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Integrated Safety, Health And Environmental Management in The Construction Industry: Key Organisational Capability Attributes

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Abstract

Purpose*:* For construction organisations to be effective at implementing an integrated safety, health and environmental (SHE) management system, they require the right level of organisational capability. This capability includes the policies, systems and resources of the organisation. However, within the academic literature, it is unclear which organisational attributes of construction companies are important for implementing integrated SHE management. This study aims at exploring the organisational attributes that determine integrated SHE management capability as well as their relative priorities.

Design/methodology/approach*:* The study employed a literature review supported by expert verification and a subsequent three-round expert Delphi technique accompanied by applying the voting analytical hierarchy process (VAHP).

Findings: The study identified 20 attributes grouped under five main thematic categories. These are (i) strategy (the organisation's vision and top management commitment); (ii) process (the organisation's procedures and processes for SHE management); (iii) people (organisation's human resources, their competence, roles, responsibilities, and involvement in SHE management); (iv) resources (organisation's physical and financial resources for SHE management) and (v) information (SHE related documents, data, records, and their communication across an organisation). While these thematic categories and the attributes within carry different weights of importance, the strategy related attributes are the most important, followed by the people related attributes.

Originality/value: The results of this study should enable construction companies and key industry stakeholders to understand construction companies' capability to successfully implement an integrated SHE management system. Furthermore, construction companies should be able to prioritise efforts or investments to enhance their SHE management capability.

Keywords: construction industry; Delphi method; health and safety; environmental management; organisational capability; voting analytical hierarchy process

Introduction

The construction industry currently accounts for more than 10% of global gross domestic product (GDP) and enables national economic growth (Bawane, 2017; Suárez Sánchez *et al.*, 2017). Despite its economic and social significance, the construction sector is one of the most dangerous industrial sectors accounting for several kinds of occupational fatalities and adverse environmental impacts (HSE, 2018; Agyekum et al., 2021). At least 60,000 fatal accidents occur yearly on construction sites worldwide, representing one fatal accident every 10 minutes (Mubita et al., 2021). Furthermore, construction operations and activities generate water, noise and air pollution and account for about 20-35% of negative impacts on the environment, such as abiotic depletion and global warming (Opoku, 2019). The International Labour Organisation (ILO) estimates that about 4% of the annual GDP is lost due to work-related accidents and their attendant injuries and illnesses (Tompa et al., 2021). There are reports of high economic costs in many countries resulting from these adverse environmental impacts and work-related tragedies. According to the Global Construction Perspectives and Oxford Economics (2015), the volume of construction output is estimated to grow by more than 85% worldwide by 2030. Notwithstanding the fact that the recent Covid-19 pandemic has the potential to affect this growth (ILO, 2021) (), the impact of construction operations on the environment and safety and health of workers could still worsen if appropriate actions are not taken.

Though the implementation of managements systems like the EMS and SHMS are useful in addressing SHE challenges within the construction industry, implementing and managing them separately in a company is onerous, costly and bureaucratic (Asah-Kissiedu et al., 2020). Ghana's construction industry is not different as construction companies have become incurious to implementing these standalone systems because of the associated cost, people's reluctance to change traditional practices, lack of expertise and staff, and the general institutional ineptness (Adjarko *et al.*, 2016). These factors, most prominently the associated cost, have been corroborated by several researchers in other developing countries as the reasons why construction firms in these countries are reluctant to implement independent MSs (Owolana and Booth, 2016).

As construction safety issues are closely connected to environmental problems, initiatives aimed at improving safety during construction could lead to enhanced environmental management and vice versa (Zutshi and Creed, 2015). Therefore, some researchers and industry stakeholders have advocated for the integration of EMS and SHMS into a single integrated management framework that integrates SHE requirements into the work planning and implementation processes to effectively manage SHE issues in a sustainable, systematic and cost-effective way (Sui *et al.*, 2018). This could be beneficial in reducing the number of fatalities, injuries, illnesses and the negative impacts of construction operations on the environment, leading to better SHE performance outcomes.

This initiative will not be bad, especially for a typical construction industry in a developing nation like Ghana, which accounts for the highest number of occupational accidents and deaths and work-related illnesses compared with other industrial sectors (Stemn, 2019; Boadu et al., 2020). The construction industry in Ghana is also tagged to be responsible for constant environmental degradation, pollution, substantial raw materials and energy consumption which continue to take their toll on the country's development (Agyekum et al., 2021). The high-risk nature of the construction industry, the weak institutional structure for implementing SHE standards and laxity in the enforcement of safety and environmental legislations on construction sites and the low commitment to SHE has seriously impeded the implementation of SHE standards and other initiatives on Ghanaian construction sites (Kheni and Braimah, 2014). This has, therefore, created the need to implement voluntary, proactive and systematic methods that will prevent accidents and negative environmental impacts on construction sites and assist construction companies in Ghana to improve SHE performance outcomes in the industry effectively.

Notwithstanding this need, the uptake of a prominent approach like the implementation of SHE management systems in the Ghanaian construction industry has been low (Adjarko *et al.*, 2016) mainly due to cost and the bureaucracy that comes with the separate implementation of standalone management systems. There is a need for an integrated SHE management framework to effectively manage SHE risks and issues in the Ghanaian construction industry. Till now, there remains no single integrated SHE management framework for construction organisations to use, especially those within developing country settings like Ghana.

Such an integrated SHE management framework will mean that construction companies in Ghana must have adequate organisational capability, which encompasses policies, systems and resources to implement the framework effectively. In a comparative review of related literature, Asah-Kissiedu et al. (2020) identified key organisational attributes that could determine integrated SHE management systems and models in the construction industry to include senior management commitment to SHE, SHE risks management, SHE objectives and programmes, staff competencies, resources for SHE implementation, SHE roles and responsibilities, SHE communication, among others. As identified by Asah-Kissiedu et al. (2020), these attributes can enable construction companies and other potential stakeholders to appreciate construction companies' capability to implement an integrated SHE management system. Unfortunately, there is the tendency for the companies to have varying capabilities in respect of integrated SHE management system implementation. A significant gap in the literature that has been identified is the lack of empirical insight into what constitutes integrated SHE management capability in the Ghanaian construction industry. , This gap is an indication of a lack of clarity regarding the determinants of integrated SHE management capability of construction companies in Ghana. Construction companies in Ghana must understand their current capability in respect of SHE management to guide continuous improvement efforts. Following the identification of this gap, this study was carried out to explore: 1) the attributes that determine the capability of a Ghanaian construction organisation to implement an integrated SHE management system; and 2) the relative priority of those capability attributes. With the identified capability attributes and their priority weights, construction companies will be able to assess their integrated SHE management capability and ascertain areas of strength and deficiencies. The paper begins with a review of relevant literature, which presents an outlook of SHE performance in the construction industry, the need for SHE improvement in construction and the research gaps relating to integrated SHE management capability. Subsequently, the research methods and findings are presented, followed by discussions and concluding remarks.

Literature review

The construction sector in many countries accounts for high rates of accidents, fatalities, injuries and illnesses. There are reports of high economic costs resulting from adverse environmental impacts and work-related tragedies. For instance, in the USA, the construction sector accounted for over 800 worker-related deaths in 2019(Bureau of Labour Statistics, 2020). Also, in the UK, the construction sector accounted for the highest number of fatal injuries to workers (i.e. 40 out of 111 worker fatalities) in 2019/20 (HSE, 2020). Across 28 European countries, the fatality rate of construction operations and activities was first among all economic activities in 2014 (Eurostat, 2017). While occupational accidents, injuries and illnesses are commonplace in construction globally (De Silva et al., 2018), their rates in developing countries are considered higher than in the developed countries (Williams et al., 2020). For instance, while in the UK 40 worker fatalities were recorded in 2019/207 (HSE, 2020), in Malaysia, the construction sector accounted for 66 out of 213 worker fatalities in 2020, which is the second highest among other industrial sectors (Department of Occupational Health and Safety, 2020).

