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ASSESSING THE LEVEL OF RESILIENCE IN CONSTRUCTION SAFETY MANAGEMENT SYSTEMS IN THE GHANAIAN CONSTRUCTION INDUSTRY.

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ABSTRACT

The traditional safety management approach is a control-oriented approach that seeks to direct and control workers to complete the expected company safety standards and regulations. This reactive approach to safety management is only partially compatible with the growing complexity of contemporary organisations. Therefore, a more comprehensive and modern approach is necessary, hence, the resilience management system. This study is part of a PhD programme. The study's objective was to establish the level of resilience capabilities of construction safety management systems in Ghana's construction industry. The targeted respondents were health and safety managers, managing directors, project managers, site engineers, and construction managers of D1K1, D2K2, D3K3, and D4K4 construction companies. The list of 144 construction companies surveyed in this study was obtained from the Association of Building and Civil Engineering Contractors Ghana and deemed to be in good standing. The study used purposive sampling techniques to reach out to the respondents. Descriptive statistics, a one-sample t-test, a one-way analysis of variance and its post hoc test, and the resilience analysis grid were employed. The results revealed that out of the seven safety management systems assessed, only 'policy' measured up to the acceptable level of resilience, thus establishing that the entire safety management system is not resilient. These findings have empirically established that safety management systems in the Ghanaian construction industry are not resilient. The results further highlight the necessity for contractors and stakeholders to switch from a conventional safety management strategy to a more proactive safety management approach and to establish a customised method to foster a robust safety management system.

Keywords: resilience, construction, safety, management systems

Introduction

Construction is a hazardous industry in developed and developing countries, contributing to a significant number of occupational accidents and ill health globally (Man et al., 2019; Tam and Fung, 2012). Managing safety effectively is an essential aspect of risk management for businesses worldwide. Over 2.7 million employees die from work-related incidents and illnesses, and over 374 million are injured in non-fatal accidents (International Labour Organisation [ILO], 2017). As a result of the threats raised by globalisation, emerging technology, and organisational complexity (Dethlefsen, 2022; Pillay, 2016), these incidents are expected to rise even further. Whereas developed countries have shown dedication to reducing accident numbers in industrial settings, the same cannot be said of developing states, especially in Sub-Saharan Africa. Accident rates in these developing economies are unacceptably high. It has been forecasted that the number of accidents in the construction industry will increase along with the pace of industrialisation. Significant industrial accidents get attention because of their devastation into people's lives, the economy, and the environment (Sayed, 2016).

Undoubtedly, the conventional method has contributed to reducing workplace accidents, yet traditional safety management systems (SMSs) have faults (Bugalia et al., 2020; Pęciłło, 2016). Researchers and organisations have created various safety management strategies to reduce undesirable outcomes, such as accident rates, incident rates, and near misses, through traditional safety means. Studies on safety have mostly considered safety practices, safety procedures, safety challenges, and safety performance in the industry, which is primarily reactive (Mohammadi et al., 2018; Okonkwo, 2019; Asah-Kissiedu, 2019). However, the gaps in the traditional safety system include the need to implement proactive measures for handling these complex, dynamic, and unstable systems appropriately. Traditional approaches to solving numerous safety problems have largely taken reactive rather than proactive measures. The traditional approach to safety management is not fully compatible with modern-day organisations' growing complexity; therefore, a more comprehensive and pragmatic approach has become necessary. Traditional approaches to safety management are often institutionalised through system rules, plans, procedures, and processes and, therefore, are not fully compatible with the growing complexity of modern-day organisations (Mullins-Jaime et al., 2021; Zailani et al., 2021; Kontogiannis et al., 2016). Despite significant efforts to achieve a high level of safety management, traditional safety systems cannot ensure continual improvements in safety performance (Cuppen et al., 2016; Mohammadi et al., 2018). In research, no known work has been done on resilience in construction safety in the

Ghanaian construction industry. For these reasons, a more proactive and pragmatic approach has become necessary.

To overcome the above problems, the concept of resilience engineering has been introduced to augment the limitations of traditional safety management systems. Resilience engineering relies on a system's ability to monitor, respond, learn, anticipate surprises, and adapt to potential failures ((Hollnagel and Nemeth, 2022). In resilience engineering, researchers have tried to link resilience to certain qualities. Scholars have categorised resilience into four capacities, noting that a robust system must balance these capacities (Aidoo et al., 2022), as indicated below.

Ability to respond: Every organisation must respond to external and internal disorders, feedback, and indicators. To preserve productivity and safety, a system must distinguish between urgent and important issues and respond effectively and on time.

Ability to monitor: According to Hollnagel (2021), a resilient system must be able to keep track of events and identify any changes that may have an impact on the organisation's capacity to carry out planned or present operations. For at least the period of the current activity or operation, a resilient system must know what to concentrate on.

Ability to anticipate: A resilient system must be able to foresee future events outside the scope of ongoing activities. It must be able to consider potential future occurrences, circumstances, or state changes that could have a favourable or negative impact on the organisation's capacity to operate, such as technological advancements, modifications in client needs, new laws, etc. (Patriarca et al., 2018; Aidoo et al., 2022).

Ability to learn: A resilient organisation must have the capacity to learn from its mistakes. It is essential to comprehend what has occurred and to draw appropriate conclusions from experience.

Resilience is an emerging concept that is being used in several disciplines. However, the need for more knowledge of the concept of resilience in construction safety management makes it a subject worth studying (Aidoo et al., 2022). In establishing a proactive safety system, resilience in construction safety management systems is essential, especially in the construction industry in developing countries. The resilience concept is recognised as a potential solution to the deficiencies of traditional safety management and in responding to the changing and unforeseen safety risks associated with the increasingly complex nature of sociotechnical systems.

