DEVELOPMENT OF AN INTEGRATED SAFETY, HEALTH AND ENVIRONMENTAL MANAGEMENT CAPABILITY MATURITY MODEL (SHEM-CMM) FOR GHANAIAN CONSTRUCTION COMPANIES

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DECLARATION

This work or any part thereof has not previously been submitted in any form to the University or to any other body whether for the purpose of assessment, publication or for any other purpose. Except for any express acknowledgements, references and/or bibliographies cited in the work, I confirm that the intellectual content of the work is the result of my own independent work/investigation and efforts and no other person.

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ABSTRACT

With high rates of accidents, injuries, illnesses, negative environmental impacts and other well-being issues still recorded in the construction industry, as well its social and economic impacts, the need for safety, health and environmental (SHE) improvement has become critical. Management systems, particularly environmental management systems (EMS) and safety management systems (SHMS), have been identified as innovative and systematic approaches for companies to manage SHE risks effectively in order to improve their SHE performance. However, the adoption and implementation of EMS and SHMS in the construction industry, particularly in developing countries like Ghana, has been slow and generally low, this is mainly due to cost and the bureaucracy that comes with the parallel implementation of standalone management systems. There is, therefore, a need for an integrated SHE management framework for effective SHE risks management and control in the construction industry. However there is no single integrated SHE management framework for construction organisations to use, especially those within developing countries. Neither is there any mechanism by which construction companies can ascertain their capability in implementing integrated SHE management in order to guide efforts to improve their SHE performance. This research was undertaken to develop an integrated SHE management capability maturity model (SHEM-CMM) that can be used by construction firms in the Ghanaian construction industry.

To achieve the aim of the study, a quantitative research approach was adopted. It involved a comprehensive literature review to generate potential capability attributes relevant to integrated SHE management. Following the literature review, a survey of experienced SHE experts was undertaken in order to verify the suitability of the identified integrated SHE management capability attributes. Subsequently, a three-round Delphi technique was undertaken with experienced SHE management experts (round 1 n=41, round 2 n=31 and round 3 n=30) and accompanied by the application of voting analytical hierarchy process, to generate consensus on the relevant attributes and also ascertain the relative weight/priority of the capability attributes. This study found 20 integrated SHE management capability attributes which are clustered into five categories, namely: strategy; process; people; resources; and information. Collectively, the attributes within the 'strategy' category are the most important, followed by the 'people' and then 'process' attributes. Drawing on the capability maturity concept, an integrated SHE management capability maturity model (SHEM-CMM) was developed. The model is composed of 20 integrated SHE management capability attributes which are mapped on to five levels of capability maturity ranging from Level 1 to Level 5, and with each level having a distinct maturity level descriptor. The integrated SHEM-CMM was then validated by 59 construction professionals including SHE experts in construction companies operating in the Ghanaian construction

industry in order to ensure the adequacy and practical usefulness of the model. This research has contributed to the existing body of knowledge on SHE management by establishing integrated SHE management capability attributes and their relative weight of importance. Furthermore, the research has developed a novel integrated SHEM-CMM which has practical usefulness in the construction industry. The model provides a systematic approach for SHE management capability evaluation and improvement in construction. It is anticipated that the developed capability maturity model would be used by construction firms to systematically assess their current SHE management capability and identify ways to further improve their SHE management in order to obtain better SHE performance outcomes.

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LIST OF ABBREVIATIONS

CAHF	Centre for Affordable Housing Finance in Africa
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
DT	Delphi Technique
EPA	Environmental Protection Agency
EMS	Environmental management systems
HSE	Health and Safety Executive
ILO	International Labour Organisation
IMS	Integrated management system
ISO	International Organisation of Standardisation
MMs	Maturity models
MS	Management system
MSS	Management system standards
OSH	Occupational safety and health
PDCA	Plan, Do Check and Act
SEI	Software Engineering Institute
SHE	Safety, health and environmental
SHEM	Safety, health and environmental management
SHEM-CMM	Safety health and environmental management capability maturity model
SHMS	Safety health management systems
TQM	Total Quality Management
UN	United Nations
WRAP	Waste and Resources Action Programme

DEDICATION

This thesis is first of all dedicated to the Almighty God, the giver of knowledge and wisdom, the Lord who is my strength, hope and the captain of my destiny. Secondly to my husband, children, parents, siblings and my entire family, for their unflinching support, encouragement and love throughout this research journey.

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CHAPTER ONE: INTRODUCTION

1.1 Background

Construction activities are important economic indicators in developed and developing economies alike. The construction industry contributes significantly to the gross domestic product (GDP) of a country's economy, total employment and also serves as an important market for manufacturers who produce construction materials and products (Myers, 2016; Suárez Sánchez *et al.*, 2017; Abubakar *et al.*, 2018). For many years, the construction industry has contributed significantly to reducing global unemployment by absorbing a total of 7% of the workforce (International Labour organisation (ILO), 2005; Lingard, 2013). Nonetheless, the global construction industry is infamous for high levels of accidents, injuries and illnesses, and also accounts for about 30-40% of global work-related fatalities (Ministry of Manpower, 2017; Health Safety Executive (HSE), 2018). For instance, in the United Kingdom (UK), the construction industry accounted for the highest number of fatal accidents (i.e. 30 out of 137 worker fatalities) between 2016 and 2017, (HSE, 2017). Across the 28 European countries, the fatality rate of construction operations and activities was ranked first among all economic activities in 2014 (Eurostat, 2017). Although, occupational accidents, injuries and illnesses are commonplace in construction globally, their rates in developing countries are generally considered to be higher than in the developed countries (Takala *et al.*, 2014). For instance, while in the UK, 30 worker fatalities were recorded in 2016/17 (HSE, 2017), in Malaysia, the construction industry accounted for 106 out of 209 worker fatalities in 2016, which is the highest compared to other industrial sectors (Department of Occupational Health and Safety, 2016). In Botswana, the construction industry is responsible for 55% of all workplace accidents (Mosanawe, 2013). Also, in Tanzania, the construction industry is responsible for about 10% of all occupational accidents (Matico and Naidoo, 2013).

Aside being responsible for high rates of accidents, injuries, illness and fatalities, the construction industry has a major impact on the enviroment in its substantial consumption of natural and processed resources, and energy (Enhassi *et al.*, 2014; Gupta and Deshmukh, 2016; UN environment, 2017). Estimates indicate that 50% of all raw material consumed, 16% of water withdrawals, 40% of the total energy consumed worldwide, 17% of waste generated and 20-30% of greenhouse emissions are all associated with the construction industry (Willmott and Dixon, 2010; Srdić nd Selih, 2011; Zoufagharin *et al.*, 2012; Enhassi *et al.*, 2014; Gupta and Deshmukh, 2016; UN environment, 2017), making it one of the least sustainable industries globally.

Occupational injuries, illnesses, fatalities, and negative environmental impacts have significant socio-economic implications (ILO, 2012). The costs arising from these occurrences in construction are colossal. For instance, in the UK alone, the cost of work-related injuries and ill-heath in a year is estimated to be over £1.1 billion (HSE, 2014). In South Africa, about 2.5 billion Rands is spent yearly on the compensation of claims related to health and safety in the construction industry (Department of Labour (DoL), 2008). Also, the direct and indirect cost associated with work-related accidents and its resultant tragic occurrences (i.e. injuries, illness and deaths) and adverse environmental impacts are not only borne by the victims and their families but also by the victim's employers, the government, construction client and the industry as a whole (Suarez Sanchez *et al.*, 2017; van Heerden *et al.*, 2018).

The Ghanaian construction industry still records high numbers of accidents injuries, fatalities and adverse environmental impacts (Chileshie and Yirenkyi-Fianko, 2012; Ameyaw *et al.*, 2014). Available statistics show an increase in work-related accidents and injuries between 2004 and 2009 (Nimo-Boakye *et al.*, 2010). According to Kheni *et al. (*2010), 5% of all reported accidents on construction sites in Ghana are fatal. Safety, health and environmental (SHE) performance in the construction industry in Ghana is, therefore, considered poor (Laryea and Mensah, 2010; Ametepey and Ansah, 2014; Mustapha *et al.,* 2016). Poor performance is largely attributed to the lack of priority given to safety and environmental considerations in delivery of building projects, an inefficient institutional and legal framework and laxity in the enforcement of existing SHE regulations, all of which point to a poor SHE management culture (Kheni *et al.,* 2010; Ameyaw *et al.*, 2014). Globally, the volume of construction output is estimated to grow by 85% to $15 trillion by 2030 (Global Construction Perspectives and Oxford Economics, 2015). Additionally, to address huge infrastructure and housing deficits, there has been an increase in investments in the construction industry in Africa (Pigato and Tang, 2015). With this significant growth and investments in construction, the current poor SHE outlooks in developing countries, like Ghana, could worsen if appropriate actions are not taken. Whilst this significant growth in construction output, has several socio-economic benefits, it also raises concerns, due to the potential adverse SHE incidents and their related cost consequences. There is, therefore, a clear case for improving SHE performance in the construction industry and especially in the Ghanaian construction industry, where minimal attention, is given to SHE issues (Ofori, 2012; Ameyaw *et al.*, 2014).

In recent years, the issue of SHE performance improvement in the construction industry has received some attention worldwide. Several continuous efforts from researchers and practitioners to address the SHE problem in construction have been wide ranging including command and control approaches, such as relying on regulations, fines, and other SHE management initiatives at workplace. However, in today's continually changing working environment, reactive SHE measures and enforcement at workplace, although important, is considered inadequate, adhoc and still renders construction sites unsafe, as well as environmentally unfriendly (Willmott Dixon, 2010; Pinto *et al.*, 2011). Hence, the need for more innovative and systematic approaches/methods to improve SHE issues in construction. Prominent amongst these approaches/methods are management systems (MSs), particularly Environmental Management System (EMS), and Safety and health management system (SHMS), which within the last few decades, have been recognised as one of the important approaches to assist construction companies to effectively manage and control the key management functions of safety and environment in a systematic way (Gasparik, 2009; Griffith, 2011; Fewings, 2013).

Construction SHE management literature shows EMSs and SHMSs can play a key role in improving the health, safety, and wellbeing of workers and tackling adverse environmental impacts (e.g. Griffith and Bhutto, 2008; Gasparik, 2009; Granerud and Rocha 2011; Vinodkumar and Bhasi, 2011; Podgorski, 2015; Owolana and Booth, 2016). The parallel implementation of separate management systems (MSs) in construction organisations has, however, been found to be bureaucratic, costly, paper-driven and arduous (Griffith and Bhutto, 2008; Zeng *et al.*, 2008; Asif *et al.*, 2010). Therefore, some researchers and industry stakeholders have advocated for integration of MSs, since such a single system could generate substantial benefits, such as streamlining activities to achieve greater organisational efficiency and effectiveness (Salomone, 2008; Abad *et al.*, 2014; Gangolells *et al.*, 2013; Rebelo *et al.*, 2016). More so, the various MSs standards in recent past, have become more aligned with international benchmark standards (e.g. ISO 14001, EMAS; OSHAS 18001 and ISO 45001), with similar methodologies in their creation, structure and implementation processes (Zeng *et al.*, 2007; Griffith, 2011; Rebelo *et al.*, 2014) making integration possible. Furthermore, as SHE issues are one of the most challenging problems facing the construction industry, the integration of an EMS and a SHMS into a single comprehensive framework could enable construction companies to use similar practices to help jointly manage SHE issues more efficiently and systematically to reduce construction accidents and negative environmental impacts (Gangolells *et al.*, 2013; Muzaimi *et al.*, 2016).

Despite the importance of MSs in assisting construction companies to systematically manage SHE issues, they only highlight management areas, and processes or practices that need to be implemented for better performance. Beyond that, they do not offer a mechanism for assessing how well a company does in implementing their SHE management activities, identifying its strengths and deficiencies and to help in prioritising actions to continuously improve (Poksinska *et al.*, 2002; Bansal and Hunter, 2003; Zeng *et al.*, 2007; Zobel, 2008). On the other hand, maturity models are management-oriented tools that could assist construction companies in assessing the maturity of their SHE management practices. Maturity models describe how organisations practices, processes and actions can show a desired progressive path of improvement in order to produce required outcomes (Wendler, 2012). Over the years, they have been proven valuable in assessing organisational processes in delivering performance in many businesses (e.g. Becker *et al.*, 2009; Pöppelbuß and Röglinger, 2012; Proença and Borbinha, 2016). Numerous researchers have, therefore, advocated and developed maturity models, both as a means of assessment and a framework for transformational progression and improvement in several management-related domains (Paulk *et al.*, 1993; Sarshar *et al.*, 2000; Macgillivray *et al.*, 2007; Yeo and Ren, 2009; Eadie *et al.*, 2012; Goh, 2014; Babatunde *et al.*, 2016; Adeniyi, 2017).

Though their popularity over the years have increased greatly, the majority of existing maturity models in construction are applied to project and risk management with a view to improving productivity and achieving quality. Contributions of maturity models and similar application in the area of health, safety and environmental management are scarce, with none existing within a developing country context, where there is reported poor, SHE performance outcomes. It is on this premise that, an integrated safety, health and environmental management capability maturity model is being developed in this study for uptake by construction companies in Ghana. Its development is expected to benefit construction companies and others in the supply chain. The model is also expected to contribute greatly in this direction within other developing countries (e.g. those in Sub-Sahara Africa region), where the benefits could be far-reaching as it could serve as a blueprint for developing similar frameworks for other developing countries.

1.2 Problem statement

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 has been found to be onerous, costly and bureaucratic (Zeng *et al.*, 2007; Griffith and Bhutto, 2008; Turk, 2009; Griffith, 2011). Ghana's construction industry is not different as construction companies have become incurious to the implementation of 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 (Ayarkwa *et al.*, 2010; Kheni, 2010; 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 (Liyin *et al.*, 2006; Selih, 2007; Griffith and Bhutto, 2008; Turk, 2009; Sakr *et al.*, 2010; Griffith, 2011; 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). Some researchers and industry stakeholders have, therefore, advocated for 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 (Hamid *et al.*, 2004; Gasparik, 2009; Griffith, 2011; Gangolells *et al.*, 2013; 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.

The Ghanaian construction industry accounts for the highest number of occupational accidents and deaths as well as work related illnesses compared with other industrial sectors in Ghana (Nimo-Boakye *et al.,* 2010; Kheni *et al.,* 2010; Chileshie and Yirenkyi-Fianko, 2012). The industry also is responsible for constant environment degradation, pollution, substantial raw materials and energy consumption which continue to take their toll on the country's development (Ofori, 2012; Dadzie and Djokoto, 2013; Ayarkwa *et al.,* 2014). 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, have 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 effectively improve SHE performance outcomes in the industry. The uptake of a prominent approach like the implementation of SHE management systems in the Ghanaian construction industry, however, has been low (Ayarkwa *et al.*, 2010; 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 for effective management of SHE risks and issues in the Ghanaian construction industry. However, there still remains no single integrated SHE management framework for construction organisations to use, especially those within developing countries like Ghana. Consequently, there are also no tools or systematic mechanisms that enable construction companies to ascertain the maturity of their SHE management practices based on an integrated SHE management framework. Organisations being able to ascertain the maturity of their processes in delivering a function is important in ensuring continuous process improvement as organisation are able to identify the strengths and weaknesses within their processes and practices. A process improvement tool like a capability maturity model can offer such a mechanism. Though maturity models have been proven valuable for assessing organisational processes or practices in delivering performance in various domains (Wendler, 2012; Bititci *et al*, 2015; Proença and Borbinha, 2016), there are few examples on its application to SHE management in construction. The development of an integrated safety, health and environmental management capability maturity model (SHEM-CMM), therefore, could be a useful process improvement tool, for assessing the maturity of a construction company's SHE management practices and to identify actions that are needed to continuously improve. An integrated SHE management system specific for Ghanaian construction companies could help ease the financial and resource burden associated with the implementation of separate stand-alone MSs by contractors. Furthermore, an integrated SHEM-CMM could enable Ghanaian construction companies ascertain their current SHE management capability, understand their capability in implementing integrated SHE management and identify ways to further improve in order to obtain better SHE performance outcomes, thereby reducing economic loss, accidents, fatalities and negative environmental impacts.

While an integrated SHEM-CMM would be beneficial, especially for contractors to enable them to improve on their SHE management practices and eventually performance, there is none existent at present and very limited research has been undertaken to inform their development. The closest, up to now, are: (1) the integrated management systems/models such as safety, health, environmental and quality (SHEQ-MS) (Hamid *et al.*, 2004) and the integrated management system-quality, environment and safety (IMS-QES) (Rebelo *et al.*, 2014) which do not enable SHE management capability maturity assessment of construction organisations in order to pave way for process improvement; and (2) the maturity models for safety culture assessments (Fleming, 2000; Goncalves *et al.*, 2010; Foster and Hault, 2013) and the Health and Safety Maturity Model by Goggin and Rankin (2009), which do not incorporate the environmental management aspects. Moreover, SHE management studies in the construction industry in Ghana have largely covered areas such as environmental impacts of construction activities, perceptions of adoption and implementation of an EMS, on-site safety and health (S&H) management issues, design for safety, legislation and procurement (Kheni *et al.*, 2008; Laryea and Mensah, 2010; Kheni and Briamah, 2014; Ametepey and Ansah, 2014; Ayarkwa *et al.*, 2014; Danso *et al*, 2015; Mustapha *et al.*, 2016; Manu *et al.*, 2019a). None of these studies has focused on integrated SHE management in construction, although construction operations' and activities' adverse impact on the natural environment, and on the safety and health of workers in the Ghanaian economy is significant. Consequently, there remain knowledge gaps regarding: (1) the key attributes or elements relating to an integrated SHE management framework that should be incorporated in an integrated SHEM-CMM; (2) the relative importance/priorities of such attributes so as to enable prioritisation of improvement actions; and (3) the levels of capability maturity that are appropriate for capturing stages of maturation in those attributes.

Based on the forgoing, the following research questions were posed to address the knowledge gaps.

1.3 Research questions

The following research questions are addressed by the study:

1. What organisational attributes regarding SHE management are required for the development of an integrated SHEM-CMM?
2. What is the relative weight/priority of those attributes? and
3. What levels of maturity are appropriate for capturing maturity in the capability attributes?

1.4 Research aim and objectives

The aim of the research is to develop an integrated SHE management capability maturity model that can be used by construction companies in Ghana.

To address the research questions and achieve the overall aim of the study, the following specific objectives are addressed.

1. To identify the current state of the art relating to safety, health and environmental management in the construction industry.
2. To identify attributes that determine integrated SHE management capability in construction.
3. To explore capability maturity model (CMM) concept to inform its application in the development of an integrated SHEM-CMM.
4. To develop an integrated SHEM-CMM.
5. To validate the model and test the industrial relevance of the integrated SHEM-CMM from the perspective of Ghanaian construction companies.
6. To draw conclusions and make recommendations relating to safety, health and environmental management practice and research in the Ghanaian construction context.

1.5 Outline of research methodology

The philosophical paradigm adopted for this study is positivism, which is founded on the belief that a single reality out there needs to be discovered, carefully observed and objectively analysed statistically and for which the researcher has to become an objective and uninvolved observer who maintains distance from the researched (Creswell, 2014). Based on this philosophical position, a quantitative research strategy, specifically a survey research design (i.e. Delphi survey) was employed in this study. The Delphi technique (DT) is a reliable method widely used when there is no or incomplete knowledge about a problem or phenomenon and also when the problems do not lend themselves to precise analytical techniques but can benefit from subjective judgment of experts on a collective basis (Skulmoski *et al.*, 2007; Linstone and Turoff, 2011). It also allows for both quantitative and semi-quantitative data to be produced (Hallowell and Gambatese, 2010; Sourani and Sohail, 2015). The research procedure, therefore, includes a literature review, expert validation, a three-round DT accompanied by the application of voting analytical hierarchy process (VAHP) and a validation survey.

To achieve objectives one, two and three, an extensive literature review was undertaken. Particularly, the review of literature was carried out to identify capability attributes germane to the effective implementation of an integrated SHE management system in construction. Existing environmental management systems, safety and health management systems, integrated management systems and maturity models were also identified through literature review. From the literature review, integrated SHE management capability attributes were identified and verified by a team of 12 SHE management experts in preliminary expert verification exercise. This preliminary verification phase was followed by a three-round Delphi survey and application of VAHP to ascertain the relative weight/priority of the identified integrated SHE management capability attributes.

To achieve objective four, an initial capability maturity model containing the integrated SHE management capability attributes and corresponding capability levels with distinct descriptors was developed. This initial maturity model was sent to experts for further verification and refinement. A final version of the integrated SHE maturity model was produced and subsequently validated from the perspective of SHE managers and other construction professionals operating in construction companies in Ghana. This achieved objective five. On the basis of the entire work, relevant conclusions were finally drawn and appropriate recommendations were made in order to achieve objective 6.

1.6 Structure of the thesis

The thesis is organised into eight chapters as shown schematically in Figure 1.1.
Contents of each chapter is summarised in the following:

Chapter 1: In this chapter the research background and problem statement are presented highlighting the research gaps. The justification for the research is also highlighted. This chapter also presents the research questions, aim and objectives, and a general overview of the research methodology as well as the thesis structure.

Chapter 2: This chapter is the first part of the literature review that provides a general overview of safety, health and environmental performance in the construction industry, environmental impacts of construction operations and an overview of SHE performance in the construction industry in Ghana. A case for SHE improvement is made. Management systems, particularly SHE management systems and their associated elements and requirements are also presented in this chapter, highlighting their implementation and role in SHE management in construction.

Chapter 3: This chapter presents a review of relevant literature on existing process improvement methods and capability maturity model. It defines the meaning of process improvement and introduces various existing process improvement methods and approaches. Further, it provides the conceptual foundation for the study by reviewing the capability maturity modelling concept, structure and components in order is to develop a detailed understanding of its design and applicability to the development of an integrated SHEM-CMM. A review of maturity models in construction is also presented.

Chapter 4: This chapter describes and justifies the philosophical stance, research strategies and research methods of this study. The research design of this study with data collection and analysis are also presented and explained in this chapter.

Chapter 5: This is the first chapter on data analyses and results. It describes all processes leading to the identification of key capability attributes for incorporation into an integrated SHEM-CMM. This includes a report on the potential integrated capability attributes identified from literature and the preliminary verification by selected experts. The follow-up Delphi survey accompanied by the VAHP conducted is also presented.

Chapter 6: This is another chapter which focusses on the data analyses and results relating to the development of the maturity model. It presents the integrated SHEM-CMM which construction companies can use to assess the state of their current SHE management capability maturity. The chapter describes the development of SHEM-CMM.

Chapter 7: This chapter describes the validation of the integrated SHEM-CMM developed in this study. It discusses the rationale for validation, the processes involved and the findings of the validation to assess the adequacy and practical usefulness of SHEM-CMM to construction companies.

Chapter 8: The conclusions and recommendation from this research are presented in this chapter. The contribution to knowledge is highlighted both in terms of theory and practice. The limitations of this study and suggested areas for further research are also presented in this chapter.

1.7 Chapter summary

The background to this study has been presented in this chapter. The aim, objectives and the specific questions that this study plans to answer have also been discussed. The structure of this thesis was also presented to guide readers on how all issues relating to the aim of the study are distributed into chapters. It is believed that a careful read of this chapter by a reader will present a clear picture of the aim of this study, as well as how the aim and associated objectives were achieved. The next chapter presents the first part of the literature review; discussing the SHE performance of the construction industry, environmental impacts and a review of managements systems specifically the EMS, SHMS and integrated management system (IMS).

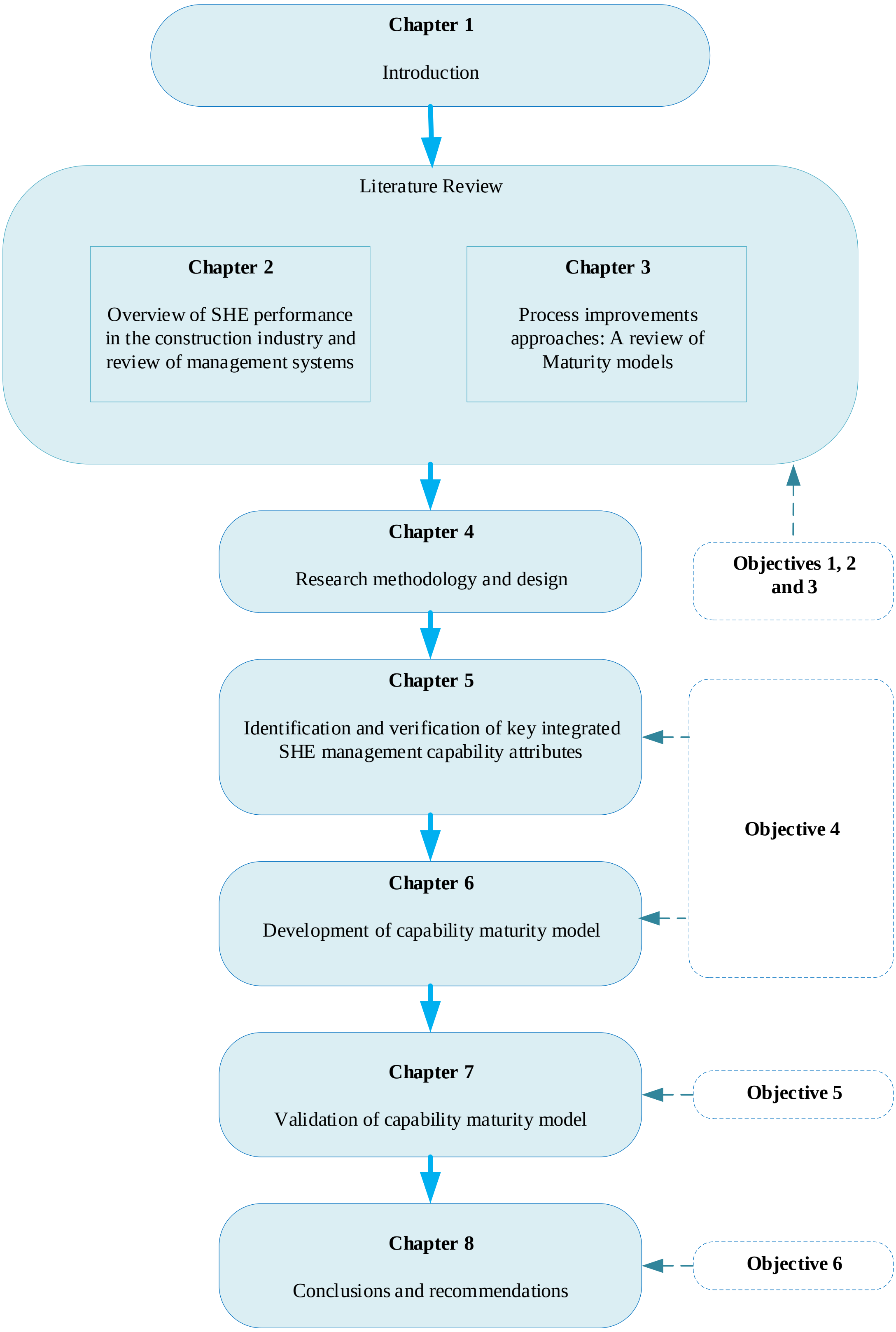

Figure 1.1: Organisation of chapters in the thesis.

CHAPTER TWO: SAFETY, HEALTH AND ENVIRONMENTAL PERFORMANCE IN CONSTRUCTION - A REVIEW OF MANAGEMENT SYSTEMS

2.1 Introduction

This chapter presents a review of literature on SHE performance of the construction industry as well as the impacts of construction activities on the environment and the role of management systems in the SHE management improvement efforts. The review is in three parts. The first part presents an overview of SHE performance in the construction industry and environmental impacts of construction operations. In the second part, the construction industry in Ghana as well as its SHE performance is also presented. Finally, a case for improving SHE performance in the construction industry and a review of existing literature related to management systems particularly the EMS, SHMS, and IMS in the construction industry is also discussed. This chapter explores the different SHE management systems and models that appear within published literature to highlight the key elements and requirements. The review of these models and frameworks is a precursor to identifying appropriate capability attributes for an integrated SHE management, which would inform the development of a conceptual integrated SHE capability maturity model.

2.2 An overview of the construction industry

Construction industries play a vital role in the economy of many countries and are frequently seen as a driver of economic growth, especially in developing countries (Alhajeri, 2014; Sanchez *et al.*, 2017). The industry contributes to about 6-10% of gross domestic product (GDP) to economies globally (Bawane, 2017) and offers employment to around 7% of the total employed work force around the world (Lingard, 2013). It is, therefore, one of the most thriving industries worldwide. Several studies have confirmed and highlighted the crucial role of the construction industry in aggregate economy and its significant impact on all aspects of human life (Anaman and Amponsah, 2007; Rameezdeen, 2008; Jorge, 2008; Testa *et al.,* 2011; Osei, 2013; Alhajeri, 2014; Khan *et al.,* 2014; Alagidede and Mensah, 2016). Despite its economic and social significance, the construction industry is one of the most dangerous industrial sectors accounting for several kinds of occupational injuries, illnesses, fatalities and adverse environmental impacts (Enshassi *et al.,* 2014; Zhou *et al.,* 2015; Schmidt and Osebold, 2017; Brahmachary *et al.,* 2018).

2.2.1 Overview of safety and health in construction

The ILO and several researchers are unanimous in the conclusion that the construction industry is one of the topmost hazardous industries (Carter and Smith, 2006; Camino *et al.,* 2008; ILO, 2012; Tau and Seoke, 2013; Mouleeswaran, 2014; Zhou *et al.*, 2015). According to ILO, more than 60,000 fatal accidents occur yearly on constructions sites worldwide, representing one fatal accident in every ten minutes (Lingard, 2013). The industry is also responsible for about 30-40% of global work-related fatalities (Wells and Watkins, 2010; ILO, 2012; Alkilani *et al.*, 2013). The high accidents injury and fatality rates in construction is largely attributed to its hazardous workplace environment and fast changing work practices (Glass *et al.*, 2008; Fan *et al.*, 2014). Therefore, construction workers are more prone to accidents, making the industry as one of the topmost contributors to work-related fatalities, injuries and illnesses (Mouleeswaran, 2014; Department of Occupational Safety and Health, 2016).

Sousa *et al.* (2014) stated that construction still contributes to a high number of work-related accidents and its attendant injuries, illness and fatalities despite considerable efforts and improvements over recent years. It is, therefore, common to hear of tragic accidents/incidents that result in death or illness and some bodily harm to workers and the people who are close or at various construction sites (Manu *et al.,* 2017). This state of affairs continues to remain in the construction industry globally. However, the occurrence of work-related injuries and fatalities is more pervasive in developing countries such as the countries in the Sub-Sahara Africa region than the developed countries (Takala *et al.*, 2014).

According to Zou (2011), higher numbers of work-related injuries and fatalities are still being recorded in developed countries. For instance, in the USA, the construction industry accounts for about 21% of all occupational deaths from injuries (Hallowell and Gambatese, 2009; OSHA, 2018). More recent statistics revealed that the construction industry accounted for 19.4% of the total fatal work injuries among other industries (Bureau of Labour Statistics, 2016). Although, the construction industry in the UK accounts for 5% of the workforce, it is responsible for the highest number of fatal injuries at work compared with other sectors (HSE, 2017). Also, the sector accounts for 22% of fatal injuries and 10% of reported major injuries (Construction Health and Safety Group, 2018). Within Hong Kong and Singapore, the construction industry accounted for 56% and 36% of all industrial fatalities, respectively (Ministry of Manpower, 2016; Labour Department, 2017). The Norwegian construction industry consistently accounted for the highest numbers of fatal injuries and incident rates compared with other industries from 2012-2016, with an average incidence rate for fatalities of 4.1 per 100,000 employees (Labour Inspection Authority, 2017). Across 28 European countries, the fatality rate of construction operations and activities was ranked first among all economic activities in 2014 (Eurostat, 2017). In Japan, the construction industry consistently accounted for the largest number of fatal accidents from 2014-2016 (JISHA, 2017). Lingard *et al.* (2010) reported an average of 46 compensated fatalities yearly in the Australian construction industry. Camino *et al.* (2008) noted that the construction industry in Spain, is responsible for the deaths of about 350 workers annually. According to Törner and Pousette (2009), the building and construction industry in Sweden is among the top 10 occupational sectors for occupational accidents in the country.

In developing countries, the construction industry is not in a state of utopia either. King and Hudson (1985) and Hamalainen *et al.* (2006) noted work-related accidents and ill-health problems in developing countries are about three times as many as in developed countries. In Malaysia, the construction industry accounted for 51% of the 209 occupational fatalities that occurred in 2016 (DOSH, 2016). According to the Ministry of Labour Invalid and Social Affairs (MOLISA), the Vietnam construction industry, accounted for about 31% of the 627 industrial fatalities in 2013 (MOLISA, 2014). In Thailand, from 2003 to 2011, industrial activities including construction with its related activities, accounted for about 155,000 accidents and diseases (Occupational Safety and Health Bureau, 2012). Although, the construction industry in India contributes about 8% to the country's GDP and employs about 7.5% of the total world labour, it contributes 16.4% of global fatal occupational accidents (Dixit *et al.,* 2017; Kanchana *et al.,* 2017).

The Construction Industry Development Board (CIDB) of South Africa (2008) indicated that the fatal injury rate (i.e. the number of occupational fatal injuries per 100,000 workers) and the accident rate (i.e., the number of occupational accidents per 100,000 workers) for Sub-Sahara African countries are estimated to be 21 per 100,000 workers and 16,012 per 100,000 workers, respectively. The construction industry in South Africa is ranked third as the largest contributor to occupational accidents and responsible for 376 fatal injuries from 2004 to 2008 (CIDB, 2008). In Tanzania, Matico and Naidoo (2013) reports that the construction industry is responsible for about 10% of all occupational accidents. In Nigeria, the construction industry contributes 3.88% to the country's GDP. However, it consistently accounts for high rate of accidents, both reported and unreported (Idoro, 2011; Okoye *et al.,* 2016). Also, in Botswana, the construction industry is responsible for 55% of all workplace accidents (Mosanawe, 2013). From the above statistics, it is apparent that the construction industry's S&H performance globally is poor, and far from achieving a reputation as an accident-free industry (Zhou *et al.,* 2015). The industry continues to remain one of the most dangerous industries globally at present. Hence, greater efforts are required to prevent construction accidents as much as possible to improve S&H performance in the industry. There is a need for collaborative efforts from all stakeholders in the reduction of construction accidents. Construction firms should therefore take the initiative to enforce their S&H standards for reducing construction accidents.

2.2.2 Construction impact on the environment

Construction activities and operations globally have significant impact on the world's environment (Schmidt and Osebold, 2017). According to several studies, every aspect of the construction process has a measurable environmental impact: from extraction of raw materials and transportation to site, the initial work on-site through the construction period, waste removal and disposal process, operational period of built assets and to the final demolition and when a building comes to the end of its life (Shen and Tam, 2002; Ding, 2008; Zutshi and Creed, 2014; Enshassi *et al.,* 2014; Schmidt and Osebold, 2017). On a global scale, construction activities adversely affect the environment in its substantial consumption of raw materials and energy, as well as the generation of water, air, and noise pollution, discharge of toxic waste and emission, global warming, ozone layer destruction, resources depletion amongst others (Chen *et al.*, 2005; Ding, 2008; Gangolells, 2010; Li *et al.*, 2010; Probert *et al.,* 2010; Chang *et al.,* 2011; Kidalova *et al.,* 2012; Macozoma, 2012; Zoufagharin *et al.,* 2012; Enshassi *et al.*, 2014).

With rapid development of the global economy in terms of infrastructure and other services, particularly in developing countries to address the housing and infrastructure deficits, construction projects will continue to negatively impact the physical environment worldwide (Ebohon and Rwelamila, 2001; Ding, 2008; Yahaya and Abidin, 2013; Ametepey and Ansah, 2014). As a result, environmental impact of construction and environmental protection has become of high relevance (Bentivegna *et al.,* 2002; Schmidt and Osebold, 2017). The construction industry cannot continue to ignore the environment since its activities significantly influence the environment and its constituents (Langston and Ding, 2001; Omoju, 2014; Mbala *et al.,* 2019). It is, therefore, crucial for insights into the impacts of construction operations on the natural environment and how these adverse environmental impacts can be decreased or limited to achieve the objectives of sustainable construction (Du Plessis, 2002; Tam *et al.,* 2006; Gangolells *et al.,* 2011; Zoufagharin *et al.,* 2012). According to Gangolells *et al.* (2011), identification of environmental impacts of construction in the early stages of projects could lead to improvements in environmental performance of construction projects and sites.

Construction processes have notable irreversible impacts on the environment (Ling and Lim, 2002; Li *et al.*, 2010; Gangolells *et al.,* 2011; Zoufagharin *et al.*, 2012; Abdul-rahman *et al.*, 2016), therefore, construction is not environmentally friendly. Additionally, the extraction of raw and natural resources causes irrevocable changes to the natural environment (Langford *et al.*, 1999; Ofori *et al.*, 2000; Majdalani *et al.*, 2006; Glass and Simmonds, 2007). For instance, construction methods, operations and activities generate water, noise and air pollution and accounts for about 20-35% of all negative impacts on the environment, such as, abiotic depletion, global warming, and ozone layer depletion (Christini *et al.*, 2004; Liyin *et al.*, 2006; Tucker *et al.*, 2006; Jeffrey, 2011; Ofori, 2012). It produces considerable volumes of waste, dust, about 20-30% of greenhouse emissions, other emissions of toxic substances (Co_2, No_2, and So_2) from production, transportation and use of construction products and materials (Ofori and Chan, 1998; Rohracher, 2001; Wallbaum and Buerkin, 2003; UNEP, 2009; Li *et al.*, 2010; Probert *et al.*, 2010; Ren *et al.* 2012; Macozoma, 2012; Kaur and Arora, 2012; Pittet and Kotak, 2012). Furthermore, construction also consumes about 30-40% of energy, 25% of wood, 12-16% of fresh water annually and approximately 40% of all raw materials used in the world economy (Willmott and Dixon, 2010; Geipele and Tambovceva 2011; Macozoma, 2012; Gupta and Deshmukh, 2016; UN environment, 2017).

According to Sharrard (2007), the impact of construction on the environment have not been sufficiently enumerated. However, Glass and Simmonds (2007) argued that there is extant literature on the examples of environmental impacts of construction activities on the natural environment. For instance, in a study by Shen and Tam, (2002) in Hong Kong, the environmental impacts were grouped into six, namely: solid and sanitary waste; living environment pollution such as noise, dust, odours, vibrations, environment resource extraction like minerals and fossil fuels; consumption of generic resources (water, energy, air and land); chemical and particulate emissions; and land for waste disposal. March (1992) also considered ten categories of construction related environmental impacts; timber consumption; health and safety hazards; energy; water; ecology; dust; sewage; landscape; traffic; and noise. According to Cole, (2000), the impacts of construction activities cover resource use and waste generation, ecological loadings and human health issues. Teixeira and Couto (2000) and Cardoso (2005) stated that the impacts include: mud, dust, soil and water contamination, waste production, noise, traffic increase, damage to public drainage, destruction of plants, and visual impact. Also, the study by Chen *et al.* (2005) in China, concluded that the impacts of construction on the environment are noise and vibration; archaeology impacts; soil and ground contamination; construction and demolition waste; dust; hazardous emissions and odours and impacts on wild life; and natural features.

In a study to investigate impacts of construction activities on the environment in Ghana, Ametepey and Ansah (2015) categorises construction industry’s environmental impacts into nine, consisting of resource consumption, effects on biodiversity, local issues, transport issues, waste generation, atmospheric emissions, accidents and incidents; soil alterations, and water emissions. Li *et al.* (2010) and Zolfagharian *et al.* (2012) in their investigation of environmental impacts associated with construction sites in China and Malaysia respectively, revealed that environmental impacts across construction processes consists of ecosystems impacts (the adverse impacts of waste, noise, dust, and hazardous emissions which cause serious damages to humans and ecosystems), natural resources impacts (energy, land, materials and water, which are used during a typical construction process), and public impact (the harmful effects on the health of people living nearby or at construction sites, due to the dust, vibration and noise of certain construction activities such as excavation). From the review above, it appears that there is no particular category of impacts that has been noted to be the most important environmental impacts associated with the construction process in the literature. However, some empirical studies have revealed some classifications. For instance, Zolfagharian *et al.* (2012) revealed that, the most important and severe environmental impacts on construction sites in Malaysia are from transportation resources, noise pollution, and dust generation with construction machinery. Additionally, their findings revealed the 'Ecosystem Impacts' as having the greatest impact on the environment (67.5% of total impacts) followed by the 'Natural Resources Impact' which accounted for 21%, while 'Public Impact' consists of only 11.5%. On the other hand, Enshassi *et al.* (2014) reported that in the Gaza Strip, the public impacts (i.e. the impacts on people who live at or close to construction sites) were the most important group that affects the environment, followed by the natural resources and the ecosystem impacts. Their study also revealed that construction workers are exposed to health problems daily such as respiratory problems, liver, cancer, hearing impairment, hypertension, annoyance, sleep disturbance, and other cardiovascular adverse effects. Ametepey and Ansah (2015) revealed that the resource consumption category (consisting of raw materials consumption, electricity consumption, water consumption and fuel consumption*)* was ranked the highest among the major impacts of construction activities on the environment in Ghana followed by biodiversity impacts and local issues.

Review of literature to date (e.g. Tse, 2001; Valdez and Chini, 2002; Chen *et al.,* 2004a; Christini *et al.,* 2004; Shen *et al.,* 2005; Liyin *et al.,* 2006; Majdalani *et al.,* 2006; Tam *et al.,* 2006; Glass and Simmonds, 2007; Gangolells *et al.,* 2009; Li *et al.,* 2010; Gangolells *et al.,* 2011; Chang *et al., 2*011; Zoufagharin *et al.,* 2012, Ametepey and Ansah, 2014; Enshassi *et al.,* 2014; Schmidt and Osebold, 2017) revealed some important impacts of construction activities on the environment. They can be summarised into several subcategories under three main headings as presented in Figure 2.1. The list of selected impacts of construction projects on the environment as reported by prior studies is also shown in Table 2.1.

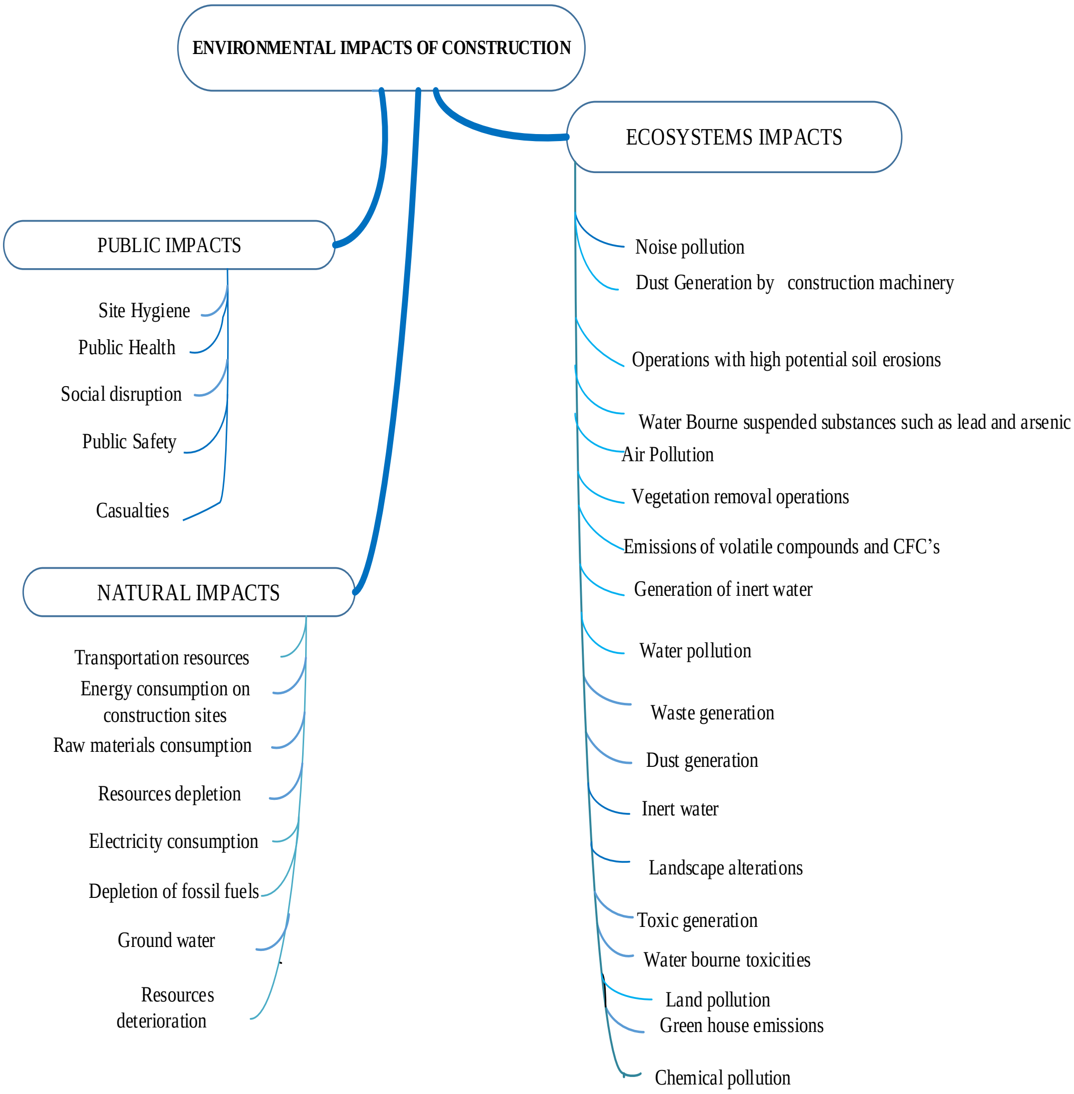

Figure 2.1: Categorisation of the impacts of construction on the enviroment
Source: Zoufagharin et al., 2014 p.1752

Construction projects causes massive direct and indirect adverse environment impacts (Fergusson and Langford, 2006; Enshassi *et al.*, 2014). According to Shen and Tam (2001), a slight impact, such as a release or spill of a harmful substance, can cause a health or environmental threat which leads to costly clean-up actions and negative publicity, which seriously affect competitive advantage. Protecting the environment has therefore become a challenge in the construction industry (Ding, 2008). The risk of construction companies in failing in its environmental duty, is substantial. Hence, the need for contractors and other construction professionals to employ more efficient approaches and strategies to environmental issues. According to Yahaya and Abidin (2013), contractors' commitment to environmental protection and reduction of pollution is absolutely necessary. Hence, a need for much focus on environmental impacts of construction operations when organising construction activities, in decision making, as well as throughout the production control (Shen and Tam, 2001; Christini *et al.*, 2004; Blücher, 2014). This will ensure that construction operations are executed in such a way that its undesirable impacts on the environment is reduced and its maximum positive impacts obtained (Kaur and Arora, 2012).

Table 2.1: List of environmental impacts of construction activities from previous research. (Adapted and modified from Enshassi et al., 2014).

	Authors / Environmental impacts	Muhwezi *et al.* (2012)	Zolfagharian *et al.* (2012)	Li *et al.* (2010)	Tam *et al.* (2006)	Enshassi (2000)	Pittet and Kotak (2012)	Chang *et al.* (2011)	Horvath (2004)	Kaur and Arora (2012)	Chen *et al.* (2000)	Eras *et al.* (2012)	Gangolells *et al.* (2011)	Gangolells *et al.* (2009)	Ijigah *et al.* (2013)	Tam *et al.* (2004)	Shen *et al.* (2005)	Svensson *et al.* (2006)
ECOSYSTEM IMPACTS	Noise pollution	√	√		√	√	√			√	√		√	√	√		√	√
	Dust Generation with construction machinery	√	√											√				
	Land pollution		√							√		√	√	√				√
	Air pollution		√		√				√	√				√	√		√	√
	Land use	√			√		√								√			√
	Operations with vegetation removal	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√
	Emission of VOC and CFC	√	√				√						√	√				√
	Generation of inert waste	√	√	√	√			√	√		√	√		√	√		√	√
	Operations with high potential soil erosion	√	√			√							√	√	√			
	Water pollution		√		√				√	√				√	√		√	√
	Dust Generation from construction activities	√	√	√	√					√	√	√	√	√	√			
	Chemical pollution	√	√			√		√										
	Landscape alteration		√										√	√				
	Toxic generation		√				√					√	√					
	Greenhouse gas emissions/	√	√									√	√	√	√			
	Climate change					√	√								√			√
	Waste water discharge/	√		√	√			√		√	√		√	√				
	Co_2, So_2, Co and No_x emissions			√	√		√	√	√	√	√	√						

Environmental impacts \ Authors		Muhwezi *et al.* (2012)	Zolfagharian *et al.* (2012)	Li *et al.* (2010)	Tam *et al.* (2006)	Enshassi (2000)	Pittet and Kotak (2012)	Chang *et al.* (2011)	Horvath (2004)	Kaur and Arora (2012)	Chen *et al.* (2000)	Eras *et al.* (2012)	Gangolells *et al.* (2011)	Gangolells *et al.* (2009)	Ijigah *et al.* (2013)	Tam *et al.* (2004)	Shen *et al.* (2005)	Svensson *et al.* (2006)
	Acidification and waste heat			√			√											√
	Bad odour		√				√							√				√
	Breakage of underground pipes electric power cables, telephone lines, water pipes)	√	√										√					
NATURAL RESOURCE IMPACTS	Transportation resources		√										√	√				
	Use of water resources	√		√	√		√		√				√	√				
	Extraction of Raw Materials		√											√				
	Energy consumption	√	√	√	√	√	√	√	√						√	√	√	
	Raw materials consumption	√	√	√		√							√				√	
	Resource depletion			√	√										√	√		√
	Increase in external road traffic due to construction site transport		√										√	√				
	Depletion of fossil fuels				√		√	√				√		√	√			√
	Ground water									√			√					
	Resource deterioration		√			√												
	Substantial consumption of both renewable and non-renewable resources	√					√							√	√			
	Electricity consumption		√				√	√					√	√	√			
PUBLIC IMPACTS	Site hygiene condition		√										√	√				
	Public health effects and safety		√	√						√				√			√	
	Casualties/fatalities						√	√					√	√				√
	Social disruption	√	√			√												

2.2.3 The construction industry in Ghana: An overview of safety, health and environmental management

In recent times, the construction industry in Ghana has become one of the fastest growing economic subsectors of the Ghanaian economy, with a growth rate of 30.6% and a 14.8% share of GDP (Ghana Statistical Service (GSS), 2018; Owoo and Lambon-Quayefio, 2018). The industry employs more than 320,000 people (GSS, 2013). Within the construction industry, there are about 23,000 registered contractors (Ministry of Education, 2010). The industry is increasingly dynamic and has a large private sector participation. The indigenous contractors are mostly small and medium-size, and just a few Ghanaians being owners of top-tier construction firms (Vulink, 2004). Even so, these well-established indigenous firms are owned by entrepreneurs who have limited formal education in project or building construction management (Vulink, 2004). The major construction players in Ghana are mostly multinational firms, with the government of Ghana and its developing partners being the largest investors in the construction industry (Osei, 2013).

Despite the socio-economic importance, the industry remains one of Ghana’s most hazardous industries, measured by the high numbers of accidents, fatalities and environmental impacts (Kheni *et al.*, 2008; Akomah *et al.*, 2010; Ayarkwa *et al.*, 2014; Djokoto *et al.*, 2014). The rates of negative environmental impacts and occupational accidents in developing countries like Ghana have generally been considered to be higher than in developed countries (Hamalainen, 2007; Yahaya and Abidin, 2013; Takala *et al.*, 2014). SHE in the Ghanaian construction industry is deemed to be alarmingly poor (Kheni *et al.*, 2008; Laryea and Mensah, 2010; Ayarkwa *et al.*, 2014). According to Chileshie and Yirenkyi-Fianko (2012), the Ghanaian construction industry accounts for the highest number of occupational accidents and deaths compared with other industrial sectors in the country. Available statistics show increase in work-related accidents and injuries between 2004 and 2009 (Nimo-Boakye *et al.*, 2010). Data held by Labour Department (2010) shows that 5% of all reported accidents on construction sites are fatal (Kheni *et al.*, 2010). Furthermore, there is constant degradation of the environment, pollution, substantial raw materials and energy consumption, which continue to take their toll on the country’s development (Ofori, 2012; Dadzie and Djokoto, 2013; Ayarkwa *et al.*, 2014).

While several efforts including Acts of Parliament seek to improve the industry’s SHE records, studies have attributed the poor SHE performance to the lack of a coherent health, safety and environmental policy solely for the industry and the violation of existing SHE policies and measures (Kheni, 2010; Ofori, 2012; Kheni and Briamah, 2014; Mustapha *et al.*, 2016). This situation has arisen because of the myriad of challenges the Ghanaian construction industry faces.

For instance, as a country, there is still no comprehensive and specific environmental, safety and health regulations solely for the construction industry considering how complex and risky the sector is. The existing safety and environmental laws for construction are fragmented and found in scattered generic requirements under different and lesser functioning government departments and agencies such as the Environmental Protection Agency (EPA), the Department of Factory Inspectorate, the Inspectorate Division of the Ghana Minerals Commission, and the Ghana Labour Commission (Tetteh, 2003; Kheni and Briamah, 2014). In these fragmented laws, environmental issues are left to the EPA to address, while all construction S&H issues are to be addressed by the client and the contractor (Dadzie, 2013). Unfortunately, the EPA, which is a regulatory body responsible for every aspect of environmental management in Ghana fail to monitor construction activities and rarely seek compliance of the EPA Act due to lack of resources and staff (Adjarko *et al.*, 2016).

The Ghanaian construction industry is also confronted with a situation whereby most of the government agencies and departments responsible for implementation of SHE standards suffer from lack of adequate resources and a high labour turnover (Kheni, 2010; Kheni and Briamah, 2014). Construction firms and organisations do not have human resource management (HRM) departments together with its associated safety and health personnel to deal with safety and environment related issues (Danso, 2005). Additionally, construction owners/managers are uninformed and do not have knowledge of the few legal frameworks governing environmental and safety issues and even which organisations to report accidents to (Kheni *et al.*, 2008). There is a general lack of awareness for safety and environmental considerations in construction activities and a lack of education, as well as the needed training of construction employees in SHE issues (Boyefio, 2008; Fugar *et al.,* 2013).

The practice of competitive tendering in the industry, where contractors with the lowest estimated tender are awarded with contracts aggravates the SHE situation further. This is because contracting companies in the quest to win contracts, are forced to tender low by cutting costs, which mostly affects the SHE aspects of projects (Kheni and Briamah, 2014). Furthermore, corruption and inadequate safety and environmental considerations in building projects delivery due to the cost involved in implementing safety measures, compounds the SHE performance problems in the industry (Kheni *et al.,* 2007; Mustapha *et al.,* 2016). The above challenges, all point to a poor SHE management culture, which is a disincentive to effective management of SHE issues in construction. It is, therefore, not surprising that the state of SHE performance in the Ghanaian construction industry is poor (Laryea and Mensah, 2010; Ametepey and Ansah, 2014; Annan *et al.*, 2015).

Due to the plethora of challenges facing the industry, the use of prescriptive regulations, where construction companies have to adhere to government regulations in managing, SHE issues have been found inadequate and ineffective (Laryea and Mensah, 2010; Adjarko *et al.*, 2016). The management of SHE issues have to be shifted from government inspectorate to individual construction company internally taking responsibility for the environment and managing their S&H risks and hazards. SHE management in Ghanaian construction companies should go beyond adherence to regulatory requirements and implement voluntary, proactive and systematic methods to ensure that construction operations impact on the environment is minimised and employees' safety and wellbeing are guaranteed. Management systems, particularly EMS and SHMS have been identified as one of the innovative and systematic approaches for companies to manage SHE risks effectively in order to improve their SHE performance. However, the adoption and implementation of EMS and SHMS in the Ghanaian construction industry, has been generally low, mainly due to the associated costs, lack of funds, expertise and staff, people's reluctance to change traditional practices and the bureaucracy that comes with the parallel implementation of standalone management systems (Ayarkwa *et al*., 2010; Kheni, 2010; Adjarko *et al*., 2016). Moreover, due to the poor SHE management culture in the industry, there is no robust mechanism by which construction companies are able to ascertain their SHE maturity in order to improve continuously. An integrated management of SHE through a single system could be less costly and onerous, and yet effective in delivering desired SHE performance outcomes, and also could be useful in stimulating greater adoption in the construction industry. This could ease the financial and resource burden associated with the implementation of separate stand-alone MSs by Ghanaian contractors. Evidence from empirical studies and the literature shows that well-structured EMS or SHMS or an integrated SHE management system can be more beneficial to construction companies than expected. Such benefits include: organisational competitiveness, improved reputation, high productivity improvements on site and project safety by lessening injuries and fatalities, creation of cost savings, in terms of waste management and pollution prevention, and identification of future environmental liabilities (Ofori *et al.*, 2002; Geipele and Tambovceva, 2011; Granerud and Rocha, 2011; Windapo and Oladipo, 2012). Consequently, there is a need for an integrated SHE management system and a robust mechanism by which Ghanaian construction companies can ascertain their capability in implementing integrated SHE management in order to guide efforts to improve their SHE performance.

2.3 Safety, health and environmental improvement in the construction industry

Occupational tragedies have significant socio-economic cost implications (ILO, 2012). According to ILO, about four percent of the annual GDP is lost due to work-related accidents and its attendant injuries and illnesses (ILO, 2012). In many countries, there are reports of high economic cost resulting from work-related tragedies. For instance, in Singapore, the Workplace Safety and Health Institute (WSHI, 2013) put the cost at occupational injuries and illnesses at $10.45 billion which is about 3.2% of the country's GDP and in the UK, the cost of work-related injuries and diseases is estimated to be around the £15 billion (HSE, 2018). In fact, the costs arising from these tragedies (i.e. accidents, injuries, fatalities and illness) in construction are huge. In South Africa, the Department of Labour (DoL) spends about 2.5 billion Rands each year on the compensation of claims related to health and safety in the construction industry exceeding that of the mining industry (DoL, 2008). In the USA, the costs of nonfatal and fatal injuries in the construction industry was estimated at $11.5 billion (Waehrer *et al.,* 2007). The costs associated with construction accidents, fatalities, illness and injuries include direct and indirect cost, which are mostly borne by the construction company, the victim and their family members, and sometimes the government and the construction client. Furthermore, construction has injurious effects upon the environment, both in the short-term and long-term. With the volume of construction output estimated to grow by more than 85% worldwide by 2030, the impact on construction workers safety and health would become much greater despite all the associated socio-economic benefits with such a significant growth (Global Construction Perspectives and Oxford Economics, 2015). This increase in construction activities raises possible adverse impacts on the environment and health and safety issues that have a financial cost. Clearly, there is, therefore, an urgency to improve SHE in the construction industry (Haslam *et al.,* 2005; Guha and Biswas, 2013; Okoye and Okolie, 2014; Muhammad *et al.,* 2015).

Efforts to address and improve SHE performance in construction have been wide-ranging including SHE reactive measures and some proactive initiatives. The rate of accidents and illnesses, negative environmental impacts and other well-being issues are still being recorded in construction through conventional practices. Also, with the social and economic impacts arising from these incidents the need for adopting and implementing voluntary and systematic approaches is critical for efficient management of SHE risks in construction. Consequently, prominent amongst these approaches is the systematic implementation of management systems in a construction company to mitigate the occurrences of injuries, illnesses and fatalities and also minimise the adverse environmental impacts of construction operations (Ayomoh and Oke, 2006; Sgourou *et al.,* 2010).

2.4 Management systems

In recent years, development and the use of management systems (MSs) has been one of the important advances in the field of management practice (Asif *et al.,* 2010). Through them, organisations promise to improve their management practices like security, health, safety, quality and environmental practices. According to Rebello *et al.* (2014), in today's competitive global business environment, organisations are under enormous pressure to meet the varied requirements of their stakeholders and their customers and so are implementing several MSs as and when they appear. For business sustainability, other relevant stakeholders other than customers, needs to be satisfied. As a result, several management system standards (MSSs) have been developed in an unprecedented manner in these last few years for voluntary implementation in all kinds of businesses with different foci.

Basaran (2018), reports 57 existing MSSs developed by International Organisation for Standardisation (ISO). Some of these standards, which are applicable for all sectors are shown in Table 2.2. Other sector specific standards are also available (e.g. ISO 13485 for medical devices production and ISO 16949 for the automotive industry). According to Heras-Saizarbitoria and Boiral (2013), these MSs are voluntary management tools that require organisations to implement certain rules and procedures to monitor different aspects of the organisations management issues and to improve their performance. They consist of requirements, processes and procedures for their implementations. A management system is, therefore, described as '*the organisational structure, responsibilities, procedures, practices, processes, activities and resources needed for the development, implementation, achievement and maintenance of an organisation's policies and objectives*' (BS 8800,1996). MSs provides a systematic management framework that assist organisations to maximise their competitiveness through continuous improvement of its product, people, services, and environment by emphasising teamwork, customer focus, long-term commitment to reduce their cost and losses during their production processes (Hoyle, 2005; Domingues *et al.*, 2012).

Table 2.2: Examples of existing management system standards

	Name	**Designations**	**Sources**
1	Occupational Health and Safety Management Systems	OHSAS 18001 ISO 45001	BSI (2007) ISO (2018)
2	Environmental Management Systems	ISO 14001	ISO (2004)
3	Quality Management Systems	ISO 9001	ISO (2008)
4	Energy Management Systems	ISO 50001	ISO (2011)
5	Risk Management	ISO 31000	ISO (2009)
6	Information Security Management Systems	ISO/IEC 27001	1SO (2005)
7	Research, Development and Innovation Management Systems	NP 4457	IDI (2007)
8	Asset Management Systems	ISO 55001	ISO (2014)
9	Business Continuity Management Systems	ISO 22301	ISO (2012)

Source: Authors construct (2017)

Considering the impacts of construction operations on the environment and the rate at which accidents occur on construction sites, construction organisations should be able to comply with safety and environmental standards like ISO 14001, OSHAS 18001and ISO 45001, since they are considered to be the authoritative ones for establishing and implementing MSs to guarantee their safe, reliable and economic management. As construction industry today is still characterised by resources depletion and deterioration, substantial resources consumption, accidents, injuries, illnesses and fatalities, the systematic implementation of SHE management practices stipulated in the MSs (i.e. EMS and SHMS) would enable construction firms to manage and control the key management functions of safety and environment for better SHE performance (Gasparik, 2009; Gangolells *et al.*, 2011; Fewings, 2013). A review of the EMS and the SHMS, as well as integrated management systems (IMS), is presented in sections 2.4.1 to 2.4.3.6.

2.4.1 Environmental management systems (EMS)

As the construction industry is one of the major generators of environmental impacts, construction companies must focus on aspects of environmental sustainablility of in all phases of construction projects. According to Rodriguez *et al.* (2011), environmental management efforts over the last few years, have grown rapidly in the construction industry due to the increase in social and environmental awareness of impacts of construction activities and stringent protocols. In achieving the objectives of cost, time and quality, as well as the environmental objective, construction firms can contribute to a considerable extent in achieving the environment goal by implementing aspects of sustainability in their business management (Srdić and Selih, 2011; Schmidt and Osebold, 2017). One of the more sustainable approach in addressing the environmental issue in construction is the adoption and implementation of EMSs in order to improve their environmental performance.

2.4.1.1 Defining an environmental management system

An EMS provides methods systematically designed to manage environmental aspects of production processes (ISO, 2015). According to Bansal and Hunter (2003), EMSs are a set of various organisational management practices focused on the identification, measurement and control of a firm's environmental impacts. Darnall and Edwards (2006) define EMS as *'systems of management processes that enable organisations to continually reduce their impact to the natural environment, requiring the assessment of their environmental impacts, establishing goals, implementing environmental goals, monitoring goal attainment, and undergoing management review*'. Similarly, Gasbarro *et al.* (2013) recognised an EMS as structured framework that encompasses organisational roles and responsibilities, and procedures for managing the organisation's environmental policy.