Aside from being responsible for high rates of injuries, illness and fatalities, the sector also accounts for substantial consumption of natural and processed resources and energy (Agyekum et al., 2021). Estimates indicate that the construction sector consumes 50% of all raw materials consumed, 16% of water and 40% of the total energy consumed worldwide. Furthermore, it is responsible for 20-30% of greenhouse emissions and generates 17% of all wastes (Agyekum et al., 2021;), making it one of the least sustainable industries globally. These occupational injuries, illnesses, fatalities, and negative environmental impacts have significant socio-economic cost implications (ILO, 2012). For instance, in the UK, the cost of work-related injuries and diseases from all industries for 2017/18 is estimated to be around GBP 15 billion (HSE, 2018). In Singapore, the cost of occupational injuries and illnesses is SGD 10.45 billion, which is about 3.2% of the country's GDP (ILO, 2015). There is, therefore, a clear case for improving the SHE performance of the construction industry (Okoye and Okolie, 2014).

Several efforts have been made to address SHE problems in construction. Such efforts include introducing health and safety, environmental management regulations, and implementing management systems, particularly the EMSs and SHMSs based on management system standards (MSSs). Different international bodies have introduced these MSSs, with the most reputable being the Occupational Health and Safety assessment series (OHSAS 18001:2007), the International Organisation of Standardisation (ISO) Environmental Management System standard (ISO14001:2015) and the International Labour Organisation guidelines (ILO-OHS 2001). Over the years, the OHSAS 18001:2007 has emerged as the most widely used standard for SHMSs and ISO 14001 for EMSs, albeit a new international certifiable standard, ISO 45001, has recently been published to replace OHSAS 18001.

In the construction industry, EMSs and SHMSs are comprehensive and systematic tools that can assist construction companies in managing and controlling safety and health risks and challenges and improving environmental performance (Vasilca et al., 2021). They play a key role in addressing SHE problems, improving safety and working conditions and minimising occupational risks (Podgorski 2015; Olivera *et al.,* 2016). However, EMSs and SHMSs implementation in construction companies are low (Tepaskoualos and Chountalas, 2017).

A good number of studies have been carried out in the last few decades regarding SHE management systems in the construction industry (Christini et al., 2004; Selih, 2007; Zeng et al., 2008; Griffith and Bhutto, 2008; Gasparik, 2009; Gangolells et al., 2011; Zutshi and Creed, 2015; Podgorski, 2015; Campos et al., 2016; Mohammadfam et al., 2017; Jazayeri and Dadi, 2017; Yiu et al., 2018). Although there has been a growing body of research on management systems in construction, particularly EMSs and SHMSs, these past researches have been mainly restricted to specific topics such as (1) awareness, motivators, costs, benefits and barriers of management systems (Owolana and Booth, 2016; Schmidt and Osebold, 2017); (2) effectiveness of SHE management systems in addressing occupational accidents, SHE performance, pollution and waste reduction (Yiu *et al.,* 2018); (3) identification of key performance indicators for measurement and monitoring SHE MS performance (Podgorski, 2015; Haas and Yorio, 2016; Mohammadfam *et al.,* 2017); and (4) integration of environment, quality, safety and health management systems (Rebelo *et al.,* 2015). Beyond these, some studies have concentrated on the elements of both stand-alone and integrated management systems (Rebelo *et al.,* 2015; Yiu *et al.,* 2018). Criticisms of individual/standalone systems have triggered studies regarding integrated management systems for being bureaucratic, costly, paper-driven and arduous (Rebelo *et al.,* 2015). However, within the existing construction SHE management literature, while arguments have been made for the integration of management systems (Rebelo *et al.,* 2015), empirical insight regarding what constitutes integrated SHE management capability is scarce. These insights are important, especially for organisations seeking to combine safety and health management and environmental management as a single integrated management function. In other words, it is unclear what organisational attributes are required to implement an integrated SHE management system by a construction company. As a result, a thorough indication of what constitutes integrated SHE management capability should be identified. This paper focuses on providing empirical realities regarding integrated SHE management capability in construction.

Research method

To identify organisational attributes relevant to integrated SHE management in construction, three research methods were employed. These comprise: (1) a systematic literature review to identify potential integrated SHE management capability attributes and a preliminary expert verification process to ascertain the appropriateness and comprehensiveness of the identified attributes; (2) application of a Delphi technique to generate consensus regarding the importance of the attributes; and (3) application of a voting analytical hierarchy process (VAHP) to generate weights of importance based on the outcomes of the Delphi technique.

The Delphi technique has proven to be a popular and reliable technique for decision making (Adler and Ziglio, 1996; Hallowell and Gambatese, 2010). Over the years, its applications in construction engineering management (CEM) research as a methodology for eliciting knowledge, prioritising elements and decision making, where there is limited knowledge about the research area, has increased greatly (Ameyaw *et al.*, 2016; Ogbeifun *et al.*, 2017; Poghosyan *et al.*, 2020; Evans et al., 2021). In this study, while the comprehensive literature review supported by expert verification enabled elicitation of integrated SHE management capability attributes, the Delphi technique combined with VAHP (a -multi-criteria decision making method) enabled the prioritisation of the attributes. The research process is shown in Figure 1.

[Insert Figure 1]

Review of literature supported with expert verification of attributes

Identification of Integrated SHE management capability attributes (literature review)

A systematic review of literature related to SHE management, and not limited to construction, was used to generate a list of potential integrated SHE management capability attributes. Literature sources comprised international standards (e.g., ISO 45001, OHSAS,18001, ISO14001), published guides on SHE management and academic publications, including journal articles, books and conference papers (Charef *et al.*, 2018). Furthermore, relevant literature related to capability maturity models on safety, health and environmental management (e.g. Fleming, 2001; Sharp et al., 2002; Strut et al., 2006; Filho et al., 2010) was also reviewed.

Searches were carried out within the academic databases: Elsevier's Scopus, Thomson Reuter's 'Web of Science', ASCE (American Society of Civil Engineers), Emerald and Google Scholar. The search terms used are: 'environmental management in construction'; 'construction health and safety'; ' 'occupational safety and health management'; 'environmental management';

‘environmental management maturity’; ‘ISO 14001’; ‘construction health and safety management system’; ‘OSHAS 18001’; ‘EMS’; ‘environmental, health and safety management’; ‘OHMS’,’ IMS’; ‘environmental management maturity model’; and ‘health and safety maturity model’. In all, a total list of 1210 publications was generated with the above search terms. This list of literature materials was then systematically scaled down to 20 most relevant literature using the four-phase PRISMA approach developed by Moher *et al.* (2009), as shown in Figure 2 below. The full-text content criteria used in assessing specific metadata are given below:

- Best practices or requirements for SHE management in construction
- Environmental, health and safety practises in construction
- Studies on the implementation of safety, health and environmental management systems

From the review, it was realised that existing SHE management guides and international standards generally follow Deming’s Plan-Do-Check-Act (PDCA) management approach and, ttherefore, share common requirements that allow most of their elements to be integrated. As a result, in developing the list of organisational attributes that determine integrated SHE management capability, information from the 20 publications, consisting of established internationally recognised SHE management standards and published works, were extracted by comparing their components to determine key similarities and differences; thereby, establishing potential integrated SHE management capability attributes. In the end, 27 potential attributes were obtained. The main literature sources are presented in Appendix A.1, and the 27 attributes are also shown in Table 1.