In view of the above discussion, this study was initiated to assess the level of resilience in construction safety management systems in the Ghanaian construction industry. The study's objective is to determine the level of resilience capabilities of construction safety management systems in Ghana's construction industry. Assessing such attributes will help construction contractors implement policies and measures to ensure safety management systems are proactive in the long term and keep operations running after accidents and incidents occur. The results of the study offer empirical data that elucidate how to foster resilient safety management in construction projects.

Literature Review

This study reviews the current Ghanaian construction industry and safety management systems to understand the subject matter. It then narrows down to resilience safety management, resilience capabilities, and the need for resilience safety management. In what follows, some current theories on resilience and the theory underpinning this study are introduced.

Occupational health and safety in Ghana

Safety and health in the industry are essential to retaining employees and employers out of operational-related injuries and sicknesses. It also prevents adverse effects on the environment and the public. In Ghana, citizens' need to practice health and safety is an essential legal requirement backed by constitutional provisions. The 1992 Constitution of Ghana, Article 24, Clauses 1 and 2 make this explicit, and because this is found in the Land's supreme law, it becomes the "Grundnorm" from which all other connected laws derive legitimacy (Annan, 2015).

The existence of various regulatory bodies in Ghana has compounded occupational health and safety (OHS) challenges (Annan, 2015), and this is plagued with non-ratification of the International Labour Organisation (ILO) convention 1981 (No. 155). Mustapha et al. (2015) observed that OHS implementation and practices are major challenges in establishing a comprehensive national OHS policy in Ghana. The authors recommended that OHS issues should be taken seriously at all levels to deal with the challenges facing the construction sector in Ghana.

Safety management systems

A safety management system's primary objective is to contain or mitigate hazards and proactively avoid accidents and injuries. Maliha (2021) revealed that "sound safety planning must be based on a detailed understanding of people's processes and activities in the system and the other components of the structures and environments in which they work, including danger detection, risk management, and safety assurance."

Elements of safety management systems

Different organisations have different definitions of the elements of safety management systems and their implementation methods. Several researchers have looked at the elements of safety management systems by comparing the magnitude of accidents in companies. To efficiently implement health and safety (H&S) management practices, there is a need to adopt an appropriate H&S management system. One of the most cited systems is the UK Health and Safety Executive's (HSE) framework for managing H&S (HSE, 2020). The key elements in this framework are H&S policy, planning, organising, risk assessment, implementation, measuring performance, and audit/review, which has been revised to follow Deming's plan-do-check-act model (HSE, 2013). Similar elements to HSE's (2020) framework have also been shown by other H&S management models, including the International Labour Organization guidance.

Resilience engineering concepts and theories

The term resilience originates from the Latin word resilire, which means "to spring back" and is used in a broad range of research fields. However, psychologists coined the word resilience in the 1950s (Akhtar, 2020). Holling (1973) contributed significantly to the concept of resilience in social-ecological science. He established that social-ecological systems could have several equilibrium states, which he presented in his paper, "Resilience and Stability of Ecological Systems" (Holling, 1973). Below are some theories of resilience in various fields.

Psychology

Individuals' resilience in the face of disasters, pivotal incidents, or aversive living environments is a subject of psychology: "The process of successfully negotiating, adjusting to, or handling significant sources of stress or trauma is referred to as resilience". This potential for adaptation and bouncing back in the face of adversity is facilitated by the individual's assets and resources, including their life and climate. Emmy Werner's longitudinal experiments on the island of Kauai in the 1950s began psychological research on resilience.

Ecology

Holling pioneered the application of the principle of resilience to ecological systems (Konaka and Little, 2021; Rutting et al., 2022). "Resilience measures the persistence of relationships within a system and measures these systems' ability to tolerate changes in state variables, moving variables, and parameters and persist" (Shi, et al., 2018). *Ecological resilience* is the maximum disruption that an ecological system (such as a forest or a stretch of water) can tolerate until crossing a critical threshold and permanently destabilising its original equilibrium.

Socio-ecological resilience discourses

The concept of resilience has moved from the individual to the systemic level in the social sciences. In geographical development studies, the concept of resilient societies has been developed to answer the question of how to improve the resilience of towns, territories, and states in the face of natural disasters (Daris, 2021; Gavalas, 2022). "Local resiliency concerning disasters means that a locality can withstand a severe natural event without experiencing catastrophic losses, injury, diminished productivity, or quality of life, and without a significant amount of assistance from outside the community" (Robertson et al., 2021). The technological aspects of resilience are not the only focus of such social-scientific conceptions.

Economics

In economics, resilience refers to a country's ability to adopt crisis prevention steps, mitigate the immediate effects of a crisis, and respond to changing economic conditions (Caldera-Sánchez et al., 2016, p. 6). The implementation of constructive steps to prevent crises and recognise important early warning indicators is emphasised here. Although resilience is often beneficial from an ecological or technical standpoint to restore a previous state of affairs, this is rarely the case in the economic domain, as national economies and businesses are subject to ongoing proclivity.

Organisational resilience

Organisational resilience is a multidimensional term. Mafabi and Kabagambe (2021) established three dimensions of organisational resilience in a study: cognitive, behavioural, and contextual.

Resilience engineering: A perspective of safety management

The lack of effectiveness of traditional approaches in reacting to evolving and unexpected safety threats associated with the increasingly complex nature of sociotechnical systems has been recognised as a potential solution (Pęciłło, 2016). Unlike traditional risk management approaches, which focus on a posteriori improvement activity based on accident analysis and occupational risk assessment, resilience engineering is a proactive approach to safety management that seeks to improve organisations' ability to monitor risks explicitly and make appropriate trade-offs between necessary safety levels and economic pressures (Griffioen et al., 2021).

Resilience engineering theory underpins this work. The basic idea behind resilience engineering is that an organisation manages safety risks proactively and creates safety through four resilience processes or capabilities, which include anticipating (knowing what to expect), monitoring (knowing what to look for), responding (knowing what to do), and resolving (knowing what to do) (Hollnagel, 2021; Pęciłło, 2016)).

