being 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 Shows the Total Variance Critical Factors for Design of Fire Safety in Buildings from the Explained from the 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						

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG511

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 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

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG511

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

V. 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. Ensuring, successful implementation of building fire safety design sustainable construction, the state and relevant 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.

REFERENCES

[1]. Abdul-Hadi, N. H. (1999) "*Factors affecting bidding and mark up decisions in Saudi Arabia."*

[2]. Master's Thesis, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia: Gold Coast, Australia. Engineering and Construction Services Department, UNRWA, Gaza City, Israel, 1999. (Thesis)

[3]. Addai, E. K., Tulashie K. S., Annan, J., & Yeboah, I. (2016). Trend of Fire Outbreaks in Ghana and Ways to Prevent These Incidents. *Occupational Safety and Health Research Institute. Vol. 7(4): 284–292*

[4]. Akadiri, E. A. Chinyio, & P.O. Olomolaiye, (2012) "Design of a sustainable building: conceptual framework for implementing sustainability in the building sector." *Buildings 2012, 2: 126-152.* (Journal Article)

[5]. Akomah, B. B., Boakye, N., &, Fugar, F. (2023). "Local government institutions in Ghana: Core partners in health and safety performance in the construction industry. Heliyon *Open Access, Volume 9, Issue 9, E19423,* September 2023

[6]. Al-Homoud, M. S., & Khan, M. M. (2004). Assessing safety measures in residential buildings in Saudi Arabia. *Building Research & Information, 32(4), 300–305.*

[7]. Amponsah, R. (2010) "*Improving project management practice in Ghana with focus on agriculture, banking and construction sectors of the Ghanaian economy*. Ph. D. Thesis, School of Property, Construction and Project Management, RMIT University.2010:p.149. (Thesis)

[8]. Arthur, c. (2012). "*A fundamental approach to educational research methods and Statistics."* Kumasi: Published by Multimedia Printing Press, 2012:p.113. (Book style with paper title)

[9]. Asiedu, R. A. (2012). *The performance of high-rise building in Ghana perspective of the occupants* (Master Thesis). Kwame Nkrumah University of Science and Technology. Kumasi, Ghana.

[10]. Assaf, B. A. Abdul-Aziz, B.A. Atiyah, &, S. Al-Shahri, M. (2021) "The Management of construction company overhead costs", 2021. *International Journal of project Management, 19, 295303*. (Journal Article)

[11]. ASTM E119-18 (2018), *Standard Test Methods for Fire Tests of Building Construction Materials,* American Society for Testing and Materials, West Conshohocken, PA.

[12]. Ayakwa, J., Danso, A. K., & Adinyira, E. (2022). "Incidence of domestic fire outbreaks in three cities in Ghana: causes and prevention". *The Ghana Surveyor, Vol. 3 (1),* pp. 7-20. 632. Retrieved from http://www.academia.edu/431516. [Citation Time(s).

[13]. Aziz, R. F. (2013) "Ranking of delay factors in construction projects after Egyptian Revolution" .2013. *Alexandria Engineering Journal Volume 52, Issue 3, (pp. 387–406*). (Journal Article)

[14]. Baabereyir, B. R., (2018). *Designers Contribution to Fire Safety in Ghana*. Scholars Press. ISSN 978-620-2-31687-3., SIA OmniScriptum Publishing Brivibas gatve 197, LV- 1039, Riga Latvia, European Union info @omniscriptum.com/www.omniscriptum.com.

[15]. Babbie,E. R.(2010) *"The Practice of Social Research (12th ed.)." Bermont, CA: Wadsworth Cengage, 2010.* (Book style with paper title and editor) BIS BS 476:20, (1967) Fire Tests on Building Materials and Structures, British Standards Institution, London, 1987.

[16]. Borg, W. R. &, Gall, M. D. (1996) "*Educational Research: An Introduction*," New York.1996.

[17]. Brushlinsky, N.N. Ahrens, M. Sokolov, S.V. and Wagner, P. (2016), "World fire statistics*",CTIF, International Association of Fire and Rescue Services, No. 21*, available at: www.ctif.org/sites/default/files/ctif_report21_world_fire_statistics_2016.pdf (accessed 30June 2019).

[18]. Brushlinsky, N.N., Ahrens, M., Sokolov, S.V., &, Wagner, P. (2017). "World fire statistics", *CTIF, International Association of Fire and Rescue Services, No. 22,* available at: www.ctif.org/sites/default/files/ctif_report22_world_fire_statistics_2017.pdf (accessed 30 June 2019).

[19]. Buchanan, A.H. and Abu, A.K. (2017), *Structural Design for Fire Safety*, 2nd ed., John Wiley and Sons, West Sussex, PO19 8SQ, ISBN: 978-0-470-97289-2.