[Insert Figure 2]

[Insert Table 1]

Expert verification

A questionnaire containing the 27 attributes was developed and sent to 12 experts with expertise in SHE management in construction. The purpose was to draw on the experts’ SHE management expertise to ascertain the appropriateness and comprehensiveness of the 27 SHE management capability attributes generated from the literature review. The experts were selected following Hallowell and Gambatese (2010) guidance in selecting experts for expert group techniques (e.g., a minimum of five years' experience in safety, health and environmental management practice and research in construction). Collectively, the experts had knowledge and expertise in SHE management in the construction industry. The demographic information of these experts is presented in Appendix A.2. The questionnaire requested the experts to review and indicate the relevance of the attributes to the development of an integrated SHE management system in construction. They were also asked to identify other suitable capability attributes that may have been missed. Results of the expert's verification are presented in Tables 4 and 5 of the results sections.

Delphi process

The Delphi technique (DT) is an iterative process used to collect and collate opinions of a group of experts on specific issues, using a series of questionnaires interspersed with controlled feedback to obtain the most reliable consensus (Adler and Ziglio, 1996; Linstone and Turoff, 2011). It has proven to be a popular and reliable technique for decision making and is best suited in fields with no or incomplete knowledge about a problem or phenomena (Adler and Ziglio, 1996; Skulmoski *et al.*, 2007). This technique has four main features: (1) anonymity of participants; (2) iteration; (3) controlled feedback; and (4) statistical aggregation of participant responses (Adler and Ziglio, 1996; Rowe and Wright, 1999). DT typically includes at least two rounds (i.e., iterations) of experts answering questions anonymously and providing opportunity between rounds for them to reconsider changes to their responses (Rowe and Wright, 1999). The process continues until consensus (i.e., certain level of agreement) has been achieved (Skulmoski *et al.*, 2007). In this study, the DT was used to generate consensus on the importance of the relevant integrated SHE management capability attributes through collective intelligence of construction professionals with knowledge and expertise in SHE management. The experts were recruited from the Ghanaian construction sector. Table 2 shows the main features of the Delphi technique as applied in this research. Purposive sampling was used to recruit participants for the study, which was supplemented by snowball sampling, whereby experts, who were invited by the researchers, subsequently invited other experts within their professional groups. Invitation letters were e-mailed to 70 potential expert panellists to explore their availability to participate. Experts were identified from construction professional groups and associations.

[Insert Table 2]

From the 70 invitations, 57 experts registered interest in participating in the Delphi process. However, only 41-30 experts participated in the Delphi rounds. Most Delphi studies in construction engineering management make use of between 7 to 35 participants. For instance, in the study of Hallowell and Gambatese (2010), eight participants were used. Skulmoski et al. (2007) made use of a minimum of ten participants in their study. Ameyaw et al. (2016) recommended that in CEM Delphi applications, participants can range from 3-90. However, most similar studies have settled on 15 to 35 participants (Ameyaw et al., 2016). With this background, the number of experts (i.e., 12) who participated in this study was considered acceptable. Three rounds of Delphi interspersed with controlled feedback were undertaken. The demographic information of Delphi experts is presented in Appendix A.3.

The 20 integrated SHE management capability attributes and the five thematic categories were incorporated in a questionnaire. In the first round, experts were asked to rank the five thematic categories based on their level of importance to the implementation of SHE management in construction. Similarly, the participants were asked to rank attributes within each of the categories. Forty-one experts completed the first round. In the second round, the median ranks for the five categories and the attributes within each category in the first round were incorporated and customised for each expert by including the expert's first-round responses. The questionnaire was sent via an email attachment, and experts were asked to reflect on the information (i.e., their responses and the median ranks) and then rank the attributes again. The ability for each member of the expert panel to re-evaluate, review, and further change their thoughts on the research matter is one of the important features of the Delphi technique (Skulmoski *et al.*, 2007).

Thirty-one experts completed the second-round questionnaire. At the end of the second round, an agreement analysis using Kendall's coefficient of Concordance (*W*) was used to ascertain the degree of agreement among the expert panel members in their rankings of the capability attributes. The Kendall coefficient of concordance (W) (Legendre, 2005) is defined as

Equation (1) $$W = \frac{12\sum R_i^2 - 3p^2N(N+1)^2}{p^2N(N^2-1) - p\sum T_j} \quad ,$$

where, $\sum R_i^2$ *is* sum of the squared sums of ranks for each of the N objects being ranked; p is the number of respondents; and T_j is the correction factor required for the jth set of ranks for tied observations given by $T_j = \sum_{i=1}^{g_j}(t_i^3 - t_i)$, where t_i is the number of tied ranks in the ith grouping of the ties, and g_j is the number of groups of ties in the jth set of ranks (Zar, 1999; Legendre, 2005). Perfect agreement is indicated by a value of 1, while complete disagreement is indicated by a value of 0. As the coefficient (*W*) moves closer to 1, there is consistency in the responses and a strong agreement (Field, 2013). Schmidt (1997) states that a coefficient (*W*) value ≤ 0.1 is unacceptable; however, a value of 0.1 up to 0.3 is low, 0.3 to 0.5 is moderate, while a value of 0.5 up to 0.7 is high and good, and 0.7 up to 0.9 or above is very high and excellent. In this study, a coefficient (*W*) value $\geq$ 0.4 was considered a suitable level of agreement. The IBM SPSS statistics version 24 was used to determine Kendall's W and the level of significance.

Voting analytical hierarchy process (VAHP)

Analytic hierarchy process (AHP) is a multi-criteria methodology, which permits the relative assessment and prioritisation of alternatives (Saaty, 1980). AHP enables complex and unstructured problems to be broken down into alternatives arranged into hierarchical order. The method then quantifies the relative weights or priorities of a given set of alternatives based on the subjective judgement of the decision maker/experts through pairwise comparison of the criteria. The paired comparison is undertaken using a scale, which indicates the strength to which one alternative or criterion dominates another alternative or criterion. Using the scaling process, numerical priorities or weights are calculated for each criterion or alternatives. Since its emergence in the 1980s, AHP has been found to be a valuable multi-criteria decision method, resulting in its application in several research domains, including CEM (Ameyaw *et al.,* 2016). In several CEM studies, AHP has been used in conjunction with DT (Ameyaw *et al.,* 2016). For instance, Vidal *et al.* (2011) combined DT with AHP to generate a list of prioritised best practices necessary for successfully managing projects requiring a higher level of fast tracking. Despite its usefulness, AHP has some limitations. A key limitation is the difficulty in applying paired comparison, particularly with several criteria/alternatives (Hadi-Vencheh and Niazi-Mortlagh, 2011). As a result, Liu and Hai (2005) developed the voting analytic hierarchy process (VAHP), an easier weighting procedure than the AHP's paired comparison. VAHP uses a voting ranking approach instead of a paired comparison method to determine the weights of a set of criteria and sub-criteria in a hierarchical structure (Lui and Hai, 2005). Given the large numbers of integrated SHE, management capability attributes in this study, the VAHP approach was used. Manu *et al.* (2019) similarly used DT followed by the application of VAHP to determine the weight and rank of attributes that determine design for health and safety capability of design firms in the construction industry.

Implementation of VAHP

In this study, the use of VAHP involved a six-step process adapted from Liu and Hai (2005).

Step 1- Selection of criteria: in the case of this study, the five thematic categories of integrated SHE management capability attributes constituted the criteria.

Step 2- Structure the hierarchy of the criteria: 20 integrated SHE management attributes constituted the sub-criteria within the five thematic categories as shown in Figure 3.

Step 3- Prioritise the criteria: From the second round of Delphi, 31 experts ranked the five categories of attributes. The ranking by the experts is shown in Table 3.

[Insert Figure 3]

Step 4- Prioritise the sub-criteria: From the second round Delphi, 31 experts ranked the attributes within the "strategy", "process", "people", "resources" and "information" categories. From the third round of Delphi, 30 experts ranked attributes within the "resources" category. Table 6 shows the ranking by the experts.