Materials and Method

Design and Methodology

A quantitative approach and a survey research design were considered the most appropriate for achieving the study objectives. Therefore, the analysis used for the study was quantitative. It was also essential to adopt a proper epistemological, ontological, and axiological approach that would allow appropriate data collection, analysis, and interpretation of findings for the benefit of practitioners and researchers. The methodology of this study consisted of a comprehensive review focusing on construction safety and health practices, with an emphasis on the concept of resilience, using both primary and secondary data to achieve the above objectives. The population for this study was the Ghanaian construction industry.

The unit of analysis focused on Ghanaian contractors of D1K1, D2K2, D3K3, and D4K4 construction companies in the construction industry. Contractors in Ghana are classified into eight categories based on their work type (A, B, C, S, D, K, E, and G) (Ministry of Roads and Highways, 2018; Ministry of Water Resources, Works and Housing, 2018). The categories are (i) roads, airports, and related structures (a), (ii) bridges, culverts, and other structures (b), (iii) labour-based road works (c), (iv) steel bridges and structures: construction rehabilitation and maintenance (s), (v) general building works (d), (vi) general civil works (k), (vii) electrical works (E), and (viii) plumbing works (P) (G). Contractors in each category can also be classified into four financial classes: 1, 2, 3, or 4 (Osei-Asibey et al., 2021; Vulink, 2004). Building and civil engineering contractors with financial class 4 can bid on contracts worth up to $75,000, class 3 up to $200,000, class 2 up to $500,000, and financial class 1 can bid on projects worth up to $1,000,000 (Ministry of Water Resources, Works and Housing, 2018, as cited by Osei-Asibey et al., 2021). The study areas were Greater Accra and Kumasi. Purposive sampling was used because the respondents were readily available and the best-fit participants to answer the questionnaire. A six-point Likert scale adapted from Hollnagel (2015) and a structured quantitative closed-ended questionnaire survey were used.

A one-sample t-test, one-way analysis of variance (ANOVA), and resilience analysis grid were used to meet the objectives. The results are presented in tables and radar charts. The data collection instrument consisted of two main sections. Section A aimed to collect demographic data about the respondents (i.e. educational background and work experience). Section B was based on a five-point Likert scale (0 = Missing, 1 = Deficient, 2 = Unacceptable, 3 = Acceptable, 4 = Satisfactory, 5 = Excellent) to measure the level of resilience in safety management systems in construction (i.e. policy, planning, organisation, risk management, implementation, performance management, and audit). Respondents were required to choose the score that best reflects/describes their organisation's safety management systems concerning the four capabilities: response, monitor, learn and anticipate.

Response Rate

A total of 200 questionnaires were distributed, both physically and online. The majority of the distribution was done online. Out of the 200 questionnaires that went out, 144 were retrieved. Of the 144 retrieved, 28 (19.44%) were received via email, and another 28 (19.44%) by hard copy. The remaining 88 (61.11%) were obtained through Google Forms. Thus, a response rate of 69.39% was attained.

Demographics of the respondents

Table 1 shows the demographic and organisational characteristics. All respondents were of various positions with safety backgrounds and had different levels of education. Experience is crucial when it comes to safety issues in general. More than 52% of the respondents had more than 10 years of work experience in the Ghanaian construction industry (GCI), indicating their capability to provide well-informed responses. However, 48% of the respondents had between 1 and 10 years of work experience in the GCI. The results further indicate that 14% of the respondents had been involved as professional safety managers, and 86% doubled as safety managers and in other capacities, enabling them to make knowledgeable contributions to issues about safety.

Table 1. Participant and organisational characteristics

Variable	Group	Frequency	Percent
Position	Safety Manager	20	13.9
	Managing Director	13	9
	Project Manager	24	16.7
	Site Engineer	29	20.1
	Construction Manager	25	17.4
	Others	31	21.5
	Missing	2	1.4
	Total	144	100
Education	Doctorate	3	2.1
	Masters	45	31.3
	First Degree	50	34.7
	HND/Diploma	32	22.2
	Technician CTC1	3	2.1
	Technician CTC 2	6	4.2
	Missing	5	3.5
	Total	144	100
Experience	Less than 6 Years	37	25.7
	6-10 Years	32	22.2
	11-15 Years	33	22.9
	16-20 Years	26	18.1
	Over 20 Years	16	11.1
	Total	144	100

Source: Survey data, 2021

Statistical Analyses Method

Data in Microsoft (MS) Excel format were downloaded from Google Forms. Coding was done in MS Excel, and the resulting data were transported to SPSS version 25 (IBM Inc., NY, USA), which was used for the data analysis. Descriptive statistics (frequency and percentages) were used to summarise the data after two questionnaires with missing items were discarded, in line with the recommendation of Shanthi (2019). According to Shanthi (2019), assessing the normality of the data associated with the dependent variable over the factor or categorical variable involved in the ANOVA is necessary. Before testing, an exploratory analysis was conducted to understand the distribution of the variables and to identify missing data and outliers. According to Garson (2012), a distribution or variable is normally skewed if its skewness is less than 3 or greater than -3. The results of all the variables in this study met this condition, which suggests that the variables were normally skewed. Kurtosis is also satisfactory if the above rule of thumb is satisfied. One variable under 'risk assessment' did not meet this condition. These two outliers were therefore removed from the data. Cronbach's alpha was computed using SPSS and was used to measure the scale's internal consistency (Kalkbrenner, 2021; Asimah et al., 2018). The rule of thumb applicable is that a domain or construct is internally consistent if its Cronbach's alpha a ≥0.7 (Kalkbrenner, M.T., 2021; Hair et al., 2020; Kwofie, 2018). All SMS of resilience capability results met this condition with Cronbach's alpha a ≥0.97. Furthermore, convergent validity and discriminant validity are met if AVE≥0.5 and ASV<AVE, respectively (Camiré et al., 2021 Asiamah et al., 2018; Kwofie, 2018). However, from Table 2, these criteria were met, AVS<AVE, which means that the convergent and discriminant validity of the scale was achieved.