Considering the above definitions, an EMS can be described as a management tool that provides a systematic and integrated management framework which assists organisations to control and improve their environmental performance on a voluntary basis through the comprehensible allocation of resources, assignment of responsibilities, continuing evaluation of practice, management of its legal compliance and a focus on continuous improvement (ISO, 2015). EMSs, therefore, assists construction companies to take responsibility for environmental management, to improve their internal environmental management practices and address their environmental concerns. According to Sheldon and Yoxon (2006), an EMS framework is established for companies to build on-going 'continuous improvement' of environmental performance. Ejdys *et al.* (2016) stated that continuous process improvement within an EMS is an important attribute which ensures that new innovations and ideas are enhanced.

EMSs are developed based on MSSs, following the Deming cycle [i.e. Plan, Do, Check, Act (PDCA)], which expresses the concept of continual improvement (Heras-Saizarbitoria and Boiral, 2013). It consists of an environmental policy, as well as a set of processes that require organisations to assess their environmental impacts, establish and implement objectives and targets, monitor targets attainment, and undergo audits and a management review (Campos, 2012; Oliveira, 2013; WRAP, 2015). The elements of an EMS are presented in Figure 2.2 and Table 2.3.

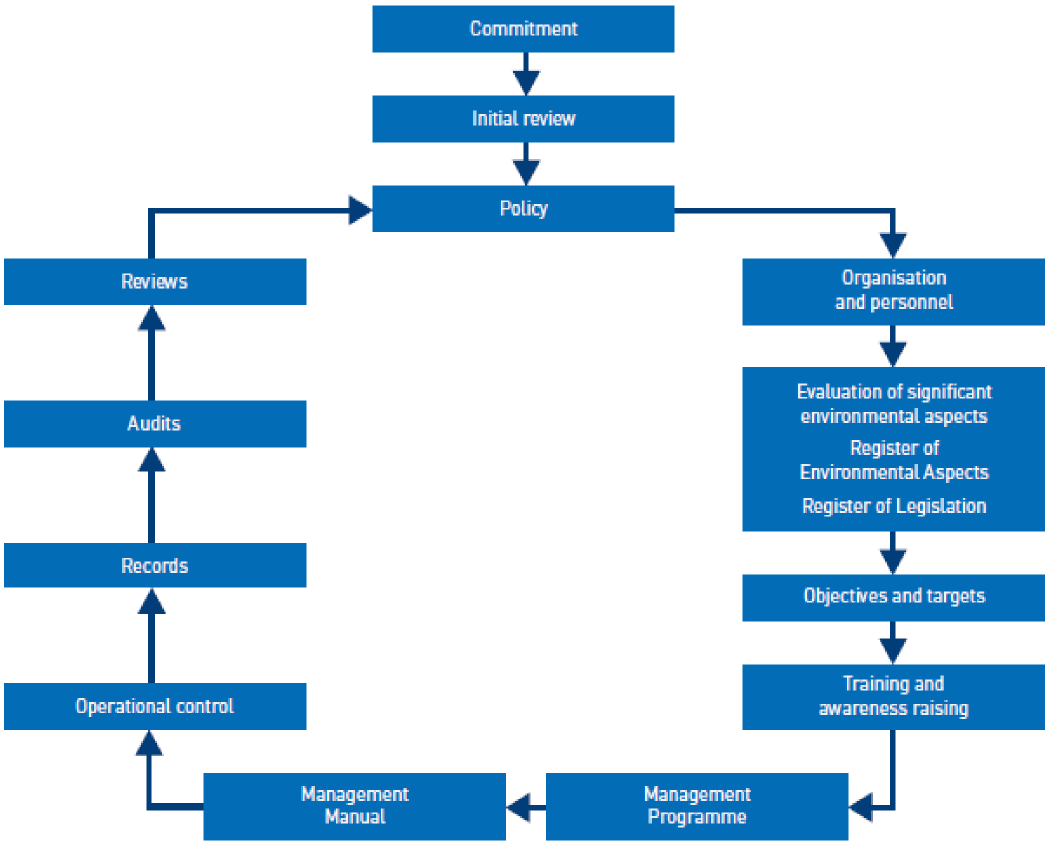

Figure 2.2: Elements of a typical EMS
Source: adapted from Waste and Resources Action Programme (WRAP), 2015 p. 3.

Table 2.3: A summary of key elements and requirements of an EMS

Management area element		Description and examples of practices
Plan(P)	Policy	• Preparing an environmental mission statement (policy). • The policy must be appropriate to the nature and scale of operations and covers all aspects of a company's operations. • It should address every legal requirements and regulatory compliance; the policy should also show a commitment toward continual improvement.
	Planning	• Planning for effective implementation e.g. registration of environmental aspects; preparing pre-project start EMS plans. • In accordance with the environmental policy, the EMS must identify formal documented goals and objectives relevant to a company's environmental, legal, and regulatory requirements.
Do (D)	Risk assessment	• Evaluation of risks and establishing necessary EMS measures to avoid further negative impacts e.g. preparing risk assessments and method statements.
	Organising	• The structural system to manage EMS e.g. human resources, financial resources, communication, and competence assessment. • The construction firm must make certain that the EMS assigns actions/ responsibilities for specific tasks, sets targets to measure progress, and establishes completion dates. • For example, the plan might identify environmental issues and select among possible mitigation responses.
	Implementation	• Actual implementation of programmes and control measures. • All the processes and procedures should be well defined and have the well-established modes of control that ensure success during implementation and operation. e.g. well-defined training programs and an effective document control system such as preparing a management manual.
Check (C)	Measuring and reviewing performance	• Maintenance and calibration of equipment and procedures: - Performance of EMS audits to ensure compliance by all individuals affected; - Maintenance of records of all checking and corrective action procedures; and • Developing requirements to track nonconformities e.g. using a controlled system of records.
Act (A)	Auditing/management review	• Undertaken of periodic auditing to ensure effective operation in order to ensure continuous improvement e.g. in-house and external consultant reviews • Top management must review (at least annually) the need for changes to the policy, objectives, and procedures.

Source: WRAP, (2015); Your Guide to Environmental Management Systems, (2015) p. 3; and Christini et al. (2004)

By adopting EMS, organisations learn to apply PDCA model into environmental management, which enables them to identify and minimise the potentially negative environmental effect of their operations and continually improve in this direction (Ozusaglam *et al.,* 2017). As an environmental management-oriented tool, EMS can be implemented in companies of any area and size, depending on the sector of activity and the needs perceived by the senior management (UNEP, 2007; Skouloudis *et al.*, 2013). In addition, an effective implementation of EMS in any organisation is dependent on senior management to gain support for the EMS at all levels within the organisations through effective communications; ensure the system remains running once it has been established and continuously reduces the organisations substantial environmental impacts (WRAP, 2015).

To date, EMSs have been the subject of academic inquiry. A number of studies have been devoted on EMS and its diffusion. Specifically, some have focused on motivations of the MSS implementation (Chan and Wong, 2006; Boiral, 2007; Gavronski *et al.*, 2008; Lopez-Gamero *et al.*, 2010; Prajogo *et al.*, 2012), while others have concentrated on the effects of the systems and standards on operational, financial and environmental performance (Melnyk *et al.,* 2003; Gomez and Rodriguez, 2011; Boiral and Henri, 2012; Zobel, 2013; Testa *et al.,* 2014). Studies have also emphasised the stronger environmental performance, improvements and increased visibility of environmental practices obtained from EMS implementation (Melnyk *et al.*, 2003; Potoski and Prakash 2005a, 2005b; Arimura, *et al.*, 2008; Gavronski *et al.*, 2008; Russo, 2009; Heras-Saizarbitoria *et al.*, 2011; Darnall and Kim, 2012; Nishitani, 2012).

Other studies have focused on the identification of internal and external factors that have impacts on the process of continuous improvement in companies (Brouwer, 2004; Neugebauer, 2012; Kim *et al.,* 2013). Though several researchers have argued that EMS is beneficial to improvements in organisations environmental performance, others are still less optimistic (Chen *et al.*, 2004; Barla, 2007; Boiral 2007; Prajogo *et al.*, 2012; Boiral and Henri, 2012; Zobel, 2013). Nonetheless, in line with extant EMS literature, a properly designed EMS can support both environmental and economic objectives of an organisation, and allow companies to manage their environmental issues such as pollution prevention and legal compliance (Maurel, 2013; IEMA, 2015).

As no process is without obstacles, the existing body of research on EMS suggest some challenges of implementation. The main barriers include: high costs, complex extensive documentation, lack of awareness and knowledge of environmental issues, huge investment in material and human resources (Ofori *et al.*, 2002; Valdez and Chini, 2002; Liyin *et al.*, 2006; Tarantini *et al.,* 2009; Turk, 2009; Zeng *et al.*, 2010; Sakr *et al.*, 2010; Geipele and Tambovceva, 2011; Gluch and Raisanen, 2012; Campus *et al.,* 2014). In relation to construction, studies on EMS adoption and implementation in construction companies have been wide and conducted from different perspectives (Ofori *et al.*, 2002; Zeng *et al.*, 2004; Abdullah, 2005; Selih, 2007; Turk, 2009; Sakr *et al.*, 2010; Campos *et al*, 2016; Schmidt and Osebold, 2017).

2.4.1.2 Existing environmental management system standards

EMSs based of management system standards are voluntary and are designed to be verified by nationally accredited bodies (Whitelaw, 2004; Chan, 2011). Most of all, the existing EMS is built on the Deming cycle (PDCA) management cycle to ensure that environmental issues are thoroughly identified, controlled, and monitored (Stapleton *et al.*, 2001). They also contain similar elements which embody specific environmental management requirements and procedures as shown in Table 2.4. For any company that wants to implement an EMS, the following four main systems/models are available.

1. The BS 7750;
2. The international standard ISO 14001;
3. The EU Eco-Management and Audit Scheme (EMAS); and
4. The British Standard BS 8555 (designed specifically for small and medium sized organisations).

Other models are:

- The responsible care model developed by the American Chemical Council (ACC). This is seen as an integrated singular environmental, health and safety and security management system. It would, therefore, be treated under integrated management systems.
- Environmental Protection Agency (EPA) National Enforcement Investigation Centre (NEIC) " Compliance Focused" EMS.

Details of some existing EMSs standards are presented next.

A) An EMS based on British Standard 7750 (BS 7750)

BS 7750 has been used as a specification of an environmental management system in organisations. It was developed in 1992, as a response to concern about real and potential environmental risks and damage. Later, it was reviewed and revised in 1994 (Quality Network, 2006). BS 7750 is compatible with the European Community's Eco-Management and Audit Scheme (EMAS) and also with ISO 14001. Organisations use this system to describe its environmental management system, evaluate its performance and also provides a basis for continuous improvement by using Deming's (PDCA) management cycle. For organisations to successfully implement an EMS based on the BS 7750, they require a clearly defined environmental policy which is fully supported by senior management, well -defined plan encompassing the objectives and targets of the company, the provision of sufficient resources, a good training programme and an effective monitoring, reporting and review process. These companies do not need to produce an independently verified environmental statement for public scrutiny as seen with the EMAS based EMS. In 1996, BS 7750 was replaced by the ISO 14001.

B) ISO 14001(Environmental management system by ISO)

The ISO 14001 is an EMS standard developed by ISO. It was first published in 1996, technically revised in November 2004, with a third edition published in September 2015 as ISO 14001:2015 (Briggs, 2012; BSI, 2013). The ISO 14001 standard was developed to help minimise negative environmental issues, such as greenhouse gas emissions (global warming), ozone depletion in the upper atmosphere, the loss of biodiversity, deforestation, and depletion of the earth's natural resources. As a strategic management and marketing tool, ISO 14001 as an EMS standard, shows a company's commitment to environmental protection and enhancement (Darnall, 2006). The unique features of this standard are its ability to embrace the concept of sustainable development and also allows for easier integration into other management systems due to the same structure, terms and definitions (ISO, 2015).

The standard was developed around Deming's (PDCA) model of improvement (Kausek, 2007). It contains 17 key requirements that are grouped into five key process areas: environmental policy, planning, implementation and operation, checking and corrective action, and management review as presented in Figure 2.3. This standard is a voluntary, consensus-based and the most widely used standard worldwide. It can be used by any company, regardless of industry, size, location, and the level of their environmental responsibilities. Additionally, it maps out a framework that a company follows to establish an effective EMS by specifying the actual requirements for the system (ISO, 2012). According to Christini *et al.* (2004), it does not require any environmental performance metrics, but the system just has to comply with applicable legislation and regulations and implement a continual improvement process. Therefore, an EMS based on ISO 14001 does not include a commitment to the continual improvement of environmental performance as in the case of EMAS, but focuses on the continual improvement of the performance of the management system.

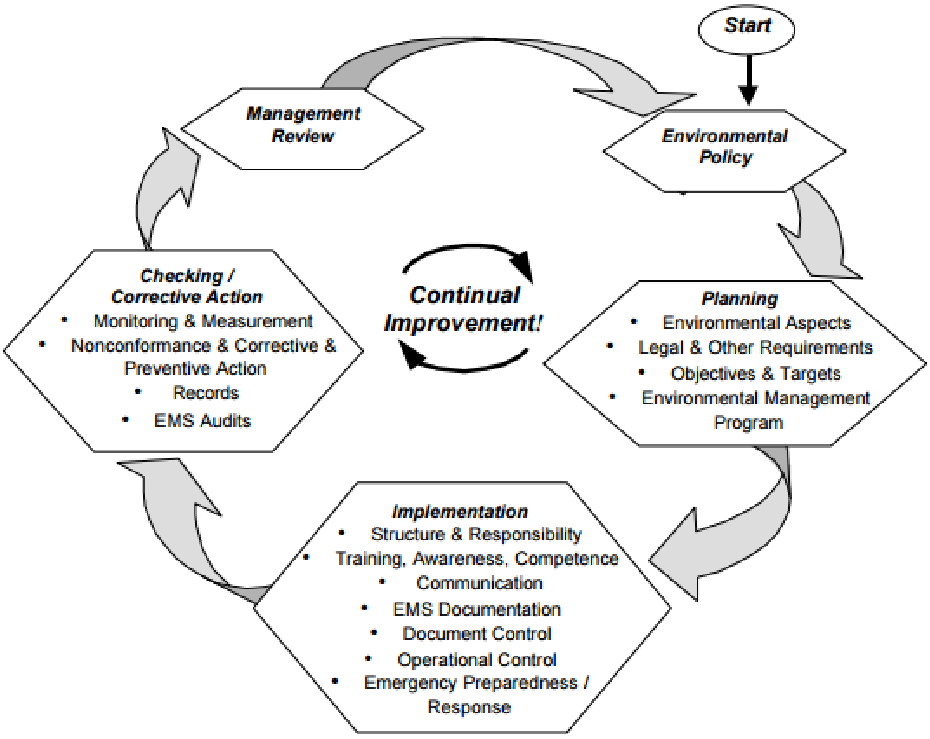

Figure 2.3: EMS model
Source: Stapleton et al., (2001 p. 14)

The revised standard ISO 14001:2015 is based on following environmental management elements: Context of the organisation, Leadership, Planning, Support Operation, Performance evaluation, Improvement (Figure 2.4). According to ISO, this EMS standard just divides the key requirements and procedures into more subcategories with more descriptions than ISO 14001:2004 but the principal requirements and intent of the standard have substantially remained intact. This management system standard, when followed, provides reasonable assurance that the resultant outputs from the system will significantly reduce the negative environmental impact and improve environmental performance. This positive influence on a company's environmental performance (Radonjic and Tominc, 2007; Iraldo *et al.*, 2009) also brings about improved financial performance (Zahra, 1993; Rais and Goedegebuure, 2009; Ferron *et al.*, 2012). According to Link and Naveh (2006) and Yin and Schmeidler (2009), companies who adopted and implemented EMS based on this standard have improved significantly on their environmental performance. ISO 14001 EMS can be effective if documented procedures are implemented and maintained such that a successful achievement of environmental goals commensurate with the nature and scale of activities. The EMS should also include appropriate monitoring and review processes to ensure effective functioning of the system and also identifies and implements corrective measures in a timely manner (Famiyeh, 2005).

Figure 2.4: EMS model for ISO 14001 (2015)
Source: 14001 International Standard 2015([**https://www.iso.org/obp/ui/#iso:std:iso:14001:ed-3:v1:en**](https://www.iso.org/obp/ui/#iso:std:iso:14001:ed-3:v1:en))

C) EMS based on the Eco-Management and Audit Scheme (EMAS)

EMAS is an environmental management scheme based on EU-Regulation 1221/2009. It was originally established by European Regulation 1836/93 but has been updated twice with Regulation (EC) no. 1221/2009 which came into effect in January 2010 (European Commission (EC), 2016). Primarily, it was confined to industrial operations, but in 2001 it was extended to all other sectors in the economy (Testa *et al.*, 2014). It was developed by the EC for companies and being operative since 1995. It allows organisations to continuously, evaluate, report, and improve their environmental performance (EC, 2016). The system also follows Deming's management cycle. EMAS requires, participating organisations, to frequently provide the public an environmental statement that reports on their environmental performance over time.

EMAS is similar to the 1SO 14001 and share the same objective, but EMAS places more emphasis on areas like the continual improvement of environmental performance; compliance with environmental legislation ensured by government supervision; public information through annual reporting and employee involvement (EC, 2008). ISO/EN ISO 14001 is the management system element of EMAS and allows companies to easily progress from ISO/EN ISO 14001 to EMAS without repeating procedures. The procedure for adopting and implementing an EMS based on EMAS standard is similar to that of an EMS based on ISO 14001 standard, since both require commitments to conform to applicable environmental regulations and to improve their environmental performance continuously (Watzold, 2001; EC, 2016). Also, legal compliance is a necessary condition for EMAS certification but not for ISO 14001.

Furthermore, EMAS standard requires companies to communicate their significant environmental impacts of their operations to the public and to publish their environmental statement whilst the ISO 14001 standard only requires a response to relevant communication from external interested parties.

D) The BS 8555 Standard (Acorn Scheme)

The BS 8555 standard for an EMS was developed and piloted in 2003 by the Institute of Environmental Management Assessment (IEMA) Acorn Scheme. The Acorn Scheme, which is a United Kingdom Accreditation Service (UKAS) accredited scheme allows for the certification of organisations to implement an EMS in the phases set out in BS 8555:2003 (Figure 2.5). An EMS based on this standard is implemented in about five individual phases, with an optional sixth phase offering the chance to progress to EMAS or ISO 14001 registration. The standard breaks EMS implementation down into a series of defined, manageable phases as follows:

- Phase 1 Commitment and establishing a baseline
- Phase 2 Identifying and ensuring compliance with legal and other requirements
- Phase 3 Developing objectives, targets and programmes
- Phase 4 Implementation and operation of the EMS
- Phase 5 Checking, auditing and review
- Phase 6 EMS acknowledgement (getting ISO14001 and/or EMAS)

(*Adapted from WRAP, 2015 p. 4)*

Each phase is sub-divided into a series of stages, and each stage is sub-divided into a range of tasks for completion. This three-tier approach breaks the implementation down into an easy to use, step-by-step methodology, which is ideal for SMEs with limited resources, but have made progress in managing their impacts on the environment, to be credited for their efforts. It also follows the Deming’s cycle. Using this approach for a functional EMS is established which is flexible and as such the rate and extent of environmental performance improvement lies with the companies themselves. The participating company can decide to implement two or more phases at a time, choose to remain at any phase for an unknown period of time, provided that they undergo annual re-inspection and can show continual improvement in environmental performance. According to WRAP (2015), BS 8555 also incorporates ISO 14031:2000, which guides the environmental performance evaluation process. This permits a company to develop tasks which concentrates on pointers that add value and are driven by company needs e.g. competitive advantage, views of interested parties and turnover. Companies implementing this type of EMS need to show documentary evidence of their environmental aspects, which they have considered or a register of environmental aspects which have been maintained in the case of certification to ISO 14001 and EMAS respectively.

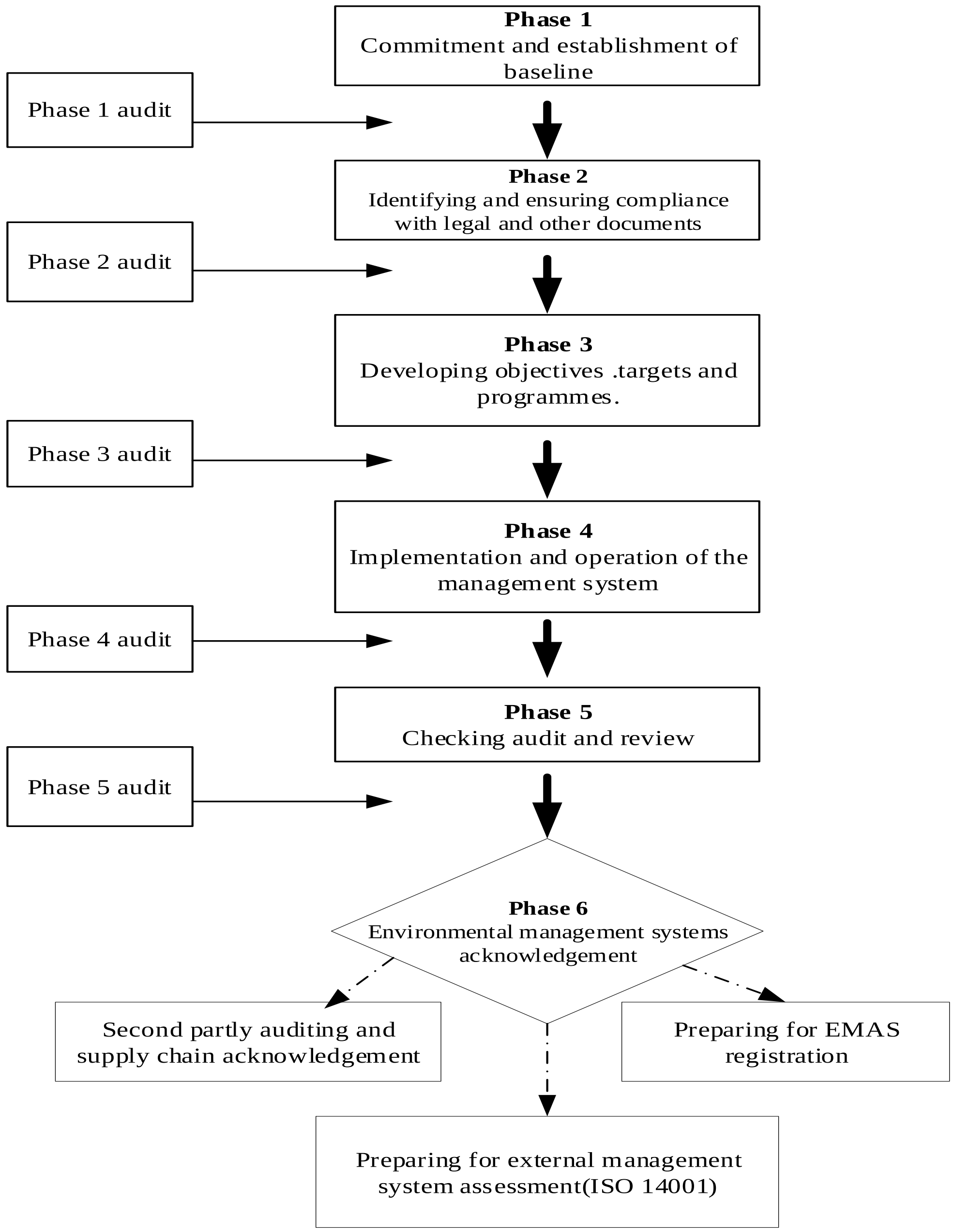

Figure 2.5: Overall process for phased implementation.
Source: BS 8555 (2003)

E) Compliance-focused environmental management system

The United States Environmental Protection Agency (EPA) National Enforcement Investigations Centre (NEIC) in 1995, developed the key elements of a compliance focused EMS (CFEMS) model as a solution to the increased noncompliance with environmental regulations as a result of inadequate EMSs. This guide has been used as the basis for EMS requirements in many enforcement settlement agreements, since it is mainly focused on compliance (Sisk, 2009). CFEMS model is implemented as part of the enforced settlement agreement when there are several environmental violations that arise from general management problems (Housman, 2004). This standard has been updated four times with the last version released in June 2005. The CFEMS model contains 12 elements that support the extensive, multimedia, beyond-compliance approaches that are the hallmarks of an effective and functioning EMS, such as an environmental policy, non-compliance investigations, environmental training and competence (Sisk, 2009). A CFEMS model can be used by organisations as a probable useful tool to supplement their existing EMS standards to address internal and external compliance concern by filling potential compliance-related gaps. The guide also embodies Deming’s (PDCA) approach for continual improvement. This system after implementation for one to three years must be audited, by an independent third-party auditor for verification. The audit helps promote EMS improvement and more effective implementation. According to Sisk, (2009), the use of CFEMS model guide allows organisations to develop an EMS that will both improve its compliance with applicable environmental requirements and ultimately improve their environmental performance through setting and achieving the organisation's environmental targets and objectives.

Table 2.4: A summary of existing environmental management systems

System Components	BS 7750	1SO 14001	EMAS	BS 8555	CFEMS
Company environmental policy	√	√	√	√	√
Senior management commitment	√	√	√	√	√
Initial review of environmental impacts and issues		√	√	√	√
Register of environmental regulations	√		√	√	
Register of significant environmental impact	√		√	√	
Allocated responsibilities	√	√	√	√	√
Objectives and targets	√	√	√	√	√
Management programme	√	√	√	√	√
Manual and Documentation	√	√	√	√	√
Operational controls	√	√	√	√	√
Records	√	√	√	√	√
Training	√	√	√	√	√
Internal audits	√	√	√	√	√
Public statement/reporting		√		√	√
System verification	√	√	√	√	√
Statement and report verification		√		√	
Commitment to continuous improvements	√	√	√	√	√

Source: Author construct (2017)

2.4.1.3 Environmental management systems in construction

An EMS for a construction company is a management solution that allows the company to demonstrate its ability to address and minimise its environmental impacts, manage legal compliance and continuously improves its environmental performance (Morrow and Rondinelli, 2002; Teriö and Kahkonen, 2011; WRAP, 2015). Its adoption and implementation within the construction industry is low mainly due to the cost involved and the lack of initiative in the industry towards the environment (Piñeiro and Garcia 2007; Glass and Simmonds, 2007; Griffith and Bhutto, 2008; Campos *et al.*, 2014). According to Oliveira *et al.* (2016), EMS implementation in some countries has been due to compulsion of the market demands within those countries and the reported benefits. On the other hand, construction companies in developing countries have found a major implementation deterrence due to the high cost of resources required for EMS implementation (Ayarkwa *et al.* 2010; Sakr *et al.*, 2010; Owolana and Booth, 2016). Although, few construction companies have implemented EMS, several benefits have been derived from its implementation (Christini *et al.*, 2004). For instance, Shen and Tam (2002) indicated that effective waste management during EMS implementation led to reduced hazardous waste generated from both onsite and offsite construction in processes and provided a safe and clean construction sites. In Hong Kong, Zeng *et al.* (2003) noted that Chinese construction companies were able to enter into international markets, reduce waste and noise control and improve S&H at workplaces by implementing an EMS. Šelih (2007) reported that in Slovenia, additional competitive advantage was gained by construction companies who implemented EMS compared to those that did not implement EMS. In Egypt, there was increased competitiveness and entry into wider markets and improved environmental awareness (Sakr *et al.,* 2010).

Extant literature suggests that, the main improvements of an EMS implementation in construction companies include: reduced cost of waste management; savings in consumption of energy and materials; lower distribution costs; improved corporate image and reputation; reduced environmental impact and eliminating unnecessary materials, including substituting costly toxic inputs for environmentally friendly ones, improving returns on assets and continuous improvement of environmental performance (Koehn *et al.,* 2003; Turk, 2009; Geipele and Tambovceva, 2011; Qi *et al.,* 2012; Su *et al.,* 2015; Ferron Vílchez and Darnall, 2016; Ozusaglam *et al.,* 2017; Schmidt and Osebold, 2017). In spite of these reported benefits of EMSs, construction companies in some developing countries in Sub-Sahara Africa have failed to implement the necessary adjustments resulting in slow progress as compared to the rest of the world (Adebayo, 2002; Sakr *et al.,* 2010; Ayarkwa *et al.,* 2010; Owulana and Booth, 2016).

2.4.2 Safety and health management systems (SHMS)

Safety and health management systems (SHMSs) are management tools that are different from traditional occupational safety and health (OSH) programs by being more proactive, better integrated internally and including elements of evaluation as well as focusing continuous improvement process (Robson *et al.*, 2007). Their ultimate objective of is to assist organisations to create and maintain a safe working environment, while protecting and preserving human life and facility resources in the workplace (Pheng and Pong, 2003). Though SHMSs take into account most aspects of OSH, there is no consensus on the definition of SHMS among researchers, organisations and institutions (Robson *et al.*, 2007).

2.4.2.1 Defining a safety and health management system

The Health and Safety Executive (HSE) definition of SHMS is a "*formal management system or framework that helps to manage S&H" (HSE, 2013).* ILO defines it as *"a set of interrelated and* *interacting elements to establish S&H policy and objectives, and to achieve those objectives"* (ILO, 2001). According to the International Civil Aviation Organisation (ICAO), SHMS is "*systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures*" (ICAO, 2007). Gallagher (2000) defines SHMS as *"a combination of the planning and review, the management, organisational arrangement, the consultative arrangements, and the specific programme elements that work together in an integrated way to improve health and safety performance*". According to Bryan (1999), a SHMS is "*a planned, documented and verifiable method of managing hazards and associated risks*". From the above definitions, SHMSs can be described as management-oriented tools that provide methods systematically designed to help organisations to reduce work-related injuries, ill-health and fatalities, and continually improve overall S&H performance by demonstrating conformity to established requirements (Abad *et al.,* 2013; Phung *et al.,* 2015; Nunhes *et al.,* 2016).

It consists of detailed program elements, requirements and procedures that are combined for health and safety performance improvements (Biggs *et al.,* 2005). The requirements of SHMS are similar to the EMS standards and the section numbering is nearly the same. The primary difference is the ''risk assessment'' section which replaces the environmental aspects section in the EMS standards, and the substitution of the words ''health and safety'' for ''environmental.'' Generally, SMHS comprises of four main elements, namely: Planning; Doing (implementing the plan); Checking (reviewing the plan) and Acting (evaluating and taking measures to improve strategy) as shown in Figure 2.6. The planning phase involves the development of a company's policy and identifying S&H issues. The DO (i.e. the implementation phase) involves risk profiling, organising and implementing measures to manage S&H risks. The checking phase involves measuring performance and investigating accidents/incidents/near-misses and finally, the acting or evaluating phase involves reviewing performance and acting on lessons learned, including from audit and inspection reports (HSE, 2013; Royal Society of Chemistry, 2014).

SHMS are developed based on management systems standards. With the most reputable being the Occupational Safety and Health Administration's Voluntary Protection Program, International Labour Organisation guidelines (ILO-OHS-2001) and Occupational Health and Safety Assess-ment Series (OHSAS 18000). Over the years the standard on Occupational Health and Safety Assessment Series (OHSAS) 18001:2007 developed by the British Standard Institute has emerged the most widely used standard for SHMS, albeit a new international certifiable standard ISO 45001 that has recently been published to replace OHSAS 18001. According to Mohammadfam *et al.* (2017), these standards have been implemented systematically in most organisations to help identify and address S&H risks and hazards. The ultimate objective of these safety standards is, therefore, to assist adopting organisations to support and promote good occupational health and safety practices through systematic and structured management systems (Chang and Liang, 2009).

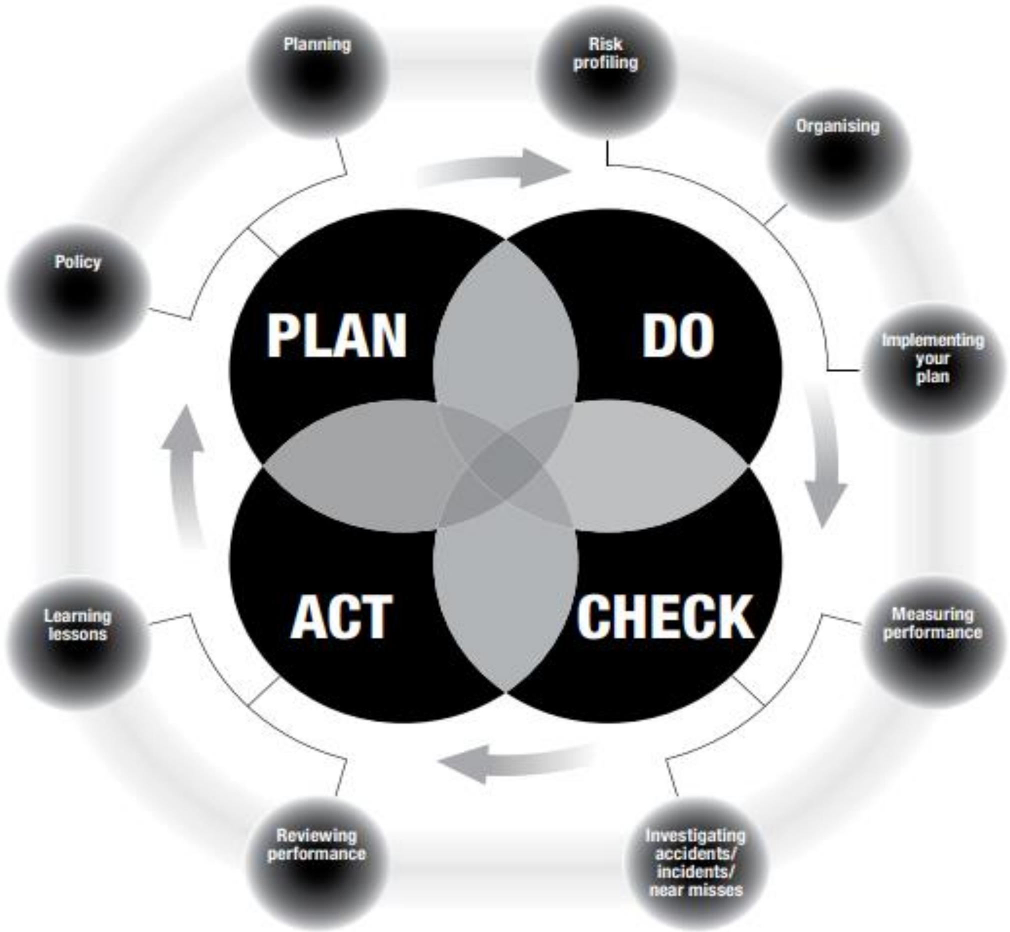

Figure 2.6: Elements and actions of a H&S management system following Deming's cycle.
Source: HSE, (2013) p.5

Recent research indicates that SHMS implementation plays a fundamental role in addressing OSH problems, reducing occupational risks as well as improving worker safety and creating better and safer workplace conditions (Granerud and Rocha, 2011; Podgorski, 2015; Mohammadfam *et al.,* 2017). As a result, a number of studies have been devoted to the implementation and efficacy of SHMSs. Particularly some studies have investigated the performance of SHMS (Hobbs and Williamson, 2003; Rosenthat *et al.*, 2006; Robson *et al.*, 2007; Bottani *et al.*, 2009; Fernandez-Muniz *et al.*, 2009; Vinodkumar and Bhasi, 2010; Arocena and Nunez, 2010; Hamidi *et al.*, 2012; Abad *et al.*, 2013). Other authors have also concentrated on the benefits of SHMS implementation workers attitudes toward unsafe acts, and its effects on the occupational accidents rate (Teo and Ling, 2006; Remawi *et al.*, 2011; Santos *et al.,* 2013;

Watcher and Yorio, 2014; Micheli *et al.,* 2019). Though, other researchers have argued that SHMS is beneficial to improvements in organisations OSH performance, Robson *et al.* (2007) suggest that the current body of evidence is insufficient to decide whether to support S&H management system. Ghahramani (2016) argued that a well-designed, effectively implemented and managed SHMS contributes to improvements in a company's working conditions and management practices, the prevention of injuries as well as increasing productivity and improving internal safety communication.

2.4.2.2 Existing safety and health management systems standards

Fernández-Muñiz *et al.* (2009) suggests that, due to the lack of empirical research in identifying the elements that makes up an adequate SHMS, a combination of the characteristics of the management systems from both national and international regulations and guidelines have been developed by various bodies and institutions from several countries. Thus, different variants of SHMS are available. The most prominent ones include: BS 8800:1996, from the British Standards Institution (BSI); HSE, 1997, 2013; OHSAS international guidelines 18001/18002:1999; Guidelines on occupational safety and health management systems from the ILO (2001) amongst others. The structures of these guidelines are comparable (Hamid *et al.,* 2004). They also contain similar elements which embody specific S&H management requirements and procedures, however, in the field of occupational health and safety management, the standard on Occupational Health and Safety Assessment Series (OHSAS) 18001: 2007 developed by the BSI is the most widely used standard for SHMS, albeit the new international certifiable standard ISO 45001 that has been established to replaced OHSAS 18001 (ILO, 2013; Granerud and Rocha, 2011; Abad *et al.,* 2013).

A review of some of existing SHMSs with its associated elements and sub-elements are presented next.

A) Successful health and safety management guidance (HSG 65)

Officially known by its series number HSG 65, the model was first published in 1991 and reviewed in 1997 by HSE (RCS, 2009). It is a universal non-mandatory blueprint, conceived as the OSH standard for all sectors of occupations. Its objective is to lessen occupational accidents through an effective and proactive management structure (HSE, 1997).

According to Snowball (1998), it embraces OSH as an integral part of the management function. The HSG65 embraces the Deming's (PDCA) management model and describes the systematic

“POPIMAR” (policy, organisation, planning and implementing, measuring, auditing, reviewing) model for managing health and safety. This model reflects exactly how Lingard and Rowlinson (2005) described a SHMS to be. According to Lingard and Rowlinson (2005) a SHMS should consist of “*a clearly defined policy, well-defined plans incorporating specific objectives, strong management commitment, the provision of sufficient resources, a systematic training programme, effective monitoring and reporting of performance and a process for reviewing performance and making improvement*.” The HSG 65, therefore, mirrors this characterisation (HSE, 1997). Though the HSG 65 is easy to understand, it has also been criticised for its lack of clarity and specification of its inputs and outputs, lack of empirical evidence to support its practicality and redundancy of auditing and measuring performance (Perezgonzales, 2005). According to Hasle and Zwetsloot (2011), the auditing phase of this model position an organisation to comply with requirements from S&H laws rather than preventing occupational injuries and illnesses. Despite these drawbacks, HSG 65 is the basis of several succeeding OSH management standards. The model comprises of mainly six components as shown in Figure 2.7.

Based on HSE (1997), the elements are defined as follows:

Policy: An effective health and safety policy crafted in line with the organisation’s core activities and current legislation to show a clear direction for the organisation to follow.

Organising: Designing an effective management structure and allocating resources for delivering the OSH policy. That is to develop the organisation to sustain effective communications, promote competence at all levels and leadership to maintain a common culture supportive of health and safety.

Planning and implementation: Having a planned and a systematic approach to implementing the health and safety policy through an effective health and safety management system.

Measuring Performance: Performance is measured against agreed standards to reveal when and where improvement is needed.

Auditing and Reviewing of Performance: Reviewing and continuously evaluating the effectiveness of the SHMS. Lessons and relevant experiences are then documented and applied correctly so as to achieve continuous improvement.

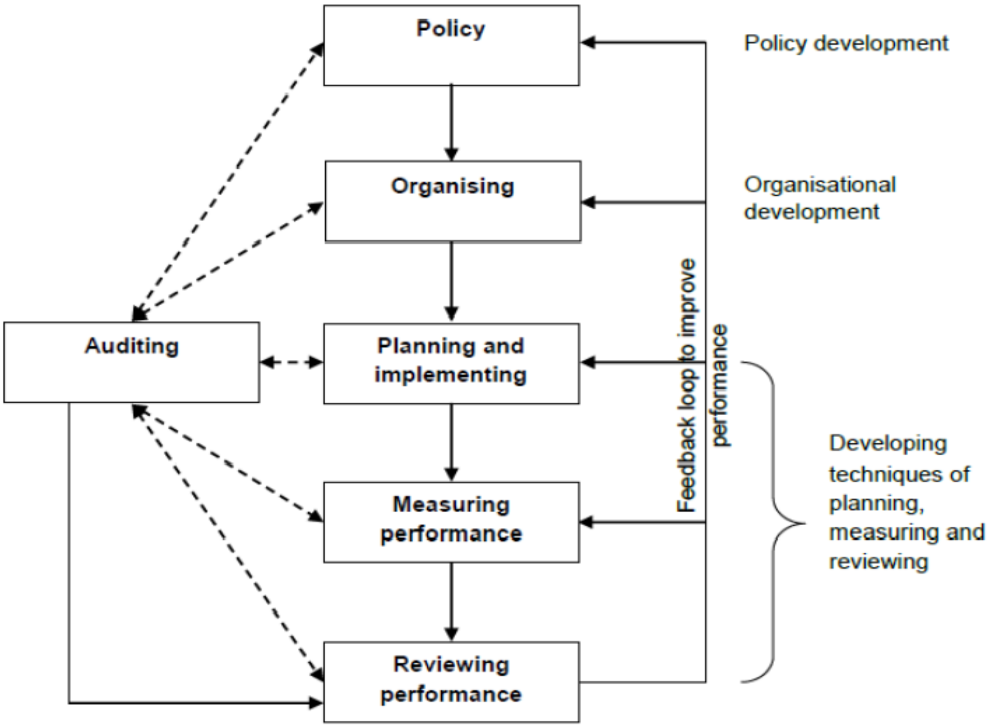

Figure 2.7: Key components of successful H&S management
Source: HSE (1997)

B) McDonald *et al.*'s safety management model

This model was adapted and proposed from the health and safety management model from HSE (1997) by McDonald *et al.* (2000). This SHMS sought to integrate the key features of a safety management system, developed as a practical guide for management (HSE, 1997) and also the main elements of safety culture as outlined by Pidgeon and O'Leary (1994). The SHMS is basically a self-regulatory and feedback model. It resulted from a study on safety management in four aircraft companies in Europe. According to McDonald *et al.* (2000), the model was used to understand how aircraft maintenance organisations manage safety in their operations, considering all human and organisational aspects of safety found in incident reports. The model contains seven components which are divided into two functions: operational performance and system auditing as shown in Figure 2.8. It emphasises on the sequential nature of safety policy (general goals and strategies to achieve the goals), standard setting (global criteria to assess the organisational safe level), planning and execution (management activities to ensure adequate resources provided for managing S&H performance), safety and normal operational practice (the normal practice and attitude carried out in the organisational functions) and the idea that this entire sequence is subject to review.

The whole process is controlled by the "monitoring" and "feedback" elements with adjustment or changes carried out accordingly at any level in the system to improve its effectiveness. McDonald *et al.* (2000) indicated that the model proved to be an effective tool for relevant features of each organisation's safety management system to be scrutinised, yet the important roles of planning and change were found to be underrated. Nevertheless, the model is understandable and its linear-structured elements are easy to follow. According to Pérezgonzález, (2005), though the model is supported by an empirical study, it needs to have more follow-up confirmations to demonstrate its effectiveness in addressing safety issues in its niche.

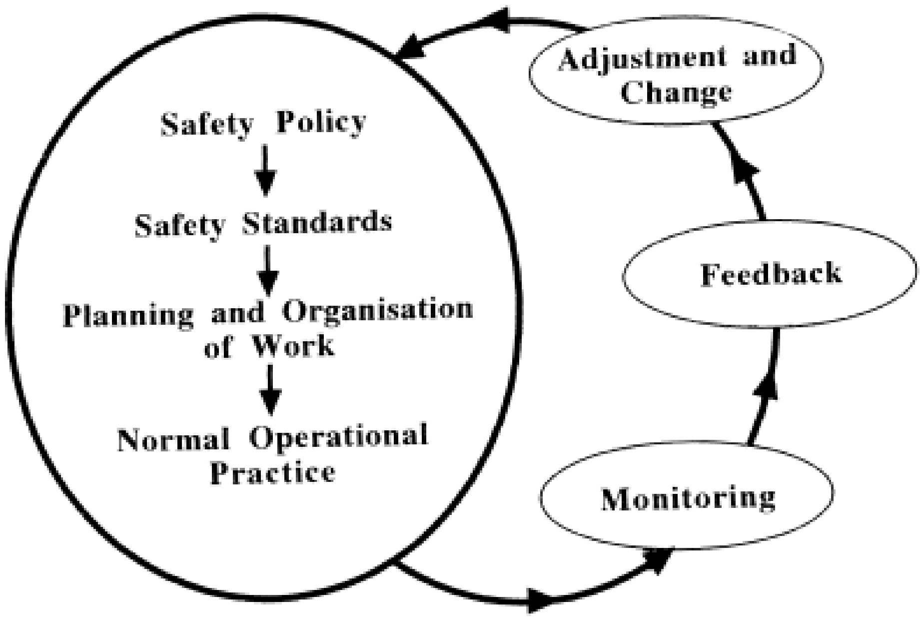

Figure 2.8: McDonald *et al's* safety management model
Source: McDonald et al., (2000) p.171.

C) Perezgonzalez safety management model

Pérezgonzález (2005) safety management model is an enhancement application of the McDonald *et al's* (2000) model and HSE (1997). The revised version gives a clearer explanation of the theory of McDonald *et al.'s* (2000) model into practice. Its main elements include policy, planning and organisation, operational practice and monitoring. Pérezgonzález (2005) safety management model also consists of a number of layers and components in two main loops; whereby, each element has influence upon the full system and allows for the logical, effective flow of information to achieve goals. As shown by Figure 2.9, the primary loop starts from the planning and organisation of work phase and finishes at the post adjustment and change phase whiles the secondary loop starts from the safety policy and also ends at the post adjustment and change (Pérezgonzález, 2005). This system is used to influence the operating system to maintain health and safety.

Pérezgonzález (2005) argues this system is different from the McDonald *et al.'s* (2000) model in two ways. First, it consists of data from day-to-day operating tasks rather than the general goals and strategies which creates the primary loop process and the second is the inclusion of risk assessment and pre-adjustment and change phases. Goals and strategies (safety policy and safety standards) therefore need to be clarified by short-term goals (e.g. weekly, monthly, quarterly or annually) through the planning and organisation of work. Additionally, feedback can be received from risk assessment (an independent element of the management process) or from pre-adjustment and change phases based on experience/knowledge. This ultimately ensures that negative results are prevented in the next stages. Both loops end at the post-adjustment and change stages, but adjustment, can be made at the planning and organisation component rather than the safety policy. However, Pérezgonzález (2005) noted that though it is a detailed management model, it still needs more practical examinations to demonstrate its effectiveness.

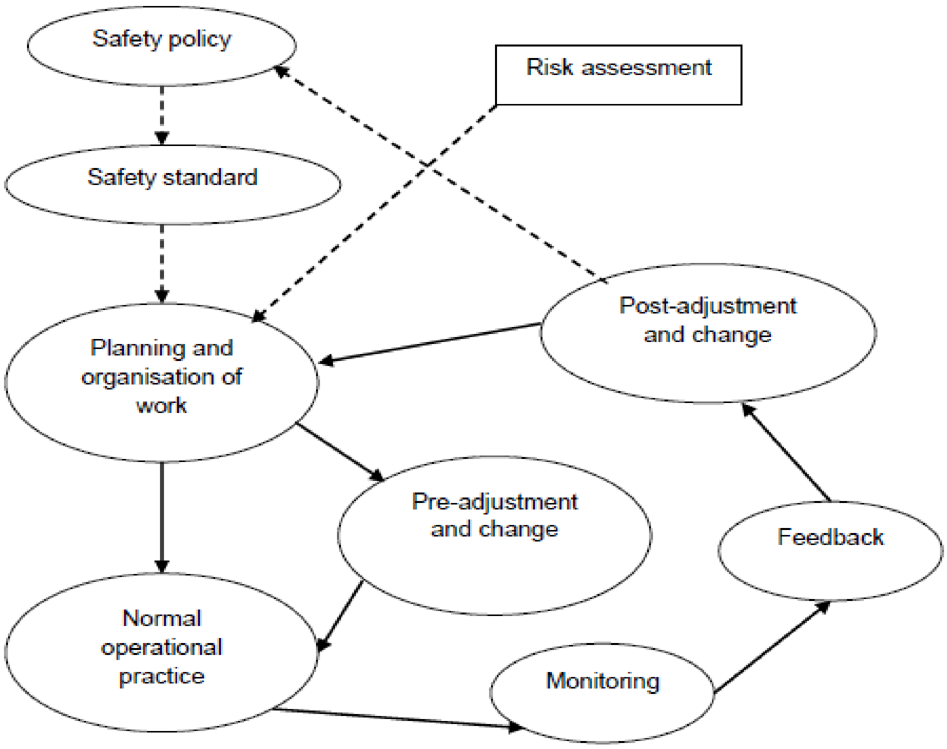

Figure 2.9: Safety management model
Source: Perezgonzales (2005)

D) ILO's Occupational safety and health management system

The ILO in 2001 developed its own non-certifiable guidance, “Guidelines on occupational safety and health management systems (ILO-OSH, 2001) after it reviewed over twenty national OHSMSs presented to it. ILO-OSH 2001 tackles the SHMS at the organisational level. It stresses on the employer being responsible for the compliance with national laws and regulations. Furthermore, the guidelines encourage the integration of SHMS elements into overall policy and management arrangements of any organisation. In general, the difference between this model and BS OHSAS 18001’s is mainly in the wording of the elements. The elements of ILO-OSH 2001 are shown in Figure 2.10.

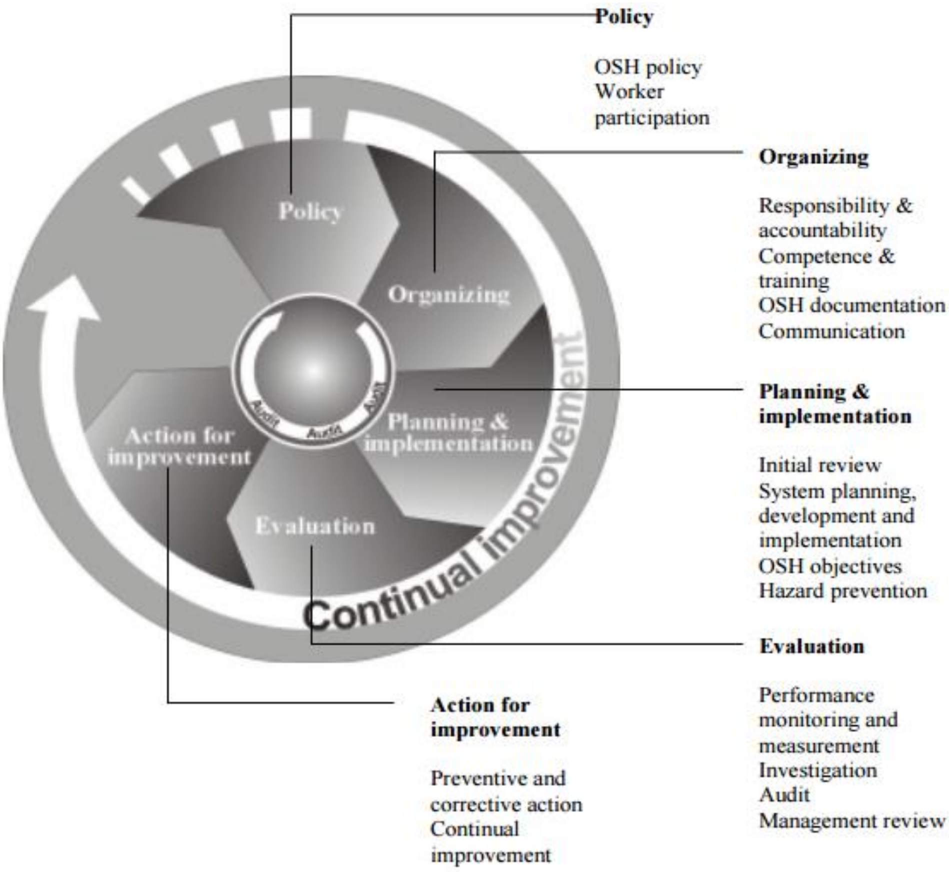

Figure 2.10: ILO Occupational safety and health management system
Source: Save world ILO Geneva p.4

E) BSI's occupational safety and health management system

This SHMS was previously BS 8800:1996 until it was revised and updated in 2004 as OHSAS 18001. The BS 8800:1996 was developed due to the demand for good practices in S&H management under the UK management of Health and Safety at Work Regulation 1992 (RCS, 2014). This OHSAS standard provides requirements and procedures that assist an organisation to develop and implement its policy and objectives considering legal requirements and occupational health and safety risks. Though OHSAS 18001 was not created by ISO, it was designed to be compatible with ISO 9001 (Quality) and ISO 14001 (Environmental) standards. This makes it possible for OHSAS 18001: 2007 to be integrated with other management requirements to help construction organisations to achieve S&H and economic objectives (BSI, 2007). OHSAS 18001 offers a useful framework for safety management in construction operations, which can inspire a safety culture towards sustainable construction, but it is still not commonly adopted in the construction industry (Zeng *et al.*, 2008). The management system model used in OHSAS 18001 is the ISO 14001 model. The distinction between OHSAS 18001 and ILO-OSH 2001 is mainly in the order in which the elements are addressed. The intent and basic requirements are common to all the two documents. Even though OHSAS18001:2007 has been criticised for its lack of cogent direction and clarification on the purpose of non-financial audit (Perezgonzalez, 2005), it is still the most widely used standard from SHMS implementation (BSI, 2007). It has been replaced by ISO 45001 which is the new international standard for OHSMS by ISO (Granerud and Rocha, 2011; ILO, 2013; Kafel, 2016; BSI, 2016). The elements of the BS OHSAS 18001:2007 are shown in Figure 2.11.

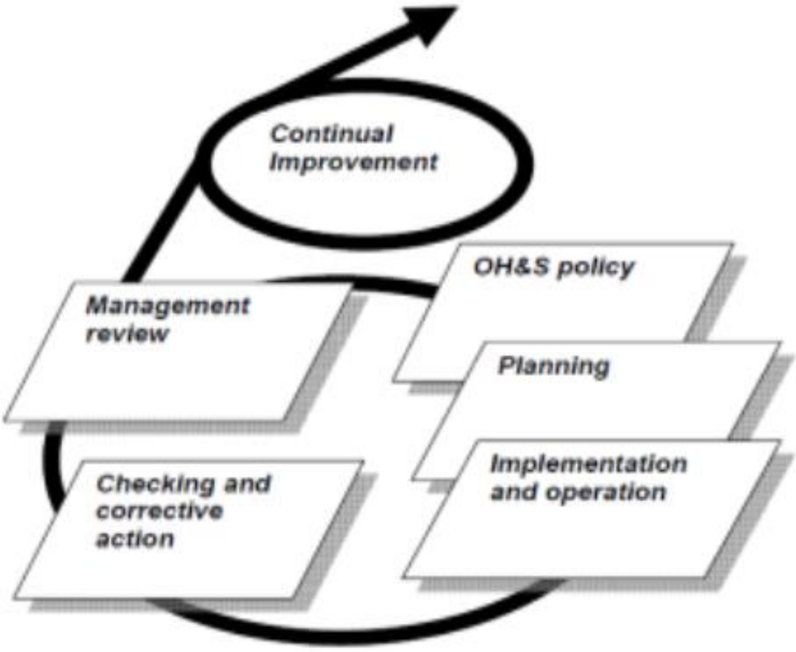

Figure 2.11: S&H management model-BS OHSAS 1800:2007
Source: OHSAS standard (BSI, 2007)

F) HSE's (2013) S&H Model

This SHMS is a revision of the HSE (1997) model, which shifts away from the POPMAR structure consisting of policy, organising, planning, measuring performance, auditing and reviewing structure to the Deming's PDCA management model (HSE, 2013) (Figure 2.12). This is because the Deming's cycle helps to achieve balance between systems and behavioural aspects of management; and also, the model is treated as part of an organisation's operation rather than a separated area (HSE, 2013). This is a guideline which encourages organisations to satisfy S&H legal requirements by orientating the organisations towards results rather than process (HSE, 2013).

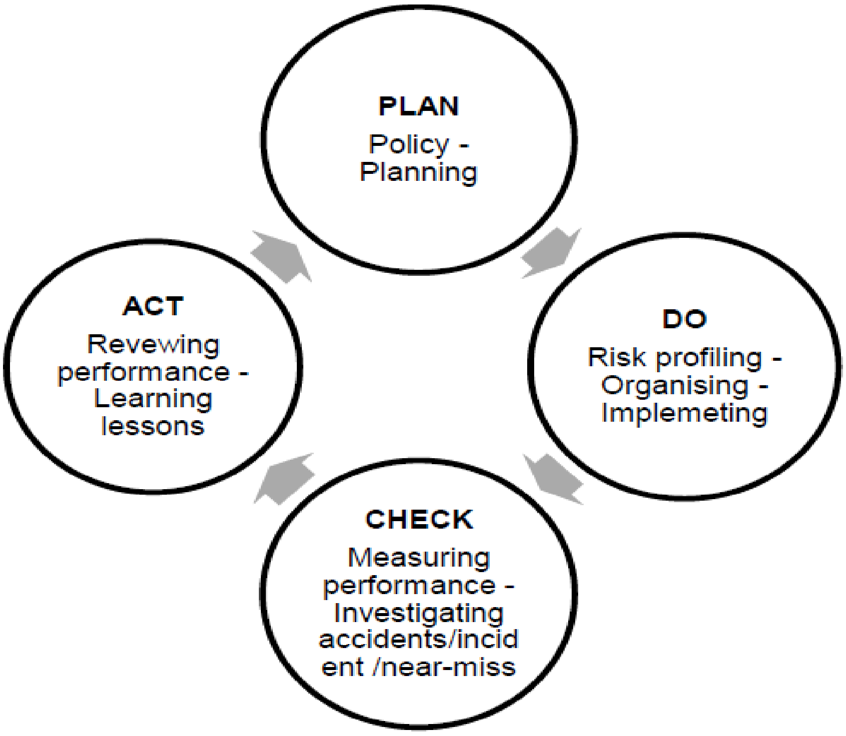

Figure 2.12: HSE's (2013) S&H Model
Source: HSE (2013)

G) ISO occupational health and safety management system standard

ISO 4500l is a new international occupational safety and health management system standard that has been developed and published in March 2018 by the ISO Project Committee to replace the widely recognised OHSAS 18001. It shares the same terms, definitions and structure as the ISO 14001 (environmental management) and ISO 9001 (quality management) system since it is based on Deming's cycle of continuous improvement. This structure makes it possible for several management systems (e.g. ISO 14001 and ISO 9001) to be integrated and implemented in a harmonised, organised and efficient way to help construction organisations achieve S&H and economic objectives.

According to ISO (2018), the new MSS was developed to provide a systematic organisational framework for an organisation (i.e. SMEs to large companies) to manage risks and opportunities to help prevent occupational injury and ill health to employees. Though both standards (i.e. OHSAS 18001 and ISO 45001) are targeted toward providing a safe and healthy workplace and improvements in working conditions, ISO 45001 takes a proactive approach to risk control instead of the reactive approach of hazard control as it is required in OHSAS 18001. ISO 45001, thus, ensures implementing organisations to incorporate safety and health in the overall management system of the organisation instead of leaving the responsibilities to safety management personnel. ISO 45001 also allows senior management to have a stronger leadership role with respect to the S&H management system/program. The intent and basic requirements of ISO 45001 and the OHSAS 18001 are similar; however, some differences exist particularly in the definition of terms and some fundamental concepts. Regardless of these differences, the overall aim of the two standard documents remain the same, which is to minimise unacceptable accident risks and ensure the safety and wellbeing of everyone involved in an organisation's activities. Overall, the majority of the models are based on the original model of the HSE (1997) in terms of their elements and corresponding OSH practices. Table 2.6 summarises the key elements of the models discussed.

Table 2.5: A summary of the key elements of various existing S&H management systems

Key requirements of SHMSs		**HSE, (1997)**	**McDonald *et al.*, (2000)**	**ILO, (2001)**	**Griffith And Howard, (2001)**	**OSHAS 18001, (2007)**	**Perezgonzalez, (2005)**	**HSE, (2013)**	**Gangolells, (2013)**	**Rebelo *et al.*, (2014)**	**ISO 45001, (2018)**
PLAN	Policy	√	√	√	√	√	√	√	√	√	√
	Planning	√	√		√	√	√	√	√	√	√
DO	Hazard identification and assessment of S&H risks		√		√	√	√	√	√	√	√
	Organising	√	√	√	√	√	√	√		√	√
	Implementation	√		√	√	√	√	√	√	√	√
CHECK	Measuring and reviewing performance (evaluation)	√	√	√	√	√	√	√	√		√
ACT	Auditing and management review	√		√	√	√		√	√	√	√

Source: Author construct (2017)

2.4.2.3 Safety and health management systems in construction

According to Bakri *et al.* (2006), S&H management in the context of construction "*is the discipline of preserving the health and safety of those who build, operate, maintain and demolish engineering works and of others affected by those works*". As the construction industry continues to experience high rates of injuries, illnesses and fatalities, an effective safety management is critical to the ongoing efforts to prevent construction accidents and its associated cost consequences as well as improving S&H performance (Aksorn and Hadikusumo, 2008; Arifin *et al.*, 2010). Hamid *et al.* (2012) argued that the use of proactive and systematic approaches is the best way to reduce or prevent construction accidents to improve S&H performance. Prominent amongst these systematic approaches for S&H performance improvements is to establish SHMS as a long-term strategy since such a system is an important defence against workplace injuries, ill-health problems and even deaths (Bakri *et al.*, 2006). Though injuries, accidents, illness and fatalities are a commonplace in construction, they are preventable. Construction companies must, therefore, see S&H as an important issue and integrate safety concerns effectively into the overall management mix to reap its benefits, especially in the reduction of the incidence of injuries and work related diseases in construction (Bakri *et al.*, 2006; Jazayeri and Dadi, 2017).

Extant S&H literature indicates that SHMS implementation improves both competences at existing operational procedures and the functioning of the organisations business (Abad *et al.*, 2013; Lo *et al.*, 2014). According to Zeng *et al.* (2008), SHMS implementation is still not commonly adopted and implemented in the construction industry. Fernández-Muñiz *et al.* (2012) argue that construction companies could be in a better position to minimise risks to its employees, and afterward reduce occupational accidents when they implement safety management systems. The contribution of SHMSs in improving a firm's productivity, its economic and financial results and prevention of injuries and accidents, have been highlighted and collaborated by several researches (Gallagher, 2000; O'Toole, 2002; Lingard and Rowlinson, 2005; Hughes and Ferret, 2007; Aksorn and Hadikusumo, 2008; Hwang *et al.*, 2009;; Fewings, 2013; Yoon *et al.*, 2013; Moorkamp *et al.*, 2014). For instance, in Australia, Caple (2000), reported that implementation of SHMS helps to reduce workplace injuries and its related compensation costs. This is affirmed by Elke (2000), who indicated that severity and frequency of injuries occurrence in a medium-sized company in Germany, reduced drastically in five years when a SHMS was implemented in the company. Also, in Hong Kong, Choudhry *et al.* (2008) showed that workplaces became safer and S&H performance increased when safety management were introduced into their decision making at project level.

To further show that SHMSs are beneficial, Yoon *et al.* (2013) reported that safety performance in Korea increased by more than 30% and fatal accident plummeted by 10.3% as a result of applying S&H management practices. Nonetheless, Robson *et al.* (2007) suggests that the current body of evidence is insufficient to decide whether to support SHMS since they lack empirical validity. Notwithstanding this criticism, a study by Yoon *et al.* (2013) showed that implementation of SHMS can yield S&H improvement.