Step 5- Calculate the weights of the criteria and sub-criteria: The equations proposed by Hadi-Vendch and Niazi-Mortlagh (2011) for calculating weights were applied based on the five thematic categories of attributes and the number of attributes within each category. The equation is expressed as:

Equation (2) $$W_1 \geq 2\,W_2 \geq \cdots \geq \mathrm{SW}_S \geq 0,$$

Equation (3) $$\sum_{s=1}^{s} ws = 1$$

Where w is a coefficient weight applied to the vote ranking of each criterion to determine the criterion weight, and s is the number of positions; therefore, w_s is the coefficient weight for the sth position. For example, for four criteria being ranked, w_1 is the coefficient weight for the first position, w_2 is the coefficient weight for the second position, w_3 is the coefficient weight for the third position, and w_4 is the coefficient weight for the fourth position. Based on equations (2) and (3), the coefficient w_s for the relevant number of capability attributes and sub-attributes were derived and presented in Table 3.

[Insert Table 3]

Based on the Delphi rankings, the VAHP was used to determine weights of the five thematic categories and attributes within each category (i.e., sub-attributes), by multiplying the coefficient weights presented in Table 3 by the ranking data from the Delphi rounds. Afterwards, the obtained weights for the categories were normalised so that they add up to one. Similarly, the obtained weights for attributes in each category were normalised, as shown in Table 9. For example, in the third round of Delphi, which involved 30 experts, for the resource category, physical resource was ranked first by 26 experts and second by four experts. Financial resource was ranked first by 21experts and second by nine experts (Table 8). According to Lui and Hai (2005), the weights of these attributes are determined as follows:

- Physical resources= (26 *0.6667) + (4 *0.3333) = 18.667
- Financial resources = (21* 0.6667) + (9* 0.3333) = 17.00

<u>Step 6- calculate global weights and rank criteria by using the VAHP formula:</u>

The final stage of the weight calculation in the VAHP procedure is to obtain the global (i.e., overall) weights of sub-attributes. This is achieved by multiplying the normalised weight of a thematic category (i.e., main attribute) by the normalised weight of the sub-attributes within that category. For example, the normalised weight of “Information’’ was multiplied by the normalised weights of its sub-attributes: “Communication”, “Documentation and control’’ and “Knowledge management’’.

Normalised weight for the thematic category “Information” = 0.1171

- Communication = 0.45974 * 0.1171 = 0.0539
- Documentation and Control = 0.29610 *0.1171 = 0.0347
- Lessons and Knowledge management = 0.24416 *0.1171 = 0.0286

Similarly, this step is applied to all the other capability attributes. The overall outcomes of the VAHP are presented in the results section.

Results and discussion

This section is structured into three main headings: results and discussion of expert's verification; results and discussion of Delphi; and results and discussion of the VAHP.

Results and discussions of expert verification

A total of nine out of the twelve experts responded to the questionnaire. Overall, the expert verification revealed that for each of the attributes, over half of the experts (i.e., a simple majority) agreed that it is relevant to the development of an integrated SHE management system in construction (Table 4). Moreover, the experts did not suggest any new attributes. Finally, the 27 validated attributes were consolidated (based on their similarity) into 20 integrated SHE management capability attributes. These attributes were subsequently categorised, based on their relatedness, into the five thematic areas of integrated SHE management capability, namely: strategy; people; process; resources; and information. Detailed descriptions of each of them are presented in Table 5.

Categorisation of the capability attributes is consistent with the concept of organisational capability maturity, although specific to integrated SHE management (Paulk *et al.*, 1993; Succar, 2009; Randeree *et al.*, 2012). Additionally, the integrated SHE management capability attributes share similarities with some existing capability maturity models' key practices and process areas. The capability attributes definitions align with the six key safety factors of the health and safety maturity model (HSMM) by Goggin and Rankin (2010), namely: "management commitment", "safety, policy and standards", "worker involvement and commitment", "hazard identification, reporting, and control", "equipment materials and resources" and "working environment". Although there are some similarities of the SHE management capability attributes to that of Goggin and Rankin's (2010) six factors, the HSMM model inadequately covers incident investigations and management and preventive actions, which feature in the integrated SHE management capability attributes found in this study.

Furthermore, attributes definitions align with the elements of the UK Coal maturity model (Foster and Hault, 2013) and the safety management processes of Strutt *et al.* (2006) Design Safety Capability Maturity Model (DCMM). While some attributes align with Strut *et al.*'s (2006) model attributes, there is much focus on the activities required to deliver a safe design than on areas of organisational capability, such as experience, which is an important attribute identified in this study. Moreover, some of the integrated SHE management capability attributes align with common features of organisational capability; senior management commitment and leadership, financial, physical, and people/ human resources (Succar, 2009; Manu *et al.*, 2019; Poghosyan *et al.* 2019), while others relate specifically to SHE management, e.g. hazards/risks identification and management, incidents investigations and SHE performance monitoring and measurement (Fleming *et al.*, 2001; Filho *et al.*, 2010). The integrated SHE management capability attributes, particularly the 'strategy' (senior management leadership, commitment, policy, responsibilities and accountability), is very vital to the success of SHE management from all levels and functions of a construction organisation (Ejdys *et al.*, 2016; Manu *et al.*, 2019).

[Insert Table 4]

[Insert Table 5]

Results and discussion of the Delphi process

The results of the three round Delphi study are summarised in Table 6. Across the three rounds, there were minimal changes in the median scores except for "information'', "auditing'', and "emergency preparedness", whose medians changed from 4 (in round one) to 5 (in round 2), as well as "management of outsourced SHE personnel" whose median changed from 3 (in round one) to 4 (in round 2), "competence" whose median changed from 2 (in round one) to 1 (in round two), "SHE training" whose median changed from 2 (in round one) to 3 (in round two) and " Employee involvement in SHE" whose median also changed from 2 (in round one) to 3 (in round two). The significant Kendall's Coefficient of Concordance (*W*) values obtained for ranking the thematic categories shows that there was consensus in the experts ranking between round one and round two. Similarly, there was consensus between round one and round two in the experts ranking of the strategy related attributes, process related attributes, people related attributes, and information related attributes. Moreover, there was consensus improvement between the two Delphi rounds, as shown by the increase in the Kendall's coefficient of concordance *W* values. While there was improvement in the Kendall's *W* for ranking the resources related attributes between Delphi round one and two, the Kendall's W was insignificant and, therefore, necessitated the third round of Delphi.

In the third round of Delphi, some of the experts' ranking of the "resources" attributes differed from round two. As a result, the median rank slightly changed. Although there was an increase in the Kendall's W at the end of the third round, consensus on the "resource" category was still not achieved. Following the suggestion by Dalkey *et al.* (1970) that states Delphi results are most accurate after two rounds but become less accurate as a result of additional rounds, the Delphi process in this study was terminated after the third round. Additionally, a check for saturation using the Wilcoxon signed rank test (Z) showed no significant statistical difference between the second and the third rounds responses for the attributes within the "resources" category. This implied a further Delphi round was unlikely to yield consensus. As a result, all the 20 capability attributes were utilised in the VAHP to ascertain their relative priorities. Results of the Wilcoxon signed rank test are shown in Table 7. The vote ranking data of the second and third rounds of the Delphi are also presented (Table 8).

[Insert Table 6]

[Insert Table 7]

[Insert Table 8]

Results and discussions of the VAHP

The results of the VAHP are summarised in Tables 9 and 10. In relation to the thematic groupings of the attributes, "strategy" is the most important, followed by "people". Collectively, these two categories account for 53.90 % of the weights of the five categories. "Information" is the least important, and "processes" is ranked 3rd above "resources". The emergence of "strategy" as the most important, is perhaps unsurprising, due to the recognition of leadership, commitment, vision, direction, statement of objectives and targets, policy and management plans as relevant keystones of SHE management (Hale *et al.,* 2010; Heras -

Saizarbitoria, 2011; Ejdys *et al.*, 2016; Zaira and Hadikusumo, 2017). Furthermore, the emergence of the "strategy" and "people" categories as the topmost categories align with the findings of Manu *et al.* (2019). Manu *et al.* (2019), in their study of design for occupational safety and health (DfOSH) organisational capability, found that "strategy" (i.e., the consideration of DfOSH in organisation's vision as well as the top management support for DfOSH) and "competence" (i.e., the competence of organisation's design staff in respect of DfOSH) were the most important categories of capability attributes.