Table 2. Reliability and validity statistics for The Safety Management Systems

Factor	Cronbach's alpha	Average variance extracted	Average shared variance
Policy	0.962	0.795	0.301
Planning	0.946	0.782	0.296
Organization	0.953	0.788	0.298
Risk assessment	0.723	0.530	0.263
Implementation	0.969	0.801	0.303
Performance Management	0.966	0.798	0.302
Audit	0.978	0.808	0.306
Whole scale	0.97	---	---

Note: --- Not applicable
Source: Survey data, 2021

Results

Table 3 shows the summary statistics associated with the level of resilience capabilities in construction safety management systems in Ghana's construction industry. The study's objective was to determine the level of resilience capabilities in safety management systems in the construction industry (CI). Seven safety management systems (SMSs) were measured with respect to four capabilities: response, monitor, learn, and anticipate. SMS has seven management systems, each with four items/variables. The mean score was obtained on a Likert scale ranging from 0 to 5, which means that the ideal mean should fall within this range. According to Hochstein et al. (2018), mean scores outside this range belong to variables with a significant outlier. Garson also reported that the mean's standard deviation (SD) should be smaller than the mean; otherwise, outliers were present in the data. Table 3 shows that the number of cases analysed for each variable is N = 144, which represents the number of questionnaires completed. Thus, there were no missing items in any of the indicators.

For the Safety Management Systems, 'Policy', 'Planning' and 'Risk Assessment' had the most significant mean scores (mean = 3.08; SD = 1.64), (mean = 3.07; SD = 1.43) and (mean = 3.15; SD = 2.13), respectively, whereas the lowest mean scores were observed for 'Organisation', 'Implementation', 'Performance Management' and 'Audit' (mean = 2.9; SD = 1.54; mean = 2.95, SD = 1.55; and mean = 2.66, SD = 1.71, respectively). According to Table 3, the majority of the mean scores of the indicators (variables) fell below the mean value of 3. This indicates that the industry's safety management systems are not resilient. According to Hollnagel (2015), all the variables/indicators must have a mean score of 3 (acceptable) and above to make the system resilient. Any mean score below 3 on the scale is 'not acceptable'.

Table 3. Summary statistics on the level of resilience capabilities in construction safety management systems in the construction industry in Ghana

Safety Management Systems	Mean	SD	Rank
Policy	**Mean**	**SD**	**Rank**
Clear statement of safety policy	3.15	1.88	1
Contains guidelines for monitoring policy implementation	3.02	1.78	4
Allows for planning based on expected future events	3.06	1.61	3
Allows for revisions based on past events	3.10	1.61	2
Planning	**Mean**	**SD**	**Rank**
Work is planned (including plans for contingencies) to ensure that all safety functions are maintained effectively at all times	3.19	1.53	1
Monitor planned safety resources Technical and Financial) for safety management processes	2.97	1.58	4
Planning systems are adequate to anticipate future safety weaknesses and threats	3.01	1.54	3
Organisation's systems allow for planning process revision based on past events and incidence	3.10	1.51	2
Organisation	**Mean**	**SD**	**Rank**
Provision of financial, technical and human resources needed for safety-related issues	2.94	1.63	2
Regular assessments of the safety process in the organisation by management	2.91	1.66	3
Employees involvement in issues concerning potential or anticipated safety and related weaknesses and threats in the organisation	2.74	1.7	4
Lessons learnt to promote high organisational safety standards	3.01	1.6	1
Risk assessment	**Mean**	**SD**	**Rank**
Level of safety risk impact and frequency forms basis for response	2.88	1.56	4
Effect of safety risk response always checked	3.02	1.56	2
Anticipated future events influence safety risk assessment and response	2.92	1.6	3
Effect of safety risk response influences future safety risk assessment and response plan	3.78	6.07	1
Implementation	**Mean**	**SD**	**Rank**
Responds to Safety management systems improvement plans	2.90	1.67	2
Monitor safety control measure implemented	2.94	1.65	4

Safety Management Systems	Mean	SD	Rank
Implement reforms to improve safety management based on predictions of the future	2.90	1.59	3
Implement reforms to improve safety management based on lessons from the past	3.04	1.59	1
Performance Management	**Mean**	**SD**	**Rank**
Measure safety programmes and controls performance	2.84	1.67	4
Monitors safety performance for feedback to improve safety management	2.92	1.67	2
Measures employee performance on safety management	2.88	1.6	3
Measure performance based on lessons from the past to improve safety management	3.06	1.56	1
Audit	**Mean**	**SD**	**Rank**
Respond to queries raised in safety audit conducted	2.62	1.79	3
Monitors safety audit recommendations to ensure it implementation	2.60	1.71	4
Audit procedures are established, implemented and maintained	2.65	1.81	2
Audit reports are relevant to learning to improve safety management	2.76	1.74	1

Source: Survey data, 2021

Level of resilience capabilities in safety management systems

This subsection analyses data on the first specific objective: establishing the level of resilience capabilities in construction safety management systems in the construction industry. Two kinds of analyses are presented in this section. The first is an estimate of the mean scores of resilience capabilities for various classes of construction companies for safety management systems. The one-sample t-test was then used to test whether the level of resilience capability for a domain (SMS) was significantly greater than 12, which is the test value for this t-test. The test value is the product of the recommended baseline value of resilience capability (Hollnagel, 2010) and the total number of variables that make up a domain (i.e. 4). With the minimum resilience capability level being 12 for a domain, the mean score of a domain should be 12 or more to conclude that the level of resilience capability is sufficient. The test value for overall resilience (which combines all the domains) was 84. The one-sample t-test helped to make this decision. Table 4 shows the results of the one-sample t-test of the various safety management systems.

Table (4) One-sample T-tests on resilience and its domains.