Success of SHMS implementation is possible when the right conditions such as senior management commitment, integration into general management systems and effective employee participation are met. Kheni (2008) noted that the effectiveness of SHMS in the construction industry has not been adequately assessed. To a certain extent, it is only the individual elements of the system which have been shown to be connected with improved S&H performance. Some researchers even observed that the adoption and implementation of SHMS for small and medium enterprises is onerous (Vassie *et al.,* 2000; Kheni *et al.,* 2010). The main challenges being increased costs, extensive documentation, lack of awareness and knowledge of S&H issues, and huge investment in material and human resources.

2.4.3 Integrated management systems

The increasing proliferation and diversity of MSSs and their separate implementation is a real challenge to organisations and has become an important subject in the field of management practice (Simon *et al.*, 2013). Stakeholders expect companies to increasingly consider quality, environmental, security, social aspects, and other management requirement in their decisions. MSs, therefore, play an important role in assisting organisations to manage and control the risks associated with their operations to achieve organisational goals and objectives, though, the implementation of two or more of the diverse individualised managements systems is reported to be costly, onerous and bureaucratic (Jorgensen *et al.*, 2006; Zeng *et al.*, 2007; Griffith *et al.*, 2011; Oliveira, 2013; Nunhes *et al.,* 2016). This has led to the advent of integrated management systems (IMS) to address the difficulties of the separate systems and also to improve efficiency and effectiveness of organisational responses in order to equitably satisfy the needs and expectations of stakeholders (Barnardo *et al.*, 2009; Santos *et al.*, 2011; Simon *et al.*, 2011; Rebelo *et al.*, 2015).

2.4.3.1 Defining an integrated management system (IMS)

According to Karapetrovic and Jonker (2003), integrating management systems is a way in which MSs are linked such that there is a loss of independence of one or both which result into a strong and full management system. In the view of Pojasek (2006), a genuinely integrated system is a system that "*combines MSs using an employee focus, a process view, and a systems approach that makes it possible to pull all relevant management standard practices into a single system*". Also, Bernado *et al.* (2009) indicated that integration is a process of linking different standardised MSs into a unique MS with common resources aiming to improve stakeholder satisfaction. Summarising from the various definitions, integration in IMS literature can be defined as the process of combining separate MSs and their processes into a single system. As a result, IMS is a management system which combines two or more separate MSs and their relevant management procedures and requirements into one coherent system, which enables an organisation to work together as a single unit with unified objectives aiming to equitably satisfy stakeholders quality, safety, health, environmental or any other identified requirement.

2.4.3.2 Management systems integration

Over the past few years, the parallel implementation of individual management systems has increasingly been seen as efforts wasted with unnecessary costs, redundancies and bureaucracies (Bhutto *et al.,* 2004; Zutshi and Sohal, 2005; Bernado *et al.,* 2009; Gangolells *et al.,* 2013). Moreover, ensuring their alignment with a company's business strategy has become a challenging management issue (Griffith and Howarth, 2001; Beckmerhgeni, 2003; Labodová, 2004; Jørgensen *et al.,* 2006; Zeng *et al.,* 2007; Karapetrovic and Casadesus, 2009; Rebelo *et al.,* 2014). This is because implementing separate and sometimes incompatible management subsystems often results in, complexity of internal management, low efficiency and effectiveness and unnecessary bureaucracies (Oliveira, 2013; Nunhes *et al.*, 2016; Chountalas and Tepaskoulas, 2018). As a result, stakeholders particularly, employees and customers are negatively affected (Beckmerhagen *et al.,* 2003; Domingues *et al.,* 2012; Sampaio *et al.,* 2012).

As the number of MSSs increases, alleviating these problems becomes difficult; hence, the strong advocacy for integration as a way to improve the overall management system efficiency (Zutshi and Sohal, 2005; Zeng *et al.*, 2007; Khanna *et al.*, 2010; Santos *et al.*, 2011; Simon *et al.*, 2012; Oliveira, 2013; Abad *et al.*, 2014; Bernardo *et al.*, 2015). This advocacy has been overtaken by a more practical approach sustained on empirical evidence that shows that an integration of management systems is very essential and beneficial (Douglas and Glen, 2000; Beckmerhageni *et al.*, 2003; Karapetrovic and Casadesus, 2009; Khanna *et al.*, 2010; Sampaio *et al.*, 2012; Rebelo *et al.*, 2014). More so much literature and results from empirical studies have suggested an IMS implementation in organisations to be more effective and more efficient, than distinct and independent management systems (Simon *et al.*, 2012; Rebelo *et al.*, 2014).

Over the past decade, MSSs, have become more aligned due to the common underlying principle: the Deming cycle (PDCA) of continual improvement, on which their structure is based on (Zeng *et al.,* 2007; Oliveira, 2013; Bernardo *et al.,* 2015). Integrating two or more separate systems into a single and more efficient IMS based on the PDCA has therefore becomes more viable (Hamid *et al.*, 2004; Zeng *et al.*, 2008; Karapetrovic and Casadesús, 2009). An IMS, therefore, is a construction to avoid duplication of management tasks, and allows an organisation to effectively share informational, infrastructural, human, material and financial resources. As a consequence, organisational efficiency and profitability are improved with synergies within the various standards (Renzi and Cappelli, 2000; Rasmussen and Jørgensen, 2007; Karapetrovic, 2008; Abrahamsson *et al.*, 2010; Crowder, 2013; Dahlin and Isaksson, 2017).

Though the various prominent systems standards have been more aligned to common principle (i.e. PDCA) and a common structure for a successful integration of their components (i.e. quality, environment, and safety and health), there is no single IMS standard that can be certified internationally (Labodová, 2004; Rasmussen, 2007). At national level, several countries have developed or are in the process of establishing their own standards on IMS, comprising of relevant references, functions of the organisations and stakeholders (Beckmerhgeni *et al.,* 2003; Salome, 2008; Karapetrovic and Casadesus, 2009; Santos *et al.*, 2012). Examples are the Publicly Available Specification (PAS) 99 (2012) in the UK, UNE 66177 (AENOR, 2005) in Spain, DS 8001 (2005) IMS in the Netherlands, New Zealand, France and Australia. Added to these is 'the integrated use of management system standards' book published by the ISO in 2008 which guides organisations on how to apply the different standards in a combined way, integrated with their business (Vrassidas *et al.*, 2010). Moreover, IMS literature across different industrial sectors have mainly focused on the fusion of two systems, Quality Management System (QMS) and EMS or EMS and SHMS and whenever possible, the three-common standardised management systems EMS, QMS, and SHMS (Santos *et al.*, 2011; Ashen, 2014) as shown in Table 2.6. Several studies on IMS exist with focus on varied topics, including benefits and challenges, methodologies, and degrees of integration (Bernardo *et al.*, 2009; Asif *et al.*, 2010; Khanna *et al.*, 2010; Lopez-Fresno, 2010). The review of IMS literature revealed that IMS implementation can provide many benefits for organisations despite the barriers to its implementation.

A) Benefits of integration

The benefits of integration, is a topic that has been well discussed in extant literature. The findings show that benefits of IMS are both intrinsic and extrinsic. The intrinsic benefits can be categorised into economic, organisational and operational. The economic benefits includes: (a) cost reduction in a different area, such as internal and external audits, training and compliance with legislation (Douglas and Glen, 2000; Karapetrovic and Jonker, 2003; Zutshi and Sohal, 2005; Jørgensen *et al.*, 2006; Zeng *et al.*, 2007; Asif *et al.*, 2010; Casadesús *et al.*, 2011; Hamid *et al.*, 2012); (b) from savings on human resources (Zeng *et al.*, 2005; Salomone, 2008; Bernardo *et al.*, 2015; Nunhes *et al.*, 2016); and (c) from efficient allocation and utilisation of financial, material or informational resources (Douglas and Glen, 2000; Zutshi and Sohal, 2005; Zeng *et* *al.*, 2007; Griffith and Bhutto, 2008; Simon *et al.*, 2013; Almeida *et al.*, 2014; Poltronieri *et al.*, 2018).

Relating to organisational benefits, an organisation, through integration, obtains a holistic approach to its standalone systems, which is guided by a joint comprehensive management review. Organisations, therefore, have a better overall picture for more rational decisions to be made (Zutshi and Sohal, 2005; Kraus and Grosskopf, 2008; Griffith and Bhutto, 2008; López-Fresno, 2010). They are also able to manage to align their objectives and targets at the strategic planning level (Jørgensen *et al.*, 2006; Kraus and Grosskopf, 2008; Khanna *et al.*, 2009; Poltronier *et al.*, 2018) and their objectives, processes and resources, at the operational level (Griffith and Bhutto, 2008; Salomone, 2008; Molina-Azorín *et al.*, 2009; Tarí and Molina-Azorín, 2010; Simon *et al.*, 2013; Rebelo *et al.*, 2015).

With regard to the operational benefits of integration, an organisation is able to simplify its systems and processes (Zutshi and Sohal, 2005; Olaru *et al.*, 2014; Bernardo *et al.*, 2015; Nunhes *et al*, 2016). This results in document control and reduction of unnecessary bureaucracy (Douglas and Glen, 2000; Beckmerhagen *et al.*, 2003; Zeng *et al.*, 2005; Griffith and Bhutto, 2008; Salomone, 2008; Molina-Azorín *et al.*, 2009; Asif *et al.*, 2010; Bernardo *et al.*, 2012; Almeida *et al.*, 2014; Oliveira *et al.*, 2013; Abad *et al.*, 2014, Rebelo *et al.*, 2015). Additionally, integration of MSs could lead to a more effective and efficient management of operational activities (Zutshi and Sohal, 2005; Zeng *et al.*, 2007; Griffith and Bhutto, 2008; Molina-Azorín *et al.*, 2009; Asif *et al.*, 2010b; Casadesús *et al.*, 2011; Abad *et al*, 2014; Bernardo *et al.*, 2018). This is due to the minimisation of duplicate tasks in implementing each activity (Zeng *et al.*, 2005; Molina-Azorín *et al.*, 2009; Abad *et al.*, 2014; Bernado *et al.*, 2015). Integration can also promote innovation efficiency (Hernandez-Vivanco *et al.*, 2018).

Some extrinsic benefits of IMS are related to the satisfaction of the requirements of stakeholders, particularly customers, public authorities or the local community (Griffith and Bhutto, 2008; Salomone, 2008; Rajkovic *et al.*, 2009; Karapetrovic *et al.*, 2010; Zeng *et al.*, 2010; Bernardo *et al.*, 2015). In light of these benefits, integration of management systems has, therefore, become one of the most important strategies for organisations to ensure survival and savings (time, cost and resources) in today's competitive and stringently regulated business enviroment (Simon *et al.*, 2013).

B) Problems with Integration

Along with the benefits, there are some difficulties associated with IMS implementation that have also be documented in IMS literature. Several problems have been reported such as lack of management commitment (Asif *et al.,* 2009; Ivanova *et al.*, 2014), increase in management costs, complexity of internal management (Zutshi and Sohal, 2005; Zeng *et al.*, 2007; Santos *et al.,* 2011; Simon *et al.,* 2012;Chountalas and Tepaskoulas, 2018), lack of resource availability, time delays, cultural incompatibility and resistance (Zeng *et al.*, 2008; Asif *et al.*, 2009; Santos *et al.*, 2011; Simon *et al.,* 2012; Bernardo *et al.,* 2012). There is also the lack of technical guidance and support by consultants and certification bodies and lack of qualified personnel to cover all system requirements (Zutshi and Sohal, 2005; Zeng *et al.,* 2007; Salomone, 2008; Asif *et al.*, 2010; Khana *et al.,* 2010, Tari and Molina-Azorin, 2010; Santos *et al.* 2011; Simon *et al.*, 2012; Bernado *et a.,* 2012). Nonetheless, early management of these potential challenges in the integration and implementation process, could avoid its failure for the reported benefits to be derived by all stakeholders (López-Fresno, 2010; Chovancova *et al.*, 2015).

2.4.3.3 Existing integrated management systems

A review of existing IMS with their associated elements is presented next.

A) Safety, health, environment and quality management system

Hamid *et al.* (2004) developed a model called safety, health, environment and quality (SHEQ) management system. It has six main elements that make up a cycle of continual improvement using the Deming's PDCA cycle (Yang, 2002) and shown in Figure 2.13. These elements are:

SHEQ Policy: A SHEQ policy statement is set to show organisation intentions and principles, in relation to its overall SHEQ performance and provides a platform for setting the SHEQ objectives and targets.

Planning: This involves formulating a plan to fulfil the SHEQ policy. It consists of various employee's identifying significant SHEQ impacts of organisation's activities, products, and services along with legal and other standards the company subscribes to.

Implementation and operation: This step involve getting the plan into action by providing resources and support mechanisms necessary to achieve SHEQ policy, the objectives and targets.

Checking and corrective action: Putting in place measures that will regularly monitor and evaluates the organisations SHEQ performances against its objectives and targets.

Management Review: Undertaken to review and continually improve the SHEQ management system, with the objective of improving its overall SHEQ performance.

Continual Improvement: The SHEQ management system, is subject to continuous improvements to achieve improvements in overall SHEQ performances, in line with organisation's SHEQ policy.

Figure 2.13: Integrated safety, health environmental and quality (SHEQ) management system model
Source: Yang (2002)

B) An integrated management system of quality, environment and safety (IMS-QES)

The IMS-QES model was designed in a Portuguese organisation where 160 employees were surveyed (Rebelo *et al.*, 2014). It consists of five principal components: integrated management policy and objectives; organisational structure and resources; implementation of IMS-QES operations; monitoring of processes and products; assessment, continuous improvement and innovation; and its corresponding guiding principles and action (Figure 2.14). Each of these five components is connected to a section of the guiding principles which shows what to be done, which is not a feature of other IMS models. According to Rebelo *et al.* (2014), this model is simple, dynamic, configured as a process, and also supported on the "Plan-Do-Check-Act-Improve" (PDCAI) cycle. This ensures a re-feed, both in terms of corrections and/or continuous improvement any of its five components (Rebelo *et al.*, 2014). Additionally, this proposed generic model enables the identification and integration of two or more MSs into one strong comprehensive and efficient integrated system with an all-inclusive set of documentation, processes, Key Process Indicators' (KPI's) and procedures (Rebelo *et al.*, 2014).

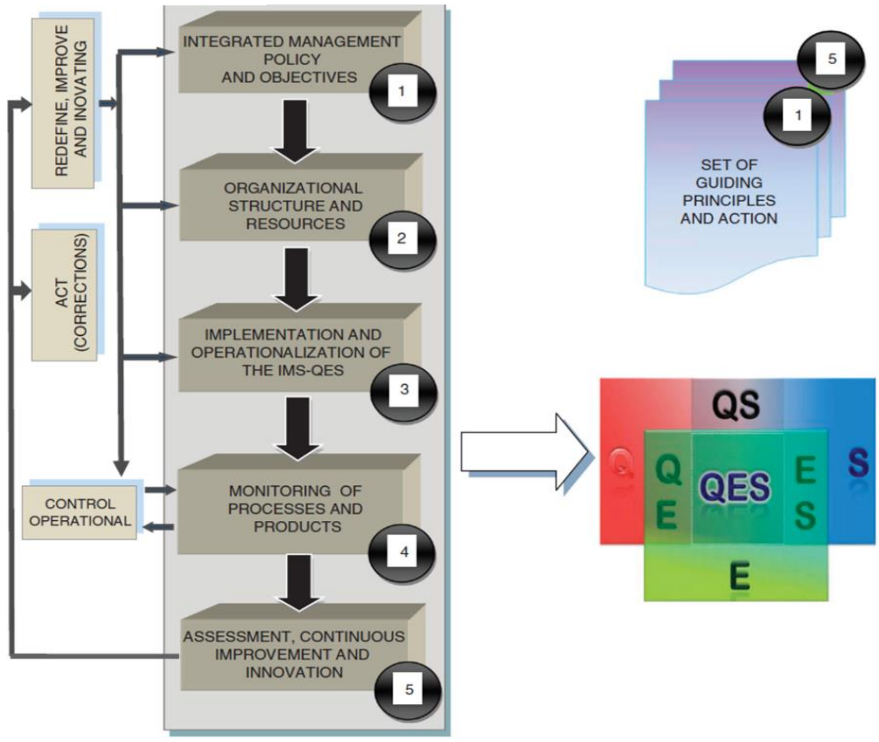

Figure 2.14: Proposal for generic IMS-QES

Source: Rebelo et al., (2014)

C) Environmental, health and safety (EHS) management system

Gangolells *et al.* (2013) proposed an integrated methodology which combined an environmental management system with a SHMS (Figure 2.15). The authors observed risk management (i.e. risk identification, risk assessment and risk control) as a vital element in the management system and hence the heart of this model. The model shows that environmental and H&S management can be integrated together by focusing on their sub-systems: identification, assessment and control. Therefore, designers, planners and project managers can use this system to successfully manage project in terms of environmental impacts and S&H performance.

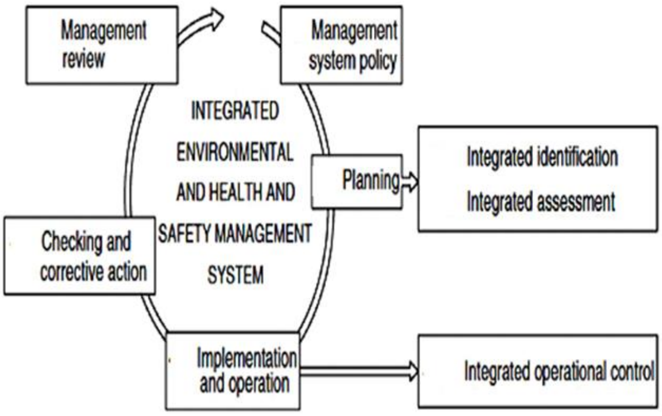

Figure 2.15: Integrated environmental and H&S management methodology framework
Source: Gangolells et al. (2013)

D) Responsible care 14001 Management System [RCMS 9RC14001®:2015)]

The responsible care model was developed and published in 1996 by the American Chemical Council (ACC) to ensure that the chemical industry makes health, safety, security and environment an important issue (Howard *et al.*, 2000). It was upgraded into RC14001® in 2015. It comprises of components of responsible care system and ISO14001 management systems, which allows organisations to "*identify and control the environmental impact of its activities, products or services, improve its environmental performance continually*" throughout the entire operating system (RC14001®, 2015 p.1). This framework was also developed based on the PDCA philosophy. Its structure is identical to ISO 14001, and basically expands an environmental mandate into an EHS&S requirement. According to ACC (2017), Responsible Care companies have been able to decrease the emissions of dangerous and harmful gasses into the air, land and water by about 74% from 1988 to 2014 and also reduced process safety incidents by 51% since 1995.

E) Health, safety, environmental and quality model (CRC-Evans Pipeline Inc., 2017)

This model consists of processes that ensure effective S&H issues in the construction industry. It aims at improving high level of health, safety, environmental and quality consciousness at all levels in an organisation by ensuring employee participation, effective communication and proper dissemination of information (CRC-Evans Pipeline International, 2017). It involves planning, delivery, monitoring and reviewing phases which helps in continuous improvement of S&H issues. The primary elements of the model are shown Figure 2.16.

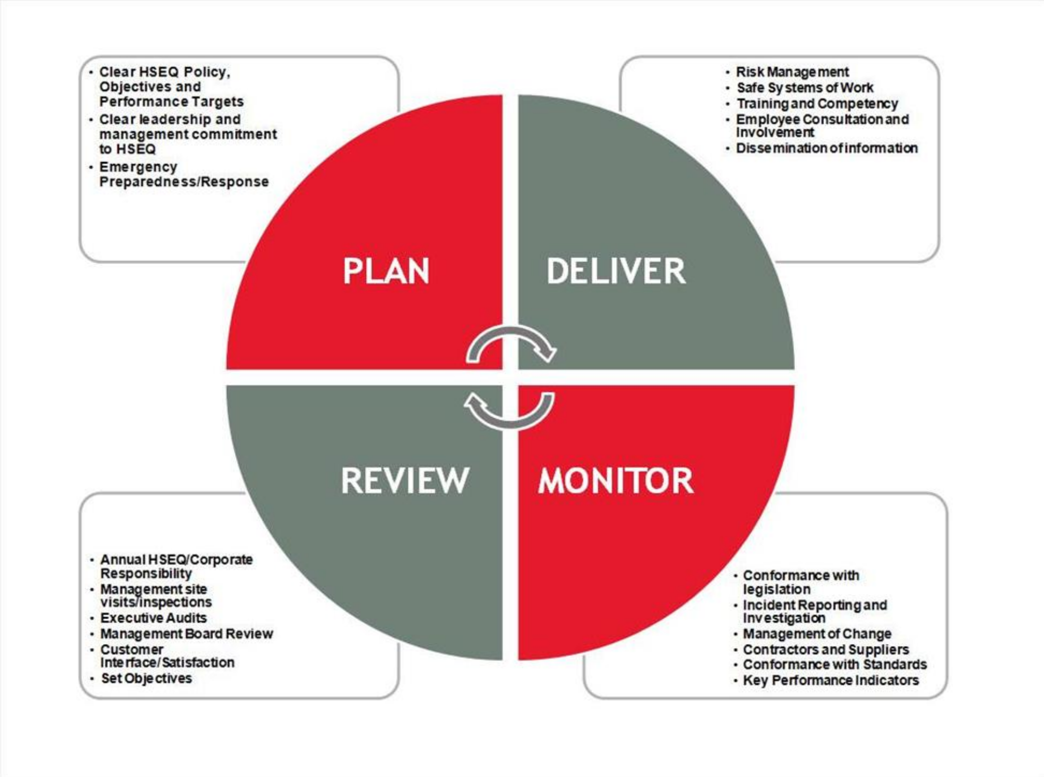

Figure 2.16: Health, safety, environmental and quality model
Source: CRC-Evans Pipeline Inc.

F) Safety, Health and Environment (SHE) Model [Lucite International, 2017]

This model was developed and implemented by Lucite International, a global leader in the design, development and manufacture of acrylic-based product. This model aims at continuous improvement in SHE performance of the company. It comprises of a SHE policy and 21 elements of the SHE excellence that helps drive the company's SHE performances. They include: participation and teamwork; legal compliance; objectives and goals; audit and follow-up; training; commitment and attitude; performance metrics; incident investigation; individual responsibility; clear accountability; rule compliance; change management; emergency preparedness; order and arrangement; process hazard review; contractor safety; mechanical integrity; pre-start-up review; operating procedures; and technology documentation. These elements are similar to the requirements of the PAS 99 product guide for IMS (BSI, 2012).

Table 2.6: Current composition of IMS in various sectors as seen in literature

Authors	QMS ISO 9001	EMS ISO 14001	SHMS ISO 18001	SAMS SA 8000	OTHERS
Karapetrovic and Willborn (1998); Wilkinson and Dale (1999); and Block and Marash (2002)	√	√	-	-	-
Pheng and Pong, 2003	√		√		
Pheng and Shiua, 2000; Zeng *et al.*, 2008	√		√		
Zeng *et al.*, 2005	√	√			
Wright (2000); Fresner and Engelhardt (2004); Labodová (2004); Hamid *et al.* 2004; Mackau (2003); Zeng *et al.* (2007); Arifin *et al.* (2009); Santos, *et al.* (2004); Santos *et al.* (2011); Mendes (2007); Mendes and Santos (2009); Rebelo (2011); Rebelo and Santos (2012); Neves *et al.*(2012); Almeida *et al.* (2012); Domingues *et al.* (2012); Santos *et al.* (2012); Santos *et al.*(2012b); Santos *et al.* (2013); Oliveira (2013); Simon *et al.* (2013)	√	√	√	-	-
Tarí and Molina-Azorín (2010)	√	√			European Foundation for Quality Management (EFQM) Excellence model
Santos *et al.* (2013)	√	√	√	-	Eco-management and audit scheme (EMAS)
Karapetrovic (2002; 2003)	√	√	√	√	Series IEC 60300: Reliability management
Campos (2006)	√	√	√	√	ISO/TS 16949
Karapetrovic and Jonker (2003); Jonker and Karapetrovic (2004); Jørgensen *et al.* (2006); Rocha *et al.* (2007); Asif, *et al.* (2011); Asif *et al.* (2013); Mežinska *et al.* (2013)	√	√	√	√	-
Rebelo (2011); Santos *et al.* (2012a); Santos *et al.* (2012b); Rebelo and Silva (2012); Santos *et al.* (2013); *Rebelo et al.* (2013) Nunhes *et al.* (2016)	√	√	√	√	NP 4457 ISO/IEC 27001 ISO/IEC 17025 ISO 31000
Gangolells *et al.* (2013); Sui *et al.* (2018)		√	√		

Source: Adapted and updated from Asif et al. (2008) and Rebelo et al. (2013).

2.4.3.4 Integrated management systems in construction

In the construction industry, construction companies are dealing with a competitive market and clients and customers who have become more demanding. Construction clients and end users are not only just concerned with the quality and reliability of building products, but also the safety and health of all workforce and the quality of environment on site and in the location for construction as well as the ability of the company to reduce environmental pollution and occupational accidents and illness. For effective management of all these aspects is the development and implementation of an IMS in a construction company (Griffith, 2000; Griffith *et al.*, 2008; Gasparik, 2009; Masood *et al.,* 2014). According to Griffith (2011), implementation of IMS in the construction industry, together with quality, cost and time controls, is an effective tool for efficient utilisation of resources to implement and maintain quality, environmental, safety and health management programs. Development, implementation and improvement of IMS in construction companies can help streamline policies, improve project and company efficiency, and also improve quality production, safety of employees, environmental protection and customer satisfaction, which are all beneficial to enhance construction project performance (Gasparik, 2009; Griffith, 2011; Masood *et al.,* 2014).

The construction industry has in the past studied MSs integration on the level of empirical research at the level of model development. According to Pheng and Kwang (2005) the integration of the three leading systems (i.e. EMS, SHMS and QMS) has significant benefits for construction companies, which more than compensate for any problems. The substantial benefits of integrating quality with environment (i.e. ISO 9001 with ISO 14001) for construction companies have been documented by Zeng *et al.* (2005), who noted that the appropriate technical guidance is needed for successful integration in construction companies. To this end, Hamid *et al.* (2004) developed the SHEQ-MS (Safety, Health, Environment and Quality Management System) and proposed some guidelines for construction companies for the integration of the three main systems. Corresponding guidance, specifically for the integration of EMS and SHMS, was also provided by Gangolells *et al.* (2013) proposing an EHS model that used risk management as a central integrating factor. Other IMSs in existence are the Integrated Management System of Quality, Environment and Safety (IMS-QES) by Rebelo *et al.* (2014), Quality, Environment, Safety and Health (QUENSH) (Renfew, 2000), QMS and EMS (Block and Marash 2002) and QMS and SHMS (Zeng *et al.*, 2008). the fusion of EMS and SHMS in construction is, however, scarce (Zeng *et al.,* 2008).

2.4.3.5 Integrating safety, health and environmental management systems in construction

The most popular standard of environmental management is ISO 14001. This standard is a framework for organisations in order to protect the environment and respond to the ever-changing environmental conditions while promoting social and economic harmony. It stipulates the requirements for an EMS that can be used by an organisation to improve its environmental performance. ISO 45001 and BS OHSAS 18001, the standards of safety and health is also a standard framework that aids an organisation to improve its S&H related performance. It specifies requirements for an SHMS that can be used by an organisation to remove or minimise and control S&H risks as much as possible by taking effective preventive measures. A review of literature revealed that these two MSSs have high consistency, agreement on generalities, some minimal differences and a general common structure, that can justify a single integrated system. Additionally, the structure of the two management systems also share a similar PDCA management structure, with both based on control of risks (Rebelo *et al.*, 2014). Hence the establishment and implementation of an integrated management system to cover the OHSAS 18001/ISO45001 and ISO 14001 standards is feasible (Karapetrovic and Casadesus, 2009; Hamidi *et al.,* 2012; Rebello *et al.*, 2014).

Though, work by these independent management systems are beneficial, implementation of independent environmental, safety and health management systems are very low amongst construction companies (Griffith and Bhutto, 2008; Ayarkwa *et al.*, 2010; Gangolells, 2010; Masood *et al.,* 2014). This phenomenon has mainly been blamed on the increasing cost of implementation, administration and maintenance of SHE policies and systems, particularly in developing countries (Liyin *et al.*, 2006; Selih, 2007; Turk, 2009; Ayarkwa *et al.*, 2010; Zeng *et al.*, 2010; Geipele and Tambovceva, 2011; Famiyeh, 2014; Campos *et al.*, 2015). As the high cost of implementation of stand-alone EMSs and SHMSs still remains a major inhibitor, an integrated these two management systems into a single integrated SHE management system could be useful in stimulating greater adoption and implementation in developing countries for effective management of SHE in construction companies. This is because effectively integrating S&H and environmental management systems will provide opportunities for rationalisation/or removal of extensive documentation, audit and review procedures and barriers across departments or functions to achieve greater organisational efficiency and effectiveness (Zutshi and Sohal, 2005; Abad *et al.*, 2014; Rebelo *et al.*, 2016; Nunhes *et al.*, 2016; Muzaimi *et al.*, 2017; Tepaskoualos and Chountalas, 2017). This will help stimulate construction business improvement and SHE risk reduction (Hamid *et al.*, 2004; Rebelo *et al.*, 2016; Tepaskoualos and Chountalas, 2017). Furthermore, as construction safety issues are closely connected to environmental problems, and initiatives aimed at improving safety during construction could lead to enhanced environmental management, and vice versa (Zutshi and Creed, 2015), integrating an EMS and a SHMS into a single system is a systematic approach to planning and management of SHE risks with maximum effectiveness and minimum bureaucracy (Griffith, 2011). This could be beneficial in reducing the number of fatalities, injuries, illnesses and the potentially negative impacts of construction operations on the environment, leading to better SHE performance outcomes in the construction industry.

An integrated management of SHE through a single system (i.e. an integrated SHE management system) could enable construction companies in Ghana use similar practices to help jointly manage SHE issues in a sustainable and cost-effective way. An integrated management of SHE could maximise the competiveness of these construction companies through continual improvements of their SHE management practices and guarantee their survival in today's environmentally friendly and stringently regulated business environment.

2.4.3.6 Towards the development of an integrated safety, health and environmental management capability maturity model for the construction industry

The key element of SHE management systems is continuous improvement of SHE performance. MSs often provide performance criteria and targets based on outcomes (e.g. number of injuries) but not based on the operational methods or processes needed to achieve continuous improvement in the outcomes. Thus, whilst EMS, SHMS and IMS, highlight management areas and processes or practices that need to be implemented to achieve positive outcomes, they do not offer a mechanism for ascertaining how well a company is performing in implementing those practices i.e. the level of maturity in performing a practice (Zobel, 2008). The premise of an EMS and a SHMS is that, if they are well established and implemented effectively, they will reduce or eliminate negative environmental impacts and S&H risks to move a company toward better SHE performance. In this vein, implementing construction companies should be able to establish their current level of SHE management performance maturity, identify the strengths and weaknesses within their SHE management practices and processes and also identify actions to improve continuously. However, there are no tools or systematic mechanisms that enable construction companies to ascertain the maturity of their SHE management practices based on an integrated SHE management framework.

Various process improvement models and approaches are available to enable organisations to improve their performance continuously. These include Lean, Six Sigma, Excellence models and capability maturity models (Sun *et al.*, 2009), however, apart from the maturity models, the other improvement models do not really show evidence of the capability improvements of the processes (Sun *et al.*, 2009). Maturity models, on the other hand, show the sequence of levels that describes how practices, processes and actions of an organisation can consistently show an expected or desired progressive path of improvement that could produce essential and desired outcomes (Paulk *et al.*, 1993; Curry and Donnallen 2012; Manu *et al.*, 2018)). Over the past few years, maturity models have been known as widely used management tools that have proven valuable for performance improvement in organisation business processes in many domains (Proença and Borbinha, 2016). They offer a framework with a systematic approach for evaluating organisations' current capabilities, identifying the actions required to improve, and helping them to implement changes and improvements in an organised way (OGC, 2006; Becker *et al.*, 2009). Consequently, an integrated safety, health and environmental management capability maturity model (SHEM-CMM) could be a useful process improvement tool for assessing the maturity of a construction company's SHE management practices and help them to enhance their processes to realize higher performance outcomes.

While an integrated SHEM-CMM would be beneficial, especially for contractors to enable them to improve on their SHE management, there is none existent at present and very limited research has been done to inform their development. The closest to date are (1) the maturity models for safety culture assessments (Fleming, 2000; Goncalves *et al*., 2010; Foster and Hault, 2013) and the Health and Safety Maturity Model by Goggin and Rankin (2009), which do not incorporate the environmental management aspects; and (2) the integrated models such as SHEQ-MS (Hamid *et al.,* 2004), IMS-QES (Rebelo *et al.,* 2014), EHS-MS (Gangolells *et al.,* 2013) and IMS-OHSE (Sui *et al.,* 2018). None of these existing IMSs, enable the assessment of SHE management capability maturity in order to pave way for process improvement. For instance, the integrated EHS-MS by Gangolells *et al.* (2013) is only a model that provides a methodology to assist designers and contractors to enhance the integration of EHS-MS by focusing on the subsystems for identifying, assessing, and operationally controlling environmental aspects and S&H hazards using a risk analysis-based approach during the planning phase of the implementation of the EHS-MS in construction companies (Gangolells, 2010). This process-oriented model helps to reduce the existing level of uncertainty linked to the integration of planning and control elements in the EHS-MS, which has been recognised as an implementation barrier in extant SHE management literature. EHS-MS therefore does not enable the assessment of EHS management maturity. Also, the IMS-OHSE is an integrated management system for occupational health, safety and environment in an operating nuclear power plant (ONPP) to improve SHE performance at a lower cost (Sui *et al.*, 2018). This integrated SHE management system was established to cover the requirements of the OHSAS 18001 and ISO 14001 standards as well as the International Atomic Energy Agency's (IAEA's) safety standards on management systems. The process of implementing the IMS-OHSE in an ONPP is formulated through the Deming management cycle (PDCA). Similarly, the proposed integrated SHE management system (SHEMS) in this study, is formulated based on the Deming’s cycle and covers the requirements of the ISO 45001, OHSAS 18001, EMAS and the ISO 14001 standards. Though, the IMS-OHSE by Sui *et al.* (2018) is closely related to the proposed integrated SHE management framework, it is focused on the nuclear sector and not construction and does not enable the assessment of OSHE management maturity. The proposed integrated SHE management system in this study is unique. It is: (1) focused on construction and consists of capability attributes that are relevant to the effective implementation of an integrated SHE management system in a construction company; (2) focused on developing countries (especially in Sub-Sahara Africa); and (3) been developed further into a capability maturity model (CMM), which would enable the assessment of SHE management maturity.

Furthermore, SHE management studies in the construction industry in Ghana have largely covered areas such as environmental impacts of construction activities, perceptions of adoption and implementation of an EMS, design for safety, on-site S&H management issues, legislation and procurement (Kheni *et al.,* 2008; Laryea and Mensah 2010; Ametepey and Ansah 2014; Ayarkwa *et al.,* 2014; Manu *et al.,* 2019b). None of these studies have focused on integrated SHE management in construction, although construction activities adverse impact on the natural environment, and on the safety and wellbeing of workers in the Ghanaian economy is significant. Therefore, knowledge gaps remain regarding: the key attributes or elements relating to SHE management in construction that should be incorporated in an integrated SHEM-CMM; the relative importance/priority of such attributes so as to enable prioritisation of improvement actions; and the levels of capability maturity that are appropriate for capturing stages of maturation in those attributes. These knowledge gaps, thus, offer an opportunity for the development of a capability maturity model focused on integrated SHE management in construction, especially for a developing country in this study. Such a model will help ease the financial and resource burden associated with the implementation of separate stand-alone MSs by contractors, and also make it possible to ascertain the maturity of their SHE management practices to guide efforts to improve processes.

2.5 Chapter summary

The SHE performance of the construction industry and environmental impacts of construction activities were reviewed in this chapter. The elements, benefits, challenges and examples of existing EMS, SHMS as well as IMS have been provided. A case is made for an integrated SHE management system as a single system for effective management and control of SHE operations and also for an integrated SHEM-CMM. The PDCA approach, which expresses the concept of continual improvement, was the basis of the core structure of several existing individual and integrated management systems. Integration of management systems is recognised as an alternative to operating various management systems in a parallel manner that cover different technical functions. A well-designed, effectively implemented and managed individual or an integrated system generates several benefits despite the difficulties in implementation. While there are management system standards on which forms the basis on which several individual management systems are developed, there is no international standard for an integrated system. In the next chapter, process improvement methods, particularly capability maturity models are reviewed to obtain a detailed understanding of its design and application

CHAPTER THREE: PROCESS IMPROVEMENT APPROACHES - A REVIEW OF MATURITY MODELS

3.1 Introduction

This chapter describes process improvements concepts and approaches/models and the fundamental principles and structure of capability maturity model (CMM). The first section of this chapter introduces process improvement definitions and the different process improvement models and methods. The second section then explains the fundamental principles of capability maturity modelling concepts and its structural components, as well as characteristics, objectives, types and weakness. It further introduces maturity models in the field of construction management. Understanding of the CMM concept and its components will assist in applying the underlying principles of CMM for the development of an integrated SHEM-CMM.

3.2 Process improvement

The idea of process improvement is to enhance underlying processes of business activities. Process improvement is a practical task of identifying, analysing and improving upon existing business processes within an organisation, for growth and to meet new standards (Appian, 2017). It, therefore, involves a structured and a systematic approach following detailed methodology that enables a team of employees to realise improvements within their organisations. A successful implementation of process improvement methods could lead to an enhancement of organisations processes, customer satisfaction, customer loyalty, increased productivity, development of the skills of employees, efficiency and increased profit resulting in higher and faster return on investment (Antony *et al.*, 2006; Appian, 2017). Though in the extant literature process improvements has been labelled in different ways, such as business re-structuring, business re-engineering, business process re-design, continuous process improvement (Harrington, 1991; Carr 1993; Bessant and Francis, 1999; Cao *et al.*, 2001), the primary aim of these concepts remains the same, while the degree, frequency and nature of the desired changes may differ slightly (Davenport, 1993). Several methods and approaches are available and used in various industrial sectors with their focus on different areas of improvement. According to Keraminiyage (2006), process improvement is not a new idea and thus, has been researched into and applied in various sectors, especially in the manufacturing sector.

In the construction industry, there have been several reports published that has identified the need of performance improvements in the industry (Lathan, 1994; Egan, 2002). Also, some authors have recommended the need for construction organisations to move towards the focus on process thinking in order to achieve desired improvements (Atkin *et al.,* 2003; Harris and McCaffer, 2013). Due to the nature of the industry and its unique characteristics, some principles of process improvement from other industries (e.g. software and manufacturing) have been borrowed and used to achieve desirable performance improvements within the industry. Over the years some process improvement initiatives have been developed for the industry to improve their processes (Sarshar *et al.,* 2000; Kagioglou *et al.,* 2000; OGC, 2000; RIBA, 2013). Amongst these initiatives is the recognised standard process improvement for construction enterprises (SPICE). This SPICE project borrowed the concepts of CMM and established a stepwise process improvement framework for the industry. It comprised of key process areas mapped onto five maturity levels which are similar to CMM (Sarshar *et al.*, 2000). In this model construction companies should be able to perform all the key process areas belonging to a particular maturity level in order to achieve the maturity level (Sarshar, 2000; Keraminiyage, 2009).

3.3 Process improvement models and approaches

Roudabush (2013, p.11) defined a process improvement model as a "*collection of process elements and practices being used as a pattern for process development and a criterion against which a process can be assessed objectively".* As process improvement plays an important role in achieving performance of improvements in companies, improved processes generate improved outcomes. Several process improvement models therefore exist, varying from revolutionary approaches to evolutionary approaches. Examples of these approaches and methods include: ISO 9001; Malcolm Baldrige National Quality Award (MBNQA); ISO 15504; SPICE and maturity models. Added to these are the Total Quality Management (TQM), Six Sigma and Lean used to guide problem solving and help in improving management processes. Each of these focus on different areas of improvement and uses different methods to achieve the best results in resolving an issue or to address a certain principle. Each of these types of process improvement methods are reviewed below.

3.3.1 ISO 9001

ISO 9001 is a Quality Management System (QMS) standard that establishes a framework for how an organisation manages its key processes. Internationally, it is recognised as the quality system of choice. It is, therefore, considered as a powerful business improvement tool that focuses on how organisations continually monitor and manage quality across their business by easily identifying any areas for improvement (ISO, 2015). This quality system is a set of co-ordinated activities and rules that are defined by a collection of policies, processes, documented procedures and records that directs and control any size organisation for continual improvement to deliver real benefits (ISO, 2008). According to Rebelo *et al.* (2012), the implementation of this system was very germane in high demanding industrial sectors, like the manufacturing, aeronautical and automotive industries, but has rapidly extended to all other sectors, and seen as a common factor of competitiveness and survival.

The main thrust of the ISO 9001 is in defining the organisations processes, which result in the production of quality products and services, reduction of lost time and striving for customer satisfaction and excellence instead of identifying defective products or services after they have been produced. For effective implementation, an organisation should tailor their QMS to its needs and ensure that none of the elements of the system as referred in the standard is missing. This is because there are processes within this process improvement model, that are designed to monitor the processes of the system and lead to improvement. Also, these processes are similar to ones stipulated in MSs. For instance, the method of auditing system processes, the application of corrective and preventive actions for problems and a management review of the system to ensure requirements are met for further improvements (ISO, 2008).

3.3.2 Total quality management

Total quality management (TQM) emerged from the amalgamation of all the similarities and overlapping approaches that were presented by quality experts such as Deming, Juran, Ishikawa, Feigenbaum, Taguchi and Crosby (Slack *et al.,* 2004). As a result, TQM is defined as "*the mutual co-operation of everyone in an organisation and associated with business processes to produce products and services, which meet and, hopefully, exceed the needs and expectations of customers*" (Dale *et al.,* 2016). It is a companywide approach to quality and centres on continuous improvements undertaken by all employees and all aspects of the organisation in solving a problem to the satisfaction of customers. It is, therefore, recognised as a philosophy and a set of management guiding principles for managing any organisation to the benefit of all stakeholders (Dale, 1999). According to Anderson *et al.* (2006), TQM improvement approach is grounded on Deming's (PDCA) continuous-improvement cycle and incremental Japanese improvement approach known as Kaizen (5S). Typically, it is applied where production, clerical, and low-level managers are deeply involved. For quality improvements in business processes the TQM approach consist of eight main components, namely: organisation; total employee involvement; customer focused; integrated systems; strategic planning; process improvement; effective communication; and recognition. This approach makes use of analytical and statistical tools like statistical process control (SPC) in improving and controlling organisational processes

(Anderson *et al.*, 2006). The Deming Prize, The Malcolm Baldrige National Quality Award and European Foundation for Quality Management (EFQM) award models and their criteria, were all in some way influenced by the development of TQM especially the seven criteria of MBNQA (Chase *et al.*, 1998; Slack *et al.*, 2004).

As a process improvement method, TQM helps organisations to reduce cost, waste and inventory and, ultimately, produce superior or high-quality products and services that brings customer satisfaction by maintaining existing quality standards (Bragg, 2013). Empirically, TQM has been very successful in terms of financial results, operating performance, quality, and customer services amongst others (Agus, 2004; Kumar *et al.*, 2009), however, its adoption has been fraught with some challenges relating to: costs and length of TQM implementation, a lack of structured approach to improve the process, difficulties in measuring TQM outcomes, and effectiveness of TQM in services sector etc. (Basu and Wright, 2004; Mehra and Ranganathan, 2008). It is worth noting that TQM can only be beneficial when there is a strong support by management and employee team's involvement in implementation, as well as a continual focus on process improvement to prevent the occurrence of errors.

3.3.3 Malcom Baldrige National Quality Award (The Baldrige Award)

This was developed mainly to award companies in the USA who have excelled in quality management and achieving in their business, and being able to facilitate the sharing and communication of best practices information (Patterson *et al.*, 2002). The MBNQA over the years, has attracted much attention. This is because it presents an excellent comprehensive framework for organisations to assess their progress toward new patterns of management that leads to customer satisfaction and an increase in employee involvement (Garvin, 1991; Pannirselvam and Ferguson, 2001; Oakland, 2014). The framework consists of seven categories which are used to assess the organisation namely: leadership; strategic planning; customer focus measurement; analyses and knowledge management; work focus; operation focus; and results (Patterson *et al.*, 2002). These criteria represent the underlying relationships between quality management and organisational performance. For any organisation to win such an award, it should be evident that their programs are customer-oriented directed and championed by senior management with the participation of employees and an understanding of internal processes to produce quality goods and services resulting in satisfied customers. Therefore, this award aims at the business excellence of an organisation by helping them to improve their competitiveness and increase the awareness of quality improvement efforts (Oakland, 2014).

3.3.4 Six Sigma

Six Sigma is a business management strategy of an organisation which aims at improving the quality of processes by reducing waste and eventually eliminating sources of errors and variations, leaving the basic processes intact (Pojasek, 2003). It was developed from the TQM movement and originated in manufacturing sector but now applied in all other businesses. According to Pyzdek (2003, p.3) Six Sigma is defined as *"a rigorous, focused and highly effective implementation of proven quality principles and techniques"*. The Six Sigma concept was introduced by Motorola, in 1986, but became popular when General Electric used it in its business processes (Pyzdek, 2003; Hayler and Nicholas, 2007). It involves either the "DMAIC" process (i.e. Define, Measure, Analyse, Improve and Control) which emphasises on improving existing business practices or the DMADV process (i.e. Design, Measure, Analyse, Design and Verify), which focussing on creating new strategies and policies. The Greek letter Sigma (σ), is used by statisticians to evaluate the variability in organisational processes (Gershon, 2010). Hence, an organisations performance is measured by the sigma level of their processes through statistical methods (Antony, 2004). With this approach, all defects and other problems that might hinder the organisation ability to reach near perfect quality level of Six Sigma are identified and removed. This leads to an improvement in the overall processes and systems of the organisation. For better delivery and effective results, the process of Six Sigma is a bit complicated than TQM since it involves only specially trained employees and professionals who are certified as "Green Belts" or "Black Belts". Six Sigma, therefore, focusses primarily on the necessary changes in the processes and systems to ensure high quality of products and services are delivered. It also appears to pay more attention on providing consulting and training services, rather than reviewing and improving the methodology (Hoerl, 2004). Indeed, it is viewed as one of the successful quality improvement methods especially in healthcare and financial sectors (Buavaraporn, 2010).

3.3.5 Lean

Lean is a process improvement method that focuses on eliminating waste from the processes of a company to enhance business performance by improving workflow resulting in a reduction on both costs and cycle time (Anderson *et al.,* 2006; Dahlgaard and Dahlgaard-Park, 2006). It originated from the Toyota Company and has developed over time (Hines *et al.,* 2004). According to Rashid and Ahmad (2013), Lean is a substitution to the conservative ways of mass production and batching principles for high efficiency, quality, speed and cost. It removes all waste, non-value-added activities, inconsistency and inflexibility, such that all activities are being performed without interruptions for an effective increase in their performance (Womack and Jones, 2005; Rashid and Ahmad, 2013). The Lean method is comprised of five steps, namely:

sort; straighten; scrub; systematise; and sustain (Valencia and Bryant, 2006; Radnor, 2008) to achieve the best results. Through the implementation of Lean, a company becomes more agile and able to respond to market needs. Lean has, therefore, become one of the notable improvement initiatives that has extended to the services and the manufacturing industries (Buavaraporn, 2010). A variant of this method is the Lean Six Sigma, which is a blend of Lean and Six Sigma. According to Gershon (2010), Lean Six Sigma is recognised as the best approach developed up till now. With the addition of more tools, Lean Six Sigma also helps achieves results much faster than Six Sigma alone.

3.3.6 Maturity models

Maturity models are techniques used for measuring various aspects of a process or an organisation, as it represents a path towards increasingly organised and systematic way of doing business in organisations (Crosby, 1979; Cooke-Davies and Arzymanow, 2003; Sun *et al.*, 2009 ; Proença and Borbinha, 2016). They are based on the premise that processes, people, functional areas, organisations, and others, progress from an initial stage to a more advanced stage, passing through a number of intermediate stages or levels (Rocha and Vasconcelos, 2004; Becker *et al.*, 2009; Wendler, 2012; Henriques and Tanner, 2017). These stages or levels of maturity are sequential in nature and represent a hierarchical progression (Kohlegger *et al.*, 2009; Wendler, 2012), which shows performance of organisational processes may be poor at the earlier stages but as the stages' advances, processes are performed more methodically and are better defined and managed (Fraser *et al.*, 2003). The application of this concept is not limited to any particular domain; hence, it has been used in various application domains, both as a means of assessment and a framework for improvements (Wendler *et al.*, 2012; Maier *et al.*, 2012).

Maturity models offer a framework with a systematic approach for evaluating organisations' current competences, identifying the actions required to improve, and helping them to implement changes and improvements in an organised way (OGC, 2006). It is, therefore, recognised as an indispensable management-oriented tool for any organisation, where measurements and improvements of current organisational capabilities are concerned (OGC, 2010).

3.4 Summary of process improvement approaches/methods

From the forgoing discussions, the quality of an organisations' product and services is recognised as directly related to the quality of the process it goes through or used to develop it. For such improvements in organisational processes, various process improvement models and approaches are available to enable organisations to continually improve their performance, however, apart from maturity models (MMs), the other process improvement approaches/methods mentioned in earlier discussions do not really show evidence of the capability improvements of the processes. MMs, on the other hand, show the sequence of levels that describes how practices, processes and actions of an organisation can consistently show desired progressive path of improvement that could produce required outcomes. Therefore, to continuously improve on organisational processes to yield positive business performance, MMs can prove very valuable.

The following sections, thus, presents a detailed description of maturity models in terms of maturity concept, definition, origination, characteristics, types and maturity levels. It also presents the existing maturity models in the construction industry.

3.5 MATURITY MODELS

3.5.1 Defining maturity models

Despite the popularity of the MM concept in recent times, there is still not a clear definition of the term "maturity model" in MMs literature (Wendler, 2012; Correia *et al.*, 2017). Generally, MMs describes a methodology with components related to definition, measurement, management and business processes control (McCormack, 2008). Kohlegger *et al.* (2009), states that MMs are tools used to assess the maturity of key process areas and selection of appropriate actions. In Röglinger and Pöppelbuß (2011), MMs are defined as a series of sequential levels, which together form a desired logical path from an initial state to a final state of maturity. According to Becker *et al.* (2009) MM's are systematic approaches to continuous improvement in an organisation that are based on several little evolutionary steps instead of larger revolutionary innovations. Furthermore, Curry and Donnallen (2012) noted that MMs are usually seen as a sequence of levels that describe how well practices, processes and actions of an entity can consistently produce the essential and desired outcomes. Wendler (2012) indicated that, MMs describes the features of an organisation's process or an activity at varied stages, evolving from some initial stage to some more advanced stage. According to Cuenca *et al.* (2013), MMs describe the development of an entity over time. In Bititci *et al.*, (2015, p.5) the authors describe MMs as a "*matrix of practices that define, for each organisational area, the level of formality, sophistication, and embeddedness of practices from ad hoc to optimising"*. Also, some definitions involve concept of continuous improvement and benchmarking, as well as common organisational concepts. For instance, in Korbel and Benedict (2007), a MM is described as an assessment framework that allows an organisation to compare their projects and against the best practices or the practices of their competitors, while outlining a structured path for improvement.

The above definitions indicate a lack of consensus on a standard definition of a MM. According to Proença and Borbinha (2018), the lack of a generic and global standard for MMs is largely the main cause of poor dissemination of this maturity model concept.

3.5.2 The concept of maturity

The concept of maturity models is built on the phrase "*Quality products are a result of quality processes"* (Paulk *et al.,* 1993; Chrissis *et al.,* 2003). The basic idea behind this maturity concept is evolution, which shows that a process, moves through a number of incremental maturity stages. According to Proença and Borbinha (2018), though there are several definitions for maturity, some of these definitions fit into the context in which each MM is developed.

The Cambridge dictionary defines maturity as the state of being completely grown or fully developed; whilst, the Oxford dictionary defines it as the state of being complete, perfect, or ready (Simpson and Weiner, 1989). In Fraser *et al.* (2002) maturity basically means 'ripeness'; that is, a development from an original state to a more advanced state. In organisational management, Andersen and Jessen (2003) describes maturity as a state where an organisation is perfectly able to pursue its objectives it sets itself. In the area of risk management, maturity is seen as the advanced state an organisation reaches, where they are able to understand their risk portfolio and its management such that they can cope and recover from any outcomes that arises (Zou *et al.,* 2010). Mettler *et al.* (2010) defines maturity as an evolutionary progress in the demonstration of a specific ability or in the accomplishment of a target from an initial to a desired or normally occurring end stage. To the CMMI Product Team (2010), maturity is viewed as the level to which an organisation has explicitly and continuously deploy processes that are documented, managed, measured, controlled, and continually improved. According to these definitions, maturity, thus, can be associated with an advanced stage or full development, competency, a perfect condition, probable growth in capability, consistency, a state of being strong and a level of sophistication.

With regards to process maturity, Paulk *et al.* (1993) defined it as the level to which a specific process is clearly defined, managed, measured, controlled, and effective. According to Lockamy and McCormack (2004), process maturity is an indication that an organisation process is being complete and capable of being defined, managed, and continuously improved through measurement and feedback resulting in consistency and productivity across the entire organisation. A 'mature' process is, therefore, one with increasing performance through consistency in process implementation (Cooke-Davies *et al.,* 2001). The 'effectiveness' in the original definition of process maturity by Paulk *et al.* (1993) can be seen as the efficacy of the processes leading to a desired outcome. As a result, to produce quality products or services, the effectiveness of the processes needs to be continually improved. Using components from these definitions, process maturity for the purpose and context of this study will be viewed as an improvement in the capability of organisations processes against its set objectives and targets.

3.5.3 The origin of maturity models

MMs concept have their roots in quality management and continuous process improvement (Fraser *et al.,* 2002; Vaidyanathan and Howell, 2007; Van Looy *et al.,* 2011). Crosby's (1979, 1986) Quality Management Maturity Grid (QMMG) is the progenitor. QMMG describes the behaviour exhibited by a company at five maturity levels for a set of aspects of quality management (Jokela *et al.,* 2006). In a sense, a company can reach a quality management excellence through these five evolutionary stages namely: uncertainty; awakening; enlightenment; wisdom; and certainty (Fraser *et al.*, 2002). QMMG, thus, led to the development of the CMM by the Software Engineering Institute (SEI) at the Carnegie Mellon University for software development, as a reference model for assessing, evaluating and improving software process maturity (Paulk *et al.,*1993; Srai *et al.,* 2013), as well as the successor, Capability Maturity Model Integrated (CMMI) (Ahern *et al.*, 2000).

3.5.4 Characteristics of maturity models

Following Fraser *et al.* (2002) typology, MMs usually have these common characteristics. They contain key process/application areas which are described by maturity or capability levels (typically 3-6 levels); a descriptor for each level; a generic description or summary of the characteristics of each level as a whole; a number of elements or activities for each process area; and a description of each activity as it might be performed at each maturity or capability level. The maturity levels are arranged from the lowest to highest possible level to be achieved; and organisations proceed between maturity or capability levels in such a way that, none of these levels are skipped (Khatibian *et al.,* 2010).

They epitomise a theory of stage-based progression, aiming at describing stages and maturation paths, as they are expected to reveal current and desirable maturity levels and to include improvement measures (Pöppelbuß and Röglinger, 2011). Additionally, MMs are one-dimensional, focusing either on process maturity, people capability or other objects maturity, with most of them typically focusing on a process perspective (Mettler and Rohner, 2009).

Another distinctive feature of MMs is that they are either presented in staged or continuous structure (Antunes *et al.,* 2014). In a staged representation, maturity levels are used to represent the overall state of the organisation's processes relative to the model as a whole. This means that the different process areas are addressed at different maturity levels and maturity grows in discrete steps. Accordingly, an organisation gets assessed against the existence or absence of their process areas and produces an overall maturity level rating (Meng *et al.,* 2011). The staged representation enables an organisation to improve a set of related processes by incrementally addressing the successive sets of process areas such that each maturity level forms a basis for the next maturity level (SEI, 2009). This presentation enables organisations to benchmark themselves and to identify the next steps or improvement routes for organisation development. In the continuous representation capability levels are used to represent the state of the organisation's processes relative to an individual process area (CMMI, 2010). An organisation chooses the set of process areas they want to improve on based on their business objectives and then each process area gets individually assessed to a capability level and improvements made accordingly (Antunes *et al.*, 2014). The continuous representation thus offers much flexibility than the staged presentation (SEI, 2006).

3.5.5 The use of maturity models

MMs are increasingly being applied in many domains, both as a means of assessment and as part of a framework for improvement. Rosenstock (2000) explains that a maturity model, by itself, does not guarantee organisational improvement. It is a tool that assist organisations to identify weaknesses but does not fix them. Also, the results of maturity model evaluation help generate improvement plans but not execute the plan. As a result, an understanding of the role of MMs and their use is essential.

MMs are mainly used for three purposes, namely: (1) Assessment of strengths and weaknesses ("as-is" assessments) as a descriptive tool; (2) Development of a roadmap for incremental improvement ("to-be" maturity) as a prescriptive tool; and (3) for evaluation of a company, compared to standards and best practices of other organisations as a comparative tool (Jeston and Nelis, 2006; Pöppelbuß and Röglinger, 2011). MMs provide guidance for action plans and allow organisations to systematically assess their capability to manage its business processes in the best way and continuously monitor their progress (Becker *et al.,* 2009; Pöppelbuß and Röglinger, 2011). A structured framework is, therefore, provided for describing current capabilities and performance improvement options and strategies (Yeo and Ren, 2009). In practice, MMs are usually used to determine the current quality in a particular area through self-assessments. Based on the evaluated level, recommendation for improvements are made and actions also taken. As a consequence, organisations have adopted the maturity model concept as a way to appraise their as-is situation and improve their competences and afterward control the progress of their implementation (Maier *et al.,* 2010). With the use of such a technique, management teams of organisations become more critical about their organisation practices, resulting in more periodic reviews and faster production of assessment results. This in turn, enhances managerial competences, strengthens organisational learning, giving priorities to actions and defining roadmaps (Curry and Donnallen, 2012; Bititci *et al.,* 2015).

Despite the lack of a generic standard for maturity model development, more practitioners in many industrial sectors are beginning to embrace the value of maturity models, with its implementation and use growing in popularity across several industrial sectors (Proença and Borbinha, 2018). According to Chan and Qi (2003), MMs are quite similar to the management concepts of Business Process Reengineering (BPR) and have attracted the interest of several researchers and organisations. The CMM and its successor the CMMI, which are the most commonly used models (Leppänen, 2013) have become a reference model for the design of several MMs in various disciplines such as quality or software, showing the different purposes that they might have (Fraser *et al.,* 2002).

3.5.6 Maturity levels

MMs describes the ideal evolution of a process toward a desired improvement using maturity levels (Tahri and Kiatouni, 2015). A maturity level is a distinct evolutionary stage towards achieving a mature process (SEI, 2005; David 2013). Maturity levels are, therefore, referred to as collections of key process areas that organisations must implement as part of a defined improvement route (Meng *et al.,* 2011). Each level covers a set of process areas that, when satisfied, stabilises an important component of the development process and results in an increase of the process capability of the organisation (Paulk *et al.,* 1993; Amaratunga, 2002). According to Sarshar *et al.* (2000), continuous process improvement is established on maturity levels that are several small, evolutionary stages, rather than revolutionary measures. Extant literature on MMs show different maturity levels, ranging from mostly three to six levels, however, the number of levels can vary, depending on the area and the concerns motivating the model. Nonetheless, the majority of existing models, have adapted five maturity levels together with best practices, key process areas, and goals from the CMM (Supic, 2005), since the general CMM has five levels of maturity (Paulk *et al.*, 1995).

Maturity levels are from low to high and are mostly labelled as initial/ad hoc (level 1), repeatable/basic (level 2), defined/intermediate (level 3), managed/advanced (level 4) and optimizing (level 5). At the initial level (i.e. the lowest level) a process is seen as ad hoc or chaotic and, thus, be made repeatable; and then, be defined or standardised. After the process is defined, it is then managed (i.e. measured and controlled). The process finally must be optimised (i.e. when it has reached its highest level) where the organisation focusses on continuous process improvement through feedback and the use of innovative ideas and technologies (Willis and Rankin, 2011; Hankel and Lago, 2015). Inherent in MMs is the use of lower levels of maturity as the basics for achieving higher levels of maturity. In a sense, each level of maturity must be built on the earlier level to ensure the full maturation of the process. Becker *et al.* (2010), indicate that an organisation will be operating more efficiently as it rises in maturity/capability level regarding a particular process area.

3.5.7 Types of maturity models

According to Fraser *et al.* (2002), maturity models are divided into three basic groups. They include, maturity grids, hybrids, Likert-like questionnaires and CMM-like models. The maturity grid comprises of brief text descriptions for each activity at each maturity level. The Likert-like questionnaires are a simple form of MMs in which questions on statement of 'good practice' are asked for respondents to rank the in a given level of maturity according to its position in a scale ranging from 1 to n. The hybrids consist of questionnaires having numeric ranks to each question with an overall description of the maturity levels without any detailed explanation of the activities (Fraser *et al.*, 2002). The CMM-like models are more formal and complex (Mettler *et al.*, 2009; Vezzetti *et al.*, 2014). They contain specific process areas and a number of subdomains with each maturity/capability level described appropriately. Some differences exist between these three types of maturity models. For instance, CMM-models tend to be more complex both in development and use, and Likert-like questionnaires offer less support in guiding improvements, since they only allow for assessment (Fraser *et al.*, 2002). The maturity grids, on the other hand, are simple both in development and use.

3.5.7.1 Capability maturity model

The concept of "capability maturity" has its roots in the field of quality management maturity developed in the 1970s (Crosby, 1996). According to Clarke *et al.* (2013), capability is '… an indication of how well a process used by an organisation does what it is designed to do' whereas maturity shows the shared impact of the capabilities on certain aspects of an organisation

(Rosemann and de Bruin, 2005). An organisational process or aspect could, therefore, be less or more mature and, as such evolve or decrease as it becomes more mature. A capability maturity model (CMM) is, thus, a simplified representation of an organisational field (e.g. health and safety management, environmental management and risk management) that distils key industry practices into a coherent process-based framework (Macgillivray *et al.*, 2007).

CMM is the best-known derivative of the quality management maturity concept developed by the Software Engineering Institute (SEI) (Vaidyanathan and Howell, 2007). According to Paulk *et al.* (1993), CMM was first developed in the software industry by the Carnegie Mellon University SEI, which was originally funded by the United States Air Force (USAF) as a framework to inspect capability maturity of software providers. The idea of CMM concept was that, all methods, practices, activities and alterations used to develop software and products become defined and accordingly implemented when the organisation reaches maturation/advanced stage (Paulk *et al.,* 1993). They are constructed according to maturity levels, from novice to best practice, which are identified by the extent to which the processes are defined, controlled and established (SEI, 2006). CMM is similar to ISO 9001 standard, since both relate to quality and process management (Paulk, 1994), however, ISO 9001 specifies the least acceptable quality level, while the CMM establishes a framework which leads to continuous process improvement. CMM, therefore, identifies a clear method to produce this continuous improvement and goes beyond the checking of a system through adoption of an ISO standard. CMMs are, therefore, tools used to assess the capability of an organisation to perform the vital processes essential to deliver a product or a service (Strutt *et al.*, 2006). Also, CMMs describes the practices that any organisation must perform in order to improve its processes; provides a benchmark against which to occasionally measure improvement; and creates an established framework within which to manage the improvement efforts (Eadie *et al.*, 2012).