A thorough check of the attributes within the thematic categories (i.e., Table 9) shows that for strategy related attributes, "Senior management commitment to SHE" and "SHE policy" together accounted for over 68.70 % of the category weight. For process related attributes, "SHE risks management" is the most important attribute, followed by "SHE operational control" and "performance measurement". Collectively, these three accounts for 58.70 % of the category weight. Regarding the people related attributes, "competency" is the most important, followed by "roles and responsibilities". Together, these two attributes account for 62.10 % of the category weight. "Physical SHE resources", which accounts for 52.34 % of the category weights, is the most important attribute of the two attributes in the resource category. "Communications" emerged as the most important attribute of the three "information" attributes.

Based on the global weights, senior management commitment to SHE emerged as the most important attribute, followed by SHE policy. This is followed by physical SHE resources, competency, financial resources, SHE objectives and targets, and SHE communications. Collectively, these seven attributes account for approximately 57.47 % of the global weights. Inclusion of the next three attributes (i.e., SHE risks management, SHE management programs and plans and, Roles and responsibilities) increases to 72.50 %, therefore indicating 10 out of the 20 attributes (i.e. half) account for over 70 % of the global weights. The least important attribute is "incidents investigations". Above it is "SHE auditing" and "Emergency preparedness and response", "management of outsourced personnel" and "performance measurements" in that order.

[Insert Table 9]

[Insert Table 10]

While all attributes within the strategy category are important for effective SHE implementation, "Senior management commitment to SHE" and "SHE policy" accounted for over 60 % of the strategy category weights and 23 % of the global weights of all the capability attributes. This emphasis is noteworthy, given earlier studies have indicated that senior management commitment in the form of providing a priority to SHE issues leads to its effective management and better performance (Aksorn and Hadikusumo, 2008; Boughaba *et al.,* 2014; Ejdys *et al.*, 2016; Zaira and Hadikusumo, 2017; Manu *et al.*, 2019). For companies to achieve their objectives and targets, there is a need for full support and firm commitment from senior management and other members of the organisation. Strong, visible leadership and commitment plays a key role in developing a strong culture of safety within a company and also creates safer and healthier workplaces (Lai *et al.,* 2011).

For effective SHE implementation, the commitment and provision of adequate and appropriate resources is paramount. As a result, it is not surprising that the attributes in the "resources" category were among the five topmost capability attributes based on the global weights. Within the "resources" category, the physical SHE resources attribute was the most important attribute, followed by financial resource. This finding reflects current trends of research and implementation in SHE management in construction, which emphasises the need for the usage of new construction materials, equipment and techniques, and the application of information technology tools for improved SHE management, all of which require financial commitment (OSHA, 2016; Suárez Sánchez *et al.,* 2017).

With the "people" category, which emerged as the second most important capability category, the "SHE competence" attribute was found to be the most important within the cluster. The category also encapsulates SHE roles and responsibilities, training and employee consultation and involvement. In this study, competence is described as the skills, knowledge and experience of personnel to undertake responsibilities and perform SHE activities. It is not surprising that it emerged as the most important people related attribute. In existing studies, SHE skills, experience, knowledge, and attitude of employees drive other aspects of organisational performance and, therefore, are critical to the success of SHE management programmes (Lopez-Arquillos *et al.,* 2015; Hallowell and Hansen, 2016; Manu *et al.,* 2019). Whereas personal competency is desirable for SHE management in a construction company and is seen as a part of organisational capability, the study highlights the relative importance of training. This attribute emerged as the third most important attribute in the people related category and ranked 13th based on the global weights. SHE training is crucial to the success of the SHE management system and is one means by which SHE management practices can be improved (HSE, 2013; Han *et al.,* 2014; OSHA, 2016). In addition, "employee's consultation and involvement" is another important attribute that influences the effectiveness of the integrated SHE management system. According to the European Commission (2008), in addition to senior management support, employees' participation is vital to the success of SHE implementation. Management needs to get their employees to be more knowledgeable and informed about SHE issues since without their commitment and involvement, SHE implementation would be an arduous task. This emphasis on worker consultation and participation is consistent with the OSHA and ISO standards, enforcement policies and procedures on health, safety and environmental management, which recognise the rights and roles of employees and their representatives in matters of SHE management. It was ranked 12th based on the global priority weights, indicating its importance to SHE management. Having the right personnel doing the right thing at the right time and promoting employee's engagement and involvement in SHE management helps to improve safety performance (Wachter and Yorio, 2014).

Hazard identification and risks assessment and control are also evident from the findings; therefore, the emergence of the "SHE risks management" as a relevant capability attribute for integrated SHE management and ranked third among the process related attributes. Altogether, the process related capability attributes have been similarly recognised as germane to effective implementation of safety management (Filho *et al.,* 2010; HSE, 2013; OSHA, 2016). However, SHE audits, which are a key aspect in enforcing SHE measures and continual improvement (HSE, 2013; ISO, 2015), emerged as one of the least important attributes based on the global priority weights. Systematic identification and reporting of SHE management system deficiencies allow management to focus on the environment, safety and wellbeing of employees, improve SHE performance and ensure the integrated system's cost-effectiveness.

"Communications" emerged as the most important attribute of the information category attribute. This finding is consistent with previous studies, which indicates that regular communication of SHE issues and other relevant SHE information and feedback at all levels of the organisation is a major SHE management practice that positively influences the safety performance of an organisation (Fernandez-Muniz *et al.,* 2012; Boughaba *et al.,* 2014). There is, therefore, the need for accurate and clear information on SHE issues coming into the organisation, flowing within it, and going out from it.

Conclusion

Construction safety issues are closely connected to environmental problems. The initiatives aimed at improving safety during construction could lead to enhanced environmental management and vice versa. There has been a strong need for construction companies to manage SHE issues consistently and effectively. Some researchers and industry stakeholders have advocated for the integration of EMS and SHMS into a single integrated management framework that integrates SHE requirements into the work planning and implementation processes to effectively manage SHE issues in a sustainable, systematic and cost-effective way. Unfortunately, the uptake of a prominent approach like the implementation of SHE management systems in the construction industry of developing countries has been low due to several issues: the industry's inadequate organisational capability to implement such a framework effectively. Therefore, this study was initiated to explore the organisational attributes that determine integrated SHE management capability and their relative priorities.

Through a systematic review of related literature supported by expert verification and subsequently a three-round expert Delphi technique accompanied by the application of the voting analytical hierarchy process (VAHP), data were obtained for the study. The findings revealed that the integrated SHE management capability comprises 20 distinct capability attributes, which are categorised into five thematic areas, namely: strategy (the organisation's vision and senior management commitment for SHE management); process (organisation’s procedures, processes and systems for SHE management); people (the organisations human capital, their roles, responsibilities and involvement in SHE management); information (the SHE related documents, data, lessons, records and their communication across an organisation); and resources (i.e. the financial and physical resources necessary for effective SHE management. The study further highlighted the varying level of importance of the attributes within the resource, people, process, and information categories. The prioritisation revealed that senior management commitment to SHE management, the presence of SHE policy statement, adequate resources, competent staff, and well-defined objectives and targets are vital to the success of integrated SHE management in construction.