Variable		t	df	p-value	Mean Difference	95% CI
Policy	(TV= 12)	0.60	143	0.55	0.33	±2.15
Planning	(TV = 12)	0.54	143	0.59	0.26	±1.88
Organization	(TV = 12)	-0.78	143	0.43	-0.40	±2.03
Risk assessment	(TV = 12)	0.86	143	0.39	0.61	±2.81
Implementation	(TV = 12)	-0.43	143	0.67	-0.22	±2.05
Performance Management(TV = 12)		-0.59	143	0.56	-0.31	±2.05
Audit	(TV = 12)	-2.40	143	0.02	-1.37	±2.25

Note: Confidence interval
Source: Survey data, 2021

Table 4 shows a one-sample t-test on all SMS of resilience capability. In Table (4), only the mean of the audit SMS was significantly larger than the test value of 12 (t = -2.4; p <0.05); mean scores of the other domains were not significantly different from 12. Thus, the level of resilience capability demonstrated in terms of the audit was relatively larger than the baseline value of 12. Since the other mean scores in Table 5 are slightly larger or lower than 12 and are not significantly different from the baseline value of 12, we can conclude that the levels of resilience capability demonstrated over the other SMSs are satisfactory. However, the fact that audit SMS accounts for the largest resilience capability level is noteworthy. Table 6 shows a one-way ANOVA that tests for a difference between the four contractor classifications regarding the level of resilience in safety management systems.

Table (5) Levene's Homogeneity of Variances Test

Safety Management Systems	Levene Statistic	df1	df2	p
Policy	2.32	3	139	0.078
Planning	3.18	3	139	0.026
Organization	1.97	3	139	0.122
Risk assessment	3.18	3	139	0.026
Implementation	1.77	3	139	0.156
Performance Management	0.89	3	139	0.447
Audit	1.29	3	139	0.282
Resilience	1.45	3	139	0.232

Source: Survey data, 2021

Table 5 shows Levene's test of homogeneity of variances. The analysis tests the assumption that the variances of the four classes of construction companies are the same. If the variances between the groups were the same for the various SMS, we would expect their corresponding p-values to be greater than 0.05 (Garson, 2012). As shown in the table, this assumption was met for all SMSs, except for planning and risk assessment, both of which produced a p <0.05. For this reason, the equality of variances assumption cannot be applied to planning and risk assessment. Again, this indicates that the construction's SMSs are not resilient. Table 6 shows the F-test test associated with the one-way ANOVA.

As shown in Table 6, there was a significant difference between the mean scores of the four groups in terms of resilience for only three of the SMS, namely planning (F = 3.1, p <0.05), organisation (F = 3.9, p <0.05), and audit (F = 3.4, p <0.05). That is, there was a difference between the four contractor classifications in terms of resilience capability for these three SMSs. There was also a significant difference between the four classifications for resilience as a whole (F = 3.4, p <0.05). In other words, some categories delivered a higher level of resilience. Table 7 shows the post hoc test or multiple comparisons based on the above-observed differences.

Table (6) F-test from Analysis of Variance (ANOVA)

Safety Management Systems	Level	Sum of Squares	df	Mean Square	F	p
	Between Groups	316.7	3.0	105.6	2.5	0.059
Policy	Within Groups	5785.8	139.0	41.6		
	Total	6102.5	142.0			
	Between Groups	294.3	3.0	98.1	3.1	**0.028**
Planning	Within Groups	4362.5	139.0	31.4		
	Total	4656.8	142.0			
	Between Groups	422.9	3.0	141.0	3.9	**0.010**
Organization	Within Groups	4994.1	139.0	35.9		
	Total	5417.0	142.0			
	Between Groups	516.1	3.0	172.0	2.4	0.068
Risk assessment	Within Groups	9870.2	139.0	71.0		
	Total	10386.3	142.0			
	Between Groups	239.1	3.0	79.7	2.1	0.103
Implementation	Within Groups	5280.3	139.0	38.0		
	Total	5519.4	142.0			
	Between Groups	240.7	3.0	80.2	2.1	0.099

Safety Management Systems	Level	Sum of Squares	df	Mean Square	F	p
Performance Management	Within Groups	5231.8	139.0	37.6		
	Total	5472.5	142.0			
Audit	Between Groups	449.1	3.0	149.7	3.4	**0.021**
	Within Groups	6201.2	139.0	44.6		
	Total	6650.3	142.0			
Resilience	Between Groups	15757.1	3.0	5252.4	3.2	**0.025**
	Within Groups	227111.2	139.0	1633.9		
	Total	242868.3	142.0			

Source: Survey data, 2021

Table 7 shows the observed differences between D2/K2 and D3/K3 (p = 0.44). This is to say that there is a difference between the mean score of D2/K2 (mean = 9.81; SD = 6.56) and D3/K3 (mean = 14.85; SD = 4.43), as shown in Table 8. For the audit, the difference is between D2/K2 and D3/K3. This is a reflection of the difference between D2/K2 (mean = 9) and D3/K3 (mean = 15.15) in Table 8. With the audit and the whole resilience construct, the differences are still between D2/K2 and D3/K3. This means that for the whole construct and the three SMS producing a significant ANOVA test, the observed difference is between D2/K2 and D3/K3. Thus, D3/K3 produced higher resilience capability scores than D2/K2.