CMM consists of series of key process areas and several maturity levels which aids in the assessment of the organisational capabilities against an agreed scale (Paulk *et al.*, 1993). It can either be presented as staged or continuous (APM, 2007) and typically contains five or six maturity/capability levels including: initial; repeatable; refined; managed; and optimising, which provide progressively the basics for the next higher level as representation of evolutionary improvements (Humphrey, 1993; Paulk *et al.*, 1993; Paulk *et al.*, 1995 ; Paulk, 2009). Since the concept of capability maturity is generic in nature, it has become very adaptable, a fact echoed by the growing number of CMMs in many industrial sectors (Fraser *et al.*, 2002; Ren and Yeo, 2004; Eadie, *et al.*, 2011). Examples are the capability maturity model integration (CMMI), Capability Maturity Model for Software (SW-CMM), Systems Engineering Capability Maturity Model (SE-CMM) amongst others. Additionally, a process model (Bootstrap) was developed by the European Commission (EC) as a version combination of CMM and ISO for the software development process improvement soon after CMM (Alshawi, 2007). Other areas of usage are project management in construction, systems engineering, risk management, supply chain, software engineering, manufacturing, service development organisation, risk management, e-learning and among others (Kwak and Ibbs, 2002; Cooke-Davies and Arzymanow, 2003; PMI, 2003; Lockamy and McCormack, 2004 ; Mullaly, 2006; OGC, 2006; Vaidyanathan and Howell, 2007; Yeo and Ren, 2000; Sun *et al.*, 2009). According to Lathi *et al.* (2009), the models in these fields, ultimately, all aim to continuously improve their organisational processes.

3.5.7.2 Capability Maturity model's integration (CMMI)

The CMM developed by Paulk *et al.* (1993) in the end metamorphosed to CMMI (Chrissis *et al.*, 2007; SEI, 2010). The CMMI emergence was as a result of complications in application of multiple models across an organisation. The model was developed by integrating Systems Engineering, Software Engineering, and Integrated Product and Process Development (IPPD) CMMs into a single, comprehensive framework for organisations to assess their growth and maintenance processes, implement improvements, and measure progress (Patterson *et al.,* 2002). The idea behind CMMI is that a high-quality process produces a high-quality product at the end (Day and Lutterworth, 2011). It, therefore, provides a stepwise evaluation of the status of an organisation as well as guidelines for process quality improvements (SEI, 2010). CMMI covers 22 process areas that are a group of related practices classified into four key process areas: engineering, project management, support and process management (SEI, 2010). Each process area consists of related practices and these practices are focused towards achieving the desired goal (SEI, 2010). It comprises of maturity levels presented in a progressive manner containing process improvement criteria across the levels (SEI, 2010; Eadie *et al.,* 2012).

The maturity levels of the CMMI framework are presented in a stepwise manner labelled one to five and has both a staged representation and a continuous representation (SEI, 2006, 2009).The staged representation is comparable with CMM (i.e. an assessment produces one maturity rating) while the continuous representation complies with SPICE (i.e. the capabilities of individual processes are examined). It, therefore, offers a company two approaches (the continuous and the staged representation) to assess and improve their organisational processes. The same number of process areas at different capability levels are seen in the continuous representation but with the staged representation, the number of process areas varies from one maturity level to another. According to SEI (2010), CMMI provides a better procedure in which the maturity level of a particular organisational process can be determined and further enhanced. Through this step by step approach, CMMI has gained recognition by researchers in the construction industry and in the academic world as an established standard for developing maturity models (Goldenson and Gibson, 2003). For example, some notable construction researchers have adopted CMMI for their studies (Sarshar *et al.*, 2000; Keraminiyage *et al.*, 2006, 2007; Sun *et al.*, 2009; Eadie *et al.*, 2011, 2012; Babatunde *et al.*, 2016, Manu *et al.*, 2018). Consequently, the basic structure of the SHEM-CMM to be developed in this study will be based on the continuous representation of the CMMI in a maturity grid format. Levels of capability maturity will be allocated against attributes thereby creating a series of cells. Each cell contains a brief text description (i.e. descriptor) for each capability maturity level.

3.5.8 Criticisms of maturity models

The popularity and adoption of MMs has increased resulting in a great deal of academic interest (Becker *et al.*, 2010) with their utilisation on an upward trajectory (Scott, 2007). This is because, MMs guide and improve the ability of organisations to develop a culture of excellence and to overcome challenges involve in quality improvement and costs reduction in the face of competitive pressure (Perkins *et al.*, 2010; Lahrmann *et al.*, 2011). Despite the benefits of MMs, both the CMMI and CMM models have not escaped criticism (Hartman and Skulmoski, 1998). For instance, MMs by their nature are seen as constructs, characterised by a step by step methods, which oversimplify reality and mostly based on espoused best practices with their reliability not justified empirically in some cases (Jugdev and Thomas, 2002; Jugdev, 2004; de Bruin *et al.*, 2005; McCormack *et al.*, 2009; Torres, 2014). They also do not capture the need for business process innovation since they do not consider the rapid pace of change, and technologies and other emerging innovative processes (Jugdev, 2002; Smith and Fingar; 2004). Furthermore, De Bruin and Rosemann (2005) noted MMs do not have much rigour in their model development process since it is focused on problem identification and raising awareness rather than solving problems. Skulmoski (2001) indicated that they are limited in scope and do not sufficiently consider the link between process capabilities and organisational performance (Mullaly, 2006). Jugdev and Thomas (2002) stated that MMs focus only on work processes, while the human resources and organisational aspects is not given much attention. Moreover, their guidelines are seen to be generic and narrow and as such overlook strategic and competitive advantage principles (Andersen and Jessen, 2003). Further criticism refers to the unknown and undisclosed documentation and development procedures, multitude of similar maturity models, and the non-reflective adoption of the capability maturity model (CMM) blueprint, (Iversen *et al.*, 1999, Smith and Fingar, 2004; de Bruin *et al.*, 2005; Becker *et al.*, 2009, 2010; Kamprath and Röglinger, 2011).

To mitigate these criticisms, some research work has been published while others continue to work on maturity models from a design process and a design product perspective. As for the design process, several procedure models have been proposed (e.g. de Bruin *et al.,* 2005; Maier *et al.,* 2009; Becker *et al.*, 2009; van Steenbergen *et al.,* 2010; SolliSæther and Gottschalk, 2010; Mettler, 2011). For instance, de Bruin *et al.* (2005) describe six steps to guide the design of descriptive maturity models and their development for prescriptive and comparative purposes of use. Based on this, *Maier et al.* (2012) developed a roadmap that is a method for the development of maturity grids, with four phases and 13 decision points. From the design science guidelines by Hevner *et al.* (2004), Becker *et al.* (2009) derived some requirements and proposed eight stages of developing and evaluating MMs. For maturity models as design products, literature deals with qualities, components, and design principles. For instance, Ahlemann *et al.* (2005) and Simonsson *et al.* (2007) suggest qualities (i.e. desirable properties or dimensions of value) specifically geared to capability assessment models. Simonsson *et al.* (2007) noted that for a capability model to be an effective assessment tool it needs to be valid, reliable and cost-efficient. As for the components of maturity models, Fraser *et al.* (2002), identified the following: maturity levels; descriptors for each level; generic description or summary of the characteristics of each level as a whole; capability areas (key process areas or dimensions); a number of elements or activities for each process area; and a description of each activity as it might be performed at each maturity or capability level. de Bruin *et al.,* (2005) also described six stages to guide the design of a descriptive maturity models, while Ahlemann *et al.* (2005) established a meta-model which included components such as criteria, competence, maturity levels, objects and methods for data collection and analysis. Pöppelbuß and Röglinger (2011) suggested that for MMs to be useful for its intended application area and purpose of use, there is a need for some design principles, which is missing from the others. They recommended a framework of general design principles for MMs that provides a well detailed guideline for researchers and practitioners involved in the design and application of maturity models. Lockamy III and McCormack (2004) also developed a supply chain management maturity model that had a good theoretical basis.

MMs are not the ultimate solutions to improve organisations processes, but they do offer a framework with a methodical approach for assessing the capability of an organisation to manage its business processes in the best way. According to Nikkhou *et al.* (2016), MMs over the years have proved and are still proving to be beneficial since they allow individuals and organisations to assess the maturity of various aspects of their performance against benchmarks and prioritise further improvement actions. In fact, Lockamy III and McCormack (2004) agreed with Dooley *et al.* (2001) that their usage improves organisational processes and business performance. Research by the SEI has also shown notable improvements in the return on investment rate in organisations implementing maturity models. More mature organisations have obtained a 75% reduction in cost and an 85% reduction in defects (OGC, 2010).

Granting that the concept of CMM originated from the area of software development, it represents a generic framework for continuous process improvement, hence, has been applied in various sectors (Sarshar *et al.*, 2000; MacGillivray, 2007; Yeo and Ren, 2009; Babatunde *et al.*, 2016). Indeed, CMM is acknowledged and widely applied in many improvement initiatives in several domains. For instance, several efforts have been made to adapt it into the automotive industry (Gonzalez *et al.*, 2007; Wilner *et al.*, 2016), oil and gas (Fleming, 2000), fashion (Battista and Schiraldi, 2012), mechatronics and transportation (Pels and Simons 2008) and Social media (Geyer and Krumay, 2015). Furthermore, it has gained recognition by researchers in the construction industry and academia. As a result, some notable construction researchers have adopted CMMI for their studies with a number focussed on project management, risk management, change management, process management and Building Information Modelling (BIM). Presented in Appendix J are some existing maturity models and the areas of application of the maturity modelling concept.

3.5.9 Maturity models in construction

Regardless of the criticisms, the construction industry has recognised the potential of MMs. Inspired by the success of MMs in the manufacturing and software industries, several efforts have been made to contextualise MMs, such as the CMM/CMMI, to the construction processes to influence the industry (Sarshar *et al.,* 2000; Amaratunga *et al.*, 2002; Eadie *et al.*, 2011; Chen *et al.,* 2014). Accordingly, some studies on CMM have been conducted. Presented in Appendix J are some existing maturity models in literature particularly in the construction domain. A notable one is the SPICE project which sought to establish a stepwise process improvement framework in the construction industry to aid in the assessment of process capability and improvements by applying the principles of SW-CMM. It consists of five maturity levels and involves key organisational processes against five process enablers. Although this model identifies process strength and weakness, it doesn't recognise the multi-organisational nature of construction work (Sarshar *et al.,* 2000; Finnemore *et al.,* 2000). Vaidyanathan and Howell, (2007) therefore, proposed a CSCMM (Construction Supply Chain Maturity Model) to remove inefficiencies in the construction supply chain and improve performance and operational excellence. The model is built on the premise that process maturity is achieved in stages by incrementally managing CSC business processes along three dimensions namely: functional, project and firm. It illustrates a four-step progression: adhoc, defined, managed and controlled.

This model adequately addresses the multi organisational aspect of construction, however, it does not take in to account other aspects like building information modelling. Khalfan *et al.* (2001) developed a Benchmarking and Readiness Assessment for Concurrent Engineering in Construction (BEACON) model to create the level of maturity for construction supply chain to improve the planning process during concurrent engineering implementation. It consisted of four key process areas with five maturity levels.

Jia and Chen (2012) also presented a program management maturity integrated model for mega construction programs in China to assess organisational performance in a structured repeatable process. Keraminiyage *et al.* (2006) established a conceptual framework for the development of higher capability maturity level dynamics. Chinowsky (2007) also developed a maturity model that provides construction organisations with a framework for developing a learning organisation culture. Sun *et al.* (2009), conducted a study on a change management maturity model for construction projects. Zou *et al.* (2010) developed a Risk Management Maturity model (RM3) which was useful to gain a broad understanding of current risk management maturity in the industry. Willis and Rankin (2011) developed the Construction Industry Macro Maturity Model (CIM3) based on the CMM concept, which consist of three levels of maturity. The model assesses the maturity of the construction industry at the macro level and to provide leading indicators of project performance. Eadie *et al.* (2012) developed measures to capture capability maturity of ICT applications in the construction industry. Meng *et al.,* (2011) also developed a maturity model for supply relationships in construction. Babatunde *et al.* (2016) used some critical factors to develop a methodology for developing capability maturity levels for PPP stakeholder organisations. Rodrigo *et al.*, (2016) developed the Construction e-business capability maturity model to enable construction organisations to systematically review and evaluate their current e-business process maturity based on five main process categories mapped onto five levels of maturity. Quaigrain (2019) developed the Construction disability management maturity model (CDM3) to evaluate the maturity of construction firm's disability management practices using 12 disability management indicators. Moreover, with the advent of Building Information Modelling (BIM), the capability maturity modelling concept has been adopted to model BIM capability (NIBS, 2007; Succar, 2010; Giel and Issa, 2015; Siebelink *et al.*, 2018).

Though MMs have been applied in different domains, its contributions and similar application in the area of health, safety and environmental management in construction are scarce. Extant literature research regarding maturity models in the safety, health and environmental management field is still at its inception.

3.5.9.1 Safety, health and environmental management maturity models in construction

It is essential to understand the positioning of construction companies towards effective management and control of SHE risks. Fraser *et al.* (2002) and Dooley *et al.* (2000) highlighted the importance of MMs for assessing the capability of an organisation to manage its business processes in a consistent manner. A better understanding of existing SHE management practices and capabilities for effective implementation of integrated SHE management systems is critical to generate positive SHE performance outcomes. Despite increasing popularity of MMs in improving performance in many domains, there is no existing maturity model that corresponds to integrated SHE management practices or capabilities in the construction industry. The ones existing are the maturity models used for safety culture assessment (Fleming and Lardner, 1999; Fleming, 2000; Lardner *et al.*, 2001; Lardner, 2004; Hudson, 2001, 2007; Parker *et al.*, 2006; Goncalves *et al.*, 2010; Foster and Hault, 2013). Only one model has so far been developed to assess health and safety in construction: The Health and Safety Maturity Model by Goggin and Rankin (2009). The model assesses safety maturity across six safety factors: policy and standards, management commitment, worker involvement and commitment, equipment, materials, and resources, working environment, and hazard management. This model is restricted to three levels of maturity namely: low maturity, intermediate maturity and high maturity, to simplify data collection and analyses (Quaigrain and Isa, 2015). The premise of this maturity model is that greater maturity in an organisation' s practices will result in enhanced performance. Though the model is a proactive tool for measuring construction company's current state of S&H management practices, it did not cover some aspects of health and safety management in construction, such as, safety planning, controlling, communication, injury management and prevention practices. There is also the Design for occupational safety and health (DfOSH) capability maturity model by Manu *et al.* (2018) which is at a stage of review and validation by industrial experts. This model is expected to access the DfOSH capability of design firms in the construction industry across 18 DfOSH capability attributes mapped onto five levels of maturity.

Apart from these two MMs focusing on safety and health management practices in construction, the literature review did not reveal any other maturity models and systematic approaches evaluating integrated SHE management in the construction industry, thus the significance of this study. Furthermore, given the poor SHE outlook of the construction industry, the development of an integrated SHEM-CMM in this study should enable construction companies to better understand their integrated SHE management practices and capabilities, and also enable them to identify strengths and weakness, and improve the SHE management practices resulting in better SHE performance outcomes.

3.6 Chapter summary

This chapter presented various process improvement approaches/methods with particular emphasis on maturity models. The chapter discussed the fundamental concepts and the structure of capability maturity model. It covered the concept of maturity, origination, characteristics, types and levels of MMs and existing maturity models in the construction industry. The review of existing maturity models concludes that the maturity models, particularly CMMI-like models can be adopted to guide organisations to assess, control and improve their processes to enable them develop a culture of excellence with a number of practices in key areas. They are therefore, both a means of assessment and a framework for improvement. Though there are several maturity models in construction most of them are applied predominantly to project management than in the area of SHE management. An integrated SHEM-CMM could provide valuable information on SHE management capability enhancement and improve SHE performance in construction. The next chapter presents the methodology employed in this study.

CHAPTER FOUR - METHODOLOGY AND RESEARCH DESIGN

4.1 Introduction

The success of any research is dependent on the effective application of existing methodological approaches for investigating the research problem under study (Fellows and Liu, 2009). Research methodology is a systematic way of solving a problem. Essentially, it represents the principles, procedures and rationale for any given research project, describing the methods for data collection and analysis, chosen to answer a specific research question(s) to potentially increase knowledge in the particular field of study (Dainty, 2008). Research methodology, therefore aims to ensure an ethical approach to inquiry and analysis of results (Fellows and Liu, 2009). Based on a review of research approaches, this chapter presents an overview of the research paradigms that informed the study's underlying philosophical assumptions, the research strategy and methods adopted for this study. The research design and a justification of the methods of data collection and analysis, within the study's scope and context are also presented.

4.2 The research approaches

Research approaches are specific plans and procedures employed in conducting research, which sets out guidelines to link up the elements of applied methodology used to study a topic or a research problem. These elements are the philosophical worldviews or paradigms; research strategies (procedures of inquiry or research designs) and specific research methods for collecting empirical data, analysis, and interpretation (Creswell, 2014). Generally, three research approaches, are mainly advanced in research method literature, they include: (a) quantitative, (b) qualitative and (c) mixed methods. In selecting any of these research approaches, a researcher needs to think through the philosophical assumptions they bring to the study, the research strategy that is related to this worldview, and the appropriate methods or procedures of research that translate the approach into practice (Creswell, 2014). In this study, the Creswell's (2014) three-pronged framework (Figure 4.1) was adopted to guide the review of the appropriate research strategies and research methods applied to the study. The adopted framework is reviewed in relation to this study in the next sections and outlined as follows:

Philosophical worldviews: discusses the researcher's worldview on the ontological and epistemological foundations of the research.

Research designs or strategies: highlights different research strategies - qualitative, quantitative and mixed methods strategies in relation to the answering of the research questions.

Research methods: discusses techniques and procedures engaged for data collection and analysis, data interpretation and validation.

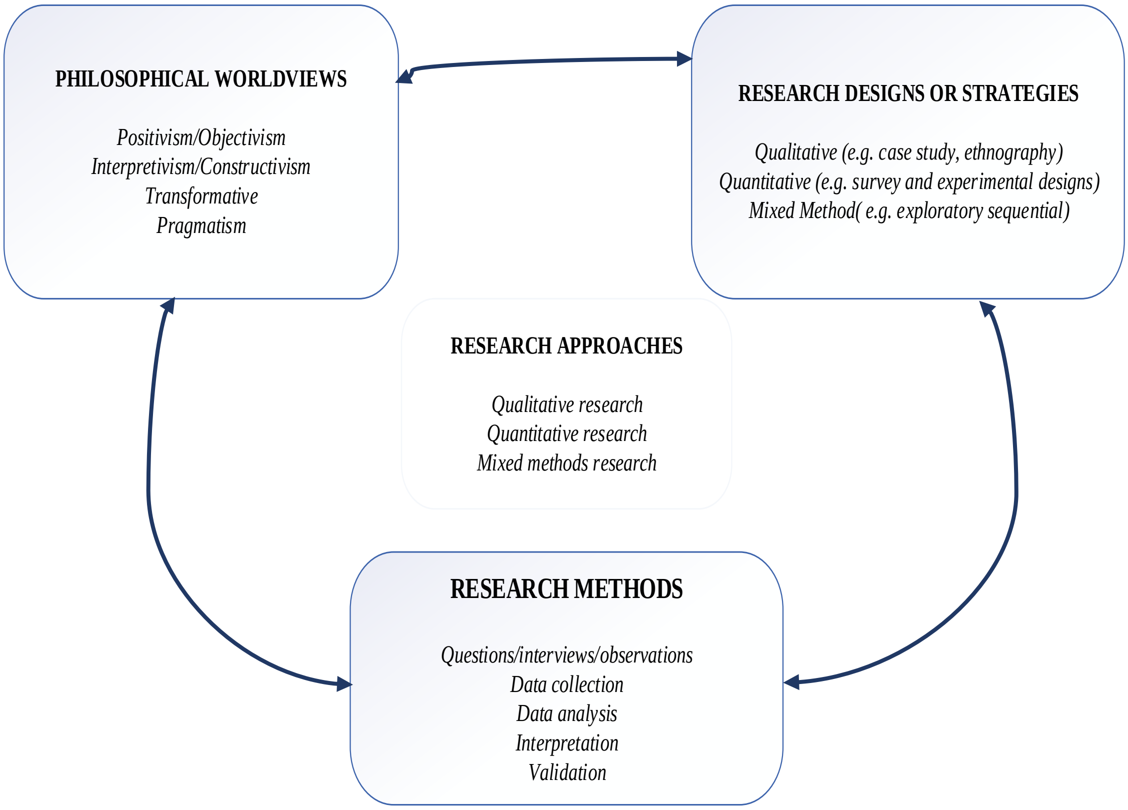

Figure 4.1: Three-way framework for research design
Source: Creswell, (2014) p.35

4.3 Philosophical worldview

According to Creswell (2014) the term ‘worldview’ generally represents the ‘basic set of beliefs that guide action” (Guba, 1990, p. 17). It can be regarded as a general philosophical orientation of an individual or a researchers’ knowledge and point of view of the world or the nature of the research. It involves how we acquire knowledge as well as its acceptability to a particular field of enquiry. It, thus, represents the understanding of the ways of seeking knowledge. Philosophical assumptions typically, are deeply rooted in most studies, but they remain hidden (Mackenzie and Knipe, 2006; Siew, 2014), however, they influence the choices of researchers’ strategies and methods (Pollack, 2007; Smyth and Morris, 2007), and thus, needs to be identified (Creswell, 2009). By knowing philosophical worldviews, research can discuss its fundamental beliefs and views, how it informs the problem to a study, the research questions and the data collection and analysis (Creswell, 2014). Though over the years several philosophical worldviews have emerged, the four reported by Creswell (2014) are highlighted below.

4.3.1 Positivists worldview

The positivists worldview assumes reality is stable, observable and measurable. They therefore, believe the causes of problems do exist in the natural world and can be reduce to empirical indicators which, represent the truth, hence can be measured through objective methods. The quantitative research philosophical approach is based on the positivist worldview. This worldview is sometimes called the scientific method, positivist/post positivist research, empirical science, post positivism or doing science research. The positivist goes forth into the world to look at, study and find absolute information concerning the single objective reality (Denzin and Lincoln, 2013). To the positivist, the reality out there can be observed and described from an objective viewpoint rather than a subjective viewpoint (Scott and Usher, 2011). Positivists advocate the application of scientific methods to study social reality and any other phenomenon (Scot and Usher, 2011). Since the meaning of the objective reality does not reside in the conscience of the researcher, it needs to be discovered.

The ontological position of positivism is one of realism, which assumes that reality can be observed independently and, thus, it can be experienced the same by everyone (i.e. there is one reality that can be known within a certain level of probability). The discoverable reality of the research situation or problem, therefore, exists independently of the researcher, regardless of his/her perspective or belief and that a phenomenon can be researched without being influenced (Scotland, 2012). The positivist epistemology is, therefore, one of objectivism. As a result, positivists view their methodology and the knowledge generated as value neutral. Their methodology is focused on explaining relationships. Positivists attempt to identify causes which influence outcomes (Creswell, 2014). They seek predictions and generalisations; therefore, their methods often produce quantitative data. As a consequence, it is commonly emphasised that the positivist approach to research is deductive in nature. Their methods of data collection are in a form of closed ended questionnaire, standardised tests, and descriptions of phenomena using standardised observation tools. Analysis of data comprises of the descriptive and inferential statistics which allows the results to be generalised to populations. Typically, the research concepts or constructs in the positivism worldview have to be defined for measurement and involves sample sizes that are larger for statistical conclusions to be drawn.

4.3.2 Constructivist world view

The interpretivist or constructivist worldview assumes problem is understood through "the participant's views of the situation being studied" (Creswell, 2009). The qualitative research philosophical approach is based on the interpretivist or constructive worldview. Its ontological position is that of a relativist, which assumes there is no existence of any possible correct reality. Reality is subjective, socially constructed and constantly changing and differs from one individual to the other (Sutrisna, 2009). Thus, constructivists believe people seek understanding of the world in which they live and work. Each person develops subjective meanings of their experiences and these meanings are varied and multiple. Therefore, with this worldview, participants' views of the situation are studied and relied on as much as possible (Creswell, 2009). This is because the researcher's intent is to make sense of or understand the phenomenon from an individual's perspective due to the interactions the individual has with the world.

Epistemologically, constructivists take the view that knowledge is subjective and that the world does not exist independently of our knowledge of it (Scotland, 2012). Knowledge and meaningful reality are, therefore, constructed in and out of interaction between humans and their world and everyone can view the world in a different way (Sustrina, 2009). The qualitative researcher and the object or subject of study are, therefore, inextricably linked so that the findings of the research are mutually created within the research context (Guba and Lincoln, 1994). Qualitative research relies largely on processes and meanings (Sale *et al.*, 2002) and uses qualitative methods, such as in-depth interviews, focus groups, participant's observations among others. The constructivist contend that qualitative research is time and context bound and that generalisations are not possible. It allows for deep, rich and observational data to be collected. Data analyses involve qualitative approaches, such as thematic analyses, grounded theory and interpretative phenomenological analysis. Samples are usually not intended to be representative of larger populations.

4.3.3 Transformative worldview

This philosophical stance assumes research inquiry needs to be interconnected with politics and the political and social change agenda, to tackle social inequities and oppression at whatever levels it occurs (Mertens, 2010). According to Creswell (2014), this philosophical worldview places much importance on the needs of groups and individuals in our society that may be marginalised. It is, therefore, regarded as a paradigm where contextual factors such as power, oppression and social justice are addressed in the type of research questions asked, the types of research strategies used, the manner in which they are used, and the kind of information gathered (Mertens, 2010). It sometimes involves the use of participants and community members in the design of the research questions, data collection and analysis. Transformative research, thus, provides a voice for these participants who have been shunned by societal margins, increasing their awareness or developing an agenda for change to improve their lives through research (Creswell, 2014). Due to its purpose, Mertens (2010) suggested mixed methods, techniques and approaches are the most appropriate methodological choice. An example being the cyclical approach which involves an ongoing relationship with the participants in the community, where the results of one cycle of inquiry feed into decisions about the next cycle of inquiry. This type of mixed method ultimately improves the validity of the research undertaken.

4.3.4 The Pragmatic worldview

This worldview is a widely-associated paradigm for the conduct of mixed methods research (Creswell *et al.,* 2009). It assumes a researcher should be able to use all available approaches to understand or address the research problem to achieve better outcomes, rather than focusing on methods and specific philosophical worldviews (Creswell, 2014). Pragmatism, therefore, does not commit to any one system of philosophy and reality. Hence, it is pluralistic and practical in nature (Amaratunga *et al.*, 2002), and works well across both interpretive (qualitative) and positivist (quantitative) worldviews (Creswell, 2014). As a result, pragmatism uses multiple data collection and analyses methods. Despite it being an intuitively stimulating research paradigm that avoids focus on rather antagonistic positions assumed by the competing positivist and constructivists worldviews (Tashakkori and Teddlie, 1998), it has been criticised for dealing with reality and truth rather than theory and opinion (Morgan, 2007). To this end, there is still a long-lasting debate around both paradigms, since purist believe the respective philosophical worldviews are incompatible.

4.3.5 The adopted philosophical worldview

The key research questions and the research phenomenon under investigation influences the type of philosophical worldview to be adopted (Pollack, 2007). It is, therefore, important to select the appropriate research paradigm to obtain the necessary information needed. From the research questions put forward in this study which include: (1) What organisational attributes regarding SHE management are required for the development of an integrated SHEM-CMM?; (2) What are the relative priority or weight of those attributes? and (3)What levels of maturity are appropriate for capturing maturity on the capability attributes?, it is evident that they involve measurements. As a result, for objective measurements to be obtained it is reasonable to adopt positivism as the philosophical worldview in this study. By adopting positivism, capability attributes and their associated weights can be viewed as a single reality that can then be discovered, carefully observed and assessed objectively. This discoverable 'single reality' exists independently of the researcher and not meditated by the researcher's sense. The ontological and epistemological position of the current study is therefore realism and objectivism. The objective answers to each research question posed in this study require the use of quantitative approaches to data collection, which also sits well with the adoption of positivism.

4.4 Research strategies

Apart from adopting a philosophical worldview, researchers have to decide on how to conduct the whole research. A research strategy, therefore, is a general plan of action or a methodology that enables the researcher to answer the research questions or problems in a systematic way (Saunders *et al.,* 2009). It is sometimes called *approaches to inquiry, research designs or methodologies* (Creswell, 2009). Research strategies are types of inquiry within qualitative, quantitative, and mixed methods research approaches that provide a particular direction for procedures in a research process. Creswell (2014) identifies three main classifications: quantitative, qualitative and the mixed methods designs.

4.4.1 Quantitative strategies

This strategy of enquiry is associated with the positivism worldview which assumes there are true answers for problems in the natural world (Sustrina, 2009). Researchers must, therefore, propose hypotheses or ask questions to seek empirical data, for confirming or disconfirming them (Easterby-Smith *et al.,* 2012). Quantitative research, therefore, relies on techniques and processes that relate to facts and figures rather than subjective opinions to describe the objects and relationships under study (Saunders *et al.*, 2009). Generally, quantitative research strategies, try to answer the questions concerning the what, how much and how many (Fellows and Liu, 2008) and, as such involves the application of a numerical approach to the issue under study as well as to the data analysis. Quantitative researchers tend to collect instrument-based data by the use of questionnaires to collect hard data and then use statistical methods to analyse the data to reach conclusions. The sample sizes used in this approach are large and representative. Hence, quantitative results can be generalised to a larger population.

Though quantitative strategies are seen to be a useful form of enquiry, some authors have criticised for its lack of context and rigidity, which affect the reliability of the research findings (Bryman 2008; Denscombe, 2010). Regardless of the criticisms, quantitative research is still useful when properly applied with respect to the purpose of an inquiry and the questions to be addressed. According to Creswell (2009), the two popular quantitative strategies used are: survey research and experiment research. Both are briefly discussed below.

4.4.1.1 Survey

Surveys provide a quantitative description of attitudes or opinions and trends of a population by studying a sample of that population (Creswell, 2013). It comprises cross-sectional and longitudinal studies using interviews or questionnaires to collect data. This is principally done with the intent of generalising from a sample to population (Babbie, 2013). In longitudinal surveys, data is collected over long periods of time, whiles in a cross-sectional survey, data is collected at the same time or within a relatively short time frame. This, provides a brief summary of the variables included in the investigation at a specific time. The sampling of participants and the mode of data collection are vital determinants of any survey data validity (Bryman, 2008).

4.4.1.2 Experiments

This quantitative strategy relies on the manipulation, control and testing of defined variables by a researcher or other persons to understand inter-tendencies and causal relationships (Fellows and Liu, 2008). In an experiment, researchers identify a sample and generalise to a population. This is because, the main intent of an experiment is to test the impact of a treatment or an intervention on an outcome, whilst controlling other factors that might have an influence on the outcomes (Creswell, 2009). Experimental research is widely used among natural and social sciences, and medical research (Kumar, 2011). In the physical sciences, experiments are laboratory-based while they are field based in the social sciences. Saunders *et al.* (2009) stated that one of the key objectives of this strategy is the fulfilment of objectivity, validity, resource predictability, and replicability. This strategy of inquiry could, however, be unreliable in terms of its demands on time (Kumar, 2011).

4.4.2 Qualitative strategies

Qualitative research approach focusses on exploring and understanding the meaning, individuals or groups ascribe to a phenomenon (Creswell, 2014). It thus, involves fieldwork that gives access to people, setting or an organisation to investigate behaviours in the natural settings using subjective measurements and then making interpretations of the meaning of the data (Creswell, 2009). It is concerned with words rather than numbers, as they focus on explaining the meaning of a phenomenon (Bryman, 2012). It is, therefore, useful in answering research questions relating to how and why (Fellows and Lui, 2008). Hence, the processes in qualitative research approach is inductive in relation to theory and literature and, thus, based on the interpretivist/constructivist paradigm (Sutrisna, 2009).

The kinds of data that are often collected in this type of research are document data, observation data, interview data and audio-visual data. Text and image analyses are usually undertaken. To obtain an in-depth meaning of the research problem, small samples are normally collected in qualitative research instead of large ones as in the case of quantitative research. Qualitative research as quantitative research has also been criticised as too subjective, unstructured and lacking transparency (Bryman, 2008). According to Gibbs (2007), a thorough check of transcripts to ensure they do not contain mistakes and also there is no drift in the definition of codes could improve its reliability Similarly, Creswell (2013) noted its validity can be confirmed by establishing themes based on joining several sources of data or the viewpoints from participants, using peer debriefing and allowing participants to comment on the findings. According to Creswell (2009), there are five different ways of undertaking a qualitative research process. These five strategies of inquiry are briefly discussed in the next sections.

4.4.2.1 Ethnography

Ethnography is a type of qualitative strategy of inquiry where researchers observe or study a group of people over a long period of time in their real enviroment by gathering observational and interview data (Creswell, 2014). This strategy is believed to be different from the others due to the depth and the intimacy of the researchers work since they get up close and quite personal with the research participants by observing not just what they say they do, but what they actually do. Ethnography thus, permits high levels of flexibility due to the ability of subject to change the method in response to requirements of the environment within which the study is conducted (LeCompte and Schensul, 1999). Ethnography research focuses on a single specific group of people to allow for in-depth study. It therefore involves observation, exploration and interpretation of targeted groups lives and behaviours. Data collection in this type of research inquiry, is generally unstructured. The key data sources are in the form of participant observation and relatively informal conversations, though, other documents and audio-visual materials can be used. Furthermore, ethnographic researches produce descriptions, explanations and theories rather than quantification and statistical analysis (Sarma, 2012).

4.4.2.2 Grounded theory

Grounded theory is a structured methodology which involves the establishment of theories through a systematic data collection and analysis. It is a systematic but flexible research strategy, which produces detailed directions for data analysis and theory generation and can be used in various situations (Sarma, 2012). This strategy of inquiry involves the simultaneous collection and analyses of multiple stages of data and refinement of categories of information (Charmaz, 2006; Strauss and Corbin, 2007).

4.4.2.3 Case study

This is a research strategy that involves in-depth studies of a particular situation, programme, activity or process, rather than a sweeping statistical survey using various data sources and procedures (Yin, 2009; Creswell, 2014). Case studies are bounded by time and activity, and thus, data collection with detailed information is done over a sustained period of time (Yin, 2009). According to Fellows and Liu (2008), case studies focus on investigating a small number of cases rather than large number of cases. A case study design comprises data collection techniques, such as detailed and structured interviews, participant/non-participant observation, documentary materials found in available data sources and others (Sharma, 2012).

4.4.2.4 Phenomenological research

In a phenomenological research strategy, researchers identify ways in which an individual's worldview is formed in part by that individual who lives it (Creswell, 2009). This strategy is, therefore concerned with the study of human phenomena within everyday social settings (Creswell, 2009) and viewed as a philosophy, as well as a method (Moustakas, 1994). In this process, the researcher sets aside his or her experiences in order to understand those of the participants in the study (Bryman, 2008).

4.4.2.5 Narrative research

This qualitative research inquiry involves the researcher studying people lives based on their self-narrated life stories, which is often retold by the researcher in a chronological account (Creswell, 2009). In the end, the narrative combines views from both the participant and the researchers' life in a corroborative manner (Clandinin and Connelly, 2000). Examples are biographies and autobiographies.

4.4.3 Mixed method strategies of enquiry

This strategy of inquiry resulted from merging qualitative and quantitative strategies together into a single research approach (Tashakkori and Teddlie, 2003; Bryman, 2008; Creswell, 2009). It originated in 1959 when Campbell and Fisk used multi-methods to study validity of psychological traits (Creswell, 2009), where they tried to eliminate or neutralise the biases and weaknesses inherent in the traditional strategies of inquiry (Bryman, 2008). According to Creswell (2014), such concurrent application of more than one strategy of inquiry (qualitative and quantitative) is known as mixed, multi or triangulation methods. A mixed method strategy is mostly used when the nature of the research problem is such that both qualitative and quantitative data can be collected and analysis made to offer a better and deeper understanding of a phenomenon (Amaratunga *et al.,* 2002). According to Creswell (2009), the three mixed method strategies are the Sequential, Concurrent and Transformative mixed methods. Each of them is succinctly described below.

4.4.3.1 Sequential mixed method

This strategy of inquiry permits findings of one method to be verified by another method. It is classified as either an explanatory sequential mixed method or an exploratory sequential mixed method (Creswell, 2014). In explanatory sequential mixed method, the researcher first collects and analyses quantitative data and subsequently collects and analyses qualitative data, in two successive stages in one study (Ivankova *et al.,* 2006). The purpose of this method is to have the qualitative data explain those quantitative (statistical) results by exploring participants' views in more depth (Tashakkori and Teddlie, 2003; Creswell, 2014). In the exploratory sequential mixed method, the researcher first collects and analyses qualitative data and use the findings in the second quantitative stage of the study. The purpose of this is to develop an instrument to administer to specific samples of populations. Though both designs provide an honest and a more detail analyses of quantitative and qualitative results, it takes quite a long time to analyse both data (Ivankova *et al.*, 2006).

4.4.3.2 Concurrent mixed method

This research inquiry allows researchers to join or merge qualitative and quantitative data to conduct a more comprehensive analysis of the research's issue (Creswell, 2009). In this type of inquiry, the researcher collects both forms of data at the same time during the study and then integrates or merges the information in the analysis and interpretation of the overall results (Tashakkori and Teddlie, 2003; Creswell, 2009), instead of starting with one strategy (quantitative or qualitative) and following it with another (quantitative or qualitative) in stages as seen in the sequential type of inquiry. The findings of such an inquiry are generally viewed as well-validated: however, the resources needed for this type of research may be enormous. It also requires great effort and expertise by the researcher to adequately study the research problem, collect and analyse data (Tashakkori and Teddlie, 2003; Creswell, 2009).

4.4.3.3 Transformative mixed method

This type of research strategy has a theoretical perspective within a design that consist of both qualitative and quantitative data that helps guide a research work. This theoretical perspective can be a conceptual framework, advocacy or a specific ideology (Creswell, 2009). Transformative mixed methods research design involves data collection method through sequential or concurrent approach. Due to the paucity of written work on this strategy of inquiry, there is a lack of information on the use of the theoretical lens to guide the methods (Creswell, 2009).

4.4.3.4 Adopted research strategy

Given that quantitative research is generally rooted in the positivist worldview (Creswell, 2014), which is the adopted philosophical position for this study, the quantitative research strategy was adopted to help answer the research questions. This study aims to develop an integrated SHE management capability maturity model; hence, the need to identify what the key integrated SHE management capability attributes or processes areas are and what levels of maturity they map onto. The suitability of quantitative strategy for answering questions relating to "what" (Fellows and Liu, 2008), which is the case in this research, supports its suitability for this research. The use of the quantitative research approach allows the researcher to collect objective evidence measured through scientific methods. Moreover, the need to have a generalised view regarding the capability attributes sits well with the quantitative strategy as it is suitable for making generalisations. Furthermore, the study aims to ascertain the relative priorities of the integrated

SHE management capability attributes. Prioritisation of elements have, however, been achieved mainly through quantitative methods (Yeung *et al.*, 2009; Mahamadu, 2017; Zahoor *et al.*, 2017; Olawumi and Chan, 2018; Manu *et al.*, 2019a). Thus, in order to achieve the research objectives, the quantitative research strategy, specifically a survey research design (i.e. Delphi survey accompanied by the voting analytical hierarchy process which are further explained in subsequent sections) was adopted as the appropriate strategy for inquiry in this research. Although some researchers regard Delphi as a qualitative method of inquiry (Hasson *et al.,* 2000; Padel and Midmore, 2005), it has been conducted in a more quantitative manner, producing quantitative or semi-quantitative data in the past two decades. Review papers by Hallowell and Gambatese (2010), Sourani and Sohail (2015) and Ameyaw *et al.* (2016) have affirmed this trend. A full description of the Delphi approach is provided in sections 4.6.3 and section 4.6.4.

4.5 Research methods

This refers to procedures and techniques that are engaged to collect data in any research study. It includes the forms of data collection, analysis, and interpretation that researchers propose for their studies. The choice of a particular type of data collection is largely dependent on the purpose of the research, as well as the strategy of inquiry (Naoum, 2007). Observations and interviews are examples of types of data collection techniques available (Kumar, 2011). According to Naoum (2007) surveys are also classified as part of data collection techniques. A review of the commonly used data collection techniques is presented in the next sections.

4.5.1 Interviews

An interview is a focussed discussion between two or more people. Interviews are important when collecting data based on the knowledge and the perceptions of individuals or groups (Saunders *et al.*, 2009). Generally, interviews are better for more complex questions and are mainly qualitative in nature. It, therefore, requires detailed description or narratives from interviewees (Robson, 2002). Saunders *et al.* (2009), stated that the nature of any interview should be consistent with research question(s) and objectives, research aim and the adopted strategy of inquiry. Interviews can be done formally (structured), semi-structured, or informally. They can be conducted in person or over the telephone and, as such, questions should be focused, clear, and encourage open-ended responses (Robson, 2002).

4.5.2 Survey Method

The survey method is a technique of gathering data by asking individuals (i.e. people who are thought to have the needed information) questions either by phone, online, in person or on paper using standardized questionnaires or interview (Denscombe, 2010). This research method can be used in both qualitative and quantitative studies. The main variations of the survey method include questionnaires, interviews and document review. Though the questionnaire is one of the survey processes, it is seen by many people as the “survey”. A questionnaire a form that comprises of a list of questions to which respondents are required to answer and return to the researcher (Kumar, 2011). Questionnaires thus, allow information to be collected from respondents and still maintain the desired anonymity producing results that are easy to compare and analyse (Denscombe, 2010). Questionnaires can be either self-administered or interviewed administered (Saunders *et al.,* 2009). The self-administered questionnaires are administered electronically using the internet and the intranet, by post or mail, where questionnaires are posted to respondents who return them by post after completion and (or) by delivery where questionnaires are delivered by hand to each respondent and collected at a later date. Responses to this type of questionnaires are generally completed by the respondents. The interviewed administered questionnaires are administered using the telephone or using structured interviews where interviewers physically meet respondents and ask the questions face to face. Responses to this type are recorded by the interviewer on the basis of each respondent’s answers. Due to its design, a questionnaire can affect the response rate and the reliability and validity of the data collected; hence, questions must be careful designed (Saunders *et al.*, 2009). Questionnaires are an inexpensive method of data collection that is useful where literacy rates are high and respondents are co-operative. Generally, responses can be analysed with quantitative methods by assigning numerical values (e.g. Likert-type scales).

4.5.3 Observations

Observation is a focused and systematic way of watching and listening to an interaction or phenomenon as it occurs (Kumar, 2011). During observations the researcher gathers first-hand data on processes, programs or behaviours being studied. Observation approaches are often used in behavioural and qualitative research. It, therefore, allows the researcher to study the dynamics of the situation and other behaviours and enable him/her to develop a holistic perspective on the issue being studied. Researchers are often able to learn and obtain more information about participants than in an interview or a focus group. Thus, observations are recognised as the most appropriate approach to collect required information when researchers are more interested in behaviour than in the perceptions of individuals (Bryman, 2004). Observations could be structured or unstructured depending on the nature of the schedule and the type of observations required (Bryman, 2004). Structured observation permits the researcher to observe behaviour based on systematic predefined rules. The unstructured observation does not follow any predefined rules, instead it permits the researcher to generally observe behaviour after which patterns could be drawn from the analysis (Kumar, 2011).

4.5.4 Adopted methods and techniques of data collection

In this study, data was collected through questionnaires deployed via the Delphi technique. This method is aligned with the quantitative research approach adopted in this study. In quantitative research, questionnaires are the most widely used (Denscombe, 2010). The questionnaire technique was suitable for the initial verification process to check the appropriateness and comprehensiveness of the capability attributes generated from the literature review. Also, it was used in a survey in conjunction with the Delphi technique as a valid approach to obtain the relevant integrated SHE management capability attributes. The Delphi technique allowed for a quantitative description of construction experts' personal opinions and perspectives for an objective computation of consensus, and determination of weightings of the relevant SHE management capability attributes using VAHP. Considering the few construction professionals in the Ghanaian construction industry who have in-depth knowledge and experience in SHE management systems implementation and its inherent issues, the use of an expert data collection technique, such as the Delphi technique, was deemed the most appropriate method to obtain reliable information. The application of the Delphi technique in construction engineering management (CEM) studies is not rare. For instance, this technique was used in some recent CEM doctoral studies (Dewi, 2013; Elsayah, 2016; Mahamadu, 2017). Specifically referring to construction safety and health studies, this approach has also been applied (Hallowell and Gambatese, 2009; Manu *et al.,* 2019a). In their study, Hallowell and Gambatese (2009) used a Delphi technique in conjunction with detailed literature review to determine the relative effectiveness of safety program elements in mitigating construction safety and health risks. The results of the comprehensive literature review fed into the development of the Delphi survey.

4.6 Data collection methods in this study

Data collection is a process of gathering information. In this study, the data collection methods included a review of literature supported by an expert verification process and a Delphi survey. The following sections discussed these processes in detail.

4.6.1 Review of related literature

Given the dearth of studies regarding integrated SHE management capability attributes, a comprehensive review of literature related to SHE management and not limited to construction, as well as literature related to maturity models on safety and health, and environment were used to generate a list of potential capability attributes of integrated SHE management. The literature sources comprised of international standards, published guides on SHE, peer-reviewed journals books and conference papers, as well and texts covering, SHE management systems or models. Furthermore, relevant literature related to capability maturity models on safety and health, and environmental management were also reviewed. Information from already established internationally recognised SHE management standards and published works were extracted, and the components of standards were compared in order to determine key similarities and differences, thereby, establishing potential integrated SHE management capability attributes.

4.6.2 Expert verification process

Though the literature review led to the identification of capabilities attributes for integrated SHE management in construction, it revealed that capability attributes for integrated SHE management in construction was not clearly outlined. This necessitated the verification of the integrated SHE management capability attributes by experts. The verification exercise was conducted to (a) verify the appropriateness and comprehensiveness of identified capability attributes for inclusion into an integrated SHE capability maturity model, and to (b) identify any further capability attributes that have been missed.

Towards achieving a successful verification, a panel of experts was constituted. They were selected following the guidance of Hallowell and Gambatese (2009) in selecting experts for expert group techniques. These include: at least five years of professional experience in the construction industry, a minimum of five years’ experience in SHE management, an advanced degree in CEM or other related fields (minimum of BSc.), an affiliation with a professional body and an academic who have carried out research in areas of environmental, health and safety management in construction particularly in Sub-Sahara Africa. The selected expert participants have industry experience and expertise in SHE management in construction, particularly in Sub-Sahara Africa. This group of experts were deemed appropriate for the verification as from their combined academic and industry experience, and expertise they are more likely to have a broader knowledge of relevant attributes that could constitute an integrated SHE management system.

Based on the above criteria, 12 experts were selected and engaged based on satisfying the set of selection criteria. The verification process was done through the administration of questionnaires to the selected panel. They were sent customised e-mails that included a hyperlink to the specific Bristol Online Survey (BOS) questionnaire to enable them respond. This approach allowed the collation of ideas towards decision-making. The respondents were given three (3) weeks to respond.

The verification process was carried out to confirm the relevance and comprehensiveness of the capability attributes for achieving effective integrated SHE management in construction. The results of the verification are presented in section 5.3.2.1 of the results chapter. Following the preliminary expert verification, a Delphi process accompanied by a voting analytical hierarchal process (VAHP) was undertaken to ascertain the relative weights/priorities of the attributes.

4.6.3 The Delphi Technique

4.6.3.1 Delphi origination

The Delphi technique was originally developed by the Research and Development (RAND) Corporation in the 1950s as a technique to solicit reliable expert opinions concerning various technological forecasts, including finding out on how Soviet forces could possibly attack the US industrial military systems (Vázquez - *et al.,* 2007; Gnatzy *et al.,* 2011). It was a structured survey for confidential military purposes and was named by the RAND corporation as the Project Delphi. The developer's principal goal was to provide a quite efficient way of helping experts share their thoughts, knowledge and insights in an anonymous way that will stimulate their thinking and bring a reliable consensus to a problem or a topic under examination (Dalkey *et al.,* 1972; Vázquez-Ramos *et al.,* 2007). Delphi's initial applications, therefore, were for future forecasting, specifically around planning of military contingencies but over the last 50 years, it has been used for more peaceful purposes (Adler and Ziglio, 1996). For instance, the first of non-military usage of the Delphi technique (DT) was the study by Gordon and Helmer (1964) that focused on forecasting emerging technological events. Subsequently, DT has been used in urban and regional planning, healthcare, curriculum development in universities and towards the evaluation of other complex social problems (Linstone and Turoff, 1975). Its usage has, therefore, broadened rapidly and become recognised as a valid instrument for obtaining reliable group opinion using a group of experts.

4.6.3.2 Overview of the Delphi technique

The DT is a method used for the systematic collection and collation of opinions and judgments on specific issues through a set of carefully designed sequential questionnaires combined with controlled feedback of opinions derived from earlier responses. (McKenna, 1994; Linstone and Turoff, 2011). It allows for unbiased information to be obtained and synthesised from a number of knowledgeable persons on the subject under study (Young and Jamieson, 2001). As a technique, Delphi is properly designed to handle opinions rather than objective facts (Schmidt, 1997; Chan *et al.*, 2001). DT aims at highlighting topics of concern and particularly useful when there is objective data unavailable and also there is a lack of empirical evidence (Linstone and Turoff, 1975; Hallowell and Gambatese, 2010). Its main purpose is to achieve the most reliable consensus of expert's opinions on specific issues through a set of sequential questionnaires combined with controlled feedback (Dalkey and Helmer 1963). By acquiring the consensus of a panel of experts using the Delphi process, researchers can identify and prioritise issues and develop a framework to recognises them (Okoli and Pawlowski, 2004).

DT involves participants who remain unknown to each other and their interaction is managed in an entirely anonymous way (Linstone and Turoff, 1975; Robinson, 1991). Following each round, the responses are analysed and based on the analysis, a new questionnaire is developed and sent to the participants in the subsequent round. The iterative nature of the method produces new information for the participants in each round, which enables each of them to re-evaluate the information they provided in earlier rounds and project them beyond their own subjective opinions (Procter and Hunt, 1994; Yeung *et al.*, 2009). During this process, the variability of the responses lessens and reliable consensus opinion is achieved. The procedure continues until a certain level of agreement has been achieved. In fact, the Delphi process stops as the research questions are answered (Skulmoski *et al.,* 2007). The Delphi method, therefore, provides an effective technique for encouraging progress toward consensus or at least some degree of convergence or agreement amongst participants in a group. Generally, the mean or median scores of the last round are used to determine the results (Rowe and Wright 1991; Mullen, 2003). The statistical group response guarantees that each expert opinion is represented in the final response (Dalkey *et al.*, 1972). As Paul (2008) explains, DT also allows the researcher or facilitator to control the collected information from selected experts' participants. This allows the researcher to have much control over any bias (Hallowell and Gambatese, 2010). The Delphi method has been widely used in many published research studies since its introduction (McKenna, 1994). In recent years, it has seen notable increase in its usage in CEM research (Ameyaw *et al.,* 2016).

4.6.3.3 Objectives of the Delphi technique

The DT differs from the traditional surveys and, thus, its main objectives are:

1. To gain insight from a group of qualified experts;
2. To establish a degree of consensus or a level of agreement;
3. To maintain anonymity of several expert participants throughout the process; and
4. To give answers to questions that cannot be addressed using standard statistical procedures because of the nature of the question.

4.6.3.4 Delphi technique and modifications

The traditional DT, since its public introduction in the 1960s has been modified in several ways to overcome certain limitations and allow for customisation to meet the demands of different studies (Adler and Ziglio, 1996; Hasson and Keeney, 2011; Hussler *et al.*, 2011). However, some authors are of the view that these modifications dilute the Delphi method and, thus, threaten reliability and validity (e.g. Sackman, 1975; Linstone and Turoff, 1975; McKenna, 1994).

Modified Delphi studies have one or more of the processes in the traditional method amended (e.g. fewer numbers of surveys can be deployed and questionnaires can be replaced by interviews) but in the end, all other procedures of the traditional Delphi are adhered to. According to Hasson and Keeney (2011), there are ten different forms of the DT. The most popular of these designs being the Classical or Traditional, Decision making and Policy Delphi methods (Hanafin, 2004; Franklin and Hart, 2007). The classical Delphi is useful for establishing facts about a specific situation or topic and used in situations where the panel are from diverse backgrounds (Mullen, 2003; Sobaih *et al.*, 2012; Kezar and Maxey, 2016). It consists of anonymity, iteration, controlled feedback, statistical group response, and stability in expert responses on specific issue. A variation of this type is the modified classic Delphi, where the researcher or coordinator distributes a generic list of pre-defined items for the experts to interact within the first round instead of the general question asked in the first round of a classic Delphi (Geist, 2010; Adnan and Daud, 2010; Hasson and Keeney, 2011).The decision Delphi is an alternative to classical Delphi that organises the decision-making procedure and tell on future reality, as opposed to merely forecasting (Rowe and Wright, 1991). It is used for collective decision making. Participation in this type of Delphi depends on one’s position in the hierarchy. Although questionnaire responses are anonymous in the decision Delphi, participants know the names of all the members involved in the study. Nevertheless, responses to the questionnaires are kept confidential, hence, termed quasi-anonymity (Linstone *et al.*, 1975).

Also available is the ranking Delphi. This type of DT shares similar principles to other Delphi types but it is done in three phases namely: brainstorming (discovering issues), narrowing down (determining the most important issues); and ranking the issues (Schmidt, 1997; Okoli and Pawlowski, 2004) and mostly used for elements prioritisation. As the name implies, Policy Delphi is concerned with gathering data from a group of professionals who are policy makers; however, this type does not aim for consensus (Turoff, 2002). The policy makers are selected to obtain contrasting views on a specific matter like policy options through structured public dialogue, while repetitions may be planned as comparable to the traditional Delphi (Franklin and Hart, 2007). It, is, therefore recognised as a tool for the "*analysis of policy issues, not a mechanism for making a decision*" (Turoff, 2002).

4.6.3.5 Delphi characteristics

The DT uses a methodological approach to reach consensus of opinions and stability of group judgment on particular issues. As a result, its reliability and strength are reliant on some fundamental principles (Linstone and Turoff, 1975; Rowe and Wright, 1999; Young and Jamieson, 2001). These fundamental principles are characterised by four key features namely: (1) Anonymity of participants; (2) Iteration; (3) Controlled feedback from the researcher; and (4) Statistical aggregation of participant responses (Adler and Ziglio, 1996; Rowe and Wright, 1999; Xia and Chan, 2012). Each of these fundamental elements are introduced in the following paragraphs.

A) Anonymity of Delphi participants

The anonymity principle is critical to the execution of the Delphi design and process (Powell, 2003; Yousuf, 2007). This characteristic enables expert participants without no prior relationships to communicate effectively and encourages them to provide true opinions (Akins *et al.,* 2005). It also ensures that participants in the Delphi process freely provide their opinions independently, without the tendency to conform to the social pressures or group's dominant opinions (Gordon, 1994; Skulmoski and Hartman, 2007). The anonymity principle, therefore, eliminates any obstacles of group thinking. Additionally, anonymity in Delphi, allows participants to change their viewpoint in subsequent iterations without any implications whatsoever (de Meyrick, 2002). As this characteristic increases the value of the Delphi technique, researchers or the facilitators must ensure that the contributions of the expert panellists throughout the Delphi study remains anonymous until completion. The use of the internet and conducting Delphi survey via e-mail is useful and effective to maintaining this confidentiality.

B) Iteration of data collection

Iteration of data is crucial in obtaining any degree of consensus. It is a process of repetitive input that allows interaction among panel members over several data collection stages (Skulmoski *et al.,* 2007). Since DT is a multi-stage process, experts participate in one or more rounds. The iteration feature ensures that experts' through a controlled feedback process, are given the opportunity to reconsider their opinions and judgment, in light of the information received from other experts, anonymously after each round (Landeta, 2006). Iteration of data collection, therefore, aids in the gradual formation of reliable group opinion.

C) Controlled feedback

Feedback occurs when information (e.g. answers provided by others) is transferred between panel members in a manner that encourages participants to consider one another's opinions, whilst protecting anonymity. It is called controlled since the researcher or the facilitator decides on the nature of the feedback. Nevertheless, after each round, the data obtained from the questionnaires is statistically aggregated and fed back to participants in a structured format that permits them to read, comment on, and critique all facets of the issue at the same time (Jahns, 2008; Geist, 2010). Meijering (2016) noted that, feedback can either be in a form of summary of statistics or rationales. The summary of statistics is based on the experts' rating or rankings and show per questionnaire item, a location and dispersion statistic (e.g. mean and the standard deviation or the median and the interquartile range), whiles the rationales consist of the summary of explanations that experts gave for their ratings or rankings. Feeding back on both types is considered most appropriate (Murphy *et al.,* 1998).

Though controlled feedback helps in achieving a consensus of opinion or judgment (McKenna, 1994), too much feedback from too many experts over many Delphi rounds can result in participants' fatigue and provision of unreliable information. Also, without the iterative and feedback aspect in the process, it is not deemed a Delphi process (Hallowell and Gambatese, 2010).

D) Statistical aggregation of group responses

The final iteration in the Delphi process involves an aggregation of group responses into one response that represents the collective group opinion. Accordingly, for the study to reflect an accurate group judgment, it is important to employ appropriate analytic methods (Alyami, 2015). As a result, a number of statistical aggregation indices like the mean, median, and inter-quartiles are deployed in the aggregation of group responses. To measure the level of agreement among experts in each Delphi round, the most commonly used methods include, the level of percentages, standard deviation and some other complex indices, such as the interrater agreement index, Kendall's coefficient of concordance (W) and the Cronbach's alpha (Ameyaw *et al.*, 2016).

4.6.3.6 Delphi limitations

Several researchers (Rowe *et al.,* 1991; Gupta and Clarke, 1996; Yousuf, 2007; Linstone and Turoff, 2011) have affirmed the intellectual value of the DT as a quick, systematic and effective process for gathering unbiased information on a specific subject from a panel of experts through consensus (Hasson *et al.,* 2000; Landeta, 2006). However the Delphi process faces some limitations in its implementation. Some of these shortcomings are listed below:

1. The vague and exclusionary nature of who an "expert" is, does not necessarily allow or include people with direct experience of the issue under study. This situation may produce erroneous results, leading to instability of responses and poor convergence of opinions (Baker *et al.,* 2006).
2. The difficulty in defining and measuring consensus (von Der Gracht, 2012).
3. The Delphi process appears to force consensus, leaving out discussion among qualified participants, and not giving them opportunities to explain their perspectives in depth; in the process of achieving consensus also extreme opinions may be removed when in fact they may provide important insights (Powel, 2003; Thangaratinam and Redman, 2005).
4. Potential of low response rates as a result of experts' lack of motivation to participate and exhaustion after two or three rounds (Landeta, 2006).
5. Delphi results can to be skewed due to the opinions of the panels which can be influenced by several personal factors (Bolger and Wright, 2011).
6. Delphi studies are at the mercy of the bias of the researchers, since they are the ones responsible for choosing participants or experts, structuring of questionnaires and interpreting all the information obtained (Lang, 2001).

Despite the above limitations, Brill *et al.* (2006) described the DT as a good research method for developing consensus among experts on a particular topic, particularly where the information required is subjective. Further, when a Delphi study is designed well and used correctly, it can be the best tool to reveal perspectives, generate new knowledge in a particular study area and encourage possible actions (Adler and Ziglio, 1996; Hasson *et al.*, 2000).

4.6.3.7 Current status of Delphi as a research Technique

Although Delphi started as a technique for futures research, numerous researchers use it today to deal with complex issues (Linstone and Turoff, 2002). The DT has, therefore, been used in research to develop, identify, forecast and to validate in various research areas. According to Linstone and Turoff (1975), it has been recognised as an accepted research methodology by the scientific community since the mid-1950s. A study by Rowe and Wright (1999) showed the DT has gained acceptance in a wide range of fields of study particularly in nursing, education, information systems, public health, tourism, public transportation, medicine, engineering, construction management and public policy (Kezar and Maxey, 2016).

Though over the years, DT has become an established survey method used for collecting data in many studies as a primary or secondary research instrument, it has received some criticisms and also been justified by others when objective data is not readily available. It has proved to be an accepted method in construction management research (Dalkey and Helmer 1963; Chan *et al.*, 2001; Okoli and Pawlowski 2004; Yeung *et al.*, 2007; Hallowell, 2009; Hallowell and Gambatese, 2010; Xia and Chan, 2012; Mahamadu, 2017; Zahoor *et al.*, 2017; Olawumi and Chan, 2018). Its usage in CEM studies has, therefore, increased greatly over the past years (i.e. from 1990 to 2016) (Ameyaw *et al.,* 2016; Ogbeifun *et al.*, 2017).

4.6.3.8 Comparison of Delphi to other consensus methods

There are several formal consensus-building methodologies. Consensus building methods are mainly directed at idea-generation, problem-solving, or determining priorities (Delbecq *et al.*, 1975). According to Venon (2009) the consensus methods that are frequently used are focus groups, nominal group and Delphi techniques. Though, they all aim to achieve a convergence of opinions or a general agreement around a specific study area, the Delphi technique was considered for this study since the others were found to be less appropriate to the development of a set of relevant integrated, SHE management capability attributes.

In focus groups, participants meet face-to-face and are asked to provide ideas and information about the research problem (Morgan, 1997; Fern, 2001). The researcher or the facilitator then limits discussion to the areas of importance. Here, the quality of the information presented will depend largely on the skill of the researcher or moderator (Gallagher *et al.,* 1993). The nominal group technique involves a well-planned face-to-face meeting, where ideas on a research problem are solicited independently and privately from experts (Delbecq *et al.,*1975). The ideas are collected and discussed sequentially and then ranked in importance. Both methods are, therefore, equally effective for finding solutions to problems where no accurate information exists (Graefe and Armstrong, 2011). It is expensive and involves much time commitment on both the researcher and the respondent. Furthermore, both methods of data collection involve face to face interactions that can be dominated by powerful individuals, 'noise' and tend to have unstructured discussions. Moreover, there is group pressure for members to conform (Dalkey, 1969; Powell, 2003). These obstacles, therefore, cause significant distortion in individual judgment (Asch, 1951). It is, therefore, not surprising that some studies have demonstrated that, after face-to-face group discussion, group collective response was often less accurate than the opinions of individuals when averaged without discussion (Dalkey and Helmer, 1963). The DT on the other hand, is a highly-structured group communication process that uses interactions between expert panel members by means of questionnaires to deal with a problem under study (Cortes *et al.*, 2012; Sourani and Sohail, 2015; McMillan *et al.,* 2016). It, therefore, does not need the qualified expert participants to meet physically hence no face-to-face communication (Okoli and Pawlowski, 2004). The DT seeks the opinions of individuals who have attained a level of knowledge and experience in their occupational fields that is respected by others and are referred to as experts. It, therefore, ensures that more accurate assessments are obtained from a group than individuals as it reflects the principle of "several heads work better than one" in cases of uncertainty (Rowe *et al.,* 1991; Ludwig, 1997).

The DT is not just a simple substitute for the other methods of face-to-face interactions but it has several advantages over them. For instance, Delphi can be used to collect qualitative and quantitative data or both types of data in combination. It, therefore, allows the researcher to make subjective judgements, as well as objective ones (Skulmoski *et al.*, 2007). The DT also permits the researcher to extract the maximum amount of unbiased information from a panel of experts (Chan *et al.*, 2001), which results in more objective outcomes. It is a relatively inexpensive method of gathering group opinion (Barnett *et al.,* 1978). The iterative nature of the DT, combined with the feedback process, ensures the reliability of the results by permitting experts to reconsider and change their responses (Vázquez-Ramos *et al.,* 2007; Geist, 2010; Eycott *et al.*, 2011). Additionally, the DT facilitates anonymity, which ensures that the process is relatively free from various impediments associated with personal interactions and group dynamics (Fraser, 2003). This guaranteed anonymity encourages participants to provide responses based on their own personal knowledge and experiences and these opinions are more likely to be 'true' (Snyder-Halpern, 2002). The Delphi method, therefore, brings in more objectivity into the judgment process than other group consensus methods. It is, therefore, considered the most prominent of the consensus reaching methodologies (Jones, 1980).