The implications of the findings manifest in three folds. Firstly, the findings contribute to the state-of-the-art issues of organisational attributes required for a typical construction company to implement an integrated health, safety and environmental management system in a developing country context. Secondly, the identified capability attributes reflect the key aspects of good health, safety and environmental management system, which emphasises a proactive and systematic approach to managing SHE issues in construction. The identified integrated SHE management capability attributes and their priority weights should enable relevant industry stakeholders to better understand the construction company's capability to implement an integrated SHE management system effectively. Additionally, with the identified capability attributes and their priority weights, construction companies should be able to assess their integrated SHE management capability, ascertain areas of strengths and deficiencies and subsequently prioritise efforts or investments targeted at addressing the areas of deficiencies to enhance their SHE management capability.

A limitation of this study is that the study was based on the professional views of SHE management experts and other practitioners within the Ghanaian construction industry. Therefore, findings may be peculiar to SHE management in the Ghanaian construction industry. As a recommendation for further study, the study could be replicated in other developing countries and in other industrial sectors other than construction for further comparison of the organisational attributes that determine integrated SHE management capability and their relative priorities.

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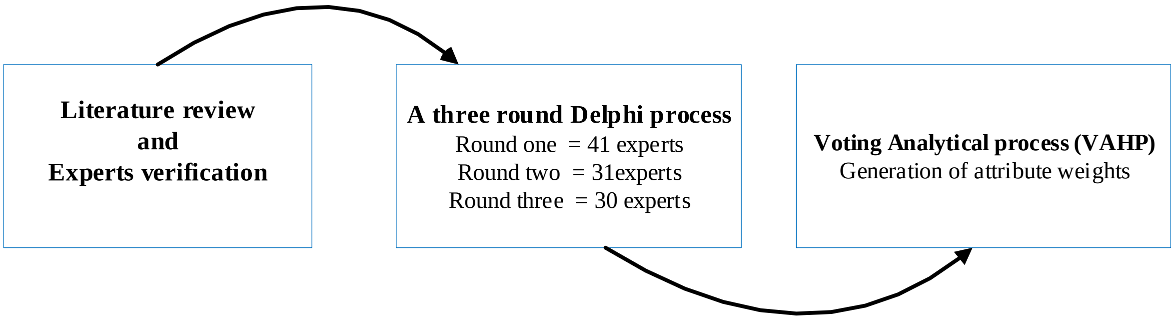