Table (7) Post-hoc or Multiple comparison test

Dependent Variable	(I) Class	(J) Class	Mean Difference (I-J)	SE	p	95% CI
Planning	D1/K1	D2/K2	2.94	1.23	0.111	±6.60
		D3/K3	-2.10	1.71	1.000	±9.15
		Non-classified	0.07	1.16	1.000	±6.23
	D2/K2	D1/K1	-2.94	1.23	0.111	±6.60
		D3/K3	-5.04	1.85	**0.044**	±9.91
		Non-classified	-2.87	1.36	0.223	±7.30
	D3/K3	D1/K1	2.10	1.71	1.000	±9.15
		D2/K2	5.04	1.85	**0.044**	±9.91
		Non-classified	2.17	1.81	1.000	±9.67
	Non-classified	D1/K1	-0.07	1.16	1.000	±6.23
		D2/K2	2.87	1.36	0.223	±7.30
		D3/K3	-2.17	1.81	1.000	±9.67
Organization	D1/K1	D2/K2	2.42	1.32	0.412	±7.06
		D3/K3	-3.73	1.83	0.258	±9.79
		Non-classified	-1.31	1.25	1.000	±6.67

Dependent Variable	(I) Class	(J) Class	Mean Difference (I-J)	SE	p	95% CI
	D2/K2	D1/K1	-2.42	1.32	0.412	±7.06
		D3/K3	-6.15	1.98	**0.014**	±10.60
		Non-classified	-3.73	1.46	0.070	±7.81
	D3/K3	D1/K1	3.73	1.83	0.258	±9.79
		D2/K2	6.15	1.98	0.014	±10.60
		Non-classified	2.42	1.93	1.000	±10.35
	Non-classified	D1/K1	1.31	1.25	1.000	±6.67
		D2/K2	3.73	1.46	0.070	±7.81
		D3/K3	-2.42	1.93	1.000	±10.35
		D3/K3	-1.75	1.98	1.000	±10.59
Audit	D1/K1	D2/K2	3.39	1.47	0.136	±7.87
		D3/K3	-3.09	2.04	0.790	±10.91
		Non-classified	0.04	1.39	1.000	±7.43
	D2/K2	D1/K1	-3.39	1.47	0.136	±7.87
		D3/K3	-6.48	2.21	**0.023**	±11.81
		Non-classified	-3.35	1.63	0.248	±8.71
	D3/K3	D1/K1	3.09	2.04	0.790	±10.91
		D2/K2	6.48	2.21	**0.023**	±11.81
		Non-classified	3.13	2.15	0.893	±11.53
	Non-classified	D1/K1	-0.04	1.39	1.000	±7.43
		D2/K2	3.35	1.63	0.248	±8.71
		D3/K3	-3.13	2.15	0.893	±11.53
Resilience	D1/K1	D2/K2	19.61	8.89	0.174	±47.60
		D3/K3	-16.95	12.33	1.000	±66.01
		Non-classified	-3.78	8.40	1.000	±44.95
	D2/K2	D1/K1	-19.61	8.89	0.174	±47.60
		D3/K3	-36.56	13.36	**0.042**	±71.50
		Non-classified	-23.39	9.84	0.113	±52.69
	D3/K3	D1/K1	16.95	12.33	1.000	±66.01
		D2/K2	36.56	13.36	**0.042**	±71.50
		Non-classified	13.16	13.03	1.000	±69.76
	Non-classified	D1/K1	3.78	8.40	1.000	±44.95
		D2/K2	23.39	9.84	0.113	±52.69
		D3/K3	-13.16	13.03	1.000	±69.76

Note: CI – confidence interval
Source: Survey data, 2021

Resilience Analysis Grid (RAG)

The resilience analysis grid was applied further to appreciate the resilience levels of the safety management systems. See Table 3. The resilience analysis grid was set to help determine how well a system performs in each of the four basic abilities. According to Hollnagel (2015), for a system to be resilient, it must meet all four resilience capability concepts; thus, the system must have the ability to respond, monitor, learn, and anticipate, as shown in Figure 1. However, considering the final resultant analysis presented in Table 3, the system failed to meet all four capabilities: response, monitor, learn, and anticipate. This was further demonstrated in the star plots in Figures 2 to 9. Thus, these findings affirm the assertion by Mustapha et al. (2016) that the construction system is more reactive than proactive. On that basis, we can conclude that the safety management system in Ghana's construction industry is not resilient. In this vein, resilience engineering has been suggested by Pęciłło (2016) as a way to overcome the limitations of traditional safety management system approaches in reacting to the evolving and somewhat unpredictable shapes of safety threats in the construction industry.