4.6.3.9 Justification of selecting Delphi technique to conduct this research

In this study, on identifying capability attributes that are relevant for inclusion in an integrated SHE management framework, understandings may be significantly influenced by the particular area of expertise, experience or occupational position of a participant. Implementation of SHE management systems in construction organisations in Ghana is less common (Ayarkwa *et al*., 2010). An integrated SHE management system implementation is, thus, expected to be characterised by relatively limited knowledge and experience amongst construction professionals in the construction industry. In view of this, it is prudent to use an expert data collection method, such as the DT, as this technique enables the use of the collective judgment of independent experts in investigating problems where limited information is available and coming up with practical solutions (Delbecq *et al.,* 1975; Adler and Ziglio, 1996). There is a significant benefit, therefore, in being able to harness the individual judgements of respondents on a collective basis.

An overarching aim of the DT is to achieve consensus (i.e. a general agreement), hence, it was selected as the research instrument. The DT enables a researcher to elicit reliable information from a group of experts on the research problem and ensures that emergent differences between and within the panel members can be accounted for in a systematic way (Loo, 2002). As a result, the DT was deemed the most appropriate to establish the relevant integrated SHE management attributes and ascertain their relative weights/priorities. As mentioned before, different versions of the DT exist; however, a modified Delphi survey was found to be the appropriate for the study. This is because it shares the same overall principles as the classical Delphi, however, the typical exploratory first round is replaced with a more structured questionnaire consisting of a set of pre-selected items for the panel of experts to refine or rate its importance, rank and/or to suggest additional items if any (Custer *et al.,* 1999). This approach, thus, improves the initial round response rate (Snyder-Halpern, 2001). Again, the use of a modified Delphi process is suitable if basic information relating to the topic under study is available and usable (Alaloul *et al.*, 2015), as was the case in this study. The literature review and subsequent preliminary expert verification served as the basis for the modified version of the Delphi process (Keeney *et al.*, 2011). The application of the DT in CEM research and more specifically safety and health studies, is not uncommon as can be seen in various studies (Dzeng and Wen, 2005; Gunhan and Arditi, 2005: Yeung *et al.,* 2009; Hallowell, 2009; Giel and Issa, 2015; Elsayah, 2016; Zahoor *et al.,* 2017; Ojo and Ogunsemi, 2019; Manu *et al.,* 2019a). This also reinforces the suitability of the Delphi method for this research. A list of Delphi applications in CEM research is summarised in Table 4.1.

Table 4.1: A catalogue of the application of Delphi in CEM research

Publication	Area of construction	Rounds	Panel size	Feedback and method of consensus
Ojo and Ogunsemi (2019)	Critical drivers of value management in the Nigerian construction industry	2	15	Mean, mode, Kendall's concordance (W)
Manu *et al.* (2019a)	Design for occupational safety and health: key attributes for organisational capability	3	32	Median, Kendall's concordance (W)
Mahamadu (2017)	Development of a decision support framework to aid selection of construction supply chain organisations for BIM-Enabled projects	2	25	Mean, Standard deviation, Relative important index, Inter ratter agreement
Elsayah (2016)	A framework for improvement of contractor selection procedures on major construction project in Libya	2	12	Cronbach's alpha
Ameyaw *et al.* (2016)	Application of Delphi method in construction engineering and management research: A quantitative perspective	N/A	N/A	N/A
Sourani and Sohail (2014)	Case studies of benefits to construction research	N/A	N/A	N/A
Giel and Issa (2014)	Identification and prioritization of owner competence in BIM	3	21	IQR
Hallowell and Gambatese (2010)	Review of usage within construction engineering and management research	N/A	N/A	N/A
Dikmen *et al.* (2010)	Prioritisation of business failure risk of construction firms' risk	2	3	AHP consistency ratio
Ke *et al.* (2010)	Identification of public private partnership risk on construction projects in china	2	46	Mean, Kendall's concordance (W)
Hallowell and Gambatese (2009)	Activity-Based Safety Risk Quantification for Concrete Formwork Construction	3	15	Median, Standard deviation
Salleh (2009)	Critical success factors of project of Brunei construction projects: Improving project performance	2	28	Median rank
Manoliadis *et al.* (2009)	Prioritised qualification-based criteria for contractor selection through two (2) rounds of Delphi survey.	2	12	Mean
Yeung *et al.* (2009)	Determine KPI for partnering procurement performance	4	31	Mean and Kendall's concordance (W)
de la Cruz *et al.* (2006)	Categorise risks on construction projects	1	20	Mean, Standard deviation
Manoliadis *et al.* (2006)	Examined the drivers for sustainable construction in Greece through two rounds of Delphi survey	2	20	Mean
Gunhan and Arditi (2005a)	Identification of factors affecting international construction	2	12	Mean, Standard deviation
Gunhan and Arditi (2005b)	Identification of factors affecting construction firm expansion	2	12	Mean, Standard deviation
del Caño and de la Cruz (2002)	Categorise risks on construction projects	1	20	N/A
Chan *et al.* (2001)	Selection of procurement method for project	4	10	Kendall's concordance (W)
Arditi and Gunaydin (1999)	Perceptions of process quality in building projects	3	14	Mean, Standard deviation
Hatush and Skitmore (1997)	Criteria for contractor selection	3	8	Qualitatively decided
MEAN		**2**	**19**	

4.6.4 Delphi design and process

Given the rationale behind the Delphi method and the main characteristics explained above, the design, construction and delivery of a Delphi study follows the basic Delphi methodology recommended by Loo (2002) and Delbecq *et al.* (1975). These included distinct stages, such as problem definition or Delphi question development, expert panel selection, panel size (sample size); and delivery of the Delphi first questionnaire, first questionnaire analysis and follow-up questionnaire iterations or rounds. This methodology forms the basis of the research study and is explained in the following sections. A summary of the procedure and structure of a typical the DT is also presented in Figure 4.2.

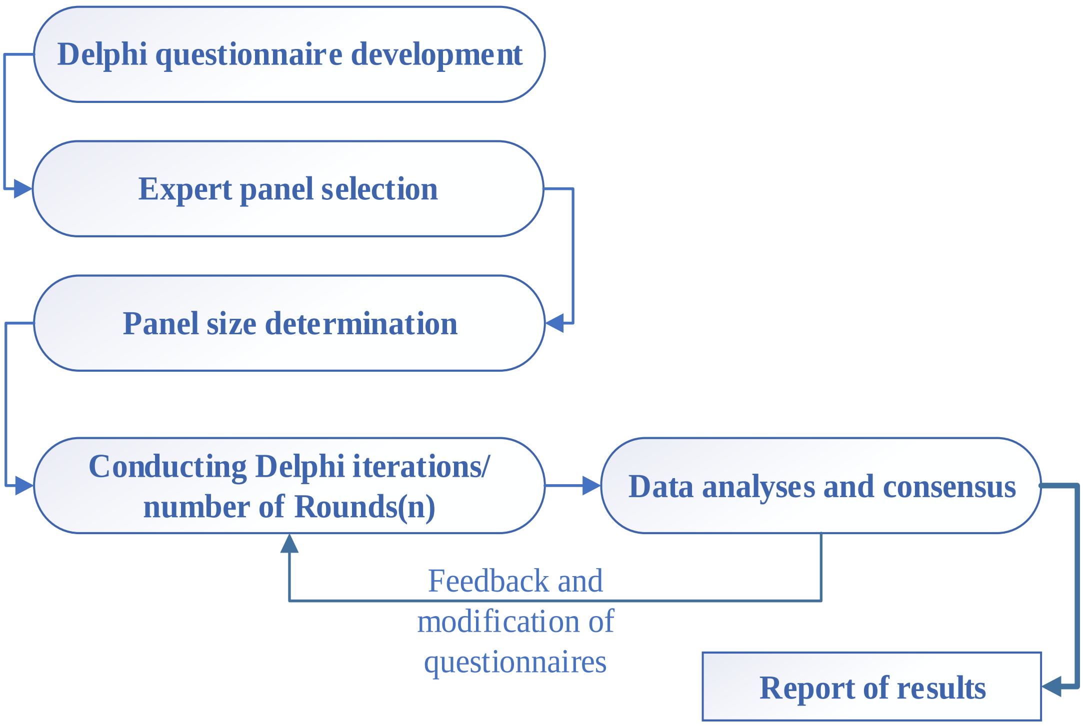

Figure 4.2: General stages in a typical Delphi technique from literature

4.6.4.1 Questionnaire development

The core of the Delphi process is a questionnaire that is sent to the expert participants and iterated several times for them to express their opinion. The questionnaire consists of some statements about the research problem under investigation. The items needed for the questionnaire developments are mainly derived from literature on the issue under investigation or based on the information gathered from another survey. According to Robinson (1991), the wording of questions and the presentation format are, therefore, very critical to the success of the Delphi process. Generally, there are two ways of developing the first round Delphi research instrument. The first method is an inductive approach, whereby participants freely brainstorm and express their views and opinions on the problem area, and then a structured questionnaire is produced by the researcher or the facilitator, based on the experts' comments, which is subsequently addressed to the panellists during the next rounds (Powell, 2003). However this method can take too much time to analyse, and may not generate very good information (Hanafin, 2004). In the second method, the researcher, generates ideas and present a structured form of questionnaire through a review of literature or earlier conducted studies for experts to verify by rating or ranking their opinion. To reduce bias and prevent limitation of experts' responses, they are also asked to suggest other items, which are not listed in the questionnaire (Keeney *et al.,* 2006). This structured format of the first round usually makes the Delphi application simpler for the researcher and the expert panellists (Ghashat, 2012).

Delphi questionnaires are designed to elicit and develop individual responses to questions posed and enable the experts to refine their views and opinions (Adler and Ziglio, 1996). As a consequence, much effort is needed to make the questionnaires simple and yet, be able to adequately convey the objectives of the study to the experts' participant.

4.6.4.2 Selecting of expert panel members

An important part of conducting a Delphi study is selecting the right experts (also known as participants, panellists or respondents) and their role is vital to the success of the study (Hasson *et al.,* 2000). As the DT does not survey a random sample, but employs a purposive sampling approach, experts selected must be sufficiently interested and involved in the subject being examined to ensure high commitment response rate (Denscombe, 2007). There are several arguments on who an 'expert' is. According to Cantrill *et al.* (1996) 'experts' are a group of informed and knowledgeable individuals or other individuals with relevant knowledge, experience and considerable interests in the subject under study. Identifying experts who have the knowledge and experience of the given topic can be a challenge for researchers, and therefore known as the "linchpin of the technique'' (Green *et al.,* 1999; Kenney *et al.,* 2006; Skulmoski *et al.,* 2007). To overcome this challenge, best practice requires that a set of qualifying criteria is used to prequalify a list of possible participants, who can then be officially invited stating the requirements for participation (Rowe and Wright, 1999).

According to Dalkey and Helmer (1963) and Rodgers and Lopez (2002) expert participants should be selected based on predetermined criteria. For instance, the experts should exhibit a high degree of knowledge and experience in the subject under study and also be representative of the profession so that their suggestions may be adaptable or transferable to a larger population. Similarly, Adler and Ziglio (1996) reported that Delphi participants in any study should meet four requirements, which are: knowledge and experience with the issues under investigation; capacity and willingness to participate; sufficient time to participate in the Delphi; and effective communication skills. A Delphi panel must be varied, consisting of participants with diverse backgrounds and experiences. This is because the involvement of individuals with differing perspective ensures that a wide range of opinions are obtained which provides accurate feedback and results that ultimately produces a credible Delphi study (Skulmoski *et al.,* 2007; Hon *et al.,* 2010). The expert's panellists are often recruited by an invitation letter via post or e-mail with a brief overview of the study objective. Also, snowball sampling which involves asking expert participants to pass on invitations to other important people can be utilised (Iqbal and Pipon-Young, 2009). Thereafter, those that consented to the invitation are sent a detailed description of the Delphi study and the questionnaires.

4.6.4.3 Determination of expert panel size

Determining the optimal number of experts in a typical Delphi survey has been a subject of debate overtime. Existing literature has not stated the number of experts needed for a Delphi study (Weidman *et al.*, 2011). Several scholars have, therefore, recommended different sample sizes. For instance, Helmer and Dalkey used a sample size of seven experts in their original Delphi experiment in 1953 (Helmer, 1983). Delbecq *et al.* (1975) suggested ten to fifteen participants. Linstone (1978) revealed that "a suitable minimum panel size is seven" and argued that the accuracy of a study deteriorates when the size of the expert panel increases. This observation was supported by Cavalli-Sforza and Ortolano (1984) who suggested a "typical Delphi panel has about eight and twelve members, while Phillips (2000) also reported the ideal sample size of an expert panel should be between seven and twelve members, citing the same reason as Linstone (1978).

Mitchell and McGoldrick (1994) also informs that the size of Delphi participants panel may be as large as time and money considerations will allow, however it should be no less than 8 to 10 members. Okoli and Pawlowski (2004) recommends panels between 10 and 18. According to Ziglio (1996) 10 to 15 experts can provide good results with the Delphi technique. Ludwig (1997) found that the majority of Delphi studies have employed between 15 to 20 participants. To Turoff (2002), a size of 10 to 50 experts is appropriate; whereas, Miller (1993) argued that beyond the first thirty responses additional responses do not generate much new information. Andranovich

(1995) suggested that if the group of experts is fairly homogeneous (sharing similar opinions) then 10 to 15 panellists will be appropriate and if the group is heterogenous (i.e. having experts with diverse interests and opinions), then the sample size will need to be increased to ensure balance (Zami and Lee, 2009). Nonetheless, Mullen (2003) suggests of an optimal size between seven and 30, while Hallowell and Gambatese (2010) reports of eight to 16 experts and recommends a minimum of eight.

According to Hallowell and Gambatese (2010) the specific number of experts should be determined by the study characteristics (e.g. the number of available experts, the desired geographic representation and the capability of the researcher) and emphasised the importance of having a sufficient number of experts at the end of the Delphi process and the need to consider this in light of the possibility of some experts dropping out in the process. In existing literature on CEM Delphi applications, Delphi participants can range from three to ninety members with most studies using panels of 15 to 35 people (Ameyaw *et al.,* 2016). As Delphi method is not like conventional surveys, where statistically large numbers are required for validity (Mullen, 2003), the quality and the expertise of the panellists should be considered more significant than the numbers of experts (Okoli and Pawlowski, 2004; Thangaratinam and Redman, 2005). Again, large numbers should be avoided since it may lead to difficulty in the summarising process; however, the panel members should be sufficiently large to provide an increase in the reliability of group responses.

4.6.4.4 Number of rounds or iterations

A fundamental part of a Delphi design is the number of rounds undertaken in the process. The number of rounds aids in reaching consensus amongst the panellists by reducing variance in their responses and improving precision. This is achieved through the use of controlled feedback and iteration (Hallowell and Gambatese, 2010). Though the literature review suggests the number of iterations in Delphi studies is variable, some Delphi studies suggests two to six rounds (e.g. Dalkey *et al.,* 1970; Linstone and Turoff, 1975; Gupta and Clarke, 1996). The number of rounds depends largely on the time, purpose and nature of the study (Keeney *et al.,* 2001; Skulmoski *et al.,* 2007). A typical classical Delphi method uses four rounds; however, this has been modified by several researchers to suit individual research aims. Typically, three rounds of Delphi would be appropriate for most studies. For accurate results in Delphi studies, at least two rounds of the Delphi are desirable. This assertion is in line with the observation of Dalkey *et al.* (1970), Fan and Cheng (2006) and Hallowell and Gambatese (2010) that, Delphi results are more precise after two iterations. Moreover, Petry *et al.* (2007) argued that two rounds of DT are adequate if there is evidence in literature that enables the development of the survey instrument and when the main purpose of DT is to elicit reliable information form experts' opinions. Hallowell and Gambatese (2010) suggests three rounds of Delphi based on the review of CEM Delphi applications. They argued that a three round Delphi helps in obtaining reasons for responses that are far-off from the second round and reporting these within the feedback in the third round. This process potentially facilitates the consideration of all options, which could lead to the achievement of a consensus about the correct value instead of "conforming to an incorrect opinion."

4.6.4.5 Statistical data analysis and consensus

One of the main objectives of the DT is to seek out information, that may generate a consensus of opinion concerning a specific issue under study (Hsu and Sanford, 2007), however, an interpretation of when consensus has been achieved remains a challenge of the Delphi process. Powell (2003) indicated that the definition of consensus is crucial to the rigour of any Delphi study, yet no universal definition exist (Hasson *et al.*, 2000). However, Mitchell (1991) noted that consensus can either mean a general agreement, a group opinion, or group solidarity in sentiment and belief. According to Ghashat (2012), a consensus is defined as the general agreement of the participants in spite of whether they were unanimously for or against the case. Skulmoski *et al.* (2007) noted that consensus is reached when a theoretical saturation is achieved, or sufficient information has been exchanged. Nonetheless, the existence of consensus does not necessarily mean the opinion or judgement or the answer generated is correct, rather it helps to identify areas most expert participants consider important in relation to the issues raised in the research question. Across the literature on Delphi studies, consensus has been defined (or achieved) in several ways (von der Gracht, 2012). For instance, consensus is defined according to the stability of rounds (Duffield, 1993); majority of participants agreement (Butterworth and Bishop, 1995); the use of a percentage level to indicate majority agreement (McKenna, 1994; Padel and Midmore, 2005), amongst others. While there is no general agreement or guidelines on the level of consensus, Keeney (2010) suggested researchers should decide on the consensus level before data collection and what percentage agreement they are willing to accept. According to Vernon (2009), Delphi consensus typically ranges from 55-100% agreement, with 70% considered the standard.

As there seems no standard criterion for defining and determining consensus in Delphi, irrespective of the type of data involved (Boote *et al.*, 2006), Delphi researchers have applied several non-parametric and parametric statistical methods to arrive at consensus. Across most

Delphi studies, descriptive statistics like mean, median, standard deviation and mode are commonly used to present the collective responses of participants (McKenna, 2000; Hasson *et al.*, 2001). The most popular being the mean, median and mode scores, however, the use of the median or the mode score is strongly favoured as an objective and rigorous way of determining consensus based on Likert-type scale (Jacobs, 1996; Hsu and Sanford, 2007). A report by Diamond *et al.* (2014) indicated the most popular definition for consensus was percentage agreement (usually 75% as the median threshold). According to Kalaian and Kasim (2012), Delphi studies with 30 or more participants can use parametric statistical methods, such as the Coefficient of Variation, the F-ratio, the Pearson correlation coefficient and the Paired t-test, but if the participants in the Delphi study are less than 30, non-parametric statistical methods such as Spearman's Rank Correlation Coefficient, the Wilcoxon Paired Signed-Ranks T-test and McNemar is suitable for achieving consensus.

4.6.5 Delphi technique in this research

The DT was used in this research due to the fact that there was no empirical data available regarding integrated SHE management capability attributes in construction. The modified DT was used to elicit the relevant integrated SHE management capability attributes through the use of collective intelligence of construction professionals with knowledge and expertise in SHE management in the Ghanaian construction industry. The DT also ensured a reliable and validated data collection process.

A review of literature and subsequent preliminary verification served as the basis for the modified DT. Literature related to, SHE management and not limited to construction, as well as relevant literature related to maturity models on, SHE from various sources (i.e. international standards, published guides on SHE and academic publications, peer-reviewed journals and books) were reviewed to generate a list of potential integrated SHE management capability attributes, which were verified by experts (Table 5.2 and Table 5.5). The most reliable experts were identified for a three round Delphi survey. Experts rankings of the questions in each round were analysed statistically using median scores. The various processes involved in the application of the DT in this study are shown in Figure 4.3 and described in detail in the Chapter five.

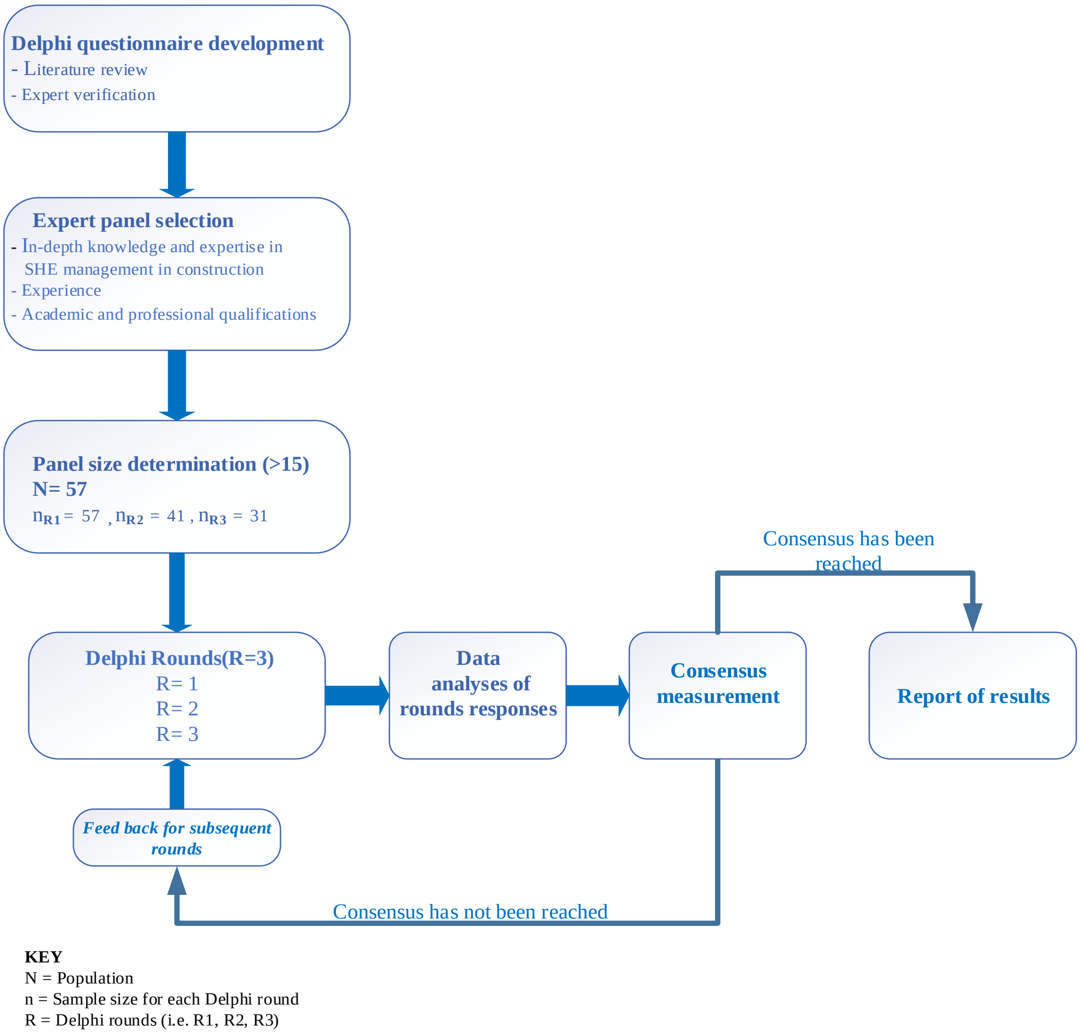

Figure 4.3: The Delphi stages and processes in this study

4.6.6 Data presentation and analysis methods

The questions a study plans to answer determines the research approach adopted by the study. The research approach also influences the kind of data collection methods used in a study (Creswell, 2014). As the research approach in this study is quantitative, data collection methods associated quantitative research approaches were employed. The data presentation and analysis methods used in this study are discussed in section 4.6.6.1 to 4.6.6.5.

4.6.6.1 Percentages

Percentage was employed in the expert verification stage to present the analysis relating to the level of agreement of experts and their acceptability of the capability attributes as relevant to SHE management in construction. An attribute that attracted a predetermined percentage of agreement (i.e. 50% and above) was maintained. 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. Percentages have been used in CEM studies for such analysis (Chan *et al.*, 2001; Onaopepo, 2017).

4.6.6.2 Descriptive statistics (median rank)

The use of descriptive statistics and inferential statistical measurement of agreement and consistency are the main statistics used to achieve consensus and stability in Delphi rounds (Von der Gracht, 2012). Descriptive statistics like the measures of central tendency and level of dispersion, are mainly used to reveal distributions, patterns and the uniqueness within a specific data sample (Denscombe, 2010). They summarise participants responses (i.e. ratings or rankings of each questionnaire item) after each round of a Delphi with the most popular being the mean, median and mode scores (Hsu and Stanford, 2007). The median, mode and the interquartile range are found to be more robust than the mean and standard deviation. Whiles medians can deal with outliers very well, the mean can be influenced by them (i.e. extreme data sets) (Saunders *et al.*, 2016). According to Brown and Helmer (1964), the true result lies within a sample; therefore, the median value can be taken as a representative of the opinion of a group. Similarly, Jacobs (1996) suggested the use of median is appropriate as it tends to give a convergent opinion, while dealing with a skewed response set. Some authors have indicated the use of the mean and median values to access the ratings or rankings of participants showed no significant difference in results obtained when the two measures were employed (Eadie, 2009). Hence, the use of the median is most suitable. Consequently, the median of the experts ranking was employed in this study, particularly during the three rounds of the Delphi process.

It was deemed appropriate to access the distribution of the data obtained for each round of Delphi since it appears to reflect the resultant convergence opinions of the expert panel. Moreover, results reported as medians can minimise the impact of potential outlying responses. Also, the median was used to compute each of the evaluation statements rated by construction professionals in the validation process.

4.6.6.3 Kendall's coefficient of concordance (W)

Kendall's coefficient of concordance (W) is a nonparametric statistic used for assessing agreement amongst raters, using the raters median or mean rankings of importance in each Delphi round. It is recognised as a suitable tool for evaluating intragroup homogeneity (Field, 2013). With this statistic (W), it is possible to make a realistic determination of whether a consensus has been reached and also be able to measure its relative strength, as well as its change (an increase or decrease in consensus) (Schmidt, 1997; Field, 2013). Yeung *et al.* (2007), Shaban (2008); Xia *et al.* (2009), Xia and Chan 2011, Hone *et al.* (2012) and others have all used Kendall's (W) to measure the degree of agreement between the members of a panel established to rate a list of issues in CEM Delphi studies. Due to the ease of application, understanding of the method and its robust computational approach in arriving at a consensus among experts, it was chosen as a suitable technique for establishing consensus in this study. Kendall coefficient of concordance was used in this study to assess the degree of agreement between the expert panel members regarding the capability attributes within each Delphi round.

As W moves closer to 1, it can be concluded that there is consistency in the responses and a strong agreement of the expert panel. Schmidt (1997) state that a value of 0.5 up to 0.7 is high and good, 0.7 up to 0.9 or above is very high and excellent, while 0.1 up to 0.3 is low, 0.3 to 0.5 moderate and ≤ 0.1 is unacceptable. Thus, for the purposes of this study a coefficient value (W) ≥ 0.4 was considered as representing a suitable level of agreement. Details of the Kendall's coefficient results in each round are presented in the next chapter.

4.6.6.4 Wilcoxon matched pairs sign test (Z)

To check for saturation of the Delphi process the non-parametric statistic measure namely the Wilcoxon matched pairs sign test (Z), was used. This test (Z) checks whether there is stability of responses between successive Delphi rounds (Linstone and Turoff, 2011). The Wilcoxon test ascertains differences between two set of scores from the same participants (Field, 2013). This test, thus, compares two dependent data of the same group of raters in "a before and after situation'' (Riley *et al.*, 2000). As most Delphi studies use ordinal scales, the Wilcoxon test can be applied (Ameyaw *et al.*, 2016). As a result, the test (Z) was used to investigate if there are any significant changes in the expert's participants ranks of particular attributes, which did not reach consensus in one Delphi round and the another. The results of the Delphi study, Kendall's concordance and Wilcoxon signed test are presented in the next chapter.

4.6.6.5 Voting analytic hierarchy process

The analytic hierarchy process (AHP), introduced by Saaty (1980), is a multi-criteria methodology, that permits the relative assessment and prioritisation of alternatives. It is a structured technique for decision-making in environments where many competing criteria or alternatives are considered (Saaty, 2006). Basically, AHP enables complex and unstructured problems to be broken down into alternatives, which are arranged into a 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 a pairwise comparison of the criteria. It, therefore, produces different and better results than ordinary logic (Saaty, 2012). The paired comparison is undertaken using a scale, which indicates the strength to which one alternative or criterion dominates another alternative/criterion. Using the scaling process, numerical priorities or weights are calculated for each criteria or alternatives. These numerical values represent the criteria or alternatives' relative ability to achieve the decision.

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). Several researchers have also combined its usage with the DT in their research. The DT is used at the initial phase of their research to identify relevant attributes or variables, while the AHP is used at the subsequent phase to determine the priority weights of the selected attributes or variables (Moradi *et al.,* 2014; Wibowo and Taufik, (2017). Combination of Delphi and AHP techniques has been use in several disciplines, such as supply chain management (Cheng and Tang, 2009), safety (Teo and Ling, 2006; Chung and Her, 2013), project management (Vidal *et al.,* 2011) and transportation (Da Cruz *et al.,* 2013; Lee *et al.,* 2014). In CEM research, Vidal *et al.* (2011) combined the DT with AHP to evaluate the complexity of projects. Likewise, Austin *et al.* (2016) used a combination of Delphi and AHP techniques to generate a list of prioritised best practices necessary for successful management of projects requiring a higher level of fast tracking. Additionally, Ameyaw *et al.* (2016) through a review of 88 CEM journals that employed the Delphi technique, revealed approximately 14% of the articles use the AHP. Despite its usefulness, AHP has some limitations.

Prominent amongst the limitations of AHP is the difficulty in applying the paired comparison particularly where there are several criteria/alternatives (Hadi-Vendch and Niazi-Mortlagh, 2011). For example, in using AHP, 12 criteria would yield over 35 paired comparison and that can be very unwieldy and arduous, if not infeasible for decision-makers. As a result, Liu and Hai (2005) developed the voting analytic hierarchy process (VAHP), which is an easier weighting procedure than the AHP's paired comparison. The VAHP technique uses a vote ranking approach instead of a paired comparison method to determine the weights of a set of criteria and sub-criteria in a hierarchal structure (Lui and Hai, 2005). Given the large numbers of integrated SHE management capability attributes in this study (Table 5.5), the VAHP approach was deemed appropriate. Moreover, the thematic categorisation of the capability (Table 5.5) attributes (constituted a hierarchal structure, which lends itself to the use of VAHP). The other strengths of VAHP that have influenced the decision to adopt it for this study are outlined below:

- The VAHP method is easy to understand;
- It is simple to use to obtain priority weights; and
- The time needed for the ranking progress is reduced by the use of voting. This method, thus, allows alternatives/variables/criteria to be ranked through voting instead of paired comparisons, which helps to reduce the time necessary for the otherwise slow and laborious ranking process (Noguchi *et al.,* 2002; Soltanifar *et al.*, 2011).

In this method, the weights of criteria are calculated through voting instead of using paired comparisons of the AHP method. Afterwards, the Data Envelopment Analysis (DEA) is used to aggregate the votes for each criterion received in different ranking positions into an overall score for each criterion (Hadi-Vencheh *et al.,* 2011). The overall scores are then normalised as the relative weights of the criteria. This method was, therefore, used to ascertain the relative weights of importance of the capability attributes.

4.7 Overview of the research design

Research design is referred to as a logical plan for navigation through the research journey (Yin, 2003). It is, therefore, a methodology that enables the researcher to answer the research questions or problems in a systematic way (Saunders *et al.*, 2009). In this study, a quantitative research strategy is used to provide an understanding of what capability attributes are relevant for inclusion into a safety health and environmental management capability maturity model (SHEM-CMM). Consequently, a comprehensive review of literature, expert verification and a Delphi survey were used to address the research objectives.

The research process began with a comprehensive literature review and synthesis; this was meant to increase the researchers' understanding of the key practices and process areas of SHE management system and the concept and design of capability maturity models. Most importantly, the review led to the identification of potential integrated SHE management capability attributes and the extraction of maturity level characteristics from existing capability maturity levels. A Delphi study, was engaged to iteratively build consensus on the relevant SHE management capability attributes. Additionally, a multi-criteria decision-making method (i.e. VAHP) was used to ascertain the relative importance weights of the SHE management capability attributes for prioritisation. Once this stage was complete, the integrated SHE management capability attributes and the maturity levels descriptors was used to develop the maturity model based on the capability maturity modelling concept. The final stage of the research design involved validation of the integrated SHE management capability maturity model, using construction professionals working in construction companies in Ghana, to assess its suitability and applicability in practice. The methodological flow chart in the study is shown in Figure 4.4.

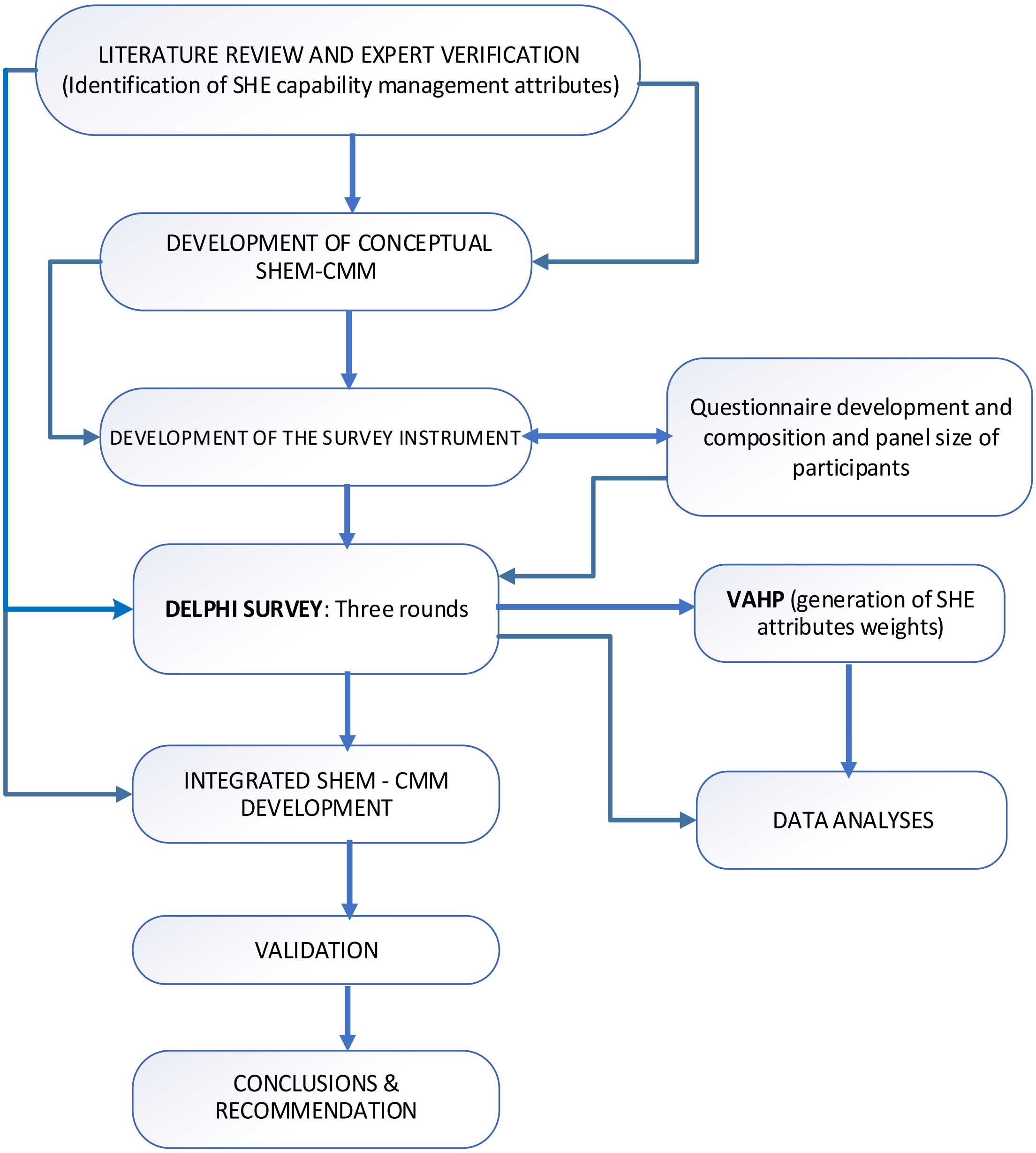

Figure 4.4: Schematic presentation of study outline in phases

4.8 Ethical considerations for research

Research ethics is a set of principle governing the way any research is conducted. Ethical considerations are, therefore, recognised as one of the most important parts of research due to its ability in protecting the integrity of research involving human participants (Bryman and Bell, 2007; Knight and Ruddock, 2008). To ensure the dignity and rights of all participants were carefully considered and respected throughout the research process, a number of steps were taken. Research was designed and conducted according to the research ethical guidelines of the University of the West of England (UWE), Bristol, and the University's Code of Good Research Conduct (2015) regarding the protection of human participants. An application of ethical review was submitted to the Faculty of Environment and Technology Ethics Committee for approval. Ethical approval was sought before recruitment of experts and collection of data began.

Per the participant information sheet provided in Appendix B research participants were fully informed about the background, purpose and objectives of the research (Cohen *et al.,* 2013). Consent forms were used to solicit participants consent and willingness to participate in the research. To maintain confidentiality during the whole process of data collection, expert participants were given a unique code for all the rounds making sure data from the questionnaires was completely anonymised. Research information sheets and consent forms are shown in Appendix B.

4.9 Chapter summary

This chapter presented the methodology this study employed to meet the aim and the specified research objectives. A wide-range of issues from the research paradigms informing the study's underlying philosophical assumptions, through the different research strategies and methods to ethical considerations have been presented and discussed. The proposed philosophical worldview of this study, the research strategy, as well as methods for data collection have also been presented and discussed. Based on the positivist's worldview, a quantitative research strategy for inquiry was adopted. The research consisted of a comprehensive 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. This was followed by a DT to generate consensus regarding the importance of the attributes and a VAHP to generate weights of importance based on the outcomes of the DT. The next chapter presents the results and analyses of the research processes discussed in this chapter relating to the identification of the integrated SHE management capability attributes.

CHAPTER FIVE – IDENTIFICATION AND VERIFICATION OF KEY INTEGRATED SHE MANAGEMENT CAPABILITY ATTRIBUTES

5.1 Introduction

This chapter presents the analyses of data, results and findings relating to the identification and verification of SHE management capability attributes. The chapter covers the initial review of capability attributes identified from literature and an expert verification by selected subject-related academics. The follow up DT accompanied by the VAHP conducted is also reported together with the research processes undertaken towards the verification of key capability attributes for implementation of an integrated SHE management system in construction. Data collected on the ranking of importance of capability attributes are analysed using descriptive statistics, median ranking, Kendal coefficient of concordance, and Wilcoxon signed rank test using Statistical Package for Social Science (SPSS) version 24. Results of the Delphi process and the VAHP are presented in this chapter, while the subsequent chapter (i.e. Chapter 6) discusses the process of developing an integrated SHE management capability maturity model.

5.2 Identification and verification of capability attributes from literature

The summary of processes involved in the identification and verification of integrated capability SHE attributes is presented (Figure 5.1) to aid the understanding of the content of this chapter.

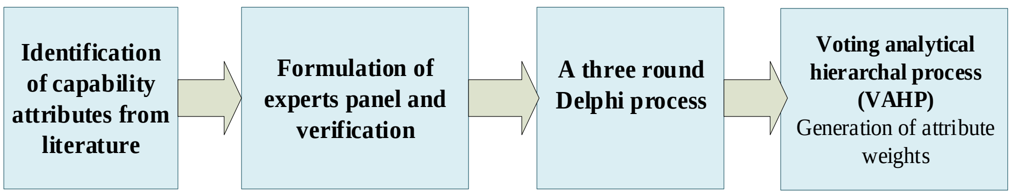

Figure 5.1: Overview of research process

5.2.1 SHE management capability attributes identification

It is of utmost importance when developing a capability maturity model to establish the capability attributes. The identification of integrated SHE management capability attributes, therefore, starts with a thorough review of literature related to SHE management (not limited to construction) to generate a list of potential SHE management capability attributes. In addition, the relevant literature related to maturity models on safety and health, and environmental management (e.g. Fleming, 2001; Sharp *et al.*, 2002; Strut *et al.*, 2006; Filho *et al.*, 2010; Ormazabel-Gooenaga, 2013) were also reviewed. The aim of the literature review was to identify, organise and refine all the available information within the existing literature. The literature sources comprised of international standards, published guides on SHE and academic publications to improve the research validity (Charef *et al.*, 2018).

Searches were carried out within several literature databases: Elsevier's Scopus, Thomson Reuter's 'Web of Science', ASCE (American Society of Civil Engineers), Emerald Insight and Google Scholar. Using combinations of the search terms '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 were generated with the above search words and or phrases. This list of literature materials was then systematically scaled down to 20 using the four-phase PRISMA flow diagram developed by Moher *et al.* (2009) as seen in Figure 5.2. 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 practices, and
- Studies on the implementation of safety, health and environmental management systems

Literature analyses reveal existing SHE management texts, guides, and international standards that generally follow the Deming's PDCA management approach and, thus, share common elements/requirements, which allow most of the elements to be integrated. As a result, in developing the list of organisational attributes for integrated SHE management, information from the 20 publications consisting of established internationally recognised SHE management standards and published works were extracted, by comparing their components in order to determine key similarities and differences; thereby, establishing potential integrated SHE capability attributes. In the end, 27 potential attributes were obtained. The main 20 literature sources are shown in Table 5.1, while the 27 attributes are presented in Table 5.2.

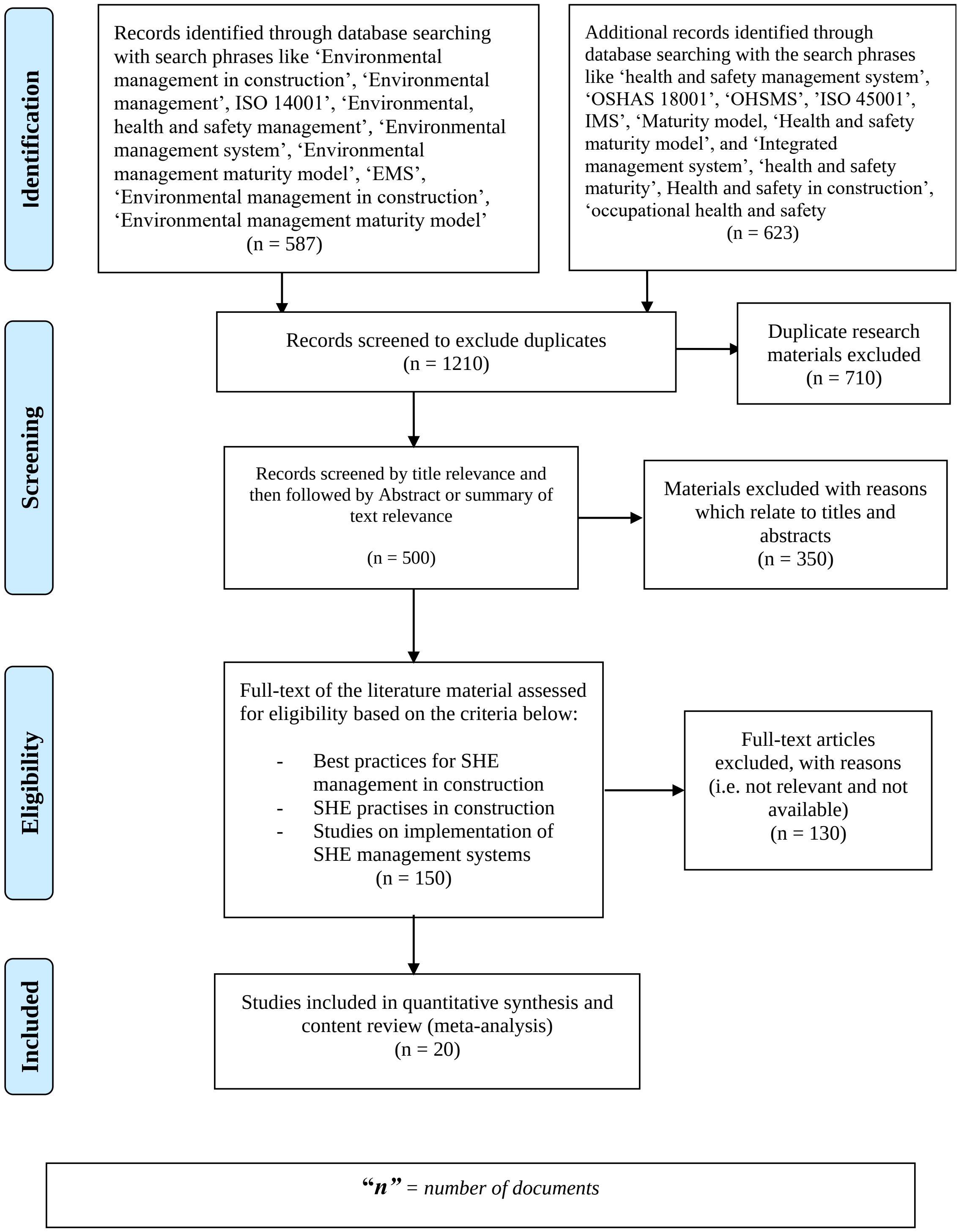

Figure 5.2: PRISMA Flowchart of the literature review process

Table 5.1: Main literature sources for derivation of SHE management capability attributes

Component/ Practices		Environmental management system (EMS) standards and published works							Component/ Practices	Safety and health management system (SHMS) standards, guidelines and published works									Component/Practices		Integrated Management system (IMS) standards and published works			
		CIA (2003)	Christini *et al.* (2004)	Arimura *et al.* (2008)	EC (2008)	Chan (2011)	ISO (2015)	BSI (2016)		ILO (2001)	AS/NZS (2001)	Gallager *et al* (2003)	Hughes and Ferret (2007)	BSI (2007)	HSE (2013)	ILO (2013)	IOSH (2015)	ISO (2018)			OGP-210 HSEms (1994)	Hamid *et al.* (2004)	BSI (2012)	Re bello *et al.* (2015)
PLAN	SMC	✓	✓	✓	✓	✓	✓	✓	SMC	✓		✓	✓	✓		✓	✓	✓	**PLAN**	Leadership and commitment	✓	✓	✓	✓
	EMS-C		✓	✓			✓	✓	SHMS-C	✓	✓	✓	✓	✓	✓	✓	✓	✓		Implementation team		✓	✓	✓
	PR	✓	✓	✓	✓				PR	✓	✓	✓	✓	✓	✓	✓	✓	✓		Baseline review		✓	✓	✓
	EMS-B	✓	✓	✓			✓	✓	SH-B	✓	✓	✓	✓	✓	✓	✓	✓	✓		Identification of IMS hazards, aspects and impacts identification	✓	✓	✓	✓
	IEAI	✓	✓	✓	✓		✓	✓	ISHH	✓	✓	✓	✓	✓	✓	✓	✓	✓		Risk assessment and identification of control measures	✓	✓	✓	✓
	AEAI	✓	✓	✓	✓	✓	✓	✓	SHRA	✓	✓	✓	✓	✓	✓	✓	✓	✓		Legal and other requirements	✓	✓	✓	✓
	ICULR	✓	✓	✓	✓	✓	✓	✓	ICULR	✓	✓	✓	✓	✓	✓	✓	✓	✓		Integrated management policy	✓	✓	✓	✓
	ENVPO	✓	✓	✓	✓	✓	✓	✓	SHPO	✓	✓	✓	✓	✓	✓	✓	✓	✓		Objectives and targets of IMS	✓	✓	✓	✓
	ENOT	✓	✓	✓	✓		✓	✓	SHOT	✓	✓	✓	✓	✓	✓	✓	✓	✓		Management programmes of IMS	✓	✓	✓	✓
	ENVMP		✓	✓	✓		✓	✓	SHMP	✓	✓	✓	✓	✓	✓	✓	✓	✓	**DO**	Organisational roles and responsibilities	✓	✓	✓	✓
DO	SRR		✓	✓	✓		✓	✓	SRR	✓	✓	✓	✓	✓	✓	✓	✓	✓		Resources	✓	✓	✓	✓
	PAR		✓	✓	✓				PAR	✓	✓	✓	✓	✓	✓	✓	✓	✓		Communication	✓	✓	✓	✓
	EINV	✓	✓	✓	✓		✓	✓	EINV	✓	✓	✓	✓	✓	✓	✓	✓	✓		Participation and consultation of employees	✓	✓	✓	✓
	COENVI	✓	✓	✓	✓		✓	✓	CSHI	✓	✓	✓	✓	✓	✓	✓	✓	✓		Training and awareness	✓	✓	✓	✓
	EINV	✓	✓	✓	✓	✓	✓	✓	EINV	✓	✓	✓	✓	✓	✓	✓	✓	✓		Competence of employees	✓	✓	✓	✓
	ITNT	✓	✓	✓	✓		✓	✓	ITNT	✓	✓	✓	✓	✓	✓		✓	✓		Documentation of the IMS	✓	✓	✓	✓
	COE	✓	✓	✓	✓	✓	✓	✓	COE	✓	✓	✓	✓	✓	✓	✓	✓	✓		Control of documents	✓	✓	✓	✓
	EMSDO	✓	✓	✓	✓	✓	✓	✓	SHDOC	✓	✓	✓	✓	✓	✓	✓	✓	✓		Operational control	✓	✓	✓	✓

	EMSDC	✓	✓	✓	✓	✓	✓	✓	SHDCO	✓	✓	✓		✓	✓	✓	✓	✓		Emergency preparedness and response plans and procedures	✓	✓	✓	✓
CHECK	OPC	✓	✓	✓	✓		✓	✓	OPC	✓	✓	✓		✓	✓	✓	✓	✓	CHECK	Performance monitoring and measurement	✓	✓	✓	✓
	EPAR	✓	✓	✓	✓	✓	✓	✓	EPAR	✓	✓	✓		✓	✓	✓	✓	✓		Evaluation of compliance	✓	✓	✓	✓
	MAM	✓	✓	✓		✓	✓	✓	PMAM	✓		✓	✓	✓	✓	✓	✓			Incidents investigation	✓	✓	✓	✓
	EOC	✓	✓	✓	✓	✓	✓	✓	EOC	✓		✓	✓	✓	✓	✓	✓	✓		Non-conformity and corrective actions	✓	✓	✓	✓
	NCP	✓	✓	✓	✓	✓	✓	✓	IIVES	✓		✓	✓	✓	✓	✓	✓	✓		Records control	✓	✓		✓
	RC	✓	✓	✓	✓	✓	✓	✓	NCP	✓		✓	✓	✓	✓	✓	✓	✓		Combined internal audits	✓	✓	✓	✓
	EMSAUD	✓	✓	✓	✓	✓	✓	✓	RCM	✓		✓	✓	✓	✓	✓	✓		ACT	Integrated management review	✓	✓	✓	✓
	TALL	✓	✓	✓	✓		✓	✓	SHAUD	✓		✓	✓	✓	✓	✓	✓	✓		Continuous improvement and innovation	✓	✓	✓	✓
ACT	MR	✓	✓	✓	✓	✓	✓	✓	TALL	✓		✓	✓	✓	✓	✓		✓						
	PER				✓		✓		MR	✓	✓	✓	✓	✓	✓	✓	✓	✓						
	CERT	✓			✓		✓	✓	CERT	✓	✓	✓	✓	✓	✓	✓	✓	✓						
	SD		✓	✓	✓		✓	✓	SD	✓	✓	✓	✓	✓	✓	✓	✓	✓						
	CI		✓	✓	✓		✓	✓	CI	✓	✓	✓	✓	✓	✓	✓	✓	✓						

Notes:

AEAI=Assessment of environmental aspects and impacts in order to select significant aspects; CERT=Certification; CI=Continuous improvement; COE=Competency of employees; COENVI=Communication of environmental information to all employers; CSHI=communication of safety and health information; EMSAUD=environmental management systems auditing ; EMS-B=EMS budgets; EMS-C=EMS champion selection; EMSDC=EMS documentation control; EMSDO=EMS Documentation; EINV=Employees involvement; ENVPO=Environmental policy; ENVMP=An environmental management program and an action plan; ENOT=Environmental objectives and targets; EIOPM=Establishment and implementation of operational control measures; EOC=Evaluation of compliance with relevant laws and regulation; OPC=Operational control; EPAR=Emergency preparedness and response; ICULR=Identification, communication and updating all applicable legal and other requirements; IEAI=Identification of all environmental aspects and related impact; IIVES=incidents investigations; ISHHR=investigation of safety and health hazards and risks; ITPT=Identification of training needs and provision training programmes; MAM=Monitoring and measurement; MR=Management review; NCCPA=Nonconformance and corrective and preventive action; PAR= Provision and allocation of resources; PER=Publishing environmental report; PMAM = Performance monitoring and measurements; PR= Preliminary review; RC= Records control; RCM=Records control and management; SD=Self-declaration of an EMS/SHMS adoption; SHAUD=SHMS Auditing; SH-B=safety and health budgeting; SHMP=safety and health management programme; SHMS-C=safety and health and management safety champion selection; SHDOC=safety and health documentation control; SHDOC=safety and health documentation; SHOT=Safety and health objectives and targets; SHPO=safety and health policy; SHRA safety and health risks assessment; SMC=Senior management commitment and leadership; SRR=Structure, roles and responsibilities; TALL=Taking action on lessons learned.

Table 5.2: Potential integrated SHE management capability attributes

SN	Aspect of PDCA	Attributes	Description
1	PLAN	Senior management commitment	Senior management commitment to safety, health and environment (SHE) management
2		SHE implementation team	A SHE team, solely for the implementation of SHE management in the company
3		Baseline review	A preliminary review of the company's current status of SHE management processes
4		Hazards, environmental aspects and impacts identification	Systems, processes and procedures for SHE hazards and environmental aspects and impact identification
5		SHE risks assessment and identification of control measures	Systems, processes and procedures for SHE risks assessment and identification of control measures
6		Legal and other requirements	Identification, having access to and analysing applicable legal and other requirements which apply to all activities
7		SHE policy	An integrated policy that serves as the foundation for a company's she development and implementation
8		SHE objectives and targets	SHE objectives and targets for a company in line with SHE policy
9		SHE management programme	Company's action plans for achieving SHE objectives and targets
10	DO	SHE roles and responsibilities	Availability of dedicated SHE roles, and responsibilities within organisational hierarchy
11		SHE resources	Provision of physical and financial resources for SHE implementation
12		SHE training	Provision of suitable SHE training for personnel
13		SHE competence	The skills, knowledge and experience of personnel to undertake responsibilities and perform SHE activities
14		Management of outsourced SHE services	Process or a mechanism for assessing the competence outsourced personnel, subcontractors and suppliers with regards to management of SHE
15		SHE communication	Communication of relevant SHE information and requirements to personnel and other relevant stakeholders
16		Employee involvement in SHE	Consultation and involvement of all employees at all stages of SHE management
17		SHE documentation	Provision and maintenance of adequate SHE documentation and records
18		Control of SHE documents	Processes and procedures for ensuring that SHE documents are maintained, current and available to employees
19		SHE operational control	Processes, procedures and measures for controlling SHE risks, to ensure SHE regulatory compliance in operational functions and to achieve the overall SHE objectives
20		SHE emergency preparedness and response	Emergency procedures and measures to minimise the impact of uncontrolled events and unexpected incidents
21	CHECK	SHE performance monitoring and measurement	Systems, processes and procedures to monitor and measure SHE performance
22		Evaluation of compliance	Processes and procedures to monitor and access compliance with SHE regulations and other applicable requirements
23		SHE incidents investigations	Processes and procedures for investigating the causes of SHE incidents
24		Non-conformance; corrective and preventive actions	Processes, procedures and systems for the identification and correction of problems and prevention of their recurrence
25		SHE records control	Processes and procedures for maintenance and management of records of SHE performance
26		SHE system auditing	Processes and procedures to conduct SHE audits to assess compliance and she management system effectiveness
27	ACT	SHE lessons learned and knowledge management	Learning lessons from inspection, accident investigations audits etc. and acting on them

5.3 Expert verification

5.3.1 Formulation and composition of experts

The criteria for selecting experts for the verification exercise was presented in section 4.6.2 in Chapter 4. The purposive sampling involving snowballing was followed to recruit the participants. Prospective participants were considered eligible if they met at least three of the following minimum requirements:

1. Minimum of five years of professional experience in the construction industry or in SHE management in construction, particularly in sub-Sahara Africa
2. Minimum educational qualification of a Bachelor's degree or an advanced degree in CEM or other related fields
3. At least one professional qualification relating to construction, safety and environmental management or a member of a safety and/or environmental management association;
4. An academic who has carried out research in areas of environmental, health and safety management in construction, particularly in sub-Sahara Africa.

Twelve experts were selected based on satisfying a set of selection criteria and engaged in the preliminary verification of capability attributes identified from literature. The purpose was to draw on the experts' SHE management expertise to verify the capability attributes (in Table 5.2), in order to ascertain and achieve an agreement on the appropriateness and comprehensiveness of the 27 SHE management capability attributes. It was ensured that all the experts involved in the process had sufficient SHE knowledge and experience in construction SHE management, particularly in sub-Sahara Africa to guarantee the reliability of their responses. The number of experts was in line with the guidance of Hallowell and Gambatese (2010) regarding the number of experts needed for expert group technique. The demographic information of these experts is shown in Table 5.3.

5.3.2 Verification of capability attributes

The 27 potential SHE capability attributes obtained from a thorough review of the literature (outlined in Table 5.2, in section 5.2.1) were used to design a simple questionnaire. The selected expert panellists were contacted via email and they indicated their readiness to participate in the study. The questionnaire (Appendix A) was sent to 12 experts for verification of the capability attributes. They were sent customised e-mails that included a link to the questionnaire hosted by Bristol Online Survey (BOS) to enable them to respond. The questionnaire sent, requested the experts to review and indicate the relevance of the attributes to the implementation of an integrated SHE management system in construction. They were also asked to identify other suitable capability attributes that may have been missed. The questionnaire was used as a structured way of extracting reliable information from expert panel members due to its aptness for statistically evaluating adequacy and consensus (Hsu and Sandford, 2007). This approach allowed the collation of ideas towards decision-making. Respondents were given three weeks to reply. In the end, a total of nine out of the 12 experts responded to the questionnaire. The results of the analyses of responses is presented in section 5.2.3.1.

Table 5.3: Background of Experts

Expert ID	Experience in health and safety research and in environmental management research	Professional body affiliation	Highest academic qualification
EP001	5 years in environment management	ASCE	PhD in Civil Engineering
EP002	10 years in safety and health 5 years in environmental management 10 years in construction management	GhIS, GIOC, IET	PhD in Construction Management
EP003	5 years in safety and health	GIOC, ICIOB, UK, MISDS	PhD in Building Technology
EP004	15 years in construction management	ICE (CEng), CIOB FHEA	PhD in Construction Engineering and Management
EP005	12 years in environmental management	IEMA	MSc in Environmental management
EP006	8 years in safety and health 10 years in construction management	CIOB, ICE, SAICE, Pr CM	PhD in Construction Management
EP007	8 years in safety and health 3 years in environmental management 8 years in construction management	FHEA	PhD in Construction Management
EP008	10 years in safety and health 7 years in environmental management	APM, CIOB, FHEA	PhD in Construction and Project Management
EP009	7 years in safety and health 3 years in environmental management	CIOB	PhD in Construction Management

Notes:

GIOC=Ghana Institution of Construction; CIOB=Chartered Institute of Building; MISDS; International Society for Development and Sustainability; APM=Association of Project management; HEA=Higher Education academy; SAICE=South African Institution of Civil Engineers; IEMA=Institute of Environmental Management and Assessment; ASCE=American Society of Civil Engineers; GhIS=Ghana Institute of surveyors; ICE= Institution of Civil Engineers; IET=Institution of Engineering and Technology.

5.3.2.1 Analyses and results of expert verification

Percentages were used to measure the level of agreement and acceptability of each capability attribute (Chan *et al.*, 2001). The results are presented in Table 5.4. A total of nine out of the 12 experts responded to the questionnaire; thereby, reflecting a 75% response rate. For each of the attributes over half of the experts (i.e. a simple majority- 50%) agreed that it is relevant to the implementation of an integrated SHE management system in construction. Also, the experts did not suggest any new attributes. Eight of the attributes were consolidated based on their similarity. For instance, "*the SHE hazards, environmental aspects and impacts identification'' and "the SHE risks assessments and management"* were merged to become "*SHE risks management*", while the "*SHE documents control*'', "*SHE documentation*'' and "*records control*'' attributes were consolidated into "*SHE documentation and control"* shown in Table 5.5. In the end, the 27 validated capability attributes were, thus, consolidated into 20 integrated SHE management capability attributes.

Following the work by Mahamadu *et al.* (2017) regarding determination of organisational capability attributes for implementation of design for occupational safety and health capability (DfOSH), as well as the categorisation of key process areas in capability maturity modelling (Paulk *et al.*, 1993), the 20 validated capability attributes forming the integrated SHE management framework were subsequently categorised into five thematic areas of integrated SHE management capability. The five thematic categories are: strategy; people; process; resources; and information. Detailed descriptions of the thematic categories and the various attributes within are presented in the Table 5.5.

Based on these 20 capability attributes and the PDCA management cycle, an integrated SHE management framework/system was established. The four main elements of the framework are shown Figure 5.3. It involves planning, implementation, checking and reviewing phases which consist of process and procedures that helps in continuous improvement of SHE issues.

Upon completion of the verification process, a three-round DT was used to generate consensus regarding the importance of the capability attributes, while the VAHP was used to generate weights of importance based on the outcomes of the DT.

Table 5.4: Results on expert survey

Proposed SHE capability attributes	Number of expert participants (12) Response received: (9) = 75%		
	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 5.5: Verified integrated SHE management capability 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

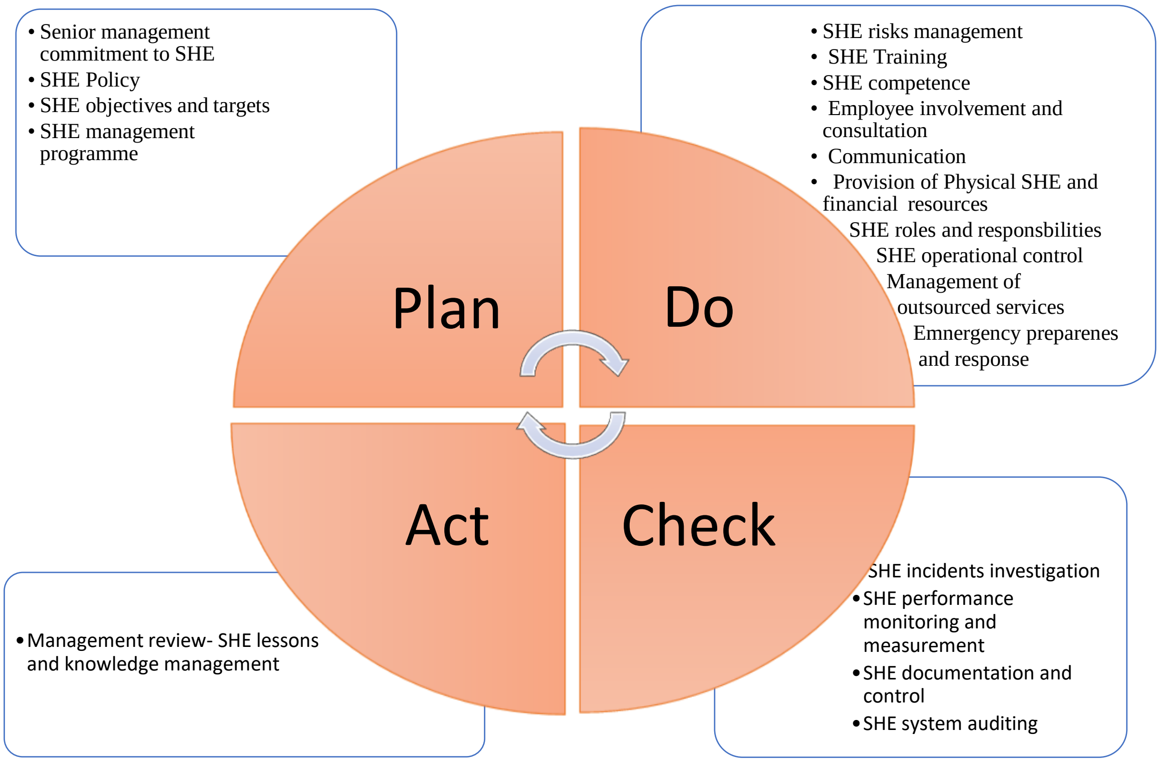

Figure 5.3: The integrated SHE management framework/system

5.4 Application of the Delphi technique in this study

In this study, the DT was used to generate consensus regarding the importance of the integrated SHE management capability attributes through the use of collective intelligence of construction professionals with knowledge and experience in SHE management in the Ghanaian construction industry. The DT ensured a reliable and validated data collection process. The various processes involved in the application of the DT in this study are described in sections 5.4.1 to 5.4.7.4.