[20]. Bulletin (2014), "World fire statistics", *The Geneva Association, No. 29,* available at: www.genevaassociation.org/research-topics/world-fire-statistics-bulletin-no-29 (accessed 30 June, 2019).

[21]. Çakiroglu, Ü. and Gökoglu, S. (2019), "Development of fire safety behavioral skills via virtual reality", *Computers and Education, Vol. 133, pp. 56-68.* n published in the Taylor & Francis e-Library, 2002.

[22]. Cost (2018), "*Federal firefighting costs (suppression only)*", available at: www.nifc.gov/fireInfo/FireInfodocuments/SuppCosts.pdf (accessed 30 June 2019).

[23]. Curwin, J. Slaterr, R. (2008)"Quantitative methods for business decisions, (6th Edition).

[24]. In J. Clark, (Ed.)," 2006:p.52. *Thomson Learning High Holborn House*; 50-51. Bedford Row, London: WC 1 R 4 L R. (Book style with paper title and editor)

[25]. Danso, F. O. (2017) . "*Occupational Health and Safety Issues Involving Casual Workers on Building Construction Sites in Ghana* (A Kumasi study)", 2010. Available at: http:// dspace. knust. edu.gh /bitstream/123456789/488/1/FREDERICK%20OWUSU %20DANSOpdf. (Published Document)

[26]. Ebenehi, I.Y.; Mohamed, S.; Sarpin, N.; Masrom, M.A.N.; Zainal, R.; Azmi, M.A.M. The management of building fire safety towards the sustainability of Malaysian public universities. IOP Conf. Ser. Mater. *Sci. Eng.* ***2017****, 271, 012034. [CrossRef*]

[27]. Elhag, T. M. S. & Boussabaine, A. H. (1999) "*Evaluation of Construction Costs and Time Attributes"*, 1999. Proceedings of the 15th ARCOM Conference, Vol. 2, Liverpool: John Moores University, 473-80. [Citation Time(s).

[28]. Enshassi, A. Mohamed, s., &, El Karriri, A. (2010) "Factors affecting the bid/no bid decision in the Palestinian construction industry", 2010. Journal of Financial Management of Property and Construction, Vol. 15, Iss: (2) pp. 118 – 142. (Journal Article)

[29]. Ferguson. A. E. &, Mulwafu,, W. O (2012) "*Decentralisation, participation and access to water resources in Malawi,"* May 26, 2012. Retrieved from http://www.basis.wisc.edu.com. (Technical Report)

[30]. Grill, R. (2003). Detection and alarm. *In A. Cote (Ed.), Fire protection handbook (19th ed., Vol. 2, Section 9, pp. 1-4).* Quincy, MA: National Fire Protection Association.

[31]. Guidance Document for ASFP Innovation Project (1999). *'Ensuring Best Practice for Passive Fire Protection*'. ASFP President: Commissioner Brian Robinson CBE, QSFM, FIFireE Association House, 99 West Street, Farnham, Surrey GU9 7EN. Retrieved from www.asfp.org.uk.

[32]. Hagen, R. & Witloks, L. (2014). *The Basis for Fire Safety Substantiating fire protection in buildings.* Fire Safety Professorship of the Instituut Fysieke Veiligheid, Brandweer Nederland, the organisation of Dutch fire services. ISBN/EAN 9789056434663

[33]. Hair, J. F., Anderson, R. E., Tatham, R. L., &, Black, W. C. (2006) "*Multivariate Data Analysis with Reading."* Prentice-Hall: Englewood Cliffs, NJ, (1998, 2006).

[34]. *Hong Kong National Fire code for practice*, (2011).

[35]. Hoonakker, P., Carayon, P. &, Loushine, T. (2010) "Barriers and Benefits of Quality Management in the Construction Industry,"2010. *Total Quality Management Routledge, 21 (9), 953-969. (Journal Article)*

[36]. Huffman, M.R. The Many Elements of Traditional Fire Knowledge: Synthesis, Classification, and Aids to Cross-cultural Problem Solving in Fire-dependent Systems Around the World. *Ecol. Soc.* ***2013****, 18, 3. [CrossRef]*

[37]. ICC: International building Code, (2007).

[38]. Idrus, A. B. & Newman, J. B. (2002*) "Construction Related Factors Influencing,"*2002. (Book style with paper title)

[39]. Isa, H. M. (2011). *Learning from Defects in Design and Build Hospital Projects in Malaysia.* 5, 238–242.