Figure.1: Overview of research process

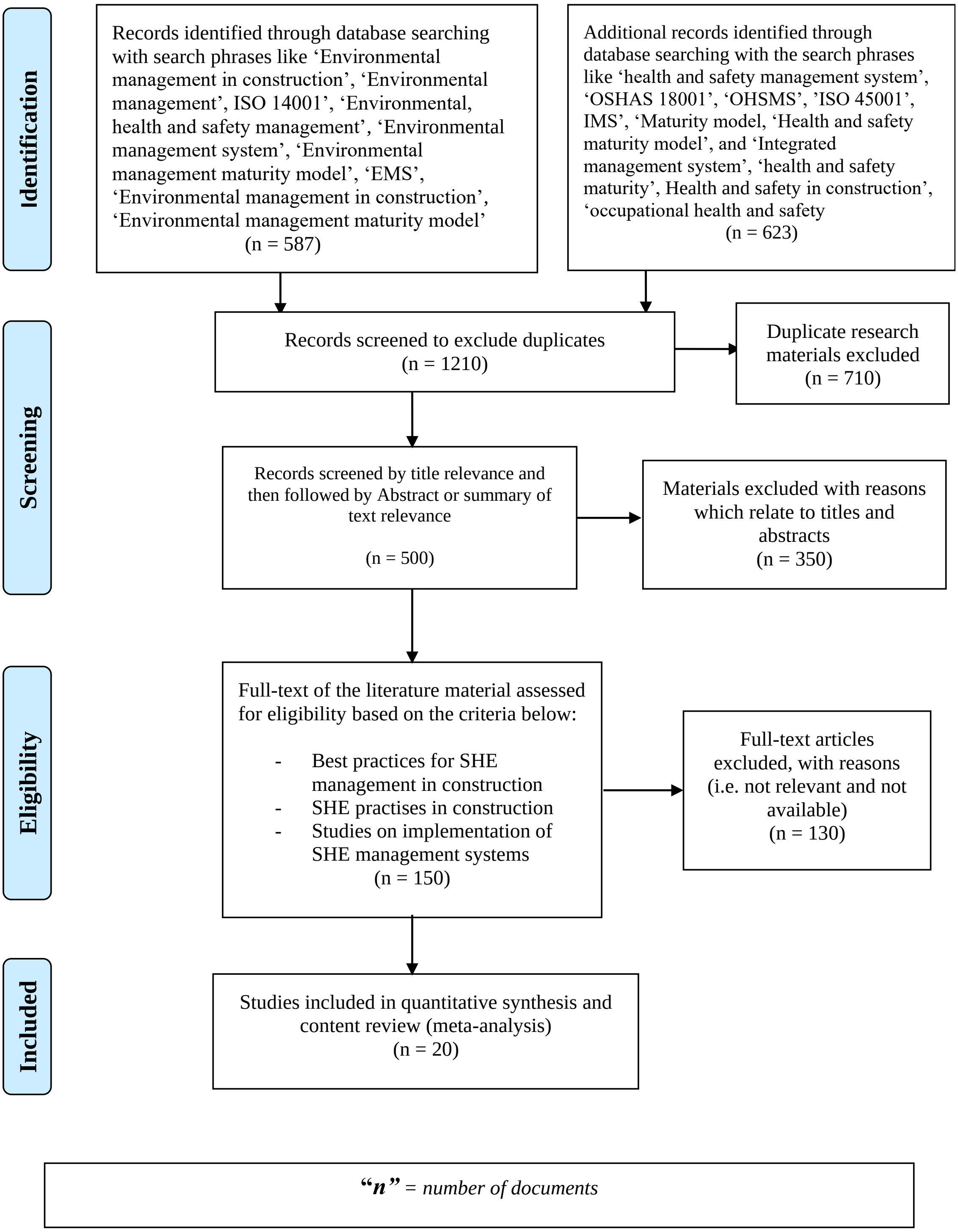

Figure 2: PRISMA Flowchart of the literature review process

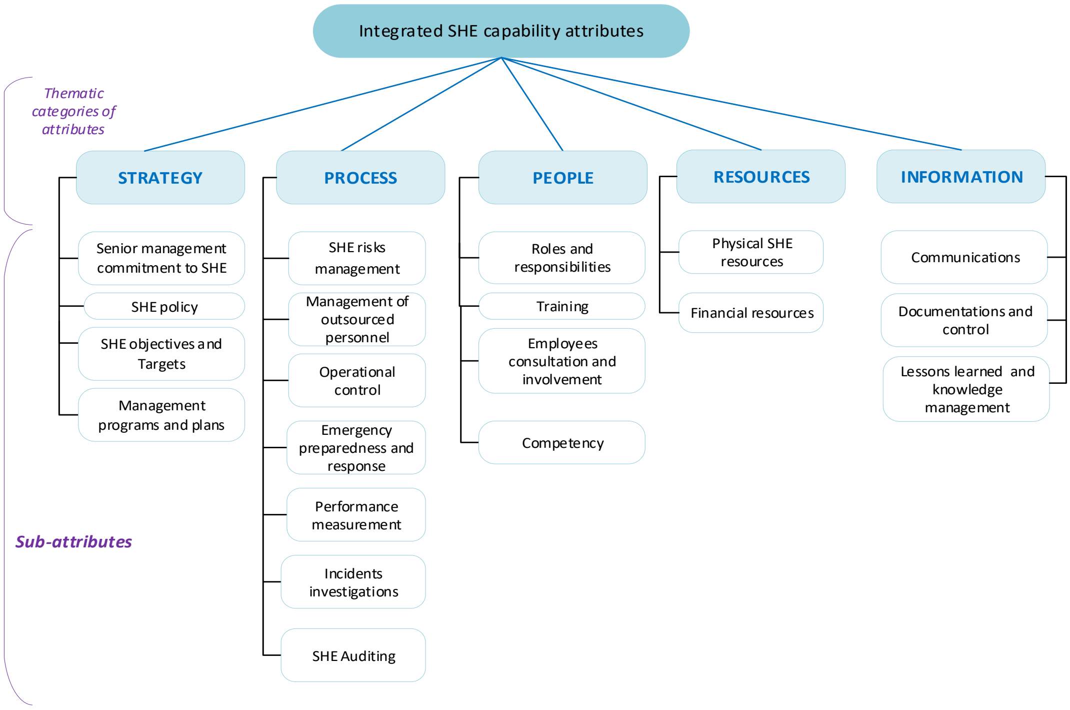

Figure 3: Integrated SHE management capability attributes hierarchy structure

Table 1: SHE management capability attributes in construction from literature

No.	Aspect of Plan-Do-Check-Act (PDCA)	Attributes
1	PLAN	Senior management commitment
2		SHE implementation team
3		Baseline review
4		Hazards, environmental aspects and impacts identification
5		SHE risks assessment and identification of control measures
6		Legal and other requirements
7		SHE policy
8		SHE objectives and targets
9		SHE management programme
10	DO	SHE roles and responsibilities
11		SHE resources
12		SHE training
13		SHE competence
14		Management of outsourced SHE services
15		SHE communication
16		Employee involvement in SHE
17		SHE documentation
18		Control of SHE documents
19		SHE operational control
20		SHE emergency preparedness and response
21	CHECK	SHE performance monitoring and measurement
22		Evaluation of compliance
23		SHE incidents investigations
24		Non-conformance; corrective and preventive actions
25		SHE records control
26		SHE system auditing
27	ACT	SHE lessons learned and knowledge management

Table 2: Characteristics of the applied Delphi process

Characteristic	Requirements offered in literature	Applied characteristic
Expertise	• In-depth knowledge and experience with the issues under investigation; capacity and willingness to participate (Adler and Ziglio, 1996; Hallowell and Gambatese, 2010) • Years of professional experience in the construction industry; Academic and professional qualifications; sufficient time to participate and effective communication skills (Adler and Ziglio, 1996)	• Participant professional role must be related SHE management in construction • A minimum of 5 years of experience in construction
Number of experts	• Optimal size between 7-30 • Minimum of eight (8) (Hallowell and Gambatese, 2010) • Minimum of ten (10) Skulmoski *et al.*, 2007) • In CEM Delphi applications participants can range from 3-90 members with most studies using panels of 15 to 35 people (Ameyaw *et al.*, 2016).	• 41 experts in Round 1 • 32 experts in Round 2 • 30 experts in Round 3
Number of iterations	• Two to six rounds (e.g. Dalkey *et al.*, 1970; Linstone and Turoff, 1975) • Three (3) rounds (Hallowell and Gambatese, 2010) with round one usually being exploratory for identification of items or elements	• Three rounds. A preliminary round to identify factors (in this case the integrated SHE capability attributes) was not needed as attributes had already been identified from literature which was validated by experts.
Controlled feedback	• Measures of central tendency and level of dispersion - Median (Hsu and Sanford, 2007, Ameyaw *et al.*, 2016) - Mean (Ameyaw *et al.*, 2016)	• Median was used due to the use of ordinal scale in the Delphi questionnaire
Measurement of consensus (i.e. level of agreement)	• Using non-parametric, measures of central tendency, level of dispersion and parametric statistical methods. - Kendall's coefficient of concordance (W) (Ameyaw *et al.*, 2016) - Consistency Ratio (Ameyaw *et al.*, 2016) - Standard Deviation (Ameyaw *et al.*, 2016) - Absolute deviation (Hallowell and Gambatese, 2010; Ameyaw *et al.*, 2016)	• Kendall's was used due to the use of ranked responses (i.e. ordinal data) • A non-parametric test -Wilcoxon signed ranked test was used to ascertain the saturation between Delphi rounds (Linstone and Turoff, 2011). This test ascertains the differences between two set of scores from the same participants (Field, 2013), thus, appropriate for investigating if there are any significant changes in participants scores from one round to another.

Table 3: The coefficient w_s according to the different attributes and sub attributes

Thematic category	Number of attributes/sub attributes	Coefficient of weights (W_S)
All five categories (i.e. strategy, process, people, resources and information)	5	w_1 0.4380 w_2 0.2180 w_3 0.1460 w_4 0.1095 w_5 0.0876
Strategy	4	w_1 0.4800 w_2 0.2400 w_3 0.1600 w_4 0.1200
Process	7	w_1 0.3857 w_2 0.1928 w_3 0.1286 w_4 0.0964 w_5 0.0771 w_6 0.0643 w_7 0.0551
People	4	w_1 0.4800 w_2 0.2400 w_3 0.1600 w_4 0.1200
Resources	2	w_1 0.6667 w_2 0.3333
Information	3	w_1 0.5455 w_2 0.2720 w_3 0.1818

Table 4: Results of the expert survey

Proposed SHE capability attributes	Number of expert participants (12) *Response received: (9) = 75% response rate*		
	Agree	% of agreement	Disagree
Top management commitment	9	100	0
SHE implementation team	7	78	2
SHE baselines review	6	67	3
SHE policy	8	89	1
SHE hazards, environmental aspects and impacts identification	8	89	1
SHE risks assessments and management	7	78	2
SHE legal and other requirements	7	78	2
SHE objectives and targets	6	67	3
SHE management programme(s)/action plan (s)	8	89	1
SHE structures and responsibility	8	89	1
SHE resources	8	89	1
SHE training	7	78	2
Competency of workforce	7	78	2
SHE supervision	7	78	2
SHE communications	8	89	1
SHE legal and other requirements	5	56	4
SHE documentation	8	89	1
SHE documents control	7	78	2
SHE operational control	7	78	2
SHE emergency preparedness and response	8	89	1
Monitoring and measurement	9	100	0
Evaluation of legal compliance	7	78	2
SHE incidents investigation	8	89	1
Non-conformance, correction/prevention action	8	89	1
Records control	6	67	3
SHE auditing	7	78	2
SHE management review	8	89	1
Learning lessons	8	89	1

Table 5: SHE management attributes

Thematic Category	Attributes
Strategy (i.e. the organisation's vision and top management commitment to SHE management)	Senior management commitment to safety, health and environment (SHE) management
	An integrated SHE policy that serves as the foundation for a company's SHE development and implementation
	SHE objectives and targets for a company, in line with SHE policy
	SHE management programme i.e. company's action plans for achieving SHE objectives and targets
Processes (i.e. the organisation's procedures, processes and systems for SHE management)	SHE risks management i.e. systems, processes and procedures for SHE hazards identification, risks assessment and identification risks control strategies
	Management of outsourced services i.e. processes and mechanisms for assessing the competence of outsourced personnel, subcontractors and suppliers with regards to management of SHE
	SHE operational control i.e. processes, procedures and measures for controlling SHE risks, to ensure SHE regulatory compliance in operational functions and to achieve the overall SHE objectives
	SHE emergency preparedness and responses i.e. emergency procedures and measures to minimise the impact of uncontrolled events and unexpected incidents.
	SHE performance monitoring and measurement i.e. systems, processes and procedures to monitor and measure SHE performance to ensure compliance with SHE regulations
	SHE incidents investigation i.e. processes and procedures for investigating the causes of SHE incidents
	SHE system auditing i.e. processes and procedures to conduct SHE audits to assess compliance and SHE management system effectiveness
People (i.e. organisation's human capital, their roles, responsibilities, and involvement in SHE management)	SHE roles and responsibilities i.e. availability of dedicated SHE roles and responsibilities within organisational hierarchy
	SHE Training i.e. provision of suitable SHE training for personnel
	Employee involvement and consultation at all levels in SHE management and operations
	SHE competence i.e. the skills, knowledge and experience of personnel to undertake responsibilities and perform SHE activities
Resources (i.e. organisation's physical and financial resources required for SHE management)	Physical SHE resources i.e. provision of physical resources for SHE implementation
	Financial resources for SHE i.e. Provision of financial resources for SHE implementation
Information (i.e. SHE related documents, data, lessons, records and their communication across an organisation)	Communications i.e. communication of relevant SHE information and requirements to personnel and other relevant stakeholders
	SHE documentation and control i.e. provision and maintenance of adequate SHE documentation and records
	SHE lessons and knowledge management i.e. capturing lessons learned and knowledge acquired from historical incidents and management of SHE
	Communications i.e. Communication of relevant SHE information and requirements to personnel and other relevant stakeholders