5.4.1 Delphi questionnaire development

In this study a questionnaire was designed for the Delphi process. The 20 verified integrated SHE management capability attributes and the five thematic categories were incorporated in the questionnaire. The questionnaire was for the participants to rank the five thematic categories and then capability attributes within the categories based on their level of importance to the implementation of an integrated SHE management system in construction. According to Hsu and Sanford (2007), a structured questionnaire could be used in the first round of a Delphi study if basic information relating to the topic under study is available and usable. Since capability attributes had already been identified from the preliminary verification stage, the exploratory first round of the typical Delphi was, therefore, replaced with a more structured questionnaire. The structured format of the first round usually makes the DT simpler for the researcher and the respondents, and also increases the response rate (Ghashat, 2012).

The first-round questionnaire (Appendix C) was, therefore, designed in a structured format consisting of a set of closed ended questions on integrated SHE management capability attributes and other questions requesting information about participants' background and years of experience in SHE management construction. Experts were asked to rank the attributes within each category. The results obtained from the first round Delphi questionnaire analyses was used to design the second-round questionnaire. The second round Delphi questionnaire (Appendix D) consisted of the expert's own first round responses, the median ranks for the five categories and the SHE attributes within each category, plus instructions on how to proceed. The third round Delphi questionnaire (Appendix E) was designed in the same format consisting of SHE attributes within only the resources category.

5.4.2 Delphi participants selection

One of the most important steps of the DT, includes identifying the experts who might be willing to participate (Hasson *et al.*, 2000). Considering the DT does not survey a random sample, purposive sampling involving snowballing was used to recruit participants for the study. In order to select qualified and experienced experts in the domain of SHE management, the guidance of Adler and Ziglio (1996) and Hallowell and Gambatese (2010) regarding the criteria for selecting experts (e.g. a professional with expertise in the subject under study, capacity and willingness to participate and a minimum of five years of experience) was followed. Prospective Delphi participants were, therefore, considered eligible if they meet at least three of the following minimum requirements:

1. Minimum five years of work experience in either industry or academia with extensive knowledge in SHE management in the Ghanaian construction industry;
2. Minimum educational qualification of diploma;

3. At least one professional qualification relating to construction, safety and environmental management and member of a safety and/or environment association;
4. Knowledge and experience with the issues under investigation; and
5. Capacity and willingness to participate in the entire Delphi studies.

5.4.3 Delphi experts' backgrounds

The DT involves gathering information from experts in a particular field to determine the answer to a particular research problem (Skulmoski *et al.,* 2007). The panellist should have the knowledge, capability, professional qualifications, relevant experience in the area being investigated and the capability to contribute useful insights (Loo, 2002; Asli *et al.,* 2016). As a result, the population for this study consisted of academics, researchers and practitioners who specialise in the areas of construction health, safety and environmental management in the construction industry in Ghana. They were recruited based on the requirements in section 5.3.2. Since the success of a Delphi process is largely dependent on the knowledge of qualified panel members, it was ensured that all the experts involved in the process had sufficient SHE knowledge and experience to guarantee the reliability of their opinions and feedback (Ameyaw and Chan, 2015). Details of background information of experts' panel are presented (Table 5.6).

5.4.4 Number of experts

According to Powell (2003), there is minimal empirical evidence on the influence of the number of experts' participants on the reliability or validity of consensus procedures. The DT is not like the conventional surveys, where statistically large numbers are required, therefore, the number of experts chosen should be such that it can be regarded as representative of viewpoints in the subject under study (Holloway and Todres, 2003; Hsu and Sanford, 2007). In a review of Delphi usage in CEM research studies, Ameyaw *et al.* (2016) report the use of at least 8-30 Delphi participants. Based on their research findings, it was ensured that the sample size of the Delphi in this study, exceeded 15 participants to conform to common practice in CEM field.

5.4.5 Invitation of prospective Delphi participants

As mentioned earlier, purposive identification and recruitment of participants is employed in Delphi studies. Based on this, invitation letters were e-mailed to 70 potential panellists in order to explore their availability to participate in this study (Appendix B). These experts were identified from addresses available from construction professional groupings and associations (i.e. Ghana Institute of surveyors [GHIS], Ghana Institute of Safety and Environmental Professional (GHISEP), Chartered Institute of Builders [CIOB], Association of Civil and Building Contractor, Association of Road Contractors [ASROC]), and through the researcher's network. The letter stated the purpose and benefits of the study, a short overview of the DT, as well as explanation of ethical issues. Included with the invitation letters was a form for Delphi participants to confirm their level of professional experience and their qualifications.

From the invitations, 57 experts registered interest in participating in the Delphi process and 30 - 41 experts participated in the Delphi rounds. Since most Delphi studies in CEM involve between 15-35 participants (Ameyaw *et al.*, 2016), the number of experts who participated in this study were deemed adequate. Three-rounds of Delphi interspersed with controlled feedback were undertaken. The sample size of experts for the three-round Delphi was n=41(round 1), n=31(round 2) and n=30(round 3) respectively. Each Delphi participant was assigned a unique code, which was the identifying information available for all the rounds. This strategy preserved the confidentiality for specific responses, which is a strength of a Delphi process. The response rate for the three rounds are in presented in Table 5.7.

Table 5.6: Response rate by iterations through the Delphi process

Rounds	Sent	Received	Response rate (%)
1	57	41	72 %
2	41	31	76 %
3	31	30	96%

Table 5.7: Professional profile of Delphi experts

Professional Role	Experience in safety, health and environmental management in construction	Professional qualifications/affiliations	Educational qualification
Senior health, safety and environment (HSE) manager	16 years in health and safety 16 years in environmental management	IOSH	MSc
Environmental manager	9 years in health and safety 9 years in environmental management	GhIE and IAIA	MSc
Health and safety coordinator	12 years in health and safety 7 years in environmental management	GhIS	MPhil
HSE Field supervisor	10 years in health and safety 4 years in environmental management	IRCA and GhISEP	PgD NEBOSH
Quantity surveyor	6 years as a safety, health and environment professional	-	MPhil
Safety superintendent	7 years in health and safety 2 years in environmental management	SIA	BSc
Health and safety officer	6 years in safety, health and environment	-	BSc NEBOSH
Health and safety manager	15 years in health and safety 5 years in environmental management	GhIS, GIOC	PhD
Health and safety officer	11 years in health and safety, 3 years in environmental management	IET	MPhil
Construction manager	10 years as a safety health and environment professional	CIOB	PhD
HSE manager	10 years as a health, safety and environmental manager	GhISEP, IOSH and ACS	MSc
Safety and environment manager	5 years as a safety and environment manager	GHIE	BSc
Health and safety manager	14 years in health and safety 5 years in environmental management	-	MSc
Resident civil engineer	11 years in health and safety 3 years in environmental management	-	MSc
Environmental compliance unit manager	13 years in environmental management	-	MSc
Health and safety manager	5 years in health and safety, 2 years in environmental management	GhIS	PhD
Health and safety manager	13 years in health and safety 2 years in environmental management	IIRSM and IOSH	MSc, NEBOSH.
Environmental and social safeguards manager	16 years in health and safety 8 years in environmental management	GhIS	MSc
Health and safety officer	6 years in health and safety	GHiSEP	Pg. Cert.
Contracts manager	5 years in health safety and environmental management	GhIS	PhD
Project manager	13 years in health and safety management 5 years in environmental management	PMP and IET	MPhil
Safety officer	7 years in health and safety	-	HND
HSE supervisor	5 years as a Health and safety supervisor	GHIS	BSc
Director of projects	6 years as a health and safety, environmental professional	PMP	MSc
Senior lecturer and construction manager	15 years as a health and safety professional	-	MSc
Facilities manager	5 years as a health and safety and environmental professional	GHIS	MSc

Professional Role	Experience in safety, health and environmental management in construction	Professional qualifications/affiliations	Educational qualification
Health, safety and environmental quality advisor	6 years as a health, safety and environmental advisor	IPED and IOSH	BSc, NEBOSH
Health, safety and environment manager	17 years as a health, safety and environmental manager	-	PgCert. NEBOSH
Health, safety and environmental supervisor	8 years as a health and safety, and environmental manager	-	MSc, NEBOSH Diploma
Health and safety manager	6 years as health, safety and environmental manager	CIOB	BSc
Facilities maintenance	5 years in health, safety and environment professional	AACE	MSc
Lecturer and a construction manager	15 years in environmental management 4 years in health and safety	GIOC and CIOB	PhD
Health, safety and environmental manager	7 years as a health, safety and environmental manager	-	BSc, NEBOSH IGC
Health, safety and environment superintendent	12 years in environmental management 4 years in health and safety	IRCA	MSc, NEBOSH Diploma
Senior health, safety and environment officer	10 years in health and safety, 7 years environmental management,	GHiSEP	Pg. Cert
Health, safety and environment unit manager	8 years in environmental management 2 years in health and safety	EIMA and IRCA	MSc
Environmental manager	22 years as an environmental manager	IAIA	MSc, Pg Env.Mgt.
Environmental superintendent	7 years as an environmental management professional 3 years in health and safety	GIPF	MSc
Environmental manager	10 years as an environmental manager	GCM	MSc
Health and safety manager	6 years as a health, safety and environmental manager	IET	MSc
Safety manager	5 years as a health and safety manger 2 years in environmental management	-	Higher certificate NEBOSH

Notes:
AACE=American Association of Cost Engineering; BSc=Bachelor of science; CIOB=Chartered Institute of Building; EIMA=EIFS Industry Members Association; GCM=Ghana Chamber of Mines; GHiSEP=Ghana Institute of Safety and Environmental Professionals; GIPF=Ghana Institute of professional Foresters; GIOC=Ghana Institute of Construction; GhIE=Ghana Institute of Engineers; GhIS=Ghana Institute of Surveyors; IAIA=International Association for Impact Assessment; IET=The Institution of Engineering and Technology; IIRSM=International Institute of Risk and Safety Management; IPED=Institute for Professional and Executive Development; IOSH=Institution of Occupational Safety and Health; IRCA=International Register of Certificated Auditors; MPhil=Master of Philosophy MSc=Master of Science; NEBOSH=The National Examination Board in Occupational Safety and Health; PhD=Doctor of Philosophy; PMP=Project management professional; PgD=Postgraduate Diploma; SIA=Safety Institute of Australia.

5.4.6 Measurement of consensus

In the Delphi process, each round was succeeded by an evaluative phase, within which the responses and opinions of all the expert participants were given to all panel members. For example, the median ranks were calculated and the Kendall's coefficient of concordance (*W*) subsequently generated using the IBM Statistical Package for the Social Science (SPSS) statistics version 24. The Kendall's *W* was to assess the degree of agreement between the expert panel members on the capability attributes within each Delphi round. Perfect agreement is indicated by values of 1 while complete disagreement is indicated by values of 0. As the coefficient (*W*), moves closer to 1, there is consistency in the responses and a strong agreement. A significance level of alpha = 0.05 was adopted (Field, 2013). A coefficient (*W*) value of ≥ 0.4 was considered as representing a suitable level of agreement. The Kendall coefficient of concordance for each Delphi round is presented in the following sections and presented in Table 5.8.

5.4.7 Delphi data collection process: the Delphi rounds

According to Hallowell and Gambatese (2010), three rounds of Delphi is seen to be appropriate on the basis of their review of CEM Delphi applications. A three-round Delphi survey interspersed with feedback was conducted to generate consensus on the integrated SHE capability attributes and also to ascertain their relative weights of importance by the use of the VAHP. The results of the three-Delphi survey are presented in Table 5.8. Each of the Delphi round is discussed in sections 5.4.7.1 to 5.4.7.3.

5.4.7.1 Delphi round one

At the beginning of the first round of the Delphi survey, each expert panel member was sent an information pack with the first-round questionnaire. This information pack included a brief overview of the research topic, the purpose of the study, a participant information sheet and a consent form, as well as the instructions to the first round of questions (Appendix B). An invitation letter with a link to the first-round questionnaire hosted by Bristol online survey (BOS), was emailed to the selected experts. The questionnaire (Appendix C) consisted of a preamble that gave sufficient information to participants to ensure clarity, so as to obtain quality responses for the next round of Delphi.

In this first round, the experts were asked to rank the five thematic categories based on their level of importance to the implementation of SHE management in construction. Similarly, participants were asked to rank attributes within each of the categories. Respondents were asked to give the topmost important attribute the rank of 1st, followed by 2nd and then other ranks in that sequence. Where they believed two or more attributes should have equal or same rank, the expert participants were asked to indicate this in their ranking of the attributes (Appendix C). The deadline was set at three weeks. Reminders (Appendix B) were sent to expert panel members, one week before the end of the round, so as to keep the response rate as high as possible. Responses for Delphi round one was returned to the researcher via the online survey.

Round 1 analysis

At the end of Delphi round one, the median ranks for the five categories and the attributes within each category were generated by the use of the Excel software. An agreement analysis, the Kendall's *W*, on SPSS was used to test for consensus on the ranking of the five categories as well as ranking of the attributes within the categories.

Agreement analysis using Kendall's *W* showed there was a moderate consensus ($W = 0.425$) in terms of ranking of the thematic categories based on the median rankings. A low consensus was attained for rankings of attributes within the "strategy", "process" and "information" categories (Table 5.8). Also, consensus for ranking of the attributes within the "people" and "resources" categories was very low. Consensus in terms of the attributes under each of the thematic categories was generally low. This necessitated a second round of the Delphi survey.

5.4.7.2 Delphi round two

The second round Delphi questionnaire (Appendix D) was customised for each expert by the inclusion of expert's own round one responses. The questionnaire was sent to round one respondents (i.e. 41 experts) via an email attachment. The 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 distil their thoughts on the research problem is one of the important features of the DT (Skulmoski *et al.,* 2007). Furthermore, panel members were asked to return the completed questionnaire within three weeks via email. Follow up reminders were also sent to the experts one week before the end of the round.

Round 2 analyses

Thirty-one experts completed the second-round questionnaire representing a response rate of 76%. This is consistent with Delphi literature, which indicated the difficulty in maintaining participation over time in Delphi studies (Keeney *et al.*, 2006). Using an Excel spreadsheet, the median ranks for the five categories and attributes within each category in round two were generated. At the end of Delphi round two, agreement analysis using Kendall's *W* showed consensus had been attained for the rankings of the thematic categories, as well as the ranking of attributes within "strategy", "process", "people" and "information" categories. The attributes within "resource'' category did not generate consensus. Consequently, the attributes under this category was taken forward to a third round of the Delphi survey.

5.4.7.3 Delphi round three

In the third round, the median ranks for attributes within the "Resource" thematic categories were incorporated in a questionnaire (Appendix E). The questionnaires were sent to the 31 SHE experts who responded in round 2. The questionnaire was customised for each of the experts by the inclusion of each expert's own second round responses. The experts were asked to reconsider their rankings in the second round, in light of the information provided and rank attributes again.

Round 3 analyses

Thirty experts completed the third-round questionnaire representing a response rate of 96%. At the end of the third round, the agreement analysis using Kendall's *W*, showed that no significant consensus has been attained. As a result, the Delphi rounds was terminated based on the suggestion by Dalkey *et al.* (1970) that Delphi results are most accurate after two rounds but become less accurate for additional rounds, and also based on the recommendation by Hallowell and Gambatese (2010) concerning the use of three Delphi rounds. Subsequently, the Wilcoxon signed rank test was used to check for stability and saturation between the second and the third rounds responses for the attributes within the "resources" category. In the end, Wilcoxon test (Z) results showed that there was no significant statistical difference between the second and third rounds responses for attributes within the "resources" category. The stability in both rounds, thus, further justified the termination of the Delphi survey at the third round. Results of the Wilcoxon signed test is shown in Table 5.9

5.4.7.4 Summary of results from Delphi survey

Across the three rounds there were largely no changes in the medians except for “information’’, “auditing’’, and “emergency preparedness’’ whose medians changed from 4 (in round one) to 5 (in round 2), as well “management of outsourced SHE services”, whose median changed from 3 (in round one) to 4 (in round 2) and “ SHE 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). In terms of ranking of thematic categories and attributes (based on medians), there was consistency throughout the rounds. At round one and round two there was significant consensus in the experts ranking of the strategy attributes, processes attributes, people attributes and information attributes. Furthermore, there was improvement in the consensus between the two rounds as shown by the Kendall’s *W* values. Whilst the was improvement in the Kendall’s *W* values for the ranking of attributes within the resource category, the Kendall’s *W* was not significant necessitating a third round. At round three, the Kendall’s *W* was still not significant. Furthermore, the Wilcoxon signed rank test, which was used to check for saturation, yielded no significant results as shown in Table 5.9. This meant that a further Delphi round was not needed as it was unlikely to yield consensus since saturation has been reached. Though consensus was not reached on the two resource-related attributes in the third round, each of the attributes throughout the three rounds were ranked first by experts. This emphasises their relevance to the implementation of an integrated SHE management in construction. Furthermore, saturation point had been attained and therefore all the 20 capability attributes (including the two resource-related attributes) were utilised in the VAHP to ascertain their relative priorities.

5.5 The voting analytical hierarchy process results

As mentioned in section 4.7.8.4, VAHP is a useful methodology for multi-criteria decision-making situations with large applications. It was used in this study to obtain the priority weights for each integrated SHE management capability attribute. The VAHP involved a six-step process adapted from Liu and Hai (2005). These six steps are presented as follows:

5.5.1 Steps in implementing VAHP

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

Step 2 - Structure the hierarchy of the criteria: 20 integrated SHE management capability attributes constituted the sub criteria within the five thematic categories as shown in Figure 5.3.

Step 3 - Prioritise the criteria: From the round two Delphi, 31 experts ranked the five categories of attributes. The ranking by experts is presented in Table 5.10.

Step 4 - Prioritise the sub criteria: From the second round Delphi, 31 experts ranked attributes within the “strategy”, “process”, “people”, “resources” and “information” categories. From the third round of Delphi, 30 experts ranked attributes within the “resources” category. As previously explained in section 5.4.7.2 only the resource category was carried forward to the third round of the Delphi survey due to a lack of consensus in the second round. Table 5.10 shows the ranking by the experts.

Thematic category /attributes	Round 1 (N = 41)				Round 2 (N =31)				Round 3 (N =30)			
	Median	Mean rank	Kendall's W	Asymp. Sig.	Median	Mean rank	Kendall's W	Asymp. Sig.	Median	Mean rank	Kendall's W	Asymp. Sig.
Thematic category of attributes												
Strategy	1	1.71			1	1.61						
Processes	2	2.73	0.425	< 0.000	2	2.94	0.481	< 0.000				
People	2	2.76			2	2.65			N/A			
Resources	3	3.49			3	3.44						
Information	4	4.32			5	4.37						
Strategy attributes												
Senior management commitment	1	1.91			1	1.66						
SHE policy	1	1.91	0.388	< 0.000	1	1.79	0.610	< 0.000				
SHE objectives and targets	3	2.84			3	3.11			N/A			
SHE management programme	3	3.33			3	3.44						
Processes attributes												
SHE risks management	1	2.32			1	1.90						
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	0.401	< 0.000				
SHE performance monitoring and measurement	3	3.98	0.258	< 0.000	3	3.66			N/A			
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			2	2.60						
SHE training	2	2.68			3	2.98			N/A			
Employee involvement in SHE	2	2.82	0.067	< 0.041	3	3.03	0.402	< 0.000				
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			1	1.26						
SHE documentation and control	2	2.04	0.231	< 0.000	2	2.23	0.549	< 0.000	N/A			
SHE lessons learned and knowledge management	2	2.41			2	2.52						

Table 5.8: Summary of Delphi results

Table 5.9: 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]	3.50	17.50	-1.633[b]	0.102
	Positive Ranks	1[b]	3.50	3.50		
	Ties	24[c]				
	Total	30				
FIN (round 3) – FIN (round 2)	Negative Ranks	1[a]	2.50	2.50	-1.000[b]	0.317
	Positive Ranks	3[b]	2.50	7.50		
	Ties	26[c]				
	Total	30				

Notes:

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

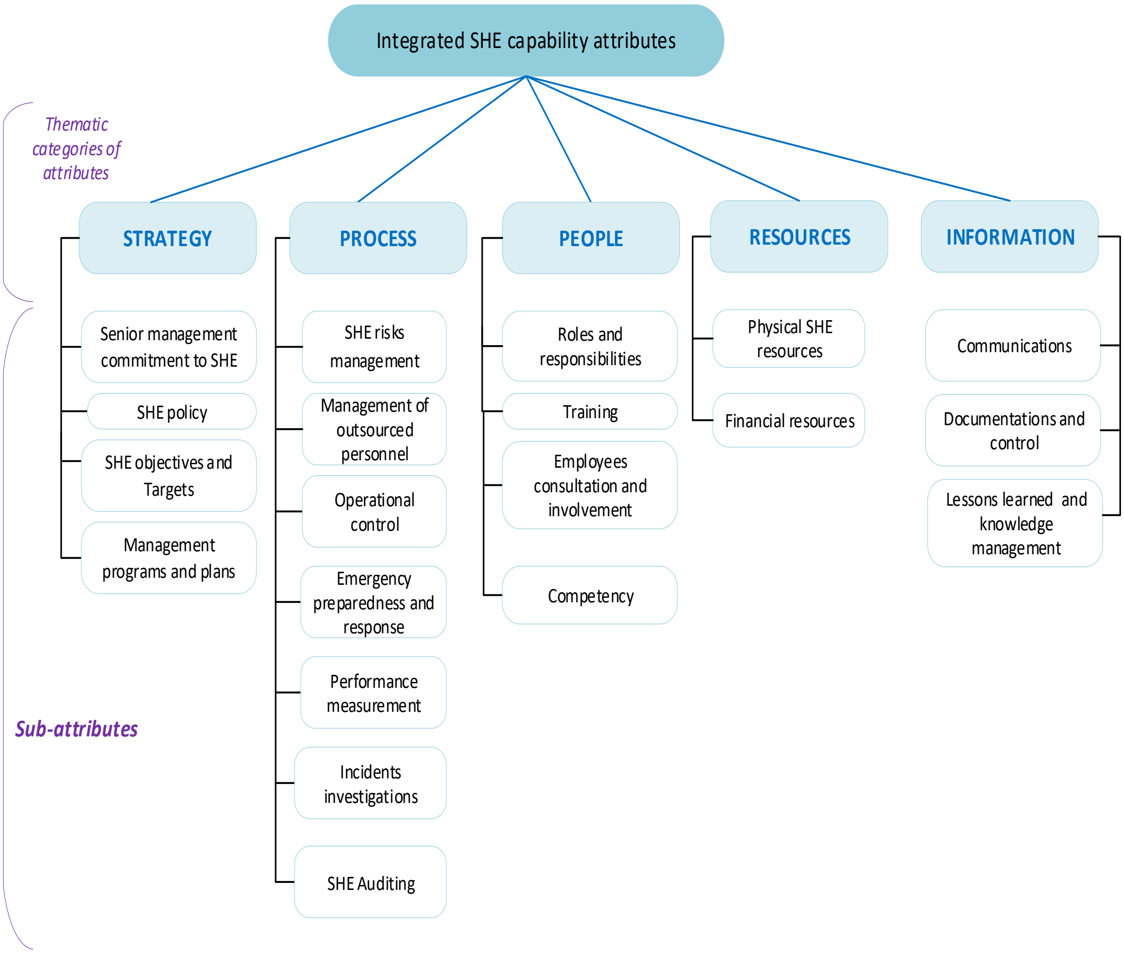

Figure 5.4: Integrated SHE management capability attributes hierarchy model

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

Eq. 5.1

$$w_1 \geq 2w_2 \geq \cdots \geq S\mathrm{w}_s \geq 0$$

Eq. 5.2

$$\sum_{s=1}^{s} ws = 1$$

Where W is the weight and s, is the number of positions/places, thus W_S is the coefficient of weight between the sth place and the sth +1. 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 5.1 and 5.2, the coefficient W_S for the relevant number of capability attributes and sub attributes were derived and presented in Table 5.11.

Example: The coefficient weights for the five positions representing each of the five thematic categories is expressed below:

$w_1+w_1/2+w_1/3+w_1/4+w_1/5 = 1$,

$$\frac{60w_1+30\mathrm{w}_1+20w_1+15w_1+12w_1}{60} = 1$$

$137w_1/60 = 1$

$w_1 = 60/137$

$w_1 = 0.438$

Therefore, $w_2 = 0.438/2 = 0.218$; $w_3 = 0.438/3 = 0.146$; $w_4 = 0.438/4 = 0.110$; $w_5 = 0.438/5 = 0.088$

Based on the Delphi rankings, the VAHP method 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 5.11 to the ranking data in Table 5.10. Afterwards, the obtained weights for the categories were normalised so that they add up to one and ranked. Similarly, the obtained weights for attributes in each category were normalised as shown in Table 5.12.

For example, the "information" category consists of three sub criteria: Communications, Documentation and control; and Lessons learned and knowledge management. Therefore, by using the formula (i.e. Eq. 5.2), the value of w_s will be: w_1= 0.546, w_2 = 0.273, w_3 = 0.182 respectively.

Based on the ranking data (Table 5.10), the total weight of each capability attribute under the information category is as follows:

- Communication = 28 *0.546 +3*0.273 +0*0.182 = 16.091
- Documentation and control = 9*0.546 + 16*0.273 + 6*0.182 = 10.363
- Lessons learned and knowledge management = 4*0.546 + 16*0.273 + 11*0.182 = 8.545

Total weight: 16.091 +10.364 + 8.546 = 35.001

<u>Normalised weights</u>

Communication = 16.091/35.001 = 0.460

Documentation and control = 10.364/35.001=0.296

Lessons learned and knowledge management = 8.546/35.001 = 0.244 (Table 5.12)

<u>Step 6 - Calculate global weights and rank criteria by using the VAHP formula</u>: The final stage of the weight calculation is to obtain the global (i.e. overall) weights of sub-criteria. This is achieved by multiplying the normalised weight of a criterion by the normalised weight of its corresponding sub-criteria. In this study, the normalised weight of each thematic category was multiplied by the normalised weight of the attributes within that category. For example, the normalised weight of "Information" was multiplied by the normalised weight of "Communication", "Documentation and control" and "Lessons learned and knowledge management". This is shown below:

Normalised weight for the thematic category ''Information'' = 0.117

- Communication = 0.460* 0.117 = 0.054
- Documentation and Control = 0.296*0.117 = 0.035
- Lessons and Knowledge management = 0.244*0.117 = 0.029

Similarly, this step is applied to all the other capability attributes. The overall outcomes of the VAHP is presented in Table 5.13

Table 5.10: 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 learned and knowledge management	4	16	11					31

Table 5.11: The coefficient w_s according to different options

Formula	Number of options (places/positions)	Coefficient w_s	
$w_1 \geq 2w_2 \geq \cdots \geq Sw_s \geq 0$ $\sum_{s=1}^{S} ws = 1$	5	w_1	0.438
		w_2	0.218
		w_3	0.146
		w_4	0.110
		w_5	0.088
	4	w_1	0.480
		w_2	0.240
		w_3	0.160
		w_4	0.120
	7	w_1	0.386
		w_2	0.193
		w_3	0.129
		w_4	0.096
		w_5	0.077
		w_6	0.064
		w_7	0.055
	4	w_1	0.480
		w_2	0.240
		w_3	0.160
		w_4	0.120
	2	w_1	0.667
		w_2	0.333
	3	w_1	0.546
		w_2	0.272
		w_3	0.182

Table 5.12: Results of VAHP of thematic category of attributes

Thematic category /attributes	**Weight**	**Normalised weight**	***Rank***
Thematic category of attributes			
Strategy	12.679	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 5.13: VAHP results of global ranking of attributes

Capability attributes	Global weights	Global ranks
Senior management commitment to SHE	0.117	*1*
SHE Policy	0.111	*2*
Physical SHE resources	0.083	*3*
Competency	0.082	*4*
Financial resources	0.076	*5*
SHE objectives and targets	0.054	*6*
Communications	0.054	*7*
SHE risks management	0.051	*8*
Management programs and plans	0.051	*9*
Roles and responsibilities	0.048	*10*
Documentation and control	0.047	*11*
Employees consultation and involvement	0.041	*12*
Training	0.038	*13*
Operational control	0.035	*14*
Lessons and knowledge management	0.033	*15*
Performance measurement	0.029	*16*
Management of outsource personnel	0.025	*17*
Emergency preparedness and response	0.020	*18*
SHE auditing	0.020	*19*
Incidents investigations	0.019	*20*

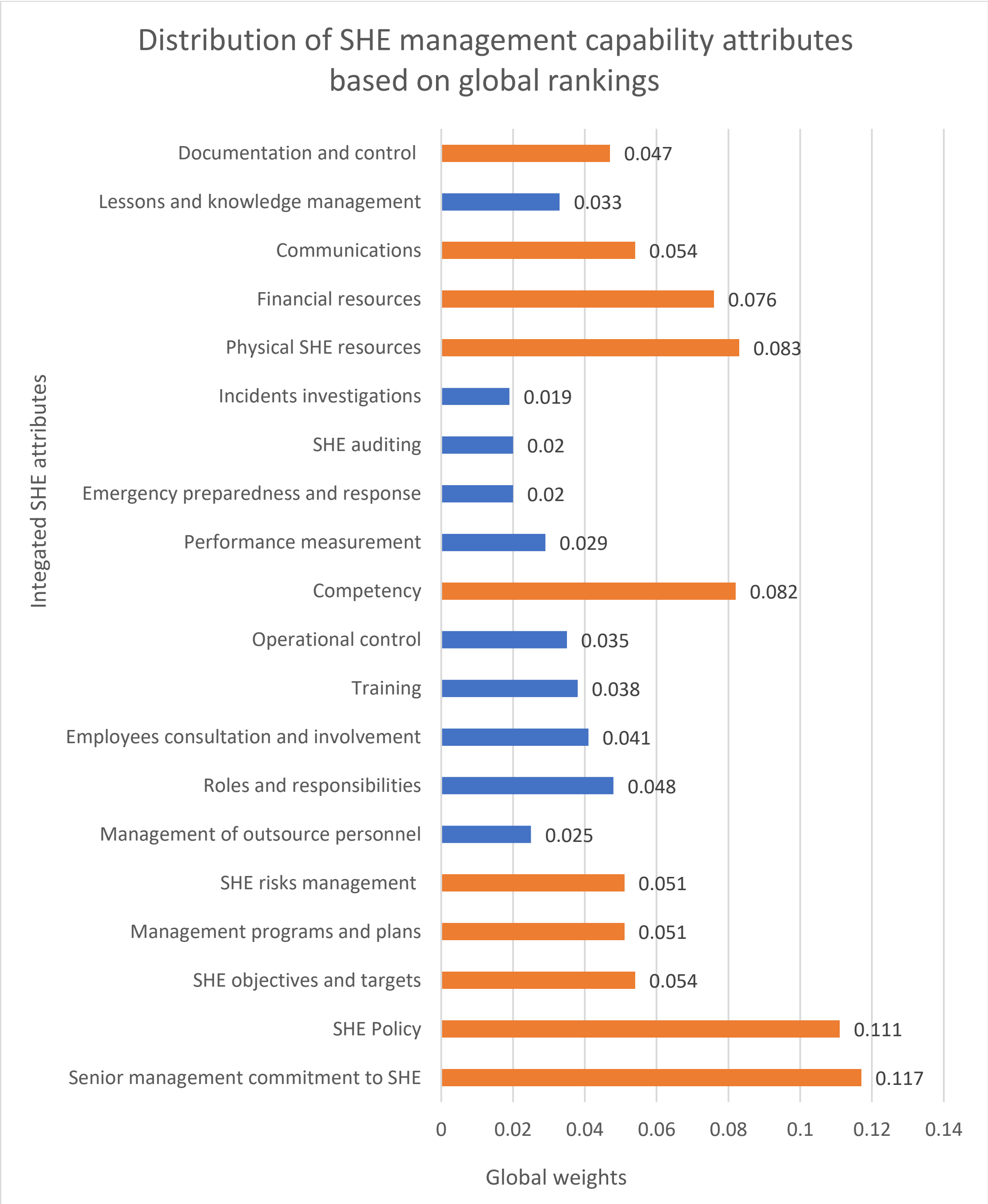

Figure 5.5: SHE attributes distribution based on global ranks

5.5.2 Results of the VAHP

The result of the VAHP in this study is presented in Table 5.11. The ten most important capability attributes are shown by the orange data series in Figure 5.6.

In relation to the thematic groupings of capability 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”. A thorough check of attributes within the thematic categories shows the strategy related attributes, “Senior management commitment to SHE” and “SHE policy” together accounted for 68.69% of the category weight. For the process related attributes, “SHE risks management” is the most important attribute, followed by “SHE operational control” and “performance measurement”. Collectively these three, account 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 resources attribute. “Communications” emerged as the most important attribute of the three “information” attributes.

Based on the global weights, “Senior management commitment to SHE” emerges as the most important attribute, followed by “SHE policy”. This is followed by the “physical SHE resources”, “competency”, “financial resources”, “SHE objectives and targets”, and “SHE communications” Collectively, these seven attributes account for approximately over half (i.e. 57.70 %) of the global weights. An inclusion of the next three attributes (i.e. SHE risks management and SHE management programs and plans, and Roles and responsibilities) increases the percentage to 72.70 %, thus 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.

5.6 Discussion of findings on capability attributes

The outcome of this stage of the research is the identification of 20 capability attributes relevant to the implementation of an integrated SHE management system in the construction industry and their relative priorities. The ability of construction companies to effectively manage SHE issues to achieve better SHE performance outcomes is dependent on the 20 integrated SHE management capability attributes. In this study, the findings are discussed in relation to existing literature on SHE management and capability maturity concept in this section.

The analysis identified five main thematic categories that are relevant to the implementation of an integrated SHE management system in construction. The categorisation of capability attributes, namely processes, people, strategy, information and resources, is consistent with the concept of organisational capability maturity, although specific to integrated SHE management (Paulk *et al.,* 1993; Hain and Back, 2011; Randeree *et al.,* 2012). Additionally, the integrated SHE management capability attributes share similarities with requirements of some existing capability maturity models. The capability attributes definitions aligned 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 identified in this study 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, capability attributes align with the 14 modules of the Sui *et al.* (2018) IMS for occupational health and safety and environment in an operating nuclear power plant and the elements of the UK Coal maturity model (Foster and Hault, 2013), as well as the 12 key safety management processes of the Strutt *et al.* (2006) Design Safety Capability Maturity Model (DCMM).

While some attributes align with the Strut *et al.* (2006) model attributes, in the Struts' (2006) model 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. Furthermore, some of the integrated SHE management capability attributes align with common features of organisational capability, senior management commitment and leadership, financial and physical, and people/human resources, while others relate specifically to, SHE management (e.g. hazards/risks identification and management and SHE performance monitoring and measurement) (e.g. Fleming *et al.,* 2001; Filho *et al.,* 2010). The SHE management capability attributes, particularly the 'strategy' (i.e. senior management leadership, commitment, policy, responsibilities and accountability), is vital to the success of SHE management from all levels and functions of a construction organisation. Moreover, the high number of process related attributes is unsurprising and supports the primary ethos of capability maturity modelling, which is premised on a philosophy that key process improvement leads to sustained and repeatable attainment of goals. The process related attributes are, therefore, recognised as an important aspect of SHE management capability, albeit the others that facilitate the processes also need full consideration.

Regarding the attribute importance, the "strategy" cluster of attributes emerged as the most important capability followed by the "people" category, and collectively these two accounts for more than 52.00% of both thematic category weights and the global weights of all the SHE management capability attributes. Among the sub-attributes making up the "strategy" cluster are: senior management commitment to SHE, SHE policy, SHE objectives and targets, management programmes and plans. The emergence of the "strategy" as the most important, is therefore, unsurprising in view of 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; Sui *et al.,* 2018; Manu *et al.,* 2019a). For instance, the study by Manu *et al.* (2019a) showed senior management commitment to design for occupational safety and health (DfOSH) was the second most important organisational attribute (out of 18 attributes) for implementation of DfOSH by design firms. While all the attributes within the strategy category are important for effective, SHE implementation, "Senior management commitment to SHE" emerged as the most important attribute followed by "SHE policy" in the "strategy" category and also amongst all the 20 SHE capability attributes. These two attributes account for 68.70 % of the strategy category weights and 22.79% of the global weights of all the capability attributes. This emphasis is significant, given that 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 (Zeng *et al.,* 2005; Kheni *et al.,* 2008; Aksorn and Hadikusumo, 2008; Tourner and Pousette, 2009; Burke *et al.,* 2011; Robotham, 2012; Boughaba *et al.,* 2014; Jitwasinkul *et al.,* 2016; Ejdys *et al.,* 2016; Zaira and Hadikusumo, 2017; Manu *et al.,* 2019a). Companies are unlikely to achieve their objectives and targets irrespective of how carefully an environmental or safety management system has been organised or to what standard it has been designed, unless the implementation has the full support and firm commitment of senior management of the organisation. Strong, visible leadership and commitment, therefore, plays a key role in developing a strong culture of safety within a company and also creating safer and healthier workplaces (Lai *et al.,* 2011; Independent Taskforce on Workplace Health and Safety, 2013). Furthermore, the overall SHE policy and associated procedures in an organisation, are produced by senior management and recognised as one of the elements most critical to setting and maintaining an organisation's approach to environmental, health and safety.

For effective SHE implementation, the commitment and provision of adequate and appropriate resources are paramount. As a result, it is not surprising that attributes in the “resources” category were amongst the five topmost capability attributes based on global weights. Within the “resources” category, physical SHE resources attribute was the most important attribute followed by financial resource. This finding reflects the 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).

Regarding the “people” category, which emerged as the second most important capability category, the “SHE competence” attribute was found to be 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. Thus, it is not surprising that it emerged the most important people related attribute. In existing studies, SHE skills, experience, knowledge, and attitude of employees drives other aspects of organisational performance and thus, is critical to the success of SHE management programmes (Vredenburgh, 2002; HSE, 2011; Ismail *et al.*, 2012; Behm *et al.*, 2014; Lopez-Arquillos *et al.*, 2015; Hallowell and Hansen, 2016). Whereas, personal competency is desirable for SHE management practice in a construction company and is seen as 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 global weights. SHE training is crucial to the success of SHE management system and it is one means by which SHE management practices can be improved (Dong *et al.*, 2004; Bahari, 2011; Lai *et al.*, 2011; HSE, 2013; Han *et al.*, 2014; Demirkesen and Arditi, 2015; OSHA, 2016). It also enables employees to improve their skills, knowledge, and abilities to effectively perform their SHE tasks, and acquire enough information about the importance of safety in their works to mitigate occupational accidents.

“Employee’s consultation and involvement” is another important attribute that influences the effectiveness of the integrated SHE management system. According to the European Commission (2014), in addition to management commitment and support, employees’ participation is vital to the success of SHE implementation. Management need to get their employees 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 environment 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 is also evident from the findings; thus, the emergence of the "SHE risks management" as a relevant capability attribute for integrated SHE management and ranked third amongst the process related attributes. Altogether, the process related capability attributes have similarly been recognised as being germane to effective implementation of safety management (Fleming, 2001; Stapleton and Glover, 2001; Filho *et al.*, 2010; HSE, 2013; Olutuase, 2014; OSHA, 2016). SHE audits which are a key aspect in enforcing SHE measures and continual improvement (Stapleton and Glover, 2001; 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 allows management to maintain focus on the environment, safety and wellbeing of employees, improve SHE performance and ensure the integrated system's cost-effectiveness. Despite the importance of SHE audits, it is considered less significant in comparison with performance measurements and emergency preparedness and response in this study. Though the "incidents investigation" attribute was the least important attribute based on the global weights, it is an attribute that enables management to obtain accurate information for preventing future accidents and for facilitating improvements of SHE (Chua and Goh, 2004).

"Communications" emerged as the most important attribute of the information category attribute. This finding is consistent with previous studies, which indicates regular communicating of SHE issues and other relevant SHE information, and feedback at all levels of organisation, as a major SHE management practice that positively influences safety performance of an organisation (Cox and Cheyne, 2000; Vredenburgh, 2002; Mearns *et al.*, 2003; Silva *et al.*, 2004; Aksorn and Hadikusumo, 2008; Vinod Kumar and Bhasi, 2011; Fernandez-Muniz *et al.*, 2012; Boughaba *et al.*, 2014). Hence, the need for accurate and clear information on SHE issues coming into the organisation, flowing within it, and going out from it.

Overall, organisational attributes in respect of integrated SHE management capability identified in this study, reflect the key aspects of a good integrated SHE management system that emphasises a proactive approach to managing SHE issues, and capable of minimising adverse environmental impacts of construction operations and construction accidents in a sustained manner (Fernández-Muñiz *et al.*, 2009; OSHA, 2016). Results showed that amongst the 20 capability attributes, senior management commitment, leadership and support to SHE, an integrated SHE policy, physical resources, competent employees, financial resources, smart objectives and targets, effective communication, SHE risk management, well-defined SHE management programs and action plans, proper designation of roles and responsibilities and SHE management programs and plans emerged as the 10 most important capability attributes on which construction managers should focus and stress the effort of improvements. These capability attributes and their priority weights would enable relevant industry stakeholders to better understand construction contracting organisations capability to implement an integrated SHE management system. It is, therefore, important to ensure the existence of all the aforementioned capability attributes in construction organisations, since the success of an integrated SHE management system hinges on them.

5.7 Chapter summary

Presented in this chapter are steps undertaken to determine the integrated SHE management capability attributes. The chapter included a comprehensive review of literature and the experts' verification of capability attributes obtained from literature. Experts verification was used to establish the appropriateness and comprehensiveness of capability attributes for effective implementation of an integrated SHE management system in construction. Twelve experts were carefully selected to verify the potential capability attributes obtained from the systematic literature review. The Delphi process together with the VAHP, as well as a discussion of the results were also presented. The next chapter presents the processes leading to the development of the integrated SHE management capability maturity model.

CHAPTER SIX - DEVELOPMENT OF AN INTEGRATED SAFETY, HEALTH AND ENVIRONMENTAL MANAGEMENT CAPABILITY MATURITY MODEL

6.1 Introduction

This chapter focuses on the integrated SHE management capability maturity model development. It introduces the background of the integrated SHEM-CMM describing the structure of the model. The model development process highlighted in this chapter includes: the development of an initial model, which consist of integrated capability attributes and capability levels definitions and characteristics, verification of capability attributes, and refinement of capability levels definitions of each capability attribute. The chapter ends with the presentation of the final integrated SHE capability maturity model.

6.2 Development of an integrated safety, health and environmental management capability maturity model

Capability maturity models are strategic tools used to assess the capability of a company to perform key practices or processes required to deliver its services or products. The value of a maturity model is mainly its focus on the combined set of key management tasks and practices essential for a company to meet strategic objectives, goals and other obligations, such as operational safety, health and environmental risks. As indicated in section 3.4.3, maturity models are regarded as both assessment and improvement tool that allows an organisation to assess its improvements in terms of increasing capability maturity levels, following the concept of capability maturity model integration (CMMI) model (Software Engineering Institute (SEI), 2009). The maturity or capability levels are characterised by well-defined evolutionary stages to which practice, process or capability is defined, controlled or established (Macgillivray *et al.*, 2007; Srai *et al.*, 2013).

CMMI has two different representations of maturity and improvement paths: either as a staged format or continuous format. The staged format of CMMI consists of maturity levels that provide an order for moving towards highest level of process maturity. This format, therefore, enables organisations to improve a set of related processes by incrementally addressing successive specific set of key process areas using maturity levels. The continuous format on the other hand, uses of maturity levels to measure process improvement; each level corresponds to a set of practices. This format, therefore, focuses on enhancing the ability of organisations to perform, manage, and incrementally improve their performance in specific key process areas by means of capability levels. In doing so, organisations are able to track, access, and establish organisational improvement within process areas.

This study considered the continuous format as reference framework for the integrated safety, health and environmental management capability maturity model (SHEM-CMM) since it provides a generic measurement of capability level for each, integrated SHE management capability attribute. Again, the continuous format was used for this study because it allows for flexibility, which means that, a company can choose to focus on some process areas which fit the company's long-term strategies or goals. It also, helps firms in the following areas: providing opportunities to companies to know about their competitive environment through an introspection (determining their strength and deficiencies); reviewing of policies and key operations; identifying opportunities for change and investments, and prioritising improvement measures (De Bruin *et al.,* 2005; Tarhan *et al.,* 2016). The developed maturity model in the continuous format would; therefore, give senior management and supervisors of a construction company, a holistic perspective of their company's SHE management capability maturity and allow these companies to prioritise their investments and target efforts at addressing any identified areas of capability deficiency in order to ensure continuous improvement.

6.2.1 Design decisions for maturity model development

In maturity model literature, maturity models (MMs) have received recurrent criticism particularly its lack of theoretical framework or methodology and traceability (Röglinger *et al.*, 2012). There is a dearth of literature on the research methods and practices on how to theoretically develop a maturity model (Becker *et al.,* 2009; Mettler, 2010; Röglinger *et al.*, 2012). In fact, the development process is not demonstrated in most of the documentation of maturity models and grids (de Bruin *et al.*, 2005; Becker *et al.*, 2009), however, in recent studies, researchers have sought to introduced structured approach to previous work done (Storbjerg *et al.,* 2015). For instance, De Bruin *et al.* (2005) recommended six phases of developing a maturity model for descriptive and prescriptive purposes. Maier *et al.* (2012) developed a roadmap from the work done by De Bruin *et al.* in 2005. This road map was a method for the development of maturity grids with four phases and 13 decision points. Becker *et al.* (2009) also derived requirements and procedures model from Hevner *et al.*'s (2004) design science guidelines and used that as a springboard to propose eight stages of developing and evaluating MMs. Mettler (2010) proposed a four-phase complete development procedure cycle based on developer perspective and experience by analysing Becker *et al.'s* (2009) design methodologies.

In this study, the procedural methodology provided by Maier *et al.* (2012) was followed since it provides rigorous and consistent development procedure, and also looks similar to some of the common steps in the approaches the aforementioned authors have developed. For emphasis, the Maier's *et al.* (2012) methodology was slightly modified in this study for ease of developing the SHEM-CMM. There are four steps of the maturity model development process namely: planning, development, evaluation, and maintenance, with each step containing design decisions. Each of the key design decisions are introduced in Table 6.1 together with how the steps are carried out in this study.

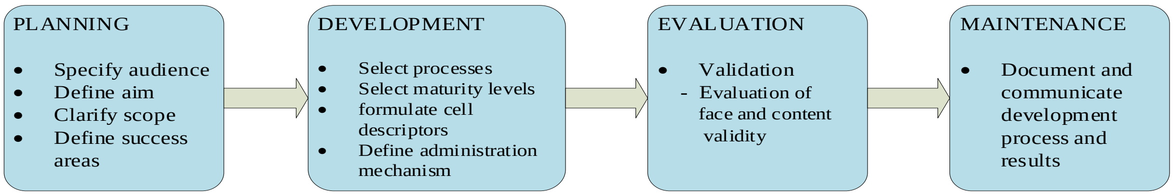

Figure 6.1: Phases and decision points of developing the integrated SHEM-CMM.

6.2.2 Structure of the model

The basic structure of the SHEM-CMM as mentioned earlier was based on the continuous representation of the CMMI (SEI, 2006) in a maturity grid format. The maturity model consists of five capability levels and the 20 capability attributes. Levels of capability maturity are allocated against the attributes thereby creating a series of cells. Each cell contains a brief text description (i.e. descriptor) for each activity at each capability maturity level. Table 6.4 illustrates excerpts of the developed CMM. The full version is in Appendix G. Figure 6.2 illustrates the structure and the fundamental components of the integrated SHEM-CMM.

SHE management capability attributes	**Capability maturity levels**				
	Level 1	*Level 2*	*Level 3*	*Level 4*	*Level 5*
Attribute 1					
Attribute 2					
Attribute 3					
Attribute 4					
Attribute 5					
Attribute 6 ….					

Figure 6.2: Structure of the developed framework (SHEM-CMM).

Table 6.1: Design decisions in the development of the SHEM-CMM

Phase	Decision points	Design decisions and specifications
Phase 1 Planning	Specify audience	The SHEM-CMM is intended to assist construction companies to improve their safety, health and environmental management. The expected audience of the model is thus construction companies.
	Define aim	The purpose of the SHEM - CMM is to assist construction companies improve SHE performance in the Ghanaian construction industry. The aim of the maturity model is therefore to assist these companies to assess their current SHE management maturity in order to facilitate continuous improvement.
	Clarify scope	While some maturity models are designed for generic purposes, others are designed for a specific domain. The SHEM maturity model, as the name indicates is designed to support a specific domain, which is safety health and environmental management in construction.
	Define success criteria	The development of the SHE maturity model is motivated by the need for improved guidance on SHE management processes and practices in the construction industry. The most important success criteria were therefore: (1) ***Usefulness for the construction industry***, determined by the relevance of the domain's components, and the ability of the model to a support improvement effort within SHE management; (2) ***Usability*** determined by the clarity and the syntactic quality of the model; and (3) ***Coverage of key SHEM attributes*** determined by how well the maturity model covers the areas important to focus on for ensuring an effective management of SHE issues in construction companies.

Phase II: Development	Select process areas	A key element of the development of a maturity model is the identification of capability areas (De Bruin *et al.*, 2005; Maier *et. al*., 2012). According to Maier *et al.* (2012) key process areas used in developing a maturity grid can be derived from (1) the experience in the field of the originator and by reference to established knowledge in a particular domain; and (2) a panel of experts in the domain, especially where there is limited prior literature about the domain. In this study, a comprehensive review of literature on SHE management and SHE-relevant maturity models and an expert verification as described in section 5.2 1 and 5.2.3 were utilised to identify and select the process areas (i.e. SHE management capability attributes) for the SHEM maturity model. From the review and expert verification, 20 SHE management capability attributes were identified (Table 5.5). These 20 capability attributes were grouped into five thematic categories namely strategy, processes, people, resources and information. In addition, a Delphi survey and the VAHP (Section 5.4 and 5.5) were utilised to determine the relative priority/weight of the attributes.
	Formulate maturity levels and descriptors	Although varying numbers of maturity levels have been used in the existing capability maturity models (i.e. between three levels and six levels) literature, it is evident from literature (e.g. Maier *et al.*, 2012; Storbjerg *et al.*, 2016), that five maturity levels, is the most common and this aligns with the original capability model by Paulk *et al.* (1993). Based on this, five capability maturity levels (i.e. Level 1 - 5) was adopted. Capability maturity level definitions and characteristics were abstracted from literature review and refined through expert review. In line with the guidelines by Maier *et al.* (2012), the maturity level descriptors at the extreme ends (i.e. level 1 being the lowest maturity level, and level five, being the highest maturity) were formulated based on the underlying notion of what represents maturity for each attribute. Based on these, the other cell descriptors in between (i.e. levels 2, 3 and 4) are then formulated. In capability maturity modelling, lower levels of maturity, is used as the basis for achieving higher levels of maturity. As a result, to reach capability level 5 or full maturation in a capability attribute, the requirements for the lower levels must be met. Each level is defined and characterised clearly, thus allowing companies to self-evaluate their level of maturity. It is therefore important to understand what these capability maturity levels represent in practice, as they are fundamental to assessing the capability maturity of a company.

<table>
<tr><td></td><td></td><td>
<table>
<tr><th>Capability level</th><th>Definition</th></tr>
<tr><td>Level 1</td><td>There are no structured processes and procedures in place. Performance is consistently poor</td></tr>
<tr><td>Level 2</td><td>Organisational processes and procedures may exist but are usually ad-hoc and unstructured. Procedures and processes are not defined. Performance is fair</td></tr>
<tr><td>Level 3</td><td>Organisational processes and procedures are formal and defined. Process and procedure are reactive. Performance is mostly good</td></tr>
<tr><td>Level 4</td><td>Organisational procedures and processes are planned, well-defined, proactive and generally conform to best practices. Performance is very good and consistently repeated</td></tr>
<tr><td>Level 5</td><td>Organisational processes and procedures are standardised, fully integrated throughout the organisation, and continually monitored, reviewed for continuous improvement. Performance is exemplary and comparable to best in the industry</td></tr>
</table>
</td></tr>
<tr><td></td><td>Formulate Cell texts (i.e. maturity level descriptors)</td><td>This decision point represents the intersection of the key process area (i.e. the capability attributes) and the capability maturity levels. Attributes characteristics, thus, need to be described at each level of maturity. This decision point is recognised as a very important step in developing a maturity model assessment (Maier et al., 2012). To be able to formulate cell descriptions that are precise, concise, and clear, three considerations are described by Maier et al. (2012): 1) using a top down or bottom approach; 2) consideration of the information source; 3) consideration of the formulation mechanism. The top-down approach, involves the writing of definitions before measures or a set of practices are developed to fit the definitions while the bottom-approach involves the determination of measures before definitions are written to reflect the measures (Maier et al., 2012). Since integrated SHE management in construction is a relatively new field in maturity model applications, not much evidence is available for what is thought to represent maturity. As a consequence, a top-down approach was deemed to be appropriate for formulating the cell texts, since this approach places emphasis first on what maturity is, before how it can be measured (Maier et al., 2012). Again, this approach was used because of the lack of empirical work on integrated SHE management capability.</td></tr>
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		In establishing what represent maturity in each of the key process area (i.e. SHE management capability attribute) in this study, the underlying notion of maturity was obtained by reviewing various sources including: extant literature relating to the key process areas, feedback from future recipients of the model (through an expert verification), existing capability maturity models and best practice guides on subjects related to SHE management capability attributes. Therefore, existing capability maturity models like the AC2E Model performance matrix by Carillon Plc (2005), the Minerals Industry Risk Management (MIRM) and the Maturity Chart by Foster and Holt (2013), the Risk Management maturity model (RM3) by the Office of Road and Rail and Health and Safety Maturity (2017), and the Design for occupational safety and health capability maturity model by Manu *et al.* (2018) were reviewed to obtain the underlying notion of maturity for each of the SHE capability attributes (refer to Table 6.2 and full version in Appendix F). In summary, the cell texts were formulated using: 1) The underlying rationale of maturity of each capability attributes and 2) The identification and the descriptions of the best and worst practices at the extreme ends of the scale (i.e. level 1 and level 5), which was then used to formulate the characteristics of the other cell descriptors in between (i.e. levels 2, 3 and F4). In the end, the model was developed with a full version presented in Appendix F and a sample shown in Table 6.2.
	Define administration mechanisms	The SHEM maturity model is developed as a stand-alone model and targeted for application in several construction companies. Following the formulation of cell texts, the developed model and an evaluation questionnaire were sent to selected experts for further verification of the model.
Phase III Evaluation	Validation of the model	Chapter seven presents details of the validation process. Once the SHEM-CMM was populated, it was evaluated by construction professionals working in construction companies in Ghana to ensure the practical utility of the model. An evaluation questionnaire was used to validate the model, to obtain feedback on whether the model fulfilled the requirements when applied in practice (Salah *et al.*, 2014).
Phase IV Maintenance	Documentation of the final model and maintenance	The purpose of the maintenance phase is to keep the final maturity model and therefore its elements or attributes current. Continued accuracy and relevance of the model can be ensured by its end-users during this phase.

Table 6.2: Sample of capability model with capability levels and their characteristics for each attribute from various sources

Capability attributes	Notion of maturity	CAPABILITY LEVELS					References
		Leve1	Level 2	Level 3	Level 4	Level 5	
SENIOR MANAGEMENT COMMITMENT	*As maturity increases, senior management commitment to safety, health and environmental (SHE) management becomes unwavering, visible and well-articulated across the company.*	• Lack of senior management commitment to SHE management. • There is no resource commitment (financial and human resources) for SHE related issues.	• Limited commitment by company's senior management to SHE implementation. • Limited resource commitment for SHE related issues.	• Partial commitment by company's senior management to SHE implementation. • Show of senior management commitment is reactive (e.g. when significant risks are anticipated or response to a major environmental impacts). • An adhoc implementation committee is established. • SHE champion is identified. • There is resources commitment for SHE related issues.	• Firm commitment by company's senior management to SHE implementation. • Senior management commitment is aligned to company's policy on integrated SHE management. • Senior management are amongst the SHE champions within the organisation. • Management commitment is well articulated across the company Sufficient resources commitment for SHE related issues.	• There is a full, unwavering and clearly visible commitment of company's senior management to SHE implementation. • Senior management continuously and visibly demonstrate their commitment to SHE and show shared values directed at continually meeting SHE objectives safely. • A cross functional SHE implementation committee is established including a SHE champions and members from all key management functions of the company. There is a ring-fenced resource commitment for SHE implementation and maintenance. Company senior manager(s) are amongst SHE management champions within the industry and are recognised as industry thought-leaders in respect of, SHE management.	Penstate BIM tool p.1 (2013) Yeo *et al.* (2009) p. 16 Defence Aviation Safety Manual (DASM, 2015) p.10 Civil aviation authority New Zealand (CAAnz, 2016) p.8 -9 (SMS evaluation tool) Department of transport, Canada, (DOTc, 2005) p. 12
SHE POLICY	*As maturity increases, company SHE policy becomes explicitly*	• No policy statement on integrated SHE management.	• SHE policy statement is outdated and vaguely worded.	• SHE policy statement is clear, setting out the intention(s) on how SHE is	• SHE policy is clear, comprehensive and well-defined, setting out the intention on SHE.	• There is a clear policy on SHE management, setting out intention(s) on integrated SHE management and	AC2E model performance matrix (Carilion Plc., 2005)

Capability attributes	Notion of maturity	CAPABILITY LEVELS					References
		Level1	Level 2	Level 3	Level 4	Level 5	
	stated, documented, well-communicated within the organisation, and interpreted and applied consistently by all managers or supervisors and employees.		• SHE policy does not meet legal requirements and employees are rarely involved in its development. • Policy has not been communicated within the company and documented.	managed, tracked and reported. • Policy meets majority of legal requirement with some employees actively involved in its development. • Policy is communicated across different levels of the company, but management or supervisors and employees have inconsistent interpretations and applications of the policy. • Policy statements are poorly documented and not displayed at workplace.	• SHE policy presents a clear approach to managing SHE • including the required accountability and responsibility for managing SHE. • SHE policy meets all the legal requirements and other requirements the company subscribes to. • More relevant employees are actively involved in SHE policy formation and strategy formulation. • SHE policy is actively communicated within the company and to other stakeholders. • Policy is accepted, understood and consistently interpreted and applied in the same way by all manager's or supervisors and employees. • SHE policy is formally documented, displayed at the workplace and is available to all stakeholders.	recognising that SHE implementation is not a separate task but an integral part of the organisation SHE activities. • All relevant people are engaged in SHE policy formation as wells as SHE strategy formulation, with clear actions, and accountabilities and targets. • Documented policy is in place, consistent with other best-performing organisation's policies, communicated and readily available to all stakeholders. • SHE policy is periodically reviewed to ensure that it remains relevant to the company, reflect industry best practices and demonstrate effectiveness and continuous improvement.	HSE (2007) p. 98 ORR (2017) RM3 p.19- 20 DASM (2015) p.10 DOTc (2005) p.12
SHE RISK MANAGEMENT	*High maturity levels would be characterised by well-defined and documented processes and procedures for SHE hazards*	• No processes and procedures for SHE hazards identification, risk assessment and control.	• Informal processes and procedures for SHE hazards identification and risk assessments. are in place	• Formal processes and procedures for SHE hazards identification and risk assessment are in place. • Processes and procedures for identification and	• Formal, more detailed and proactive processes and procedures for SHE hazards identification and risk assessment. • Processes and procedures for identification and management focusses on specific, hazards	• Well-defined processes and procedures for SHE risks management are in place and practicable. • SHE risks management processes and procedures are embedded into company's SHE	AC2E model performance matrix Carillon Plc. (2005) Hillsong (2003), p8. HSE (2007) p. 102

Capability attributes	Notion of maturity	CAPABILITY LEVELS					References
		Level1	Level 2	Level 3	Level 4	Level 5	
	identification, risks assessment and control		• Risk control measures are poorly defined, understood and have limited application. • SHE risks assessments and management are poorly documented.	management of SHE risks, focuses on the most significant and obvious SHE risks. • SHE risks assessments are carried out in isolation. • Risk control measures are somewhat defined and used to reactively managed identified SHE risks. • Most important SHE risks assessment activities and plans are documented.	and risks, including less obvious and immediate risks. • Processes and procedures are consistently applied to identify and manage SHE risks. • SHE risks control measures are well defined, understood and implemented in a consistent manner. • All levels of SHE employees and other stakeholders can contribute to risks assessments. • Appropriate SHE risks assessment records are accurately documented and maintained. Processes and plans for SHE risks management are modelled on best practice risks assessment standards e.g. ISO 31000.	planning activities and considered as a core measure of operational excellence. • The approach to SHE risks assessment are routinely applied consistently throughout the company in a pragmatic manner to drive continual improvement in the SHE risks profile of the company. • SHE risks management processes, procedures and control measures are monitored, reviewed and improved on a regular basis to address changing circumstances and ensure continuing success.	Foster and Holt (2013) p. 5 CAAnz (2016) p. 16-18 DASM (2015) p.17

6.3 Selection of expert members for the refinement of maturity model

For the model verification and refinement exercise, experts were selected based on some specific criteria listed below.

1. Expert must have a minimum of five years of professional experience in the construction industry or in SHE management in construction
2. Actively working in a construction company operating in the Ghanaian construction industry
3. An academic that has carried out extensive research in the area of SHE management in construction in Ghana

Apart from the above criteria, the expert must be ready to participate in the study.

Based on the set of selection criteria, a six-member expert panel was purposively selected and engaged to review and refine the model (Appendix G) that was developed. This panel size was deemed appropriate since their input was to help refine the model and not for the purpose of full/complete validation or verification of the model, which would require a large number of participants (see chapter 7). The six SHE expert's designation, years of experience and reference code as well as their areas of expertise in SHE management in construction in Ghana are presented in Table 6.3.

6.4 Expert review of conceptual capability maturity model

After the selected experts agreed to participate in the verification and refinement process, the model (see Appendix G) and supporting documents was forwarded to them. The supporting documents include:

a) An email which served as a cover letter;
b) Instruction sheet; and,
c) The initial maturity model developed.

They were asked to contribute to the refinement of the maturity model, by further verifying the capability attributes and checking whether the capability levels and their characteristics sufficiently represent maturation in each of the capability attributes. The distribution of the documents was followed by follow-up interactions with some of the experts who sought some clarifications. Clarifications were also obtained from some experts after receiving their comments. After considering the comments and suggestions of the experts (refer to section 6.3.2) the maturity model was modified. The outcome is shown in Table 6.5 and a full version is presented in Appendix H.