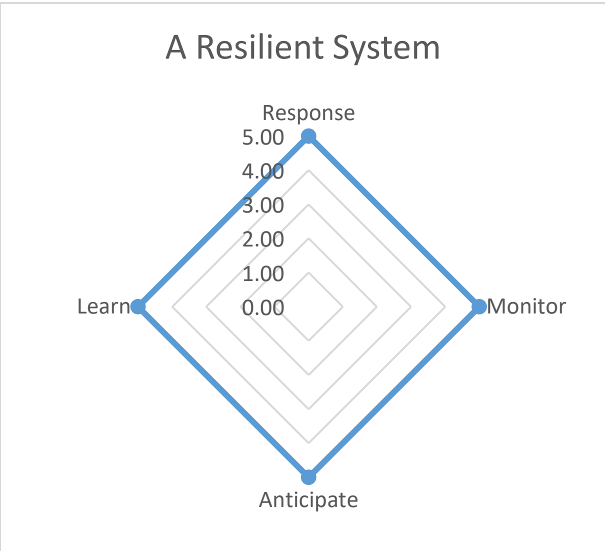

Figure 1. A resilient safety management system

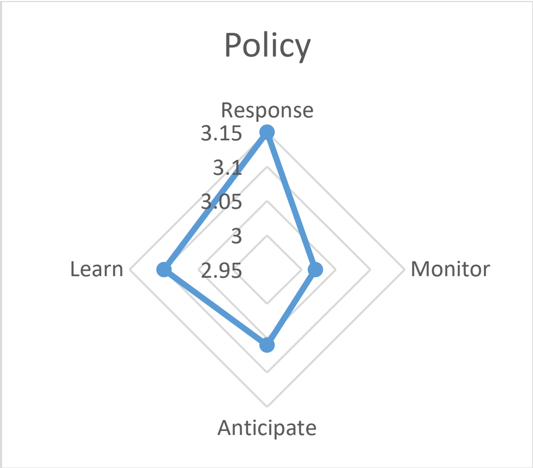

Figure 2. SMS policy

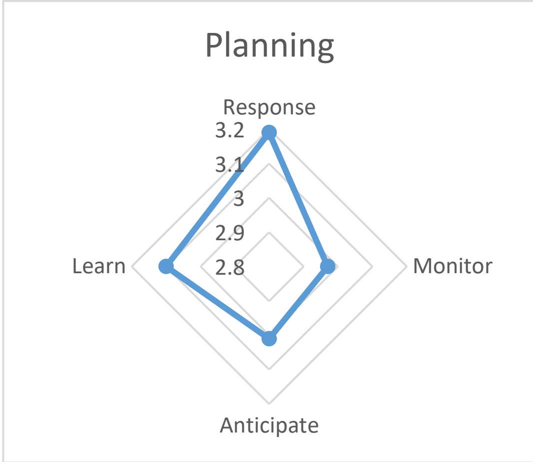

Figure 3. SMS planning

Figure 4. SMS organisation

Figure 5. SMS Risk assessment

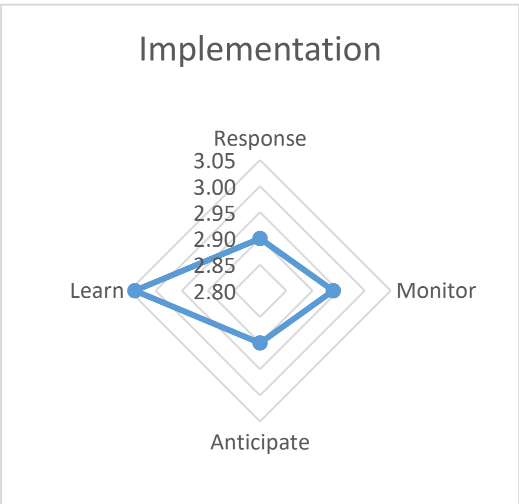

Figure 6. Implementation

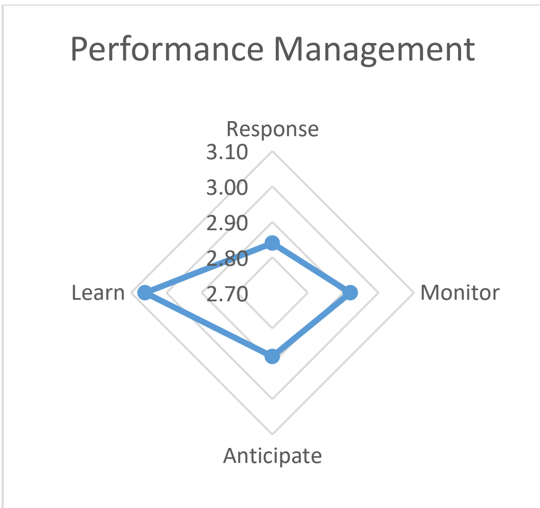

Figure 7. Performance management

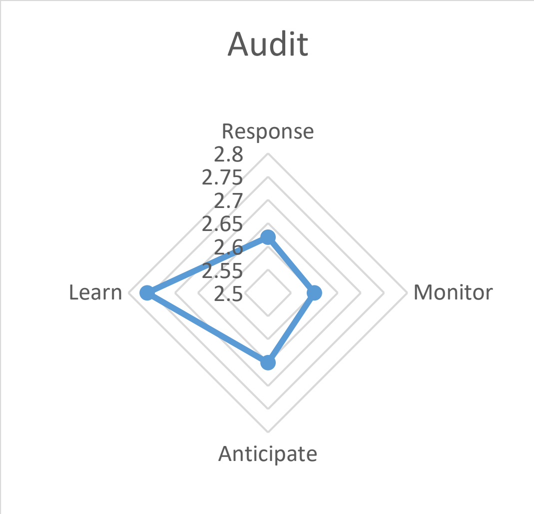

Figure 8. Audit

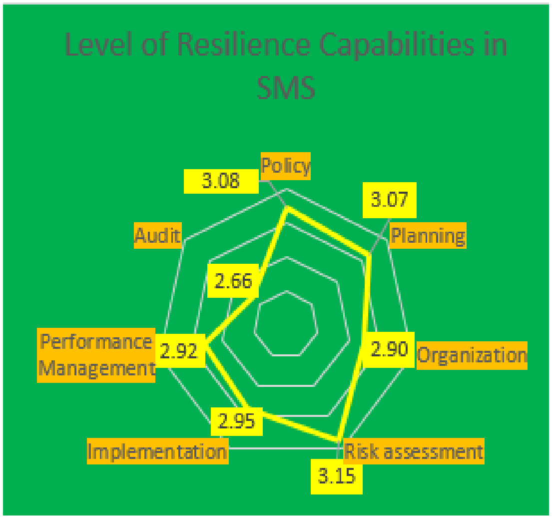

Figure 9. Level of resilience capabilities

DISCUSSIONS

Policy

The complete responses to the policy by respondents show an excellent score, with a mean of above 3. This indicates that most construction companies have a policy in place and that safety policy is key to the development and progress of safety. According to Tear et al. (2022), safety policies and procedures exemplify the organisation's expression in prioritising safety in the workplace. Management commitment and reinforcement are fundamental elements for ensuring that a policy is observed and implemented thoughtfully by everyone (Petersen, 1998). This also supports the findings of Shafie et al. (2021), who demonstrated that management commitment and safety policy are factors that promote safety management practices. According to Khalid et al. (2021), an effective safety policy not only results in the achievement of safety goals but also the accomplishment of an organisation's overall mission. See Figure 2.

Planning

In examining the response with respect to planning, all variables except one fell below a mean of 3, as seen in the case of "Monitor planned safety resources (Technical and Financial) for safety management processes." This shows that much effort is needed to improve the planning of the safety process. However, this cannot be achieved without the resources committed to planning. One of the most critical components in the success of any construction project is effective safety planning. The capacity to recognise possible hazards on construction sites before actual work begins is a critical component of safety planning. These findings agree with those obtained by Eiris et al. (2018) and Khalid et al. (2021).