Table 6**:** Summary of Delphi result

Thematic category /attributes	Round 1 (N = 41)				Round 2 (N =31)				Round 3 (N =30)			
	Median	Mean rank	Kendall's W	Significant value	Median	Mean rank	Kendall's W	Significant value.	Median	Mean rank	Kendall's W	Significant value
Thematic category of attributes												
Strategy	1	1.71	0.425	0.000	1	1.61	0.481	0.000	N/A			
Processes	2	2.73			2	2.94						
People	2	2.76			2	2.65						
Resources	3	3.49			3	3.44						
Information	4	4.32			5	4.37						
Strategy attributes												
Senior Management Commitment	1	1.91	0.388	0.000	1	1.66	0.610	0.000	N/A			
SHE Policy	1	1.91			1	1.79						
SHE Objectives and Targets	3	2.84			3	3.11						
SHE Management Programme	3	3.33			3	3.44						
Processes												
SHE Risk Management	1	2.32	0.258	0.000	1	1.90	0.401	0.000	N/A			
Management of Outsourced Services	3	4.67			4	4.53						
SHE Operational Control	2	2.98			2	2.71						
SHE Emergency Preparedness and Responses	4	4.38			5	4.84						
SHE Performance Monitoring and Measurement	3	3.98			3	3.66						
SHE Incidents Investigation	5	4.96			5	5.35						
SHE System Auditing	4	4.72			5	5.00						
People attributes												
SHE roles and responsibilities	2	2.27	0.067	0.041	2	2.60	0.402	0.000	N/A			
SHE Training	2	2.68			3	2.98						
Employee Involvement in SHE	2	2.82			3	3.03						
SHE Competence	2	2.23			1	1.39						
Resources attributes												
Physical SHE Resources	1	1.52	0.004	0.695	1	1.53	0.008	0.617	1	1.42	0.064	0.166
Financial Resources for SHE	1	1.48			1	1.47			1	1.58		
Information attributes												
Communications	1	1.55	0.231	0.000	1	1.26	0.549	0.000	N/A			
SHE documentation and control	2	2.04			2	2.23						
SHE Lessons and Knowledge Management	2	2.41			2	2.52						

Notes: N/A = Not applicable

Table 7**:** Wilcoxon signed rank test

Comparison		N	Mean rank	Sum of ranks	Wilcoxon signed ranks (Z)	Sig. (2-tailed)
Phy.Res (round 3) - Phy.Res (round 2)	Negative Ranks	5[a]	3.500	17.500	-1.633[b]	0.102
	Positive Ranks	1[b]	3.500	3.500		
	Ties	24[c]				
	Total	30				
FIN3 - FIN2	Negative Ranks	1[a]	2.500	2.500	-1.000[b]	0.317
	Positive Ranks	3[b]	2.500	7.500		
	Ties	26[c]				
	Total	30				

Notes:
Phy.res = Physical resources. FIN = Financial resources.
a = the count of the round 3 ranks that are less than the round 2 ranks
b = the count of the round 3 ranks that are greater than the round 2 ranks
c = the count of the round 3 ranks that are equal to the round 2 ranks

Table 8: Delphi priority votes applied in VAHP

Thematic category of attributes	Priority votes at round 2					Total
	1st	2nd	3rd	4th	5th	
Strategy	28	1	0	1	1	31
Process	7	10	8	6	0	31
People	9	12	8	0	2	31
Resources	6	4	8	11	2	31
Information	4	1	2	5	19	31

Strategy attributes	Priority votes at round 2				Total
	1st	2nd	3rd	4th	
Senior management commitment	25	4	1	1	31
SHE Policy	22	8	1	0	31
SHE objectives and Targets	3	4	20	4	31
Management programs and plans	3	4	11	13	31

Process attributes	Priority votes at round 2							Total
	1st	2nd	3rd	4th	5th	6th	7th	
SHE Risks Management	25	2	0	2	2	0	0	31
Management of Outsource personnel	3	3	9	5	3	5	3	31
Operational control	7	15	6	3	0	0	0	31
Emergency preparedness and response	4	3	2	4	11	6	1	31
Performance measurement	4	7	12	5	1	2	0	31
Incidents investigations	3	2	4	3	4	7	8	31
SHE Auditing	4	2	4	3	7	7	4	31

People	Priority votes at round 2				Total
	1st	2nd	3rd	4th	
Roles and Responsibilities	9	9	8	5	31
Training	4	5	18	4	31
Employees consultation and involvement	7	4	9	11	31
Competency	27	4	0	0	31

Resources	Priority votes at round 3		Total
	1st	2nd	
Physical SHE resources	26	4	30
Financial resources	21	9	30

Information	Priority votes at round 2			Total
	1st	2nd	3rd	
Communications	28	3	0	31
Documentation and control	9	16	6	31
Lessons and knowledge management	4	16	11	31

Table 9**:** VAHP Results of thematic category of attributes

Thematic category /attributes	Weight	Normalised weight	*Rank*
Thematic category of attributes			
Strategy	12.678	0.332	*1*
Process	7.080	0.185	*3*
People	7.912	0.207	*2*
Resources	6.051	0.158	*4*
Information	4.475	0.117	*5*
Strategy attributes			
Senior management commitment to SHE	13.240	0.351	*1*
SHE Policy	12.640	0.336	*2*
SHE objectives and Targets	6.080	0.161	*3*
Management programs and plans	5.720	0.152	*4*
Process attributes			
SHE Risks Management	10.375	0.275	*1*
Management of outsource personnel	4.093	0.108	*4*
Operational control	6.653	0.176	*2*
Emergency preparedness and response	4.053	0.107	*5*
Performance measurement	5.123	0.136	*3*
Incidents investigations	3.546	0.094	*7*
SHE auditing	3.942	0.104	*6*
People			
Roles and responsibilities	8.360	0.233	*2*
Training	6.480	0.181	*4*
Employees consultation and involvement	7.080	0.196	*3*
Competency	13.920	0.388	*1*
Resources			
Physical SHE resources	18.667	0.523	*1*
Financial resources	17.000	0.477	*2*
Information			
Communications	16.091	0.460	*1*
Documentation and control	10.364	0.296	*2*
Lessons learned and knowledge management	8.546	0.244	*3*

Table 10: VAHP results of global ranking of attributes

Capability attributes	Global weights	Global ranks
Senior management commitment to SHE	0.1166	1
SHE Policy	0.1113	2
Physical SHE resources	0.0829	3
Competency	0.0805	4
Financial resources	0.0755	5
SHE objectives and targets	0.0540	6
Communications	0.0539	7
SHE risks management	0.0511	8
Management programs and plans	0.0509	9
Roles and responsibilities	0.0483	10
Documentation and control	0.0471	11
Employees consultation and involvement	0.0409	12
Training	0.0375	13
Operational control	0.0347	14
Lessons and knowledge management	0.0326	15
Performance measurement	0.0286	16
Management of outsource personnel	0.0251	17
Emergency preparedness and response	0.0201	18
SHE auditing	0.0199	19
Incidents investigations	0.0193	20