Table 6.3: Designation and area of practice of expert review panel members

SN	Code reference	Role /Experience
1	AAP	Health, safety and environmental (HSE) supervisor 15 years in health and safety 5 years in environmental management
2	AL	Health and safety officer 13 years in health and safety 2 years in environmental management
3	WGA	Construction manager 15 years in construction management
4	DA	HSE supervisor 10 years in health and safety 5 years in Environmental management
5	KN	HSE consultant 12 years in health and safety 3 years in environmental management 8 years in construction management research
6	SK	HSE manager 16 years in HSE

Table 6.4: Sample initial model for expert refinement

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	Level 2	Level 3	Level 4	Level 5	
SENIOR MANAGEMENT COMMITMENT	*As maturity increases, senior management commitment to safety, health and environmental (SHE) management becomes unwavering, visible and well-articulated across the company.*	• Commitment by company's senior management to SHE management does not exists. • No or minimal SHE resources commitment from senior management.	• Limited commitment by company's senior management to SHE implementation. • Limited resource commitment for SHE related issues. • Limited commitment is given to very basic controls for the purposes of tracking progress.	• Partial commitment by company's senior management to SHE implementation. • An adhoc implementation committee is established. • SHE champion is identified. • Some resources commitment for SHE related issues.	• Firm commitment by company's senior management to SHE implementation. • SHE champion is appointed with adequate skills and motivation to SHE implementation. • Management commitment is well articulated across the company. • Adequate resources (financial and human resources) commitment for SHE related issues.	• There is a full, unwavering and clearly visible commitment of company's senior management to SHE implementation (SHE policy, objectives). • Show of commitment is aligned to company's' SHE policy. • Senior management continuously and visibly demonstrate their commitment to SHE and show shared values directed at continually meeting SHE objectives safely. • A cross functional SHE implementation committee is established including a SHE champions and members from all key management functions of the company. • There is a ring-fenced and sufficient resource commitment for SHE implementation and maintenance.	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	Level 2	Level 3	Level 4	Level 5	
SHE POLICY	*As maturity increases, company SHE policy becomes explicitly stated, well-communicated within the organisation, and interpreted and applied consistently by all managers/supervisors and staff.*	• No policy statement on integrated SHE management.	• SHE policy statement is basic and vaguely worded. • SHE policy does not meet the legal requirements and personnel are rarely involved. • Policy has not been communicated and documented.	• Policy on SHE management is clear, setting out the intention(s) on how SHE is managed, tracked and reported. • Policy meets some of the legal requirement with some personnel actively involved. • Policy is communicated across different levels of the company, but management/supervisors and personnel have inconsistent interpretations and applications of the policy. • Policy statements may not be displayed at workplace and not formally documented.	• SHE policy is comprehensive, well-defined and presents a clear approach to managing SHE including the required accountability and responsibility for managing SHE. • SHE policy meets all the legal requirements and other requirements the company subscribes to. • SHE policy is actively communicated within the company and to other stakeholders. • Policy is accepted, understood and consistently interpreted and applied in the same way by all manager's /supervisors and employees. • SHE policy is formally documented, displayed at the workplace and is available to all stakeholders.	• Clear policy on SHE management, setting out intention(s) on integrated SHE management and recognising that SHE implementation is not a separate task but an integral part of SHE management. • Documented policy is consistent with other best-performing organisation's policies. • SHE policy is periodically reviewed and optimised to ensure that it remains relevant to the company, reflect industry best practices and demonstrate effectiveness and continuous improvement.	
SHE RISK MANAGEMENT	*High maturity levels would be characterised by well-defined and documented processes and procedures for SHE hazards identification and risks assessment applied in a consistent manner throughout the company.*	• No processes and procedures for SHE hazards identification and SHE risk assessments.	• Informal processes and procedures for SHE hazards identification and SHE risk assessments. • Risk control measures are poorly defined. • Limited involvement of SHE personnel • Poor records are maintained.	• Formal processes and procedures for SHE hazards identification and SHE risk assessment. • SHE risks control measures are somewhat defined. • More involvement of SHE personnel. • Adequate records are maintained.	• Formal, more detailed and proactive processes and procedures for SHE hazards identification and SHE risk assessment. • Processes and plans for SHE risks management are modelled on best practice risks assessment standards. • SHE risks control measures are well defined and comprehensive. • All levels of SHE personnel and other stakeholders are involved.	• Processes and procedures for SHE hazards identification and risk assessments are explicitly defined and embedded into company's SHE planning activities and routinely applied in decision making process in a consistent and pragmatic manner by all. • The approach to SHE risks assessment and management are applied consistently throughout the company to drive continual improvement in	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	Level 2	Level 3	Level 4	Level 5	
					• Appropriate records are accurately maintained.	the SHE risks profile of the company. • SHE risks management processes, procedures and control measures are monitored, reviewed and improved on a regular basis to address changing circumstances and ensure continuing effectiveness.	

6.4.1 Experts' comments on capability maturity level descriptions

A thorough review of the initial model was made by the six experts who were engaged in the verification and refinement process. Their specific contributions are presented below. The code references in this section should be read with the maturity model presented in Appendix F and Table 6.3. The light orange colour fill text indicates capability level descriptors of attribute after experts' review (Table 6.5 and a full version in Appendix H).

AAP suggested the addition of "key safety performance indicators are in place to monitor SHE performance" to the descriptors at level 4 of the "SHE performance monitoring and measurement" attribute. This suggestion was adopted and included in the model. Also, AL, KN and SK recommended that the text, "relevant stakeholders are involved in the formulation, monitoring and regular review of SHE objectives and targets", should be included in the level 5 descriptor of the "SHE objectives and target" attribute. This suggestion was accepted and included in the model. Further, AL stated that the maturity level descriptors are comprehensive enough and appropriate for small and medium construction companies, but some of them might not have the competence to fully appreciate the capability maturity approach. AAP and AL also indicated that the model was well developed.

DA was largely satisfied with the descriptors at each maturity level of the attributes. He suggested that the term "continuous improvement" at level 5 of integrated SHE policy should be replaced with continual improvement since in SHE management, once a gap is identified, time is required to rectify or redress and then improvement continues. DA also indicated that at level 1, an organisation has not institutionalised SHE management, and hence no objectives are set, hence the adjective "*few*" should be removed. This suggestion was accepted and, therefore, removed from level 1 descriptors of the "SHE objectives and target" attribute.

Furthermore, WGA suggested that 'structured' should be included to the level 1 cell descriptors of the "management of outsourced personnel" and the "lessons learned and knowledge management attributes". This suggestion was adopted and included in the model. WGA suggested that the level 1 definition of the "SHE performance monitoring and measurement" attribute should be changed to "SHE performance measurement and monitoring procedures" are *not well developed'* instead of 'not established'. This was accepted and included in the model. In all, WGA commended the comprehensiveness of the model and requested that the final version of the model should have the cell definitions summarised instead of using bullets. This was not accepted as the use of bullets was a simpler way of representing the maturity level descriptors for ease of application.

KN commented that the "documentation and control" attribute is already embedded in others hence not necessary to stand alone. This comment was not accepted because the documentations of all processes that make up, the integrated SHE management system (e.g. policy, procedures, work instructions, forms, drawings amongst others) needs to be properly organised, controlled and maintained such that employees can easily assess the right documents and tools to work with. Further, KN requested that the statement "there is a well-structured procedure for appointing, monitoring and assessing the performance of outsourced personnel, subcontractors and suppliers should be included in level 5 descriptors of the management of outsourced personnel attribute since similar definitions have been introduced in level 1 to 4. KN suggestion was accepted and added to level 5 descriptors of the management of outsourcing of personnel attribute.

SK indicated that "all relevant people engaged in SHE policy formation" should be added to level 5 definitions of the SHE policy attribute. Also, he suggested the statement "SHE objectives and targets are included in critical tasks or role descriptions of employees" should be included in level 5 definitions of SHE objectives and target attribute. Both suggestions were accepted and included in level 5 definition of the respective attributes. Subsequently appropriate definitions were included in level 1-4 of each attribute. Additionally, SK suggested that the statement "SHE training strategies are incorporated into the company's overall, SHE management strategies and policies" should be added to level 5 definitions of the SHE training attribute. This suggestion was accepted and added to level 5 definitions of the attribute. Furthermore, SK indicated that in response to Lessons learned and knowledge management capability attribute, there is need for technological innovations to fundamentally change the way work is done, and remove people from risk, particularly making use of digital technologies for capturing and disseminating of lessons learned. This suggestion was found to be important in assessing this attribute. As a result, a statement referring to the use of digital technologies was added to the maturity level descriptor of the "Lessons learned and knowledge management" attribute.

The expert review was aimed at further verifying and refining model. From the discussion above, it is clear that some of the expert suggestions and recommendations were adopted while some were not taken on. In addition to the comments offered by the experts for improving the model, all the six experts commended the comprehensiveness of the model. Overall, they thought the model was well developed. After careful consideration of the experts' comments and suggestions (refer to section 6.4.1), the initial integrated SHEM-CMM was modified and a final maturity model produced (Table 6.5, full version in Appendix H).

Table 6.5: Sample integrated safety, health and environmental management capability maturity model (Model after expert review)

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
3	**SHE RISK MANAGEMENT**	• No processes and procedures for SHE hazards identification, risk assessment and control.	• Informal processes and procedures for SHE hazards identification and risk assessments are in place. • Risk control measures are poorly defined, understood and have limited application • SHE risks assessments and management are poorly documented.	• Formal processes and procedures for SHE hazards identification and risk assessment are in place. • Processes and procedures for identification and management of SHE risks, focuses on the most significant and obvious SHE risks. • SHE risks assessments are carried out in isolation. • Risk control measures are somewhat defined and used to reactively managed identified SHE risks. Most important SHE risks assessment activities and plans are documented.	• Formal, more detailed and proactive processes and procedures for SHE hazards identification and risk assessment. • Processes and procedures for identification and management focusses on specific, hazards and risks, including less obvious and immediate risks. • Processes and procedures are consistently applied to identify and manage SHE risks. • SHE risks control measures are well defined, understood and implemented in a consistent manner. • All levels of SHE employees and other stakeholders can contribute to risks assessments. • Appropriate SHE risks assessment records are accurately documented and maintained. • Processes and plans for SHE risks management are modelled on best practice risks assessment standards e.g. ISO 31000.	• Well-defined processes and procedures for SHE risks management are in place and practicable. • SHE risks management processes and procedures are embedded into company's SHE planning activities and considered as a core measure of operational excellence. • The approach to SHE risks assessment are routinely applied consistently throughout the company in a pragmatic manner to drive continual improvement in the SHE risks profile of the company. • SHE risks management processes, procedures and control measures are monitored, reviewed and improved on a regular basis to address changing circumstances and ensure continuing success.
4	**SHE OBJECTIVES AND TARGETS**	• No formal SHE objectives and targets identified and documented. •	• SHE objectives and targets are vaguely worded and not based on any baseline review of the company's SHE operations. They are not 'specific, measurable, attainable, relevant and timely (SMART) and prioritised. • People in relevant functional area(s)are not involved in setting SHE objectives and targets. • Objectives and targets not included in critical tasks or role descriptions of employees • SHE objectives and targets are poorly documented and not	• SHE objectives and targets are defined, formal, based on a baseline review and consistent with SHE policy and applicable legal and other regulatory requirements • Some SHE objectives and targets may be SMART and prioritised. • Some people in relevant functional areas(s) are involved in setting objectives and targets • Objectives and targets are rarely included role descriptions of employees • SHE objectives and targets are somewhat documented and informally communicated to employees and relevant stakeholders	• SHE objectives and targets are formal, well defined, mostly SMART, and consistent with SHE policy and applicable legal and other regulatory requirements • More people in relevant functional areas (s)are involved in setting SHE objectives and targets • Objectives and targets are included role descriptions of employees • Objectives and targets are properly documented and formally communicated to all relevant functions across the company	• SHE objectives and targets are clear, SMART, prioritised and aligned to the overall SHE policy and focused towards continually improving SHE performance. • All relevant people are involved in setting SHE objectives and targets • Objectives and target are included in critical tasks or role descriptions of employees • SHE objectives and targets are adequately documented, monitored, routinely reviewed and updated to ensure continuous improvement.

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
			communicated to employees and other stakeholders	within the company.		
5	**SHE MANAGEMENT PROGRAMME**	• There are no clearer or well defined SHE management programme(s) for achieving objectives and targets.	• SHE plans and programme(s) are available but without a clear definition of specific responsibilities and the time frame. • Little involvement of employees in establishing SHE plans and programme(s)	• Formal and detailed management plans and programme(s) are available • Key responsibilities, tactical steps, resources needed and schedules are clearly defined to achieve SHE objectives and targets. • More involvement of employees in establishing SHE programmes	• SHE management plans and programme(s) are adequate, more detailed and integrated with company objectives, strategies and budgets • Greater number of employees' involvement in establishing SHE programmes • SHE plans and programme(s) are clearly communicated to all who needs to know.	• SHE management plans and programmes are dynamic and integrated with company's SHE planning strategies • Full involvement of employees and other stakeholders in establishing SHE programmes. • SHE management programmes are continuously reviewed and modified to address changes to company's operations for continuous improvement of SHE programmes.
11	**MANAGEMENT OF OUTSOURCED PERSONNEL**	• No structured procedure is used in appointing competent outsourced employees, subcontractors and suppliers with regards to the management of SHE. • No structured monitoring and assessment of the performance of outsourced employees, subcontractors and suppliers.	• Informal procedure in place but rarely used in appointing competent outsourced SHE employees, subcontractors and suppliers. • Rare monitoring and assessment of the performance of outsourced employees, subcontractors and suppliers in respect of SHE management. • Procedures are poorly documented and maintained.	• Formal procedures in place and used occasionally and reactively appointing competent outsource employees, subcontractors and suppliers. • Occasional and reactive assessment of the performance of outsourced employees, subcontractors and suppliers in respect of SHE management. • Procedures are adequately documented and maintained.	• Regular and proactive procedures are in place for appointing competent outsource employees, subcontractors in a consistent manner. • Regular and proactive assessment of the performance of outsourced employees, subcontractors and suppliers in respect of SHE management. • All competency definitions are explicitly defined and include industry recognised best practice. • Procedures are accurately documented and maintained.	• There is a well-structured procedure for appointing, monitoring and assessing the performance of outsourced personnel, subcontractors and suppliers. • The well-structured and clear competence management system is integrated within the company's performance of SHE management. • Competence and performance assessment procedures are reviewed regularly to ensure their current suitability and continuous improvement.

Note: Please see the full version of Table 6.5 in Appendix H

Table 6.20 shows the final integrated SHE management capability maturity model that was sent for evaluation and validation. The maturity model was also produced in a Microsoft Excel format for ease of application during assessment. Checkboxes were introduced to aid the use of the model for organisational assessments during evaluation. Check boxes 1-5 represents the current and target maturity levels for each capability attribute and are meant to be ticked if the assessor believes that a particular level definition suits the company being assessed.

In using the maturity model for assessment, the assessor is expected to go through some five steps involving computations to arrive at the current capability maturity level score of the organisation. A construction company is at level 1 if the score is up to 1.49; Level 2 if the score is between 1.5 - 2.49, Level 3, between 2.5 - 3.49, Level 4, between 3.5.0 -4.49 and Level 5 if the score is 4.5 - 5.0.

A flowchart of the steps involved in calculating the capability maturity level score is shown in Figure 6.3. Also, a sample evaluation of a construction company using the maturity model developed is presented in section 6.5.

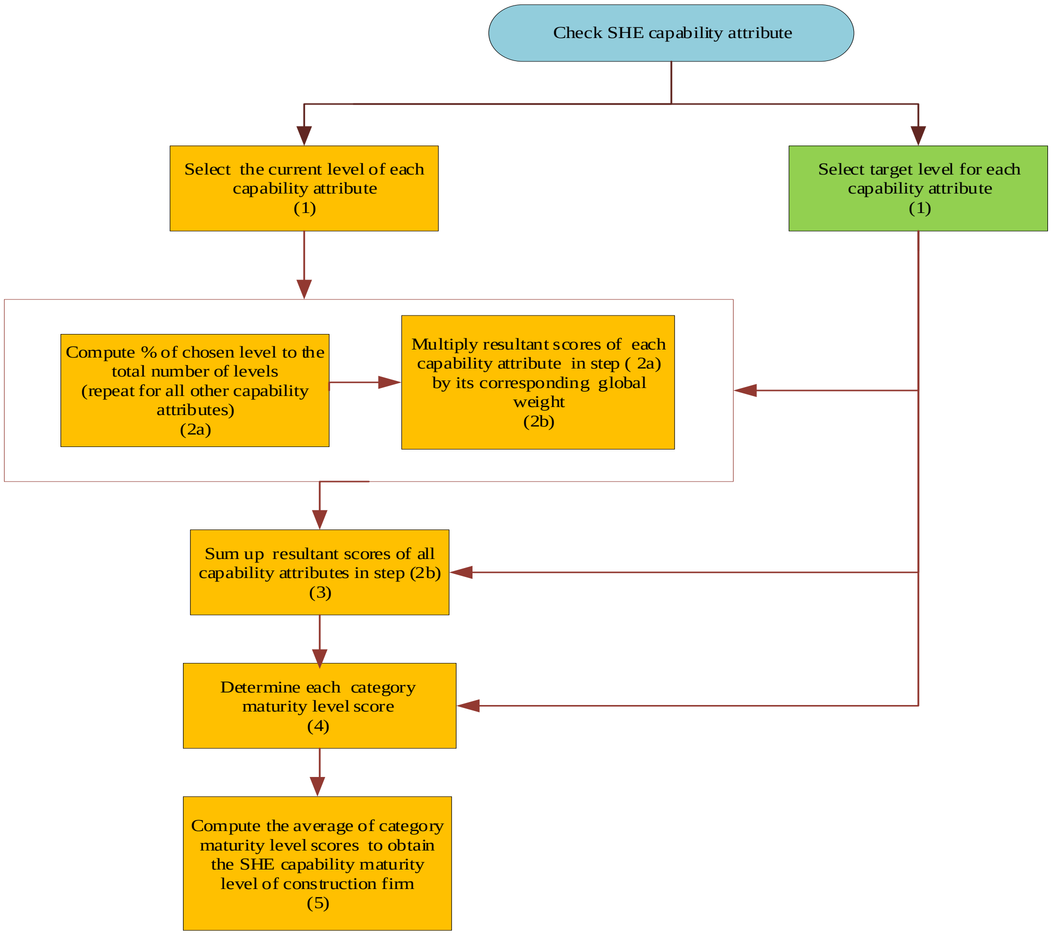

Figure 6.3: Flowchart of capability maturity assessment of a construction company.

6.5 Sample assessment of the capability maturity level of a construction company

The steps to be followed in using the model for organisational SHE management capability assessment is as follows:

1. <u>First Step</u>

For a construction company (e.g. company X) to know its SHE capability maturity level, the assessor in the company would first need to tick (✔) appropriately its current and anticipated (target) levels (out of five) that best describes the company in performing at each capability attribute. A sample of the filled-out response is shown in Table 6.5.

Table 6.6: A sample filled-out responses of company X

CAPABILITY ATTRIBUTES	CURRENT LEVEL					TARGET LEVEL				
	1	2	3	4	5	1	2	3	4	5
SENIOR MANAGEMENT COMMITMENT TO SHE		✓								✓
SHE POLICY			✓						✓	
SHE OBJECTIVES AND TARGETS			✓							✓
SHE MANAGEMENT PROGRAMMES(s)			✓							✓
SHE RISKS MANAGEMENT			✓							✓
MANAGEMENT OF OUTSOURCED SERVICES			✓							✓
SHE OPERATIONAL CONTROL			✓							✓
SHE EMERGENCY PREPAREDNESS AND RESPONSES				✓						✓
SHE PERFORMANCE MONITORING AND MEASUREMENT			✓							✓
INCIDENT INVESTIGATIONS	✓								✓	
SHE SYSTEM AUDITING				✓						✓
ROLES AND RESPONSIBILITIES			✓							✓
TRAINING			✓							✓
EMPLOYEE INVOLVEMENT AND CONSULTATION			✓							✓
COMPETENCE				✓						✓
PHYSICAL RESOURCES		✓							✓	
FINANCIAL RESOURCES			✓							✓
COMMUNICATIONS		✓							✓	
DOCUMENTATION AND CONTROL				✓						✓
LESSONS LEARNED AND KNOWLEDGE MANAGEMENT	✓									✓

E) <u>Second Step</u>

After ticking the appropriate numbers (levels) for each capability attribute, the second step is to divide (÷) each of the ticked number (levels) by five (5) and then multiply (*) the resultant value by its corresponding global weights (i.e. global weights are seen in section 5.5.1 and Table 5.13). This formula is expressed as: $GW\left(\frac{C}{5}\right)$ and $GW\left(\frac{T}{5}\right)$ where GW is the assigned Global Weights; C is the chosen current level and T is the target level. A sample computations of company X's assessment are presented in the Table 6.6 below:

Table 6.7: Sample computations of both current and target level values using the Global Weight as the factor

SN	Capability Attributes	Global Weight	Current $GW\left(\frac{C}{5}\right)$	Resultant values	Target $GW\left(\frac{T}{5}\right)$	Resultant values
			STRATEGY			
1	SENIOR MANAGEMENT COMMITMENT TO SHE	0.117	2/5 * 0.117	0.047	5/5* 0.117	0.117
2	SHE POLICY	0.111	3/5* 0.111	0.067	4/5* 0.112	0.089
3	SHE OBJECTIVES AND TARGETS	0.054	3/5* 0.054	0.032	5/5* 0.054	0.054
4	SHE MANAGEMENT PROGRAMMES(s)	0.050	3/5* 0.050	0.030	5/5* 0.050	0.050
			PROCESS			
5	SHE RISKS MANAGEMENT	0.051	3/5* 0.051	0.031	5/5* 0.051	0.051
6	MANAGEMENT OF OUTSOURCED SERVICES	0.020	3/5* 0.020	0.012	5/5* 0.020	0.020
7	SHE OPERATIONAL CONTROL	0.033	3/5* 0.033	0.020	5/5*0.033	0.033
8	SHE EMERGENCY PREPAREDNESS AND RESPONSES	0.020	4/5* 0.020	0.016	5/5* 0.020	0.020
9	SHE PERFORMANCE MONITORING AND MEASUREMENT	0.025	3/5* 0.025	0.015	5/5* 0.025	0.025
10	INCIDENT INVESTIGATIONS	0.017	1/5* 0.017	0.003	4/5* 0.017	0.014
11	SHE SYSTEM AUDITING	0.019	4/5* 0.019	0.015	5/5* 0.019	0.019
			PEOPLE			
12	ROLES AND RESPONSIBILITIES	0.053	3/5* 0.053	0.032	5/5* 0.053	0.053
13	TRAINING	0.047	3/5* 0.047	0.028	5/5* 0.047	0.047
14	EMPLOYEE INVOLVEMENT AND CONSULTATION	0.042	2/5* 0.042	0.017	5/5* 0.042	0.042
15	COMPETENCE	0.065	4/5* 0.065	0.052	5/5* 0.065	0.065
			RESOURCES			
16	PHYSICAL RESOURCES	0.083	2/5* 0.083	0.033	5/5* 0.083	0.083
17	FINANCIAL RESOURCES	0.076	3/5* 0.076	0.045	4/5* 0.076	0.060
			INFORMATION			
18	COMMUNICATIONS	0.054	2/5* 0.054	0.022	4/5* 0.054	0.043
19	DOCUMENTATION AND CONTROL	0.035	4/5* 0.035	0.028	5/5* 0.035	0.035
20	LESSONS LEARNED AND KNOWLEDGE MANAGEMENT	0.027	1/5* 0.029	0.006	5/5* 0.029	0.029

F) Third Step

Having done the computations in the second step above, the third step is to sum up all the resultant scores for all the capability attributes under the current level and as well as the target levels. The tables show the thematic category and the various attributes with their respective sum up values. Figures show the current and target levels of the various attributes in a thematic category.

Table 6.8: The current and target levels of the strategy attributes

STRATEGY		
	CURRENT LEVEL	TARGET LEVEL
SENIOR MANAGEMENT COMMITMENT TO SHE	2	5
SHE POLICY	3	4
SHE OBJECTIVES AND TARGETS	3	5
SHE MANAGEMENT PROGRAMMES(s)	3	5

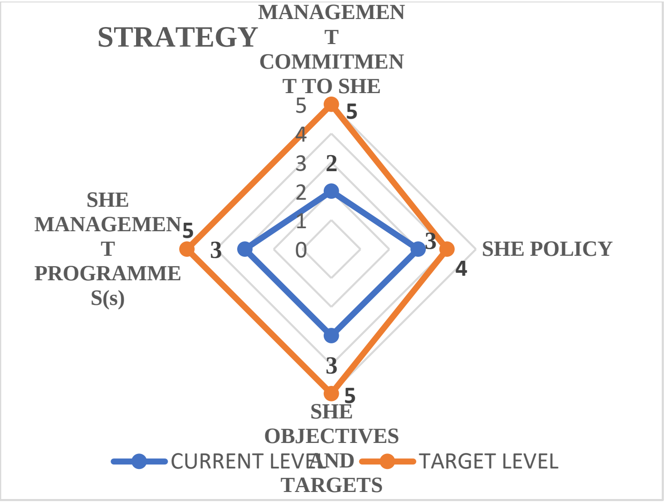

Figure 6.4: Radar chart of current and target levels of attributes within the strategy category

Table 6.9: The sum-up scores of the various strategy attributes

STRATEGY		
	CURRENT LEVEL	TARGET LEVEL
SENIOR MANAGEMENT COMMITMENT TO SHE	0.047	0.117
SHE POLICY	0.067	0.089
SHE OBJECTIVES AND TARGETS	0.032	0.054
SHE MANAGEMENT PROGRAMMES(s)	0.030	0.050
Total	0.176	0.310

Table 6.10: The current and target levels of the various process attributes

PROCESS		
	CURRENT LEVEL	TARGET LEVEL
SHE RISKS MANAGEMENT	3	5
MANAGEMENT OF OUTSOURCED SERVICES	3	5
SHE OPERATIONAL CONTROL	3	5
SHE EMERGENCY PREPAREDNESS AND RESPONSES	4	5
SHE PERFORMANCE MONITORING AND MEASUREMENT	3	5
INCIDENT INVESTIGATIONS	1	4
SHE SYSTEM AUDING	4	5

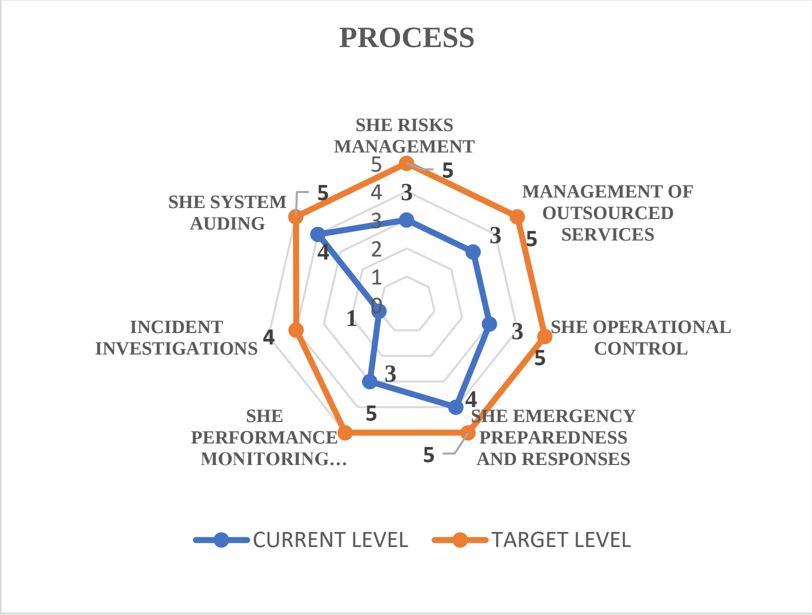

Figure 6.5: Radar chart of current and target levels of attributes within process category

Table 6.11: The sum-up scores of the various process attributes

PROCESS		
	CURRENT LEVEL	TARGET LEVEL
SHE RISKS MANAGEMENT	0.031	0.051
MANAGEMENT OF OUTSOURCED SERVICES	0.012	0.020
SHE OPERATIONAL CONTROL	0.020	0.033
SHE EMERGENCY PREPAREDNESS AND RESPONSES	0.016	0.020
SHE PERFORMANCE MONITORING AND MEASUREMENT	0.015	0.025
INCIDENT INVESTIGATIONS	0.003	0.014
SHE SYSTEM AUDING	0.015	0.019
Total	0.112	0.182

Table 6.12: The current and target levels of the people attributes

PEOPLE		
	CURRENT LEVEL	TARGET LEVEL
ROLES AND RESPONSIBILITIES	3	5
TRAINING	3	5
EMPLOYEE INVOVEMENT AND CONSULTATION	3	5
COMPETENCE	4	5

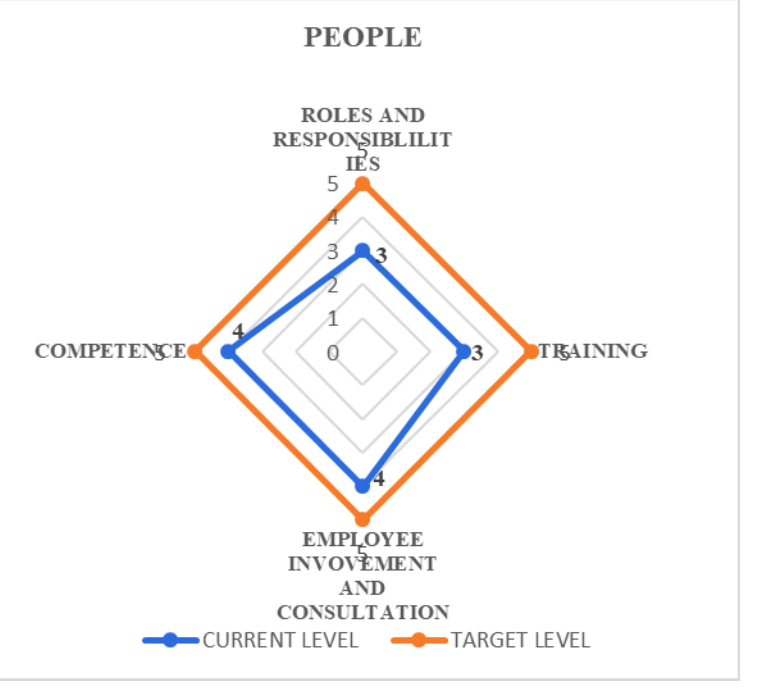

Figure 6.6: Radar chart of the various attributes within the people category

Table 6.13: The sum up scores of the various people attributes

PEOPLE		
	CURRENT LEVEL	TARGET LEVEL
ROLES AND RESPONSIBILITIES	0.032	0.053
TRAINING	0.028	0.047
EMPLOYEE INVOVEMENT AND CONSULTATION	0.017	0.042
COMPETENCE	0.052	0.065
Total	0.129	0.207

Table 6.14: The current and targets levels of the resource attributes

RESOURCES		
	CURRENT LEVEL	TARGET LEVEL
PHYSICAL RESOURCES	2	4
FINANCIAL RESOURCES	3	5

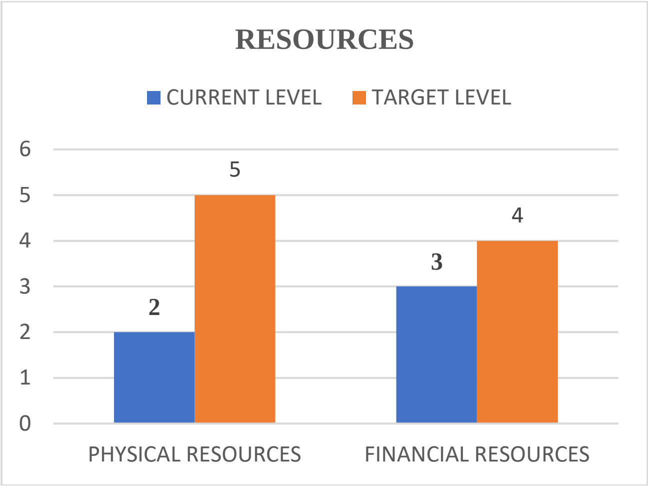

Figure 6.7: Bar chart of the various attributes performance within resource category

Table 6.15: The sum-up scores of the various resource attributes

RESOURCES		
	CURRENT LEVEL	TARGET LEVEL
PHYSICAL RESOURCES	0.033	0.083
FINANCIAL RESOURCES	0.045	0.060
Total	0.078	0.143

Table 6.16: Current and target levels of information attributes

INFORMATION		
	CURRENT LEVEL	TARGET LEVEL
COMMUNICATIONS	2	4
DOCUMENTATION AND CONTROL	4	5
5LESSONS LEARNED AND KNOWLEDGE MANAGEMENT	1	5

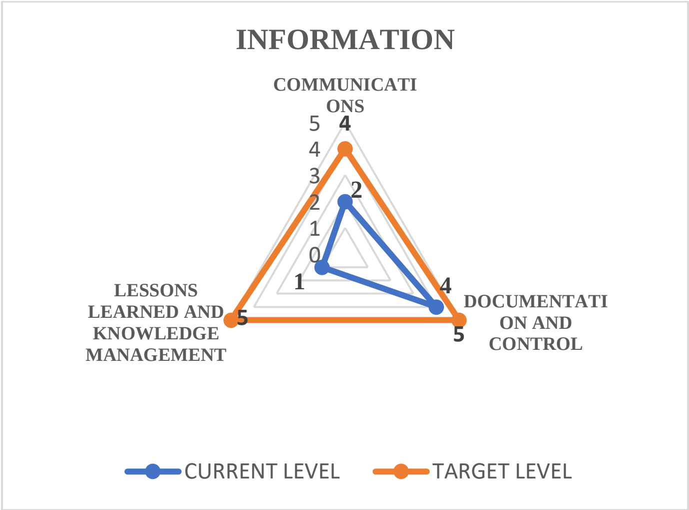

Figure 6.8: Radar chart of the various attributes within information category

Table 6.17: The sum-up scores of the various information attributes

INFORMATION		
	CURRENT LEVEL	TARGET LEVEL
COMMUNICATIONS	0.022	0.043
DOCUMENTATION AND CONTROL	0.028	0.035
LESSONS LEARNED AND KNOWLEDGE MANAGEMENT	0.006	0.029
Total	0.055	0.106

G) Fourth Step

Divide each of the total values obtained from step 3 by the total of the global weights in each thematic category and multiply each resultant value by 5 to obtain category capability maturity level score (expressed in terms of the 1-5 maturity levels).

Table 6.18: Category capability matuirty level score

THEMATIC CATEGORY	TOTAL VALUES		TOTAL GLOBAL WEIGHTS	CURRENT LEVEL	TARGET LEVEL
	Current Level	*Target level*		*Category maturity level score*	*Category level maturity score*
STRATEGY	0.176	0.310	0.332	2.649	4.361
PROCESS	0.112	0.182	0.185	3.024	4.906
PEOPLE	0.129	0.207	0.207	3.111	5.000
RESOURCES	0.078	0.143	0.158	2.477	4.523
INFORMATION	0.055	0.106	0.117	2.348	4.540

H) Fifth Step

Add all the individual category maturity level scores under current level and find the average to obtain the integrated SHE management capability maturity level of the construction organisation (repeat same for the scores under the target level). Below is the organisation integrated SHE management assessment profile presented in Table 6.19.

Table 6.19: Integrated SHE management capabilty assesemt profile of company X

ORGANISATIONAL INTEGRATED SHE MANAGEMENT ASSESSMENT PROFILE		
THEMATIC CATEGORY	CURRENT LEVEL	TARGET LEVEL
STRATEGY	2.649	4.361
PROCESS	3.024	4.906
PEOPLE	3.111	5.000
RESOURCES	2.477	4.523
INFORMATION	2.348	4.540
Capability maturity level	**2.722**	4.727

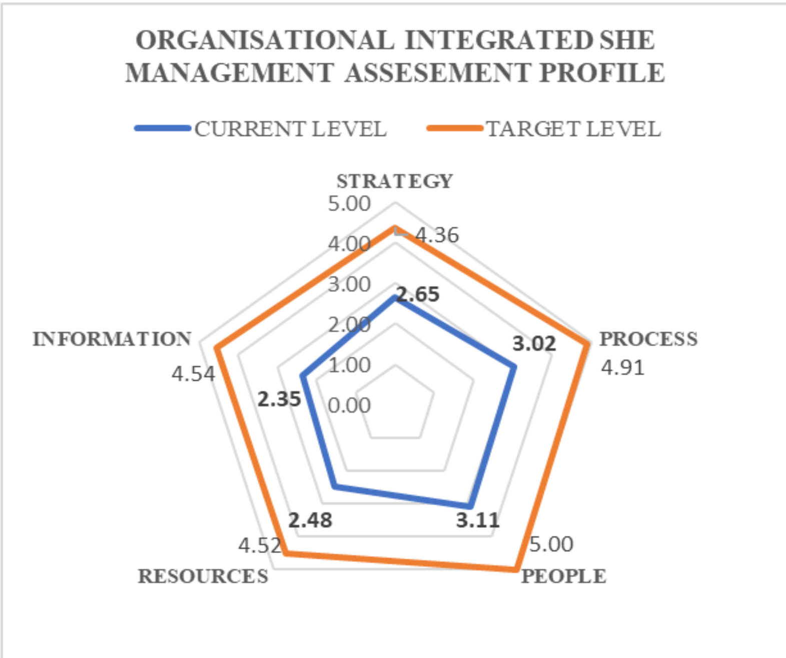

Figure 6.9: Radar chart of the company's X organisational SHE capability assessment

From the organisational assessment and computation above, company X is currently at maturity level 3, since its current capability maturity level score falls within 2.5-3.49, which approximates to 3**.**

Table 6.20: Final integrated safety, health and environmental management capability maturity model

Integrated safety, health and environmental management capability maturity model (SHEM-CMM)							
SHE CAPABILITY ATTRIBUTES	**CAPABILITY LEVELS**					**Current Level**	**Target level**
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**		
SENIOR MANAGEMENT COMMITMENT	• Lack of senior management commitment to SHE management. • There is no resource commitment (financial and human resources) for SHE related issues.	• Limited commitment by company's senior management to SHE implementation. • Limited resource commitment for SHE related issues.	• Partial commitment by company's senior management to SHE implementation. • Show of senior management commitment is reactive (e.g. when significant risks are anticipated or response to a major environmental impacts). • An adhoc implementation committee is established. • SHE champion is identified. • There is resources commitment for SHE related issues.	• Firm commitment by company's senior management to SHE implementation. • Senior management commitment is aligned to company's policy on SHE management. • Senior management are amongst the SHE champions within the organisation. • Management commitment is well articulated across the company. • Sufficient resources commitment for SHE related issues.	• There is a full, unwavering and clearly visible commitment of company's senior management to SHE implementation. • Senior management continuously and visibly demonstrate their commitment to SHE and show shared values directed at continually meeting SHE objectives safely. • A cross functional SHE implementation committee is established including, a SHE champion, and members from all key management functions of the company. • There is a ring-fenced resource commitment for SHE implementation and maintenance. • Company senior manager(s) are amongst SHE management champions within the industry and are recognised as industry thought-leaders in respect of SHE management.	**1 | 2 | 3 | 4 | 5**	**1 | 2 | 3 | 4 | 5**

SHE POLICY	• No policy statement on SHE management.	• SHE policy statement is outdated and vaguely worded. • SHE policy does not meet legal requirements and employees are rarely involved in its development. • Policy has not been communicated within the company and documented.	• SHE policy statement is clear, setting out the intention(s) on how SHE is managed, tracked and reported. • Policy meets majority of legal requirement with some employees actively involved in its development. • Policy is communicated across different levels of the company, but management or supervisors and employees have inconsistent interpretations and applications of the policy. • Policy statements are poorly documented and not displayed at workplace	• SHE policy is clear, comprehensive and well-defined, setting out the intention on SHE. • SHE policy presents a clear approach to managing SHE including the required accountability and responsibility for managing SHE. • SHE policy meets all the legal requirements and other requirements the company subscribes to. • More relevant employees are actively involved in SHE policy formation and strategy formulation. • SHE policy is actively communicated within the company and to other stakeholders. • Policy is accepted, understood and consistently interpreted and applied in the same way by all manager's or supervisors and employees. • SHE policy is formally documented, displayed at the workplace and is available to all stakeholders.	• There is a clear policy on SHE management, setting out intention(s) on SHE management and recognising that SHE implementation is not a separate task but an integral part of the organisation SHE activities. • All relevant people are engaged in SHE policy formation as wells as SHE strategy formulation, with clear actions, and accountabilities and targets. • Documented policy is in place, consistent with other best-performing organisation's policies, communicated and readily available to all stakeholders. • SHE policy is periodically reviewed to ensure that it remains relevant to the company, reflect industry best practices and demonstrate effectiveness and continuous improvement.	**1 2 3 4 5**	**1 2 3 4 5**
SHE OBJECTIVES AND TARGETS	• No formal SHE objectives and targets identified and documented.	• SHE objectives and targets are vaguely worded and not based on any baseline review of the company's SHE operations. They are not 'specific, measurable, attainable, relevant and timely (SMART) and prioritised.	• SHE objectives and targets are defined, formal, based on a baseline review and consistent with SHE policy and applicable legal and other regulatory requirements. • Some SHE objectives and targets may be SMART and prioritised. • Some people in relevant functional areas(s) are	• SHE objectives and targets are formal, well defined, mostly SMART, and consistent with SHE policy and applicable legal and other regulatory requirements. • More people in relevant functional areas (s)are involved in setting SHE objectives and targets.	• SHE objectives and targets are clear, SMART, prioritised and aligned to the overall SHE policy and focused towards continually improving SHE performance. • All relevant people are involved in setting SHE objectives and targets.	**1 2 3 4 5**	**1 2 3 4 5**

		• People in relevant functional area(s)are not involved in setting SHE objectives and targets. • Objectives and targets not included in critical tasks or role descriptions of employees. • SHE objectives and targets are poorly documented and not communicated to employees and other stakeholders.	involved in setting objectives and targets • Objectives and targets are rarely included role descriptions of employees. • SHE objectives and targets are somewhat documented and informally communicated to employees and relevant stakeholders within the company.	• Objectives and targets are included role descriptions of employees. • Objectives and targets are properly documented and formally communicated to all relevant functions across the company.	• Objectives and target are included in critical tasks or role descriptions of employees. • SHE objectives and targets are adequately documented, monitored, routinely reviewed and updated to ensure continuous improvement.		
SHE MANAGEMENT PROGRAMME	• There are no clearer or well defined SHE management programme(s) for achieving objectives and targets.	• SHE plans and programme(s) are available but without a clear definition of specific responsibilities and the time frame. • Little involvement of employees in establishing SHE plans and programme(s).	• Formal and detailed management plans and programme(s) are available. • Key responsibilities, tactical steps, resources needed and schedules are clearly defined to achieve SHE objectives and targets. • More involvement of employees in establishing SHE programmes.	• SHE management plans and programme(s) are adequate, more detailed and integrated with company objectives, strategies and budgets. • Greater number of employees' involvement in establishing SHE programmes. • SHE plans and programme(s) are clearly communicated to all who needs to know.	• SHE management plans and programmes are dynamic and integrated with company's SHE planning strategies. • Full involvement of employees and other stakeholders in establishing SHE programmes. • SHE management programmes are continuously reviewed and modified to address changes to company's operations for continuous improvement of SHE programmes.	**1 2 3 4 5**	**1 2 3 4 5**
SHE RISK MANAGEMENT	• No processes and procedures for SHE hazards identification, risk assessment and control.	• Informal processes and procedures for SHE hazards identification and risk assessments are in place. • Risk control measures are poorly defined, understood and have limited application. • SHE risks assessments and	• Formal processes and procedures for SHE hazards identification and risk assessment are in place. • Processes and procedures for identification and management of SHE risks, focuses on the most significant and obvious SHE risks.	• Formal, more detailed and proactive processes and procedures for SHE hazards identification and risk assessment. • Processes and procedures for identification and management focusses on specific, hazards and risks, including less obvious and immediate risks.	• Well-defined processes and procedures for SHE risks management are in place and practicable. • SHE risks management processes and procedures are embedded into company's SHE		

		management are poorly documented.	• SHE risks assessments are carried out in isolation • Risk control measures are somewhat defined and used to reactively managed identified SHE risks. • Most important SHE risks assessment activities and plans are documented.	• Processes and procedures are consistently applied to identify and manage SHE risks. • SHE risks control measures are well defined, understood and implemented in a consistent manner. • All levels of SHE employees and other stakeholders can contribute to risks assessments. • Appropriate SHE risks assessment records are accurately documented and maintained. • Processes and plans for SHE risks management are modelled on best practice risks assessment standards e.g. ISO 31000.	planning activities and considered as a core measure of • operational excellence. • The approach to SHE risks assessment are routinely applied consistently throughout the company in a pragmatic manner to drive continual improvement in the SHE risks profile of the company. • SHE risks management processes, procedures and control measures are monitored, reviewed and improved on a regular basis to address changing circumstances and ensure continuing success.	**1 | 2 | 3 | 4 | 5**	**1 | 2 | 3 | 4 | 5**
MANAGEMENT OF OUTSOURCED PERSONNEL	• No structured procedure is used in appointing competent outsourced employees, subcontractors and suppliers with regards to the management of SHE. • No structured monitoring and assessment of the performance of outsourced employees, subcontractors and suppliers.	• Informal procedure in place but rarely used in appointing competent outsourced SHE employees, subcontractors and suppliers. • Rare monitoring and assessment of the performance of outsourced employees, subcontractors and suppliers in respect of SHE management. • Procedures are poorly documented and maintained.	• Formal procedures in place and used occasionally and reactively appointing competent outsource employees, subcontractors and suppliers. • Occasional and reactive assessment of the performance of outsourced employees, subcontractors and suppliers in respect of SHE management. • Procedures are adequately documented and maintained.	• Regular and proactive procedures are in place for appointing competent outsource employees, subcontractors in a consistent manner. • Regular and proactive assessment of the performance of outsourced employees, subcontractors and suppliers in respect of SHE management. • All competency definitions are explicitly defined and include industry recognised best practice. • Procedures are accurately documented and maintained.	• There is a well-structured procedure for appointing, monitoring and assessing the performance of outsourced personnel, subcontractors and suppliers. • The well-structured and clear competence management system is integrated within the company's performance of SHE management. • Competence and performance assessment procedures are reviewed regularly to ensure their current	**1 | 2 | 3 | 4 | 5**	**1 | 2 | 3 | 4 | 5**

					suitability and continuous improvement.		
SHE OPERATIONAL CONTROL	• No procedures for identification of SHE operations that need to be controlled to ensure risk associated with them are minimised or eliminated. • SHE risks control measures are not in place.	• Informal procedures are in place for identification of SHE operations and activities that need to be controlled to ensure risk associated with them are minimised or eliminated. • SHE controls measures, are unclear and poorly documented.	• Formal procedures are in place for identification of SHE operations and activities that need to be controlled. • Control measures for identified SHE risks are more detailed and clearly stated. • Operation control procedures and measures are adequately documented.	• Formal and comprehensive procedures are in place for identification of SHE operations and activities that need to be controlled. • Control measures for identified SHE risks are comprehensive and well defined. • Identified SHE operations that needs to be controlled and their associated control measures are appropriately documented and well communicated to relevant employees (e.g. suppliers, contractors and other interested parties).	• Well-structured procedures are in place for identification of SHE operations and activities that need to be controlled to ensure compliance, and to achieve objectives. • Documented SHE control procedures and measures are continually reviewed and improved.	1 2 3 4 5	1 2 3 4 5
SHE EMERGENCY PREPAREDNESS AND RESPONSE	• No emergency preparedness and response *(*EPAR) procedures. • No measures for identification of possible emergencies and SHE accidents, and how to respond if they arise.	• Undefined and inappropriate EPAR procedures and measures for identification of possible emergencies and SHE accidents, and how to respond if they arise. • EPAR procedures and measures are poorly documented and not accessible. • Employees are rarely trained in emergency responses.	• Defined procedures and measures are available for identification of possible emergencies and SHE accidents, and how to respond if they arise. • EPAR procedures and measures are adequately documented but not easily accessible. • Employees are trained in formal emergency responses.	• Well-defined and sufficient EPAR procedures and measures for identification of possible emergencies with focus on specific emergency situations. • EPAR procedures and measures are appropriately and accurately documented. • EPAR procedures and measures are communicated and accessible to all employees involve. • Employees are adequately trained in emergency responses.	• Appropriate and comprehensive EPAR plans, procedures and measures are in place to effectively respond to emergency situations. • EPAR plans and procedures are fully integrated with other control measures and benchmarked consistently against best practices. • EPAR plans are periodically tested for the adequacy of the plan and the results reviewed to improve its effectiveness for continuous improvement.	1 2 3 4 5	1 2 3 4 5

SHE PERFORMANCE MONITORING AND MEASUREMENT	• No performance measuring and monitoring system in place. • SHE procedures for performance monitoring and measurement (MaM) are not well developed. • SHE performance indicators and measures are not established. • SHE system performance is poor.	• There are vague procedures for MaM of SHE performance. • Some SHE performance indicators and measures are in place but not well defined. • Performance MaM are rarely undertaken. • Some employees are aware of the SHE. performance measures in their areas of responsibilities. • SHE system performance is fair.	• SHE performance MaM procedures and performance indicators and other measures are in place and defined. • Performance MaM are undertaken occasionally. • Monitoring is reactive. • More employees are aware of the SHE performance measures in the areas of responsibilities. • SHE system performance is mostly good.	• Well-defined and appropriate performance procedures, key SHE performance indicators and other measures are in place to monitor SHE performance. • Performance monitoring and measurement are undertaken regularly with the purpose of improving the SHE system. • Performance MaM procedures and measures are compliance led and used to track SHE performance. • MaM procedures and measures are adequately documented and communicated to all employees. • Employees at all levels are aware of the critical SHE performance measures in their areas of responsibility. • SHE system performance is very good and constantly repeated.	• Well-designed and defined proactive procedures and measures for monitoring, measuring and recording of SHE performance on a regular basis is in place and institutionalised within the company, focusing on operational excellence and continuous improvement. • Results of SHE performance MaM are documented and effectively communicated throughout the company, to facilitate subsequent corrective and preventive actions analysis. • SHE performance MaM procedures and measures are continuously used to improve the SHE management system. Best practice is shared across the entire company. • SHE performance MaM system is periodically reviewed and improved to make sure they remain relevant to the company's risk profile • SHE system performance is exemplary and comparable to best in the industry	1 | 2 | 3 | 4 | 5	1 | 2 | 3 | 4 | 5

SHE INCIDENTS INVESTIGATIONS	• No structured processes and procedures for SHE incidents investigations. • No organised evidence of SHE investigations.	• Vague processes and procedures for SHE incidents investigations are in place. • The range of incidents investigated is limited to immediate causes of accidents and environmental aspects. • Limited employees' involvement. • SHE investigations processes and procedures are not documented.	• Formal processes and procedures for SHE incidents investigations are in place. • Investigations tend to focus on the immediate and root causes of SHE incidents, near misses and environmental aspects and their impacts. • Incident investigations tend to be reactive. • More employees' involvement in SHE investigations. • SHE incident investigations processes and procedures are somewhat documented.	• Formal comprehensive and standard processes and procedures for SHE incidents investigations. • Incidents investigations are proactive and probe more deeply to identify direct and indirect causes of SHE incidents and environmental aspects that result in significant SHE risks. • Greater employees' involvement in SHE incidents investigations. • SHE incidents investigations procedures are communicated to relevant committees for appropriate recommendations and actions. • SHE investigations processes and procedures are well documented and corrective actions well communicated to best utilise any lessons to be learned.	• There are documented structured processes and procedures in place for consistently high quality SHE incidents investigations. • SHE incidents investigations procedures are linked to SHE hazards identification and risk mitigation process and institutionalised within the company. • Outcomes of SHE incidents investigations are seen as opportunities for improvement, and are documented, monitored and shared with industry. SHE incident trends are used to identify and help manage SHE risks. • Lessons learned from incidents investigations are shared and implemented across the company. • Corrective and preventive actions are reviewed regularly and updated to ensure actions taken are effective. • SHE incidents investigations procedures are routinely reviewed and updated to drive continuous improvement	**1 2 3 4 5**	**1 2 3 4 5**
SHE SYSTEM AUDITS	• No auditing of SHE system.	• Company rarely undertake planned SHE system audits.	• Company occasionally undertake planned SHE system audits.	• Company regularly undertake planned SHE audits.	• There is a company-wide standardised audit system in place and institutionalised		

	• No clear SHE audits processes and procedures.	Adhoc audit with no follow up. • SHE audits processes and procedures are not defined and may not be documented. • Procedures for assessing SHE compliance is limited. • Legal and regulatory obligations noncompliance.	• SHE audits processes and procedures are somewhat defined and poorly documented. • Most aspects of SHE system is audited with some follow-up. • Minimal legal and regulatory compliance. • SHE audits processes and procedures are focused on achieving compliance with legal and regulatory obligations.	• SHE audits processes and procedures are well defined and designed, and modelled on best practice of audits. • All aspects of SHE system audited with some follow-up. • Total legal and regulatory obligations compliance Written recommendations, (e.g. non-compliances) are well documented and communicated to form the basis of SHE improvement and innovation. • SHE audits processes and procedures are modelled on best practice standards for auditing management system e.g. ISO 19011:2018 guidelines for auditing management systems, OHSAS 18001 :2007.	within the company, with best practice shared internally with other functions of the company. • SHE audits are undertaken regularly by competent employees to demonstrate compliance with required standards, legal and regulatory obligations. • SHE audits processes and procedures are planned and prioritised, and covers all aspects of the SHE system. • SHE audits process and procedures are reviewed periodically to ensure they are current and consistent with leading internal audit practice and standard requirements in order to ensure continuous improvement in audit processes.	1 2 3 4 5	1 2 3 4 5
ROLES AND RESPONSIBILITIES FOR SHE	• No clear SHE roles, and responsibilities (i.e. there are no roles, tasks and objectives given to people and teams to meet the organisation's SHE objectives).	• SHE roles and responsibilities are are unclear with some specific responsibilities and authorities somewhat defined and developed. • SHE roles and responsibilities are not recorded in job descriptions.	• SHE roles and responsibilities are mostly defined and assigned to employees. • SHE roles and responsibilities are inconsistently recorded in job descriptions.	• SHE roles and responsibilities are well defined, sufficiently comprehensive and well communicated to designated employees at all levels. • All SHE roles and responsibilities are consistently recorded in key documentation (e.g. job descriptions) and appropriate communication media.	• Clearly defined SHE roles, responsibilities and authorities at all levels of the company. • SHE roles and responsibilities are unambiguous, clearly understood and accurately documented. • SHE roles, responsibilities and authorities are continuously reviewed, realigned to effort and tracked to ensure proper	1 2 3 4 5	1 2 3 4 5

					distribution and continuous Improvement.		
SHE TRAINING	• No provision of SHE related training for employees. • No formal training needs analysis undertaken.	• Provision of SHE related training for employees is very low and unplanned. Provision of SHE training is rarely informed by a formal training needs analysis. • Training needs are not well defined and documented.	• Provision of SHE related training is reactive. • Provision of SHE training is occasionally informed by a formal training needs analysis. • Identified training needs are somewhat defined and based on the wider competency and performance objectives. • Training needs adequately documented.	• Regular provision of adequate SHE related training for employees, informed by a formal and objective training needs analysis undertaken on a regular basis. • Training is typically based on employees SHE roles and respective competency objectives. • Training needs are well defined and accurately documented (e.g. in the employees' personal files). • Training is usually proactive, tracked and evaluated to be improved upon.	• Appropriate and timely SHE training is in place and integral to company's human resource strategy to improve SHE performance. • SHE training strategies are incorporated into the company's overall, SHE management strategies and policies. • SHE related training programmes or plans are reviewed for its effectiveness and periodically reviewed to ensure their current suitability. • SHE related training programme and training are continuously assessed and updated to reflect organisational, regulatory changes and any other changes in technology and techniques, to allow continuous learning and improvement. • The various training methods are incorporated into the knowledge and communication channels of the company. • Training needs analysis procedures are regularly reviewed.	1 2 3 4 5	1 2 3 4 5

EMPLOYEE INVOLVEMENT IN SHE	• No consultation of employees on SHE related issues. • Employees are not involved and have no interested in participating in SHE related issues.	• Limited consultation on SHE related issues, but not carried out in a systematic way. • Minority of the employees are involved and interested in participating in SHE-related issues	• More consultation on SHE issues is carried out in a systematic way. • Majority of the employees are involved and interested in participating SHE related issues.	• All employees are regularly consulted on SHE related issues and carried out in a range of ways (e.g. surveys, workshops, site meetings and committees). • Overwhelming majority of the employees are involved and interested in participating in SHE-related issues. • Employees involvement and consultation arrangements are documented and interested parties informed.	• All employees are fully consulted and actively engaged in SHE related issues at all company's levels. • All employees are interested in participating SHE related issues. • Company's uses employees' involvement to gather ideas for improvement on SHE issues. • Company makes full use of employees' potential to develop shared values and a culture of trust, openness and empowerment.	**1 2 3 4 5**	**1 2 3 4 5**
SHE COMPETENCE	• Company's employees do not have the skills, knowledge and the experience necessary for SHE management.	• An overwhelming majority of company's employees have basic SHE knowledge and skills, with no employees having advanced or expert skills and knowledge. • Company's employees have limited experience in SHE management tasks.	• A majority of company's SHE employees have intermediate SHE skills and knowledge with very few having advanced and/or expert skills and knowledge. • Company's employees have some experience in SHE management tasks.	• A majority of company's employees have sufficient and advanced SHE skills, and knowledge with very few having basic or no SHE skills and knowledge. • Company's employees have appropriate experience in SHE management tasks.	• An overwhelming majority of company's employees have expert SHE skills and knowledge with very few or none having basic or no SHE skills and knowledge. • Company's employees have vast and experience in SHE management tasks. • Company's employees feel competent and capable to perform their SHE tasks.	**1 2 3 4 5**	**1 2 3 4 5**
PHYSICAL SHE RESOURCES	• No physical resources available to enable SHE employees to perform SHE related tasks.	• Company is ill-equipped with physical resources for employees to perform SHE related tasks. Physical SHE resources are limited. • Resource provision is not or rarely informed	• Company is equipped with adequate physical SHE resources to enable employees to perform SHE related tasks. • Resource provision is usually reactive and occasionally informed by strategic resource plan.	• Company is well equipped with sufficient physical resources for employees to perform SHE related tasks. • A strategic resource plan is available to inform timely provision of physical resources to enable employees to perform SHE related tasks.	• Company is fully equipped with sufficient resources in quality and quantity for employees to perform SHE related tasks. • Company's SHE physical resources are considered to be		

		by any strategic resource plan			integral to SHE performance and competitiveness. • Physical resources are continuously tested, upgraded and deployed. • Resource plans for provision of physical resources are documented and integrated into company's processes and systems to improve effectiveness and efficiency. • Resource plans are regularly reviewed to ensure the provision of adequate and current resources to meet planned and agreed targets and objectives.	1 2 3 4 5	1 2 3 4 5
FINANCIAL RESOURCES FOR SHE	• No financial resources for SHE implementation. • Unstable or uncertain funding.	• Limited financial resources for SHE implementation and rarely informed by a strategic resource plan. • No established sources of funding.	• Company has adequate financial resources for SHE implementation. • Provision of financial resources is occasionally informed by strategic resource plan. • Established source of funding.	• Company has sufficient and well organised funding lines for SHE implementation. • A strategic resource plan is available to inform timely provision of financial resources for effective SHE management. • Stable sources of funding.	• Dedicated and adequate financial resources in place for effective SHE implementation and considered to be an integral part of the company's finance plan • Highly stable funding. Resource plans are regularly reviewed to ensure the provision of adequate and current resources to meet planned and agreed targets and objectives	1 2 3 4 5	1 2 3 4 5
SHE COMMUNICATIONS	• No formal communication of any SHE related issues to employees. • No formal communication channels for effective flow of SHE information internally	• Limited communication of SHE information to employees. • Communication is ad hoc and restricted to those involved in specific incidents.	• Some communication of SHE information to employees on a need to know basis. • There is a communication strategy for SHE information flow internally and externally	• Adequate SHE information is routinely and regularly communicated to all employees. Employees are aware of critical SHE information. • There are established, good and appropriate	• There is an open, proactive and effective SHE communication between the company and its employees and stakeholders. • SHE communication is a strong, and		

	and externally in the company.	• Company's employees are unaware of important SHE information. • Some informal and formal communication channels are established for information flow internally to all employees.	occasionally to all employees. • Employees are aware of pertinent SHE information. • Specific informal and formal communication channels are in place for communicating SHE issues to employees	informal and formal communication channels for communicating critical SHE information and resultant actions. • All levels of employees are involved, and there are robust mechanisms for them to feedback	consistent two-way process. Good practice is communicated both externally and internally. • The company communicates to its employees on all the SHE-related issues and aspects of the company. • Established communication channels and methods are fully adopted throughout the supply chain in the company and consistently used for efficient coordination of SHE activities. • All pertinent SHE information and resultant actions are well communicated to all employees across the company. • Communication methods for SHE information flow internally and externally are continuously monitored and regularly reviewed against identified best practices in other sectors for potential continuous improvement.	**1 2 3 4 5**	**1 2 3 4 5**
SHE DOCUMENTATION AND CONTROL	• No organised documentations (e.g. SHE policy, SHE manual, emergency plans and work instructions etc.) and records that describes company's SHE system elements and their interrelationships.	• Documentations of some elements of a company's SHE system and other related SHE records are available to employees. • SHE documentations and records are not	• Documentations and records of more elements of a company's SHE system and other related SHE records are available to employees. • SHE documentations and records are compiled and organised in a format that	• Documentations and records of all elements of the company's SHE system and other related SHE records are available to all employees. • All SHE documentations are compiled and mostly organised in an	• SHE documentations including other related SHE records are compiled and well organised in a clear, concise and functional format, traceable and readily accessible to all.		

		organise, easily not traceable and accessible.	is somewhat traceable and accessible.	appropriate format, traceable and accessible.	• SHE documentations and records are integrated with other organisational documentations (such as human resource plans) for continuous improvement of company’s functions. • SHE reports and SHE documentations are systematically maintained regularly reviewed and updated with appropriate version control in place, based on system improvements, to drive efficiency and effectiveness of the management system.	1 2 3 4 5	1 2 3 4 5
LESSONS LEARNED AND KNOWLEDGE MANAGEMENT	• Company has no structured system for capturing lessons in order to facilitate future improvement of the SHE management system. • No promotion of knowledge sharing and lessons learned across the company. • No records of lessons learned. There is highly reliance on individual memory.	• Company’s processes and procedures for capturing and disseminating lessons learned are characterised by poor or unstructured records keeping and inconsistent data. • Limited promotion of knowledge sharing and lessons learned across the company. • Reliance on manual record keeping of lessons. • Lesson learned are rarely used for SHE management system continuous improvement and innovation.	• Company's processes and procedures for capturing and disseminating lessons learned are characterised by well-structured record keeping and good information. • Knowledge sharing and lessons learned is promoted across the company. • Little reliance on manual record keeping and greater usage of digital technologies for record keeping. • Records of lessons learned are sometimes relied on for SHE management system continuous improvement and innovation.	• Company's processes and procedures for capturing and disseminating lessons learned are characterised by routinely well-structured record keeping and consistent high-quality information. • Knowledge sharing and lesson learned is promoted systematic ally across the company. • Reliance on advanced digital technologies for capturing and disseminating lessons. • Records of lessons are consistently relied on for SHE decision making, continuous improvement and innovation. • Processes and procedures for capturing and disseminating lessons learned are modelled on best practice knowledge management standards e.g. ISO 30401 - 2018, ISO 9001: 2015.	• There is well structured system for capturing and disseminating lessons learned and knowledge gained across the whole company. Heavy reliance on technological innovations for capturing and disseminating lessons. • The processes are institutionalised within the company and are considered a key measure of operational excellence. • Knowledge and lessons learned are continuously shared and consistently relied upon across the company to continuously improve SHE.	1 2 3 4 5	1 2 3 4 5

					• Processes and procedures for capturing and disseminating lessons learned are routinely reviewed and updated to drive continuous improvement and innovation.		