Organisation

One variable scored a mean above 3, with the remaining variables having a mean value of below ‘acceptable’. This means that proper organisation is lacking in Ghana’s construction industry. Organising is the foundation of structures specifying obligations, connections, and relationships that would advance and guarantee the safety approach’s execution and improvement. An organisation’s ability to monitor health and safety incidents and its business goals strongly affects its management structure and safety culture. A proper management process must be in place, properly operating, and communicated to all staff to have adequate control over health and safety and all business operations. This will allow people to exercise the appropriate authority to carry out their duties (Figure 4).

Implementation

In examining the response for implementation, the only variable that scored a mean of above 3 was “Implement reforms to improve safety management based on lessons from the past”. There is a plethora of literature on the challenges that developing countries face in implementing safety programmes. Inadequate resources are a stumbling block that can wreak havoc on safety programmes. Management must supply sufficient resources to enforce safety programmes, including qualified staff, time, money, information, safety work practises, facilities, tools, and machinery. This also supports the findings of Buniya et al. (2021).

Risk assessment

To have a successful safety management system, it is necessary to have a risk management system that involves hazard identification, risk assessment, and risk control. Two variables scored a mean score of 3, which was above average. These variables are “Effect of safety risk response always checked” and “Effect of safety risk response influences future safety risk assessment and response plan.” The remaining variables scored an average mean score below the acceptable threshold. This indicates that risk must be taken very seriously for the system to be more effective. This, however, collaborates with the findings of Ivan et al. (2020), who conclude that a proper “Risk Management System” (RMS) is one of the most important aspects of construction safety. Further, according to Feng and Trinh (2019), contractors will help provide the context for responses to safety issues by strengthening their risk management practices. See Figure 6.

Performance measurement

Response to performance management is no different from implementation. Only one variable scored above the mean of 3, with the remaining variable falling below the acceptable threshold. This variable, “Measure performance based on lessons from the past to improve safety management." Measurement offers the requisite information and intelligence to recognise, guide, and concentrate enhancement. High-performing organisations will positively affect the success of their safety management systems by committing to achieving productivity in these main enablers (Seno, 2022). This clearly demonstrates how it fared on the radar chart in Figure 7.

Audit

In the case of audit, none of the four variables made the average mean of 3, which is the acceptable level, as shown in Figure 8. This is a clear indication that much effort should be devoted to the audit aspects of the safety management system. This is in support of Stolzer et al. (2018), who posited that efficient tracking systems should be developed involving accountable personnel, appropriate standards for correction, hazard rating, potential consequences and probability, and corrective actions required. Figure 9 shows the overall level of resilient safety management systems in the Ghanaian construction industry.

SUMMARY

The objective of this study was to assess the level of resilience capabilities in construction safety management systems in Ghana's construction industry. A one-sample t-test and descriptive statistics (i.e., mean, and standard deviation) were employed. The mean was an indicator of the perceived level of resilience for safety management systems in the construction industry. The mean (i.e., point estimate) was associated with the 95% confidence interval, which provides a range within which the actual population mean falls. Beyond these statistics, a one-sample t-test was used to test whether the mean of each process was significantly greater than the median score of that process. A one-sample t-test was used because the data involved were continuous, and the goal of the study was to compare the mean score from a baseline or test value (Mondal et al., 2022). Thus, comparing a single mean score with a theoretical baseline, which in this study was the median score of the variables, was done with one-sample t-tests.

Furthermore, ANOVA was used to assess whether resilience differed between the various classes of companies (D1K1, D2K2, D3K3, and D4K4). Subsequently, the levels (i.e. mean scores) of resilience delivered by these classes of companies were compared across various construction processes. The ANOVA was accompanied by the test of homogeneity of variances, which is an assumption like the normality of the distribution of data applied to the ANOVA. The rationale for using ANOVA at this stage was that at least three classes of companies were compared. According to Garson (2012), ANOVA is used exclusively to compare means for two or more groups, whereas the t-test is used to compare two groups.

The resilience analysis grid measures an organisation's resilient performance potential or capabilities. Several researchers have used resilience analysis grids in similar work (Pardo-Ferreira et al., 2018). According to Hollnagel (2015), the resilience analysis grid is not a ready-made method that can be used right away, and it must be used in conjunction with other tools to offer more meaning to the results of the analysis. Subject to this assertion by Hollnagel, and further giving more meaning to the results, the resilience analysis grid was employed together with the mean to determine the resilience level safety in the construction industry and the results presented in radar chart. The results and analysis revealed that safety management systems in Ghana's construction industry are not resilient. Resilience innovation is a valuable method for organisations to use, in addition to traditional safety systems. It changes the focus from reactiveness to proactiveness in safety management.

CONCLUSIONS

This research presented an objective evaluation of the level of resilience in safety management systems in the Ghanaian construction industry using a quantitative approach. Compared to the traditional method, the level of resilience in construction safety management systems is a significant issue, according to the findings of this study. Thus, the result is that the safety system is reactive rather than proactive. Creating and sustaining resilient safety management systems for the construction industry is necessary if any significant improvement in the sector's safety performance is realised.

Several recommendations can be made based on the findings of this study. The management of construction organisations must raise their level of commitment towards safety management by setting policy statements that promote safety programmes in their organisation. Management must show exemplary leadership decisions by being proactive in the safety management of their organisations. Further, deliberate efforts should be made to allocate an adequate budget for the safety department for its operations that will enhance resilient management systems.

The findings presented in this study alert construction companies to the importance of putting safety systems in place to improve safety management performance. The outcomes of this study have significant theoretical and practical ramifications. Theoretically, this study adds to the growing body of knowledge about resilience in construction safety management. Regarding the uniqueness of resilience in construction safety management systems, this study has shown through empirical assessment and approaches from contractors and experts that resilience safety management system is an alternative organisational safety management system to the traditional safety management system in the construction industry.

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