[40]. Kecklund, L.; Andrée, K.; Bengtson, S.; Willander, S.; Siré, E. How do people with disabilities consider fire safety and evacuation possibilities in historical buildings?—A Swedish case study. Fire Technol. 2012, 48, 27–41

[41]. Kodur, V.; Kumar, P.; Rafi, M.M. Fire hazard in buildings: Review, assessment and strategies for improving fire safety. PSU Res. Rev. **2019**, 4, 1–23. [CrossRef]

[42]. Kish, L (1965) "Survey Sampling." New York: John Wiley and Sons, Inc. (Book style with paper title)

[43]. Lahndt, L. (1999b) "TQM Tools for the Construction Industry", 1999b. Engineering Management Journal, 11(2): 23-27. (Journal Article)

[44]. Maluk, C., Woodrow, M. and Torero, J.L. (2017), "The potential of integrating fire safety in modern building design", *Fire Safety Journal, Vol. 88, pp. 104-112.*

[45]. Masril, M., Deddy, K., Rosli, M. Z., &, Mohammad, I. (2024*). Determinant Factors of Safety Impact to the School Buildings in West Sumatera – Indonesia.* 245th ECS Meeting, May 26-30, 2024. San Francisco, C A. doi:10.1088/1755-1315/1022/1/012010

[46]. Menzemer, L.W.; Ronchi, E.; Karsten, M.M.V.; Gwynne, S.; Frederiksen, J. A scoping review and bibliometric analysis of methods for fire evacuation training in buildings. *Fire Saf. J.* ***2023****, 136, 103742. [CrossRef]*

[47]. National Fire Protection Association (NFPA) (2010b). Standard for the installation of sprinkler systems in residential occupancies up to and including four stories in height. *NFPA 13R, Quincy*.

[48]. New Zealand Centre for Advanced Engineering (CAENZ). *Fire Engineering Design Guide, 3rd edition.* Christchurch, 2008.

[49]. Nimlyat, P.S.; Audu, A.U.; Ola-Adisa, E.O.; Gwatau, D. (2017). An evaluation of fire safety measures in high-rise buildings in Nigeria. Sustain. Cities Soc. **2017**, 35, 774–785. [CrossRef]

[50]. Nordic Committee on Building Regulations (NKB, 1994). Performance Requirements for Fire Safety and Technical Guide for Verification by Calculation. *Report No: 07 E, 1994*. Nystedt, F. (2011) "*Verifying Fire Safety Design in Sprinklered Buildings*". Department of Fire Safety Engineering and Systems Safety. Lund University, Sweden, 2011:p.9. Report, 3150. ISSN: 1402-3504 ISRN: LUTVDG/TVBB-3150-SE. (Technical report with report number)

[51]. Oladapo, A. A. (2005) *"An Investigation Into The Use Of ICT." In The Nigerian*, 2005. (Book style with paper title)

[52]. Paul, S. & John A. (2002). Fire from First Principles: A design guide to building fire safety Third edition E & FN SPON An imprint of Routledge London and New York This editio Brushlinsky, N.N. Ahrens, M. Sokolov, S.V. and Wagner, P. (2017), "World fire statistics", *CTIF,International Association of Fire and Rescue Services, No. 22*, available at: www.ctif.org/sites/default/files/ctif_report22_world_fire_statistics_2017.pdf (accessed 30 June 2019).

[53]. Ramly, A., Ahmad, N. A. & Ishak, N.H. (2006). The effects of design on the maintenance of public housing buildings in Malaysia-*Part two. Building Engineer. 34-36.*

[54]. Roberts, J. (2003). Automatic fire detectors. *In A. Cote (Ed.), Fire protection handbook (19th ed., Vol. 2, Section 9, pp. 17-34).* Quincy. MA: National Fire Protection Association.

[55]. Rusydie, A. B. R., & Ahmadon, B. B. (2016). *Building Safety Index: Contributing Factor*.

[56]. Faculty of Civil Engineering, Universiti Teknologi, Malaysia.

[57]. Sagun, A., Anumba C. J., & Bouchlaghem, D. (2013). *Designing Buildings to Cope with Emergencies*: Findings from Case Studies on Exit Preferences Buildings. ISSN 2075-5309, vol. 3, 442-461; doi: 10.3390/buildings3020442.

[58]. Simpson D. E. (2010). *Fire protection and safety*. A presentation of Ghana National Fire Service (GNFS). Ashanti Regional office at a Symposium of Building Technology Students Society (BTSS) Week celebration, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, 24–27 March 2010.

[59]. Society of Fire Protection Engineers (SFPE). (2012). *Guidelines for Designing Fire Safety in Very Tall Buildings*: Public Review Draft p. 6-11.

[60]. Thevega, T.; Jayasinghe, J.; Robert, D.; Bandara, C.; Kandare, E.; Setunge, S. (2022).

[61]. Fire compliance of construction materials for building claddings: *A critical review. Constr. Build. Mater. 2022, 361, 129582*. [CrossRef]

[62]. Willar, D (2012). "*Improving Quality Management System Implementation in Indonesian Construction Companies*", 2012. Available at:http: //eprints.qut.edu.au/59202//Debby Willar Thesis pdf. (Thesis).

[63]. Yung, D. (2008). "*Principles of Fire Risk Assessments in Buildings*". John Wiley & Sons Ltd. (Book style with paper title and editor).