6.6 Chapter summary

Presented in this chapter are the processes involved in the development of the integrated SHE management capability maturity model. The discussions in the chapter included the decisions for the development of the model and the procedure for selecting a team of experts for the verification and refinement of the model. The model development began with the identification and verification of integrated capability attributes (Chapter 5); followed by the development of an initial model and subsequent verification and refinement of the model by a team of experts. After refinement and improvement, a final version of model was ready for validation in order to ascertain the practical utility of the model. The next chapter presents the validation of the model by construction professionals working in the Ghanaian construction industry.

CHAPTER SEVEN - VALIDATION OF CAPABILITY MATURITY MODEL

7.1 Introduction

This chapter focuses on the validation of the maturity model. A validated model is that which has established validity, practicality, acceptability and generally fit for use to support decision making process in an organisation (Macal, 2005; Cheung, 2009; Hu *et al.*, 2016). This chapter, therefore, highlights the rationale for the validation exercise, the validation process employed and the eventual results.

7.2 Rationale for validation

Validation is a major part of a model development process (Kennedy *et al.*, 2005). It is undertaken to confirm the quality, acceptability and validity of a research (Cheung, 2009). Model validation is essential to credibility. Generally, it is done to test the reliability and acceptability of the research outputs or models (Cheung, 2009; Ameyaw, 2014). According to Macal (2005) and Hu *et al.* (2016), validation is mostly carried out to assess the extent to which a model or system fulfils user needs. Essentially, it ensures that the model meets it intended requirements. Validation is, therefore, crucial if the model is to be used (Macal, 2005).

Several approaches have been proposed for validation of research findings or a model. The most widely cited methods of validation are categorised as either external or internal validation (Al-Zahrani, 2013). External validity is the degree to which findings of a study hold or generalise over variations in settings, persons and outcomes (Hu *et al.*, 2016). The essence of external validation is, thus, to gain confidence in the research findings or increases confidence in a model to make it more beneficial. There are three aspects of external validation: replication, boundary search and convergence analysis. Replication refers to the process whereby research processes may be repeated to determine whether it results in the same outcomes (Brinberg and McGrath, 1985; Rosenthal and Rosnow 1991). Given the logistical constraints of repeating the processes involved in social research and the time and financial constraints of conducting a PhD research, external validation through replication is seldom used (Ankrah, 2007; Bashir, 2013; Mahamadu, 2017). It was not therefore not considered for validation in this study. Likewise, the boundary search approach to validation is the process of identification of conditions under which the findings of a study will not hold (Brinberg and McGrath, 1985). Considering that boundary search is established over time through a series of replication or convergence analysis to define the scope and boundaries of the findings of particular research, it is rare for researchers to use in their studies. Due to time and cost constraints, this approach was not possible to be used in this study. The convergence analyses, was therefore, adopted in the study.

Convergence analyses involve the use of different research strategies to ascertain the level of agreement in the findings of particular research (Denzin, 2009). Convergence validation can be achieved through a process called respondent validation (Silverman 2006), which involves the use of research participants' opinion to validate research findings (Creswell, 2014). This approach to convergence analyses is considered as a characteristic to good research and therefore, has been adopted for the conduct of several CEM research (Ankrah, 2007; Manu, 2012; Mahamadu, 2017; Osei-Kyei, 2017). Respondents validation was therefore employed in this study using construction professionals working in the Ghanaian construction industry.

The validation was conducted to provide feedback on the usefulness of the integrated SHE management capability maturity model developed. Additionally, it was carried out to confirm the appropriateness, comprehensiveness, accuracy, understandability, relevance, ease of use, usefulness and practicability of the maturity model from the industry perspective. This is an important step in the development of a CMM as previously discussed in Table 6.1(i.e. the "Evaluation - Validation of the model"). The next sections present the validation process and the results of the validation exercise.

7.3 The validation process

Upon the completion of the refinement of the capability maturity model using the contributions from the experts, the maturity model's evaluation and validation process was undertaken. Debrium *et al.* (2005) recommended the evaluation process of a maturity model should mainly focus on the models constructs and the model instruments (i.e. the reference model, performance scale and assessments procedure). In view of this, the validation process involved real organisational assessment of SHE management capability of construction companies operating in Ghana and a validation survey which appraised both content of the maturity model (i.e. the relevance and appropriateness of the capability attributes and levels) and its usability (i.e. understandability, ease of use and practicality). In general, validation mainly authenticate the adequacy and usability of the model overall. The processes of the validation exercise, is shown in Figure 7.1.

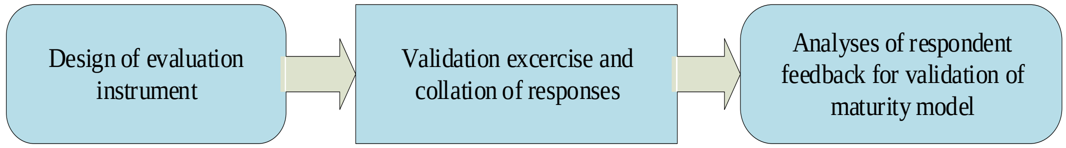

Figure 7.1: Validation processes

7.3 1 Design of evaluation instrument

To validate the capability maturity model (i.e. SHEM-CMM), an evaluation questionnaire was used as the instrument for evaluating the model by construction professionals in the Ghanaian construction industry. The utilisation of questionnaire is supported in literature as an appropriate method for model or framework evaluation and validation (Yeung, 2007; Cheung, 2009; Babantunde, 2016; Adeniyi, 2017). The validation questionnaire consisted of two sections. The first section solicited for information on the respondent background details. In the second section, respondents were asked to evaluate the model based on six criteria (i.e. relevance of attributes, comprehensiveness of attributes, appropriateness, adequacy of capability maturity levels, ease of understanding, ease of use and level of usefulness and practicality). These validation criteria are similar to the survey developed by Salah *et al.* (2014). Moreover, these criteria were used by Yeung (2007); Cheung (2009); Babatunde *et al.* (2016); Adeniyi (2017); Osei-Kyei (2017). A five-point agreement scale (i.e. 5= Strongly agree, 4= Agree, 3= Neither agree nor disagree, 2= Disagree, 1= Strongly disagree) was used. The evaluation questionnaire is shown in Appendix I.

7.3.2 The validation exercise

Given that, the aim of this study is to develop an integrated SHEM-CMM for uptake by construction companies in Ghana, the validation of the maturity model was undertaken by construction professionals working in the Ghanaian construction industry. An electronic mail was sent to 70 construction companies operating in Ghana as a formal invitation to participate in the validation process. Fifty-nine construction companies consented. After confirming their readiness to participate, the validation questionnaire (Appendix I) and the maturity model developed (Table 6.15) were sent to the construction professionals in their respective companies.

The validation exercise required the construction professionals to assess their company's SHE management capability maturity by using the developed maturity model. This was to ascertain the practical applicability of the maturity model. In addition, they were required to evaluate the capability maturity model based on six criteria using a Likert scale of 1-5 after the completion of their organisational assessments. This was to confirm their level of agreement to the validity and the suitability of the developed maturity model.

7.3.2.1 Background of respondents in the validation survey

As summarised in Table 7.1, majority of the respondents (i.e. construction practitioners including SHE experts) were Health and Safety managers (15.3%), followed by Project managers and construction managers (13.6%), Environmental Managers (13.6%), and Site Managers, Safety, Health or Environmental Consultants and Health and Safety Officers (11.9%). A majority of the respondents (67.8%) have over five years of professional experience. This is indicative of an experienced and knowledgeable group of construction professionals. This, therefore, enhanced the credibility of the results of the maturity model validation exercise.

Building and civil construction companies in Ghana are grouped into categories (e.g. A, B, C, D and K) and classified as large or small based on their levels of outputs which are in turn largely dependent on their financial classes. A category A can execute large projects such as road, airports and related structures; a category B is able to execute projects such as concrete bridges, culverts and other structures; a category C company is able to execute projects relating to labour intensive works. Companies in category D are able to execute general building works while companies in category K undertake general civil engineering works. Based on a construction company financial standing, previous experience, technical experience and equipment and plant holding, each category is grouped into four financial classes 1, 2, 3 and 4. Building contractors are divided into classes ranging from D1, D2, D3 and D4 and K1, K2, K3, K4 for civil engineering works. The Ghanaian construction industry is dominated by a large number of small and medium size firms, that is, classes 3 and 4 (Dansoh, 2005; Kheni *et al.*, 2008). Class D3/D4 and K3/K4 are generally referred to as small scale building contractors while D1/D2 and K1/K2 are typically referred to as large construction companies. D1K1/A1B1 is the highest classification level eligible for large contracts while D4K4/A4B4 is the minimum level eligible for small contracts as shown in Table 7.

With regards to the type of construction companies, a majority of the respondents (45.8%) belonged to construction companies in Class 1 followed by those in Class 2 (33.9%). Also, a majority of the companies (50.8%) are involved in building construction works.

Table 7.1: Classification of construction companies in Ghana (Dansoh, 2005)

Financial class	**Designation**	**Size of projects**	**Number of persons employed**
Class 1	D1K1	Above US$ 500,000	Above 100 persons (large enterprises)
Class 2	D2K2	up to US$ 500,000	30-99 persons (Medium-sized enterprises)
Class 3	D3K3	up to US$ 200,000	6-29 persons (small enterprises)
Class 4	D4K4	Below US$ 75, 000	1-5 persons (micro enterprises)

Table 7.2: Validation respondents (construction professionals) background

		Frequency	%
Profession	Health and safety manager (H/S manager)	9	15.3
	Site Manager	7	11.9
	Project manager/construction manager (PM/CM)	8	13.6
	Architect	4	6.8
	Civil / structural engineer	3	5.1
	Safety and health / environmental consultant (S&H/Env. Manager)	7	11.9
	Quantity surveyor (QS)	6	10.2
	Environmental manager	8	13.6
	Others (H/S supervisor, safety officer)	7	11.9
Professional Experience	1-5 years	19	32.2
	6-10 years	22	37.3
	11-15years	15	25.4
	Over 15 years	3	5.1
Type of Firm	Building construction works	30	50.8
	Mechanical installation works	1	1.7
	Construction within the mining sector	5	8.5
	Civil engineering construction works	17	28.8
	Electrical installation works	2	3.4
	Others (e.g. railway construction)	4	6.8
Firm Classification	D1K1/A1B1 (Class 1)	27	45.8
	D2K2/A2B2 (Class 2)	20	33.9
	D3K3/A3/B3 (Class 3)	9	15.3
	D4K4/A4B4 (Class 4)	3	5.1

7.3.3 Analyses of respondents' feedback and results

Responses from the validation process were collated and analysed. Considering that some arguments in literature indicates the inadequacy of using statistical mean as an appropriate measure for analysing Likert scale responses of ordinal data (section 4.6.5.2), the statistical median was used to evaluate the model validation rating of the construction professionals. In addition, the results were based on percentages of the responses on the 5-point Likert scale. The results of the validation survey by questionnaires are presented in Table 7.2 and Table 7.3.

The results of the validation exercise indicated that respondents were pleased with the maturity model and considered it useful and practicable with capability attributes being relevant as well as having a good coverage of key aspects of integrated SHE management in construction. This is discussed in sections 7.3.3.1 to 7.3.4.

Table 7.3: Summary of responses feedback for maturity model evaluation

Assessment criteria	**Evaluation response (%) (n=59)**					
	Strongly agree	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Total (%)**
Attributes used in the SHEM-CMM worksheet						
Attributes are relevant to SHE management capability.	35.6	**62.7**	1.7	0	0	100
Attributes cover all aspects of SHE management capability.	20.3	**62.7**	16.9	0	0	100
Attributes are correctly assigned to their respective capability level.	15.6	**71.2**	13.6	0	0	100
Attributes are clearly distinct.	40.7	**50.8**	8.5	0	0	100
Capability maturity levels						
The capability levels sufficiently represent maturation in the attributes.	18.6	**69.5**	8.5	3.4	0	100
There is no overlap detected between descriptions of maturity levels.	6.8	**52.5**	27.1	13.6	0	100
Ease of understanding						
The capability levels are understandable	33.9	**61.0**	5.1	0	0	100
The documentations (i.e. assessment instructions) are easy to understand	13.6	**71.2**	11.9	3.4	0	100
The results are understandable	13.6	**79.7**	6.8	0	0	100
Ease of use						
The scoring scheme [i.e. drop-down options for maturity levels (1-5)] is easy to use	39.0	**57.6**	1.7	1.7	0	100
The SHEM-CMM is easy to use	18.6	**71.2**	8.5	1.7	0	100
Usefulness sand practicality						
SHEM-CMM is useful for assessing SHE management capability	**49.2**	47.5	3.4	0	0	100
SHEM-CMM is practical for use in industry	28.8	**64.4**	6.8	0	0	100

Table 7.4: Results of respondent validation of maturity model

Summary of validation responses (N = 59)				
Assessment criteria	**Mean**	**Median**	**Mode**	**Standard deviation**
Attributes used in the SHEM-CMM worksheet				
Attributes are relevant to SHE management capability.	4.34	4.00	4.00	0.51
Attributes cover all aspects of SHE management capability.	4.03	4.00	4.00	0.62
Attributes are correctly assigned to their respective capability level.	4.02	4.00	4.00	0.54
Attributes are clearly distinct.	4.32	4.00	4.00	0.63
Capability maturity levels				
The maturity levels sufficiently represent maturation in the attributes.	4.03	4.00	4.00	0.64
There is no overlap detected between descriptions of capability levels.	3.53	4.00	4.00	0.82
Ease of understanding				
The capability levels are understandable	4.29	4.00	4.00	0.56
The documentations (i.e. assessment instructions) are easy to understand	3.95	4.00	4.00	0.63
The results are understandable	4.07	4.00	4.00	0.45
Ease of use				
The scoring scheme [i.e. drop-down options for capability levels (1-5)] is easy to use	4.34	4.00	4.0	0.61
The SHEM-CMM is easy to use	4.07	4.00	4.0	0.58
Usefulness and practicality				
SHEM-CMM is useful for assessing SHE management capability	4.46	4.00	5.0	0.57
SHEM-CMM is practical for use in industry	4.22	4.00	4.0	0.56

7.3.3.1 Relevance and comprehensiveness of attributes to integrated SHE management capability.

Majority of the construction practitioners (i.e. the respondents) were of the opinion that the capability attributes proposed by the study were adequate and comprehensive as well as relevant to SHE management capability. Most respondents (i.e. 98.3%) agree or strongly agree that capability attributes were relevant. Also, respondents agreed that the attributes were clearly distinct (i.e. 50.8% agree and 40.7% strongly disagree). Over all, a significant number of respondents were satisfied with the comprehensiveness of the attributes (i.e. 62.7% agree and 20.3% strongly disagree). The validation criteria had a median score of 4.0. This confirms that the capability attributes are relevant and did cover all aspects of integrated SHE management capability in construction.

7.3.3.2 Correct assignment of attributes to their respective capability levels and sufficient maturation of attributes

Majority of construction professionals (i.e. 86.8%) agree or strongly agree that the attributes were correctly assigned to their respective maturity levels. Similarly, over half of the respondents (i.e. 69.5%) agree that the capability levels identified by SHEM-CMM are adequate to represent all maturation stages of integrated SHE maturity. While over half (i.e. 59.3%) of the respondents agree or strongly agree that no overlap was detected between descriptions of maturity levels. With a median score of 4.0, respondents were generally satisfied with the accuracy of the capability attributes and their capability levels in the developed model.

7.3.3.3 Ease of understanding of the capability levels and results obtained

Majority of the respondents were of the opinion that the capability levels, supporting documentations and the results were easy to understand. Most of the respondents (i.e. 94.9%) agree or strongly agree that the maturity levels and their definitions are understandable. Similarly, a majority of the respondents (i.e. 84.8%) agree or strongly agree that the documentations (i.e. assessment instructions) for the model were comprehensible. The model results were regarded as understandable according to the majority of the construction professionals (i.e. 93.3%).

7.3.3.4 Ease of use of SHEM-CMM and its practical usefulness in industry

Lastly, the majority of the construction professionals were of the opinion that the integrated SHEM-CMM was easy to use, useful for assessing SHE management capability and practical for use in the construction industry. In particular, the construction practitioners appreciated the ease of using the Microsoft Excel format of the SHEM-CMM during evaluation. The scoring scheme (i.e. drop-down options for capability levels) was regarded as user friendly, according to a vast majority (i.e. 96.6%) of respondents. A vast majority of the respondents (i.e. 96.7%) agree that the SHEM-CMM is useful for assessing SHE management capability in construction. Also, over 90% of the respondents agree or strongly agree that the SHEM-CMM is practical for use in the industry. With respect to the overall suitability and usefulness of the model, respondents rated the model with a median score of 4.0.

7.3.4 Summary of validation exercise

The overall feedback from the validation survey by construction professionals on the proposed integrated SHEM-CMM was very positive. With a modal score of 5 on the usefulness and practicality of the model for assessing SHE management capability, and a median score of 4.0 on all the other validation criteria, it can be concluded that the integrated SHEM-CMM is comprehensive and suitable for assessing SHE management capability maturity of construction companies. The high rating also indicates a convincing level of approval of the developed capability maturity model. Based on the overall results of the validation exercise, the developed integrated SHEM-CMM was generally well-received by practitioners in industry.

7.4 Chapter summary

The validation process conducted on the proposed integrated SHE capability maturity model developed was presented in this chapter. The validation process was conducted with construction professionals in 59 construction companies operating in Ghana. Based on the outcome of the model validation exercise, the model is suitable for use and should enable practitioners to assess the current SHE management capability of construction companies and to help identify areas for improvement. The next chapter presents the conclusions of this study.

CHAPTER EIGHT - CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This chapter presents the conclusion of the entire research work. The research objectives are reviewed with the summary of findings in respect of each objective and major conclusions highlighted. The contribution of the research to knowledge, as well as implications for practice, are also detailed. The chapter also highlights the limitations of the research and provides recommendations for future research.

8.2 Review of research objectives

The overall aim of this study was to develop an integrated safety, health and environmental management capability maturity model (SHEM-CMM) that can be used by construction companies in Ghana. This is to enable them to determine the maturity of their SHE management process and practices so as to guide process improvement efforts. Consequently, six specific objectives were pursued. To achieve these objectives, different methods were applied including an extensive literature review supported by expert validation review (sections 5.2.1 and 5.3), a three-round Delphi survey accompanied by a voting analytical hierarchical process (sections 5.4.7 and 5.5), and development and validation of the maturity model (Chapter 7). The achievement of the objectives is reviewed in this section.

Objective 1: 'To conduct a critical review of literature relating to safety, health and environment in the construction industry in order to identify the current state of the art'.

The findings from literature in Chapter two addressed this objective. A comprehensive review of the literature revealed an empirical paradox of the construction industry; an industry which has economic, social and cultural significance and at the same time the most dangerous industrial sector within the global ecosystem, which is mainly responsible for several types of occupational fatalities and adverse environmental impacts. Consequently, upon a critical review, researchers have classified the negative environmental impacts of construction operations into three main headings namely: Ecosystem impacts (e.g. air, water, land and noise pollution, waste and toxic generation and greenhouse emissions), Natural resources impacts (e.g. energy and raw materials consumption, resources depletion and deterioration); and Public impacts (e.g. social disruption and public safety and health). Literature also suggested that construction operations affect the environment throughout the life cycle of a construction project. As a result, in addition to time, cost and quality of project considerations, contractors and other construction professionals need to focus on the environmental impacts of their operations when organising their construction activities, in decision making and throughout the production control.

Furthermore, the critical review revealed that the fragmented nature of the industry; the casual nature of employment; difficult work-site conditions; the inadequate integration among the supply chain members; the large number of small and medium construction companies and the different types of work being carried out simultaneously by different types of several skilled and unskilled workers within the industry, present difficulties to improving safety and health performance at the construction site. Hence, the sector's significant contribution to high percentages of accidents which usually results in ill-health, injuries and fatalities. It was also discovered through literature that the safety and health performance in construction industry globally is poor, but the situation in developing countries, particularly in the Sub-Sahara African countries like Ghana is alarming. This is the case in those countries because SHE issues are often neglected since safety and environmental considerations in building projects delivery process are not given any priority.

The costs arising from these accidents, injuries, fatalities and illness in construction are huge and borne by the construction companies, the victim and their families, the government and the construction client. The literature reviewed also suggested an urgency in improving the environmental, safety and health situation within the construction industry, particularly in developing countries where the situation seem to dire. The review showed that several improvement efforts have been made and continue to pursued through various initiatives. Notable among these efforts are the introduction of environmental and health and safety legislations, innovative and systematic management solutions, such as the adoption and implementation of SHE management systems and research into the implementation of SHE management systems in construction and other safety initiatives.

Objective 2: 'To conduct a critical review of literature relating to safety, health and environmental managements systems, in order to identify the prevailing models/systems, their associated elements and attributes that determine SHE management capability'.

This objective was also addressed in Chapter two. As a key step towards developing an integrated safety, health and environmental (SHE) management capability maturity model, a comprehensive review of health and safety management systems and environmental management systems literature (not limited to construction), was undertaken to obtain the elements and practices that are relevant to integrated SHE management. The review revealed that several safety and health management systems (SHMS) and environmental management systems (EMS) exist and have been developed and published by various bodies and institutions (e.g. Health and Safety Executive's (HSE), International Organization for Standardisation (ISO), and the British Standard Institute (BSI). Furthermore, it was revealed that these existing SHE management systems are based on management system standards (MSSs) and specifications that follow Deming's Plan-Do-Check-Act (PDCA) model of continuous quality improvement. Also, the literature review revealed the emergence of integrated management systems (IMSs) with advocates citing management effectiveness as an important aspect justifying their use. Though several IMSs have been published, literature on the integration of EMS and SHMS remains lacking. Moreover, the existing standalone MSs and several IMSs are developed following the PDCA management approach and contains similar elements and common requirements with a general common structure which allows the elements to be integrated. Consequently, to identify the integrated SHE management practices and elements, the information from the SHE management literature consisting of established internationally recognised SHE management standards were extracted by comparing their components in order to determine key similarities and differences; thereby, establishing the potential integrated SHE management capability attributes (i.e. the integrated SHE practices and elements) for implementation of an integrated SHE management system and for incorporation into a maturity model. Examples of the existing SHE management systems and their elements are presented in Table 2.4 in section 2.4.1.2 and Table 2.5 in section 2.4.2.2 and Table 5.1 in section 5.2.1 of this study. From the comprehensive review of literature, 27 integrated SHE management capability attributes were identified (section 5.2.1). Through an expert verification process and a Delphi technique, a final list of 20 capability attributes emerged as relevant to the implementation of an integrated SHE management system in construction (section 5.3 in Chapter 5). Further details are also provided under objective four.

Objective 3: 'To conduct a critical review of process improvement tools, in particular the capability maturity modelling (CMM) concept, in order to develop a detailed understanding of its applicability to the development of an integrated SHEM-CMM'.

This objective was addressed and presented in Chapter three. With several process improvement methods and approaches available to improve business processes within an organisation for growth and to meet new standards, a review of process improvement methods and approaches, in particular CMM was undertaken with the intent of obtaining insight into maturity model design and application. The literature review revealed that the quality of an organisations' product and services is directly related to the quality of the process it goes through or uses to developed it, hence the processes need improvement. Prominent, amongst these processes improvement methods are the Total quality management (TQM); Six sigma; CMM/CMMI and Lean, which enable organisations to identify, analyse and continually improve their performance. Also, it was realised that apart from the maturity models, the others do not really assess the effectiveness of the processes involved and show no evidence of the capability improvements of organisation processes. Maturity models, on the other hand, show an expected, or desired progressive path of improvement that could produce essential and desired outcomes. The review revealed that, though maturity models offer a framework with a systematic approach for assessing the capability of an organisation to manage its business processes in the best way, it has been criticised for oversimplifying reality and for being mostly based on espoused best practices with their reliability not justified empirically in some cases, and for lacking rigour in their model development process. A critique of maturity models revealed several basic design principles and methodology for maturity model development and the basic architecture of maturity models, which is described as either a staged or continuous representation. The review revealed that the continuous representation allows for flexibility which means that, a company can choose to focus on some process areas which fit the company's long-term strategies or goals. Again, the continuous representation provides a generic measurement of capability level of each specific process area. This gives a company a holistic perspective of capability maturity of their processes and allows it to identify opportunities for change, prioritise investments and target efforts for continuous improvement. A continuous representation was therefore found suitable for the maturity model development in this study. Generally, maturity models contain key process areas that are described by maturity or capability levels; a generic description or summary of the characteristics of each level as a whole; a number of elements or activities for each process area; and a description of each activity as it might be performed at each maturity or capability level. Typically, the maturity or capability levels ranges from three to six, which are arranged from the lowest to highest possible level to be achieved. A five-level maturity scale (i.e. Level 1-5) was adopted in the capability maturity model development. The identification of components of capability maturity models, its design and applicability to the development of an integrated SHEM-CMM represented an achievement of the third research objective.

Objective 4: 'To develop an integrated safety health, environmental management capability maturity model'.

This objective was addressed and presented in Chapters five and six. Towards the development of an integrated SHEM-CMM, the concept of capability maturity model was explored (refer to section 3.4.1 - 3.4.6 in chapter 3 for details). There was the need to establish: (1) key process areas (i.e. integrated SHE management capability attributes); and (2) the capability maturity levels. Considering the lack of empirical work regarding integrated SHE management capability in construction, a literature review supported by a preliminary SHE expert verification process, combined with a Delphi technique (DT) and voting analytical hierarchy process (VAHP) were used to identify the relevant capability attributes for effective implementation of integrated SHE management system in construction. This approach was deemed appropriate to ensure that relevant capability attributes were used in developing the integrated SHE management capability maturity model.

- In chapter five, a thorough analysis of relevant literature was conducted to generate a list of potential capability attributes germane to effective implementation of an integrated SHE management system in construction. From the review, 27 integrated SHE management capability attributes were identified (section 5.2.1).

- The list of 27 integrated SHE management capability attributes were subjected to expert verification to ensure the appropriateness and clarity of the integrated SHE management capability attributes. After the verification process, there were no additions to the list and none was also eliminated. The 27 validated attributes were consolidated (based on their similarity) into 20 integrated SHE management capability attributes and subsequently categorised, based on their relatedness into five thematic areas of integrated SHE management capability. The five thematic categories are**:** strategy; people; process; resources; and information (see section 5.3 and Table 5.5 in chapter 5 for details).

- After ascertaining the appropriateness and comprehensiveness of the identified attributes, a three round Delphi technique was used to generate consensus regarding the importance of the attributes (section 5.4.7), while the voting analytical hierarchy process (VAHP) was used to generate weights of importance based on the outcomes of the Delphi technique (section 5.5). Through all these research methods, a final list of 20 integrated SHE management capability attributes with weights emerged for inclusion in the integrated SHE management capability maturity model.

- In CMM/CMMI literature, the usage of five levels in maturity model development is common and it is in line with the original capability model by Paulk *et al.* (1993), Maier *et al.* (2012) and Storbjerg *et al.* (2016). Similarly, in this study, a five-level maturity scale (i.e. Level 1-5) was adopted in the capability maturity model development, with level 1 being the lowest maturity level, and level five, being the highest maturity level. As previously discussed in section 6.2.1, Table 6.1-development phase in Chapter 6 and Appendix F, capability maturity level descriptor characteristics were extracted from literature, however, adequate attention was placed on maturity level characteristics that are relevant to SHE capability maturity. Using the knowledge gained from studying the existing maturity models found in literature, the top down approach was used in establishing the capability maturity level descriptors used in developing the maturity model in this study (refer to Table 6.1-formulating cell texts).

- After defining capability maturity level descriptors in the context of capability attributes for integrated SHE management in construction, an initial integrated SHEM-CMM maturity model was produced (i.e. Appendix G and Table 6.4).

- The structure of the SHEM-CMM is a continuous representation adapted from CMMI. The conceptual model contains the list of 20 integrated SHE management capability attributes and the capability levels definitions arranged with respect to capability maturity levels 1-5 (i.e. Level 1 being lowest maturity and Level 5 being the highest maturity level). Levels of capability maturity are allocated against the capability attributes; thereby, creating a series of cells (see Appendix G). Each cell contains a maturity level descriptor.

- The conceptual maturity model was then presented to selected experts from construction companies for review. The experts made suggestions for the model improvement and this resulted in the construction of the final integrated SHE management capability maturity model (Table 6.20 in Chapter 6). The development of the integrated SHEM-CMM, thus represented the achievement of the fourth research objective.

Objective 5: 'To validate the model and test the industrial relevance of the integrated SHEM-CMM from the perspective of Ghanaian construction companies.'

The above objective was realised and presented in Chapter seven. Construction professionals including SHE experts from 59 construction companies operating in the Ghanaian construction industry were engaged in the evaluation and validation exercise. Findings from the validation exercise (Table 7.2 and 7.3) showed that the respondents generally agreed that the model met the evaluation criteria. The validation process was detailed in Chapter seven.

Objective 6: 'Draw conclusions and make recommendations towards using the integrated SHEM-CMM as a tool for improving SHE performance in the Ghanaian context'.

The achievement of this objective is addressed by this chapter as given in the following sections.

8.3 Conclusions

This study, through several research methods, identified 20 capability attributes that are relevant for the effective implementation of an integrated SHE management system in a construction company and for inclusion in the maturity model. The capability attributes are classified under five thematic categories, namely: strategy (the organisations 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). While these thematic categories and their associated attributes carry varying weights of importance collectively, the strategy related attributes statement are the most important followed by the people, process, resources and information related attributes, respectively. These integrated SHE management capability attributes were used to develop capability maturity level definitions that range from Level 1 to Level 5 based on the continuous presentation of CMMI. An integrated SHE management capability maturity model was therefore devised based on these integrated SHE capability attributes and its five capability levels presented as a matrix.

The model developed embodies new insights into what constitutes capability attributes required for effective integrated SHE management in construction and it also provides a systematic approach to organisational SHE capability assessment and improvement. The novel contribution of this study lies in the development and validation of an integrated SHE management capability maturity model that can assist construction firms to ascertain the areas of strength and deficiency in respect of their capability. In doing so, they can prioritise investments and efforts targeted at addressing any identified areas of capability deficiency in order to ensure continuous improvement. Furthermore, the developed maturity model enables construction firms to get a systemic and holistic overview of the current state of SHE management maturity.

8.4 Contributions of the Research

The result of this study provides contributions to both knowledge and practice.

8.4.1 Contributions to knowledge

The contributions of this study to knowledge are as follows:

1. The identification of capability attributes, relevant for integrated SHE management in the construction domain. The identified capability attributes can be adopted as elements of an integrated SHE management system for use by construction organisations. It can also be adopted by researchers for use in subsequent studies.
2. The establishment of weights of the capability attributes. This was achieved through a three-round Delphi survey and a voting analytical hierarchy process. These established weights give a clearer pointer to the capability attributes and their sub attributes that are important to focus on in order to prioritise efforts for improvement.
3. This research has shown that the capability maturity concept can be applied to the integration of management systems to develop practical tools for effective management. This has expanded the boundary of CMM application and has contributed to the knowledge on integrated SHE management capability improvements.
4. This research has also contributed to the existing knowledge by establishing integrated SHE management maturity characteristics applicable to construction. This can be adopted by researchers for use in subsequent studies.

8.4.2 Practical contributions

The following are the practical contributions of this study:

1. An integrated SHE management capability maturity model has been developed. At present there is no model developed to achieve the purpose and functions of the maturity model developed in this study. This model is expected to serve as a self-assessment tool to assist construction companies to identify their current SHE capability maturity levels and potential to improve SHE management capability attributes.
2. The model contains capability attributes and their weights that will enable construction companies to systematically self-examine their SHE management capability. This would enable them to ascertain the areas of strength and deficiency in respect of their SHE capability. On the basis of the SHE management capability self-assessment, construction companies could prioritise their investments and target efforts at addressing any identified areas of capability deficiency to ensure continuous improvements and avoid sub-optimisation.
3. The model provides integrated SHE management capability attributes that construction clients (including government agencies) could consider as part of the SHE management criteria for selecting companies to undertake building and civil projects during tender evaluation.
4. The model can serve as a framework for benchmarking or comparing construction safety, health and environmental management performance to identify opportunities for improvements.
5. The model as a management tool will enable safety and health, and environmental management consultants to evaluate their construction client's firm current SHE capability maturity and provide guidance on how they can achieve further improvements in their SHE management practices and processes.

8.5 Limitations of the research

Like any other research, this study has some limitations, which are presented below:

1. The study was based on 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.

2. Successfully scoring an organisation requires some domain knowledge due to its comprehensiveness. Hence, assessment with the model cannot be done by just any one in a company but by a suitably competent person (e.g. SHE personnel). As a result, some small to medium construction firms may need further assistance to complete a self-assessment.
3. The development of the integrated SHEM-CMM focused on the construction industry. This may hamper with its immediate applicability to other industrial sectors.

8.6 Recommendations

Based on the findings and conclusions of this study, three sets of recommendations are given. The first is applicable to construction companies in Ghana, the second for policy makers and the third for future research.

8.6.1 Recommendations for construction companies in Ghana

1. Given the construction professionals involved in the validation of the proposed maturity model recognised the model as a useful tool, construction firms should be encouraged to use the model to self-assess their current state of SHE management maturity so as to define and plan strategies for future process improvements.
2. Capability attributes identified and used to develop the integrated SHE management capability maturity model in this study are critical to the effective management of SHE issues in construction. Construction firms should adopt and implement these integrated SHE management capability attributes effectively to improve SHE performance.
3. Construction firms operating in both the public and private sector should embed the integrated SHE management capability maturity model as a planning tool and a guide for integrated SHE management programmes. They should be aware that a higher SHE management capability maturity means an effective management and control of SHE functions, which can significantly reduce occupational accidents and adverse environmental impacts.

8.6.2 Recommendations for policy makers

1. Relevant government agencies, institutions and others key stakeholders responsible for safety and environmental issues in the construction industry, should frequently undertake SHE capability enhancement programmes for construction companies. This is necessary for these companies to gain a deeper and better understanding of their capability to implement an integrated SHE management system.
2. As SHE management systems implementation is growing in prominence in the construction industry globally, the relevant government and industry institutions should promote and encourage construction firms in Ghana to adopt and implement SHE management systems in their businesses to effectively manage safe and health, and environmental challenges on construction sites.
3. Considering environmental issues are closely linked to safety issues in construction, SHE management capability maturity improvement should be a key point of discussion in SHE training, workshops, seminars, conferences for construction firms, relevant government agencies, SHE professionals and other key industry stakeholders. Integrated capability attributes and other information contained in the model can serve as guide or outline for such discussions.
4. Integrated SHE management capability attributes can be incorporated into SHE management schemes for construction procurement as part of the SHE management criteria for selecting companies to undertake projects.
5. Both private and public construction clients, when appointing construction companies, can consider integrated SHE management capability attributes and their priority weights to ensure appointed companies have the required SHE management capability.

8.6.3 Recommendations for future research

Based on the findings of this study, the following areas are recommended for further research.

1. Further work can be done to extend the maturity model into a web-based tool to facilitate ease of use and wide accessibility.

2. The study should be replicated in other developing countries as well as in other industrial sectors other than construction for further comparison of integrated SHE management capability maturity across these industrial sectors.

3. The maturity model should be used to assess construction firms SHE maturity and identify the impact of maturity on performance of SHE objectives or other preconditions for success.

8.7 Chapter Summary

This chapter has given a review of the research objectives and how they were achieved. The main conclusions that address the research questions and research aim have also been outlined together with the contributions of the research and the limitations of the research. Finally, recommendations for practice and for future research have been provided. It is envisaged that these recommendations would help to improve safety, health and environmental management in the Ghanaian construction industry.

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APPENDICES

Appendix A: Expert verification questionnaire

Safety, Health and Environmental Management Capability Maturity Research

Page 1: Information Sheet

This survey is part of a doctoral research that seeks to develop an integrated safety, health and environmental (SHE) management capability maturity model for construction companies in Ghana. The research, which is sponsored by the Commonwealth Scholarship Commission, is being undertaken by Ms Millicent Asah - Kissiedu under the supervision of Dr Patrick Manu, Dr Colin Booth, and Dr Abdul-Majeed Mahamadu at the University of the West of England (UWE). The survey is the initial phase of a Delphi process and it is intended to help with preliminary validation of a set of attributes that could be relevant to the development of the integrated SHE model.

You have been identified as someone whose expertise in health and safety and/or environmental management would benefit the validation exercise. The research team would be most grateful if you could participate in this study. The survey should take you approximately 15 minutes to complete.

Participation in this research is voluntary and you may withdraw your responses from the research at any time prior to when all the responses from this survey have been analysed. You will be asked to create your own unique ID which you can use to request for withdrawal of your responses should you wish. All information collected will be stored securely and you will not be identified at any point in this research.

The research is granted ethical approval by the UWE ethics committee. If you have any ethical queries that you want to be addressed by an independent person, you may contact the ethics committee at UWE by email.

Please direct any enquiries about this research to:

Ms Millicent Asah-Kissiedu (Doctoral Researcher)

Please click on the "Next" button below to proceed with the survey.

Page 2: Participant Background and consent

1. Your name

2. Your email addresses.

3. Your role (e.g. lecturer in construction management)

4. Please indicate your area (s) of expertise. (Tick as appropriate, multiple options are applicable
☐Health and safety
☐Environmental management research
☐Construction management research

5. Please indicate your overall years of experience in health and safety research and in environmental management research e.g. 3 years in health and safety research and 0 years in environmental management research

6. Please provide your professional qualifications/affiliations e.g. member of CIOB

7. Please provide your highest academic qualification e.g. PhD in Construction Management.

8. I confirm that I have read the Information Sheet (on previous page) for this research and understood the information provided therein

9. I agree to participate in the research

☐Yes ☐No

Page 3: Determination of Attributes of an Integrated safety, health and environmental (SHE) Management Framework

Preamble

Below is a list of attributes that have been drawn from a variety of individual safety and health, and environmental management systems. The attributes are now being proposed for inclusion in a single integrated safety, health and environmental (SHE) management framework that could help construction companies in Ghana to manage SHE challenges. We would like to know whether the attributes are appropriate for inclusion in the integrated framework and also whether the list is comprehensive enough (i.e. are there other suitable attributes that have been missed out).
In the sections that follow, please indicate by ticking the appropriateness of the listed attributes for inclusion in a single integrated SHE management framework. Tick to indicate that an attribute is appropriate.

Proposed Planning related attributes

10. Please indicate by ticking the appropriateness of the listed attributes.

☐Top management commitment (i.e. Gaining top management commitment to support SHE development and implementation)

☐A SHE implementation team (i.e. A team with representatives from key management functions and an overall champion with responsibility for SHE management tasks)

☐ SHE baselines review (i.e. A preliminary review of the company's current status of SHE management processes)

☐SHE policy (i.e. An integrated SHE management policy supported by senior management reflecting its management commitments, leadership and continual improvement)

☐SHE hazards, risks and environmental aspects and impacts identification (i.e. Identification of SHE scopes, SHE hazards, risks, environmental aspects and related impacts of the company's operations)

☐SHE risks assessments and management (i.e. Identification of SHE risks assessments procedures, costs and control measures)

☐SHE legal and other requirements (i.e. Identification, having access to and analysing applicable legal and other requirements which apply to all SHE activities)

☐SHE objectives and targets (i.e. Definition of SHE objectives and targets consistent with SHE policy and legal requirements)

☐SHE management programme(s)/action plan(s) (i.e. Development of SHE management programs including procedures for dealing with emergency situations and for achieving SHE objectives and targets)

Proposed SHE implementation and Organisation attributes

11. Please indicate by ticking the appropriateness of the listed attributes.

☐SHE structures and responsibility (i.e. Establishment of a management structure where roles and responsibilities for SHE management are clearly identified and workforce duly designated)

☐SHE resources (i.e. Allocation of all necessary resources for SHE management (e.g. human resources and specialised skills, technology, financial resources and competent advice where needed)

☐SHE training (i.e. Identifying specific training needs of personnel and the provision of appropriate training to address identified training needs)

☐Competency of workforce (i.e. Developing a mechanism for assessing the competence of employees, outsourced personnel, subcontractors and suppliers on the basis of appropriate education, training and/or experience necessary to comply with the law)

☐SHE supervision (i.e. Supervise to make sure all arrangements are followed)

☐SHE communications (i.e. Maintaining the relevant information flow of SHE issues to workforce and other interested parties (e.g., supplier and subcontractors) through appropriate channels (internally and externally)

☐SHE legal and other requirements (i.e. Identification, having access to and analysing applicable legal and other requirements which apply to all SHE activities)

☐SHE documentation (i.e. A description that summarises how the SHE management system elements and other related documents (e.g. SHE Policy, SHE manual and SHE procedures and instructions) fit together and maintained)

☐SHE documents control (i.e. Ensuring all personnel are working with the correct SHE documents, instructions and procedures which are available and easily located, periodically reviewed and obsolete ones disposed of)

☐SHE operational control (i.e. Ensuring that assessed significant hazards, risks and environmental impacts associated with company's operations and activities and legal requirements are controlled and managed)

☐SHE emergency preparedness and response (i.e. Implementing SHE emergency plans for efficient response to unexpected and uncontrolled incidents to minimise their impacts)

Proposed SHE Performance Evaluation and Audits related attributes

12. Please indicate by ticking the appropriateness of the listed attributes

☐ Monitoring and Measurement (i.e. Assessing how well the integrated SHE system is performing by evaluating SHE performance against key process and outcome measures) Evaluation of legal compliance (i.e. Accessing compliance with applicable SHE regulations, laws and other requirements that the company subscribes to)

☐ SHE incidents investigation (i.e. Putting in place systematic procedures to investigate immediate and underlying causes of SHE incidents e.g. occupational injuries, illnesses, near misses, pollution amongst others)

☐ Non-conformance, Correction/Prevention Action (i.e. Fixing SHE problems and avoiding them in future by identifying the problem and its root cause, implementing a solution, communicating and evaluating the solution for effectiveness)

☐ Records control (i.e. Keeping and managing all the records that the company's SHE management system generates, such as the list of significant environmental aspects and impacts, management reviews, SHE audits reports, SHE accident and incident reports amongst others)

☐ SHE auditing (i.e. Verifying that the SHE management system is operating as intended and in conformance with SHE criteria, and communicating the results to management)

Proposed SHE Management Review related attributes

13. Please indicate by ticking the appropriateness of the listed attributes.

☐ SHE management review (i.e. Critical analysis and an integrated review of the overall performance of the SHE management system by top management which involves checking whether the system is suitable, adequate and effective to meet the company's needs and to ensure continuous improvement and innovation)

☐ Learning lessons (i.e. Learning lessons from SHE inspection, SHE accident investigations, and near misses reports and SHE audits and taking action on them).

Other SHE management related attributes

14. Apart from the above attributes, could you suggest other appropriate attributes. If there are no more attributes to be suggested please leave the space blank.

Further Participation in the research

15. If you would be interested in participating in further phases of the research please indicate by ticking "Yes" below.

    ☐ Yes

Page 4: Thank You

Thank you very much for participating in this survey. The research team will be in contact if you indicated interest in participating in a further phase of this research.

Appendix B: Samples of Invitation letter to Delphi participants, information sheets, consent forms and reminder letters.

INVITATION LETTER

Faculty of Environmental and Technology
University of the West of England, Bristol
BS16 1QY
United Kingdom
Date…/…/ 2017

Dear Sir/Madam,

REQUEST FOR PARTICIPATION IN RESEARCH

INTEGRATED SAFETY, HEALTH AND ENVIRONMENTAL CAPABILITY MATURITY MODEL (SHEM-CMM) FOR UPTAKE BY CONSTRUCTION COMPANIES IN GHANA.

As part of a PhD thesis in the Faculty of Environment and Technology at the University of the West of England, Bristol, I am, developing an integrated safety, health and environmental (SHE) maturity model for construction companies in Ghana. Part of the research involves a questionnaire survey that aims to identify construction experts' views about the relevant elements of an integrated SHE management system. The outcome of the survey can provide helpful guidance on the appropriate SHE elements for the development of a maturity model for assessing and improving SHE capability of construction organisations in Ghana. This research is sponsored by the Commonwealth Scholarship Commission, London.

You are cordially invited to contribute your expert knowledge and experience in a Delphi survey which will form part of the data collection for this research. Delphi procedure will be used to solicit your opinion on elements/attributes of SHE management necessary to be incorporated into a SHE management maturity model. Participation is voluntary and you do not have to take part if you do not want to. If you decide to take part, all information you provide will be considered highly confidential and anonymised. You will be identified by a unique code for the purposes of data analyses. The Delphi procedure will require you to fill out a questionnaire (about 15- 20 mins) at least twice. A reply within two weeks would be helpful. A summary of responses from the entire group of experts will be presented to you after each round of questionnaire administration. Details of the study and requirements for the Delphi survey are presented in the attached information sheets. The study aims to contribute knowledge on the subject area as well as provide recommendations towards overall improvement in the operationalisation of an integrated SHE management system within construction organisations.

Thank you for reading this invitation, your favourable consideration of this request is greatly appreciated.

Yours sincerely

....
(Millicent Asah- Kissiedu (Doctoral Researcher)

Appendix B

PARTICIPANT INFORMATION SHEET

A SURVEY OF INTEGRATED SAFETY, HEALTH AND ENVIRONMENTAL ELEMENTS/ACTIVITIES

Project Information

Research: Developing an integrated safety, health and environmental management capability maturity model for uptake by construction companies in Ghana

Aim: The primary aim of this research is to identify the relevant safety, health and environmental (SHE) management elements/attributes to be incorporated into an integrated SHE management maturity model.

Invitation

You are cordially invited to participate in this research as an expert panellist in a Delphi survey.
A Delphi survey is a structured communication technique for collecting data from experienced or knowledgeable individuals in a particular subject. These experts are required to respond to short questionnaires in two or more rounds.

Research Procedure

Your expertise and participation are vital to the validation and reliability of this study. I will, therefore, be very grateful if you could answer all questions to the best of your ability. No response shall be considered wrong. You are not required to provide any data that will make you identifiable. Information you provide is strictly for research purposes and aimed at informing the development of an integrated SHE management maturity model. Participation in this research is voluntary, but if you decide to take part it will be very helpful. However, if you do not want to take part, you are under no obligation to do so. You may withdraw your responses at any time(before/during/after) if you so wish. However, as the Delphi technique is such that subsequent rounds are informed by the results of the previous rounds, you will be given seven (7) days after your responses has been received to withdraw from any round you participate in.

If you wish to withdraw at any time, you will be required to email the Doctoral researcher or the Director of studies, respectively stating your unique identification code

All information collected will be stored securely. You will not be identified at any point in this research because the data collection is anonymous. The research is granted ethical approval by the University of the West of England, Bristol, ethics committee. If you have any concerns that you want to be addressed by an independent person, you may contact the head of department of Architecture and the Built environment at UWE.
The questionnaire should take you approximately **15-20 minutes** to complete. Please return the completed questionnaire by email to the doctoral researcher below. Kindly take note of the unique identifier code you are provided with as a member of the expert panel. You will need this code for any confidential future correspondence you may wish to have with the research team about your completed questionnaire. Findings and final report will be available for your perusal upon request.

Thank you for reading this information sheet and considering participation in this research project**.** If you are unsure about what is written here, please do not hesitate to contact us with any queries.

Kind regards,

Millicent Asah-Kissiedu

Delphi Panel ID/code ……………………… ……………..

PARTICIPANT CONSENT FORM - DELPHI STUDY

Research Title: Developing an integrated safety, health and environmental management capability maturity model for uptake by construction companies in Ghana

You have been invited to participate in a Delphi survey as part of the PhD research on the relevant integrated safety, health and environmental (SHE) management elements/attributes. The thoughts, knowledge and experience you share will feed into the development of an integrated safety, health and environmental management capability maturity model for uptake by construction companies in Ghana.

Please tick (☑)in the appropriate boxes (*Point the cursor on the box and click)*

I confirm that I have read and understood the *Participant Information Sheet* for the above study and have had an opportunity to ask questions.	☐
I understand that participation is voluntary and that in each round of the Delphi survey, I may withdraw my responses up to 7 days after submitting the questionnaire.	☐
I understand that my identity will never be revealed to anyone outside the researcher and supervision team.	☐
I understand the reason for this study and agree to participate	☐

Date…………………………………………………………………………………

PLEASE KEEP A COPY AND RETURN A COPY TO THE RESEARCHER

<u>Invitation letter to participate in the Delphi Exercise (Round 1)</u>

Dear …………...

Expert Unique ID: ……………………………...

Integrated Safety, Health and Environmental Management Capability Maturity Survey-Round One

I would like to thank you once again for joining the expert panel assembled for this research. You are part of an expert panel of 30+ Safety, health and environmental management professionals who will participate in this research. This phase of the research involves expert panellists responding to about three rounds of a brief questionnaire survey.

Your expert ID is provided above. You will be asked to provide your ID when you complete the questionnaire. The questionnaire is available online at https://uwe.onlinesurveys.ac.uk/safety-health-and-environmental-management-capability-sur**.** The next couple of weeks might be busy times for you and so the research team really appreciates you taking about **10-15 minutes** of your time to complete the survey. Kindly complete the survey by **Tuesday, 6th June 2018**. I will send reminders as the deadline draws closer. I look forward to receiving your responses promptly.

If you have any queries, please do not hesitate to email me or any member of the supervisory team.

Thank you for your help.

Invitation letter to participate in the Delphi Exercise (Round 2)

Dear……………….

Integrated Safety, Health and Environmental Management Capability Maturity Survey-
<u>Round Two.</u>

Thank you very much for responding to the Delphi Questionnaire (Round 1). Attached to the email is the second-round questionnaire of the Delphi study on ranking the level of importance of organisational attributes to the practice of SHE management by a construction company. It is estimated that this round of questionnaire will take approximately **15 - 20** minutes to complete.
The second-round Delphi questionnaire contains your own ranking of attributes from the **first round of Delphi** and the **median ranking** based on all the responses from the expert panellists. You are required to reflect on this information and then rank the attributes again.

Kindly complete and return your questionnaire by email by **29th June 2018**. I will send reminders as the deadline draws closer. I look forward to receiving your responses promptly. Your response will be analysed and you will be contacted for the final round (3) in due course.
Once again, thank you for your co-operation and continued participation in this survey. If you have any further questions concerning this survey please do not hesitate to contact the researcher or any member of the supervisory team.

Thank you for your help.

REMINDER EMAIL

Dear Sir/Madam

REMINDER: Integrated Safety, Health and Environmental Management Capability Maturity Survey

I trust that you are fine.

I sent you an email a couple of days ago to participate in the above-mentioned survey. This is a gentle reminder for you to complete the survey which is available at https://uwe.onlinesurveys.ac.uk/safety-health-and-environmental-management-capability-matu . I would be very grateful if you could complete the survey by **Monday 22nd February, 2018**. The questionnaire should take you approximately **15-20 minutes to complete.**

If you have any questions or would like further information, please do not hesitate to email me or a member of the supervisory team.

Thank you for your help.

Appendix C: Delphi round one questionnaire

Safety, Health and Environmental Management Capability Survey: Round 1

Page 1: Information Sheet

This survey is part of a doctoral research that seeks to develop an integrated safety, health and environmental (SHE) management capability maturity model that would assist Ghanaian construction companies to better manage SHE challenges. The research, which is sponsored by the Commonwealth Scholarship Commission, is being undertaken by Ms Millicent Asah-Kissiedu under the supervision of Dr Patrick Manu, Dr Colin Booth, and Dr Abdul-Majeed Mahamadu at the University of the West of England (UWE), Bristol.

You have been identified as someone whose expertise in safety and health and/or environmental management would benefit the research. The research team would be most grateful if you could participate in this study. You have been given a unique ID in the email you received requesting you to participate in this research. You will be asked to provide this ID on the next page of the survey. Participation in this research is voluntary and you may withdraw your responses from the research at any time prior to when all the responses from this survey have been analysed. Should you wish to withdraw your responses, kindly contact the research team, while providing your unique ID. All information collected will be stored securely and you will not be identified at any point in this research.

This aspect of the research involves panellists responding to about three iterations of a questionnaire survey. The questionnaire is in two sections. Section A requests for your expert panel member unique identifier code and other personal information. Section B seeks to identify the relative importance of a set of SHE attributes for the development of an integrated SHE management model for a construction company.

Please answer all the questions to the best of your ability. The questionnaire should take you approximately 10-15 minutes to complete. If you have any queries regarding this survey please contact the research team using the contact information below.

The research is granted ethical approval by the UWE ethics committee. If you have any ethical queries that you want to be addressed by an independent person, you may contact the ethics committee at UWE by email.

Thank you very much for your time.

Please click on the "Next" button below to proceed with the survey.

Page 2: Section A: Expert Identifier Code, Background and Consent

1. Please provide your expert panel member unique identification code which was given to you for this research via email. Please specify:

2. I confirm that I have read the Information Sheet (on the previous page) for this research and understood the information provided therein
   ☐ Yes

3. I agree to participate in the research
   ☐ Yes

4. Type of organisation you work for
   ☐Client organisation
   ☐Contractor organisation
   ☐Consultancy
   ☐Other

4a. If you selected Other, please specify:

4b. If you chose Consultancy, please specify

5. Your role (e.g. Health and Safety manager or Environmental manager)

6. Please indicate your area(s) of expertise. (Tick as appropriate, multiple options are applicable)

☐ Health and safety
☐ Environmental management
☐ Construction management
☐ General Construction
☐ Other

6a. If you selected Other, please specify:

7. Please indicate your overall years of experience in health and safety e.g. 3 years in health and safety

8. Please indicate your overall years of experience in environmental management e.g. 2 years in environmental management

9. Please provide your professional qualifications/affiliations e.g. member of GHIS

10. Please provide your highest academic qualification e.g. MSc in Construction Management.

Page 3: Section B: Safety, Health and Environmental Management Attributes.

Preamble

Below is a list of SHE attributes of an integrated safety, health and environmental (SHE) management framework that will form the basis for the development of a SHE management capability maturity model for construction companies in Ghana to manage SHE challenges.

You are asked to rank the attributes with each category based on their level of importance to the practice of SHE management by a construction company. The topmost important attribute should be given the rank of **1st,** followed by **2nd**, in that order. Where you believe two or more attributes should have equal or same rank, please indicate this in your ranking of the attributes. For example, a ranking of four attributes (A, C X and Y) as: **A= 1st. Y=2nd, C= 2nd and X = 4th**

In this example, two of the four attributes are considered to have the same rank of

importance.

11. Please rank the following five (5) attributes based on their level of importance to the practice of SHE management by a construction company. *Please type the ranking in the boxes provided.*

THEMATIC CATEGORY	**Required**
STRATEGY i.e. the organisation's vision and top management commitment to SHE management.	

PROCESSES i.e. the organisation’s procedures, processes and systems for SHE management	
PEOPLE i.e. organisation's human capital, their roles, responsibilities, and involvement in SHE management.	
RESOURCES i.e. organisation's physical and financial resources required for SHE management	
INFORMATION i.e. SHE related documents, data, lessons, records and their communication across an organisation	

12. **STRATEGY ATTRIBUTES**: **-** Please rank the following four (4) attributes based on their level of importance to the practice of SHE management by a construction company. *Please type the ranking in the boxes provided.*

STRATEGY ATTRIBUTES	**Required**
SENIOR MANAGEMENT COMMITMENT i.e. senior management commitment to safety, health, and environment (SHE) management.	
SHE POLICY i.e. an integrated SHE policy that serves as the foundation for a company's SHE development and implementation.	
SHE OBJECTIVES and TARGETS i.e. the SHE objectives and targets for a company, in line with SHE policy.	
SHE MANAGEMENT PROGRAMME i.e. the company’s management action plans for achieving the SHE objectives and targets.	

13. **PROCESS ATTRIBUTES: -** Please rank the following seven (7) attributes based on the level of importance to the practice of SHE management by a construction company. *Please type the ranking in the boxes provided*.

PROCESS ATTRIBUTES	**Required**
SHE RISKS MANAGEMENT i.e. systems, processes, and procedures for risks assessment and identification of 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 RESPONSE 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 INVESTIGATIONS 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.	

14. **PEOPLE ATTRIBUTES**: **-** Please rank the following four (4) attributes based on their level of importance to the practice of SHE management by a construction company. *Please type the ranking in the boxes provided.*
15.

PEOPLE ATTRIBUTES	**Required**
SHE ROLES AND RESPONSIBILITIES i.e. availability of dedicated SHE roles and responsibilities within an organisational hierarchy.	
SHE TRAINING i.e. provision of suitable SHE training for personnel.	
EMPLOYEE INVOLVEMENT IN SHE i.e. consultation and involvement of personnel at all levels of SHE management.	
SHE COMPETENCE i.e. the skills, knowledge, and experience of personnel to undertake responsibilities and perform SHE activities.	

16. **RESOURCES ATTRIBUTES: -** Please rank the following two (2) attributes based on their level of importance to the practice of SHE management by a construction company. *Please type the ranking in the boxes provided*.

RESOURCES ATTRIBUTES	**Required**

PHYSICAL SHE RESOURCES i.e. provision of physical resources for SHE implementation (e.g. personal protective equipment)	
FINANCIAL RESOURCES for SHE i.e. provision of financial resources for SHE implementation	

16. **INFORMATION ATTRIBUTES: -** Please rank the following two (2) attributes based on their level of importance to the practice of SHE management by a construction company. *Please type the ranking in the boxes provided*

INFORMATION ATTRIBUTES	**Required**
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.	

Page 4: Thank You!

Thank you very much for completing the questionnaire. The research team will be in touch soon for the 2nd round of the questionnaire survey. In the 2nd round, you will be given feedback based on the aggregated responses of all the experts. Your own responses will also be sent to you, and then in the light of the feedback you will be asked to reconsider your responses

Appendix D: Delphi round two questionnaire

SAFETY, HEALTH AND ENVIRONMENTAL MANAGEMENT CAPABILITY SURVEY: Round 2

INFORMATION SHEET

Thank you for completing the round 1 questionnaire survey and welcome to Round 2.

The round 2 questionnaire consists of two sections. Section **A** shows your expert panel member unique identification code. **Section B** seeks to identify the relative importance of the organisational attributes/characteristics that can be used to ascertain a construction firm's organisational capability in relation to safety health and environmental (SHE) management. In this section, you are shown your ranking of attributes from the **round 1** survey and the median ranking based on all the responses from the expert panellists in round 1. You are then asked to reflect on this information and rank the attributes again. This is to give experts the opportunity to re-consider their ranking of the attributes.

You can either change your rankings of the attributes or rank the attributes same way as you did in the round 1.

The questionnaire should take you approximately **10-15 minutes** to complete. **Please email the completed questionnaire to the researcher.** If you have any queries regarding this survey please contact the research team using the contact information below.

Thank you very much for your time.

Section A: - Identifier Code

Your expert panel member unique identification:

Capability Attributes

Preamble*:*

In this section, you are given SHE management capability attributes of a construction company. You are also shown **your ranking of the attributes from the round 1 survey** and the **median ranking**** based on all the round 1 responses from the expert panellists. You are then asked to reflect on this information and then rank the attributes again. The topmost important attribute should be given the rank of **1st**, followed by **2nd** and then other ranks in that sequence. Where you believe two or more attributes should have equal or same rank, please indicate this in your ranking of the attributes.

******Median*** *is the value which occupies the* ***middle position*** *when all the values are arranged in an ascending order. For example, if the ranking of an attribute, X, by 7 experts is 1, 2, 3,* ***3****, 4, 5, 6, then the median rank for X is* ***3****.*

Question 1: Please rank the following **six** attributes based on their level of importance to the practice of SHE management by a construction company. Please type the ranking in the "**My Round 2 Rank**" boxes provided.

Attributes	Round 1 Median Rank	My Round 1 Rank	My Round 2 Rank
STRATEGY i.e. the organisation's vision and top management commitment to SHE management.			
PROCESSES i.e. the organisation's procedures, processes and systems for SHE management			
PEOPLE i.e. organisation's human capital, their roles, responsibilities, and involvement in SHE management			
RESOURCES i.e. organisation's physical and financial resources required for SHE management			
INFORMATION i.e. SHE related documents, data, lessons, records and their communication across an organisation			

Question 2: Strategy attributes: **-** Please rank the following **six** attributes based on their level of importance to the practice of SHE management by a construction company. Please type the ranking in the "**My Round 2 Rank**" boxes
provided.

Strategy attributes	Round 1 Median Rank	My Round 1 Rank	My Round 2 Rank
SENIOR MANAGEMENT COMMITMENT i.e. Senior management commitment to safety, health and environment (SHE) management			
SHE POLICY i.e. An integrated policy that serves as the foundation for a company's SHE development and implementation			
SHE OBJECTIVES AND TARGETS i.e. SHE objectives and targets for a company, in line with SHE policy			
SHE MANAGEMENT PROGRAMME i.e. Company's management action plans for achieving SHE objectives and targets			

SENIOR MANAGEMENT COMMITMENT i.e. Senior management commitment to safety, health and environment (SHE) management			

Question 3: Processes attributes: - Please rank the following three attributes based on their level of importance to the practice of SHE management by a construction company. Please type the ranking in the "**My Round 2 Rank**" boxes provided.

Strategy attributes	Round 1 Median Rank	My Round 1 Rank	My Round 2 Rank
SHE RISK 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.			

Question 4: People attributes - Please rank the following four attributes based on their level of importance to the practice of SHE management of a construction company. Please type the ranking in the "**My Round 2 Rank**" boxes provided.

Systems attributes	Round 1 Median Rank	My Round 1 Rank	My Round 2 Rank
SHE ROLES AND RESPONSIBILITES 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 IN SHE i.e. consultation and involvement of workforce 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			

Question 5: Resources attributes: **-** Please rank the following two attributes based on their level of importance to the practice of DfOSH by a design firm. Please type the ranking in the "**My Round 2 Rank**" boxes provided.

Infrastructure attributes	**Round 1 Median Rank**	**My Round 1 Rank**	**My Round 2 Rank**
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			

Question 6: Information attributes: **-** Please rank the following two attributes based on their level of importance to the practice of DfOSH by a design firm. Please type the ranking in the "**My Round 2 Rank**" boxes provided.

Systems attributes	**Round 1 Median Rank**	**My Round 1 Rank**	**My Round 2 Rank**
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.			

THE END

THANK YOU!!!

Appendix E: Delphi round three questionnaire

SAFETY, HEALTH AND ENVIRONMENTAL MANAGEMENT CAPABILITY SURVEY: Round 3

INFORMATION SHEET

Thank you for completing the round 2 questionnaire survey and welcome to Round 3.

The round 3 questionnaire consists of two sections. Section **A** shows your expert panel member unique identification code. **Section B** seeks to identify the relative importance of the organisational attributes/characteristics that can be used to ascertain a construction firm's organisational capability in relation to safety health and environmental (SHE) management. In this section, you are shown your ranking of attributes from the **round 2** survey and the median ranking based on all the responses from the expert panellists in round 2. You are then asked to reflect on this information and rank the attributes again. This is to give experts the opportunity to re-consider their ranking of the attributes.
You can either change your rankings of the attributes or rank the attributes same way as you did in the round 1.

The questionnaire should take you approximately **10 minutes** to complete. **Please email the completed questionnaire to the researcher.** If you have any queries regarding this survey please contact the research team using the contact information below.
Thank you very much for your time.

Section A: - Identifier Code

Your expert panel member unique identification:

Section B: Safety, Health and Environmental Management Capability Attributes

Preamble:

In this section, you are given SHE management capability attributes of a construction company. You are also shown **your ranking of the attributes from the round 1 survey** and the **median ranking**** based on all the round 1 responses from the expert panellists. You are then asked to reflect on this information and then rank the attributes again.

The topmost important attribute should be given the **rank of 1st, followed by 2nd and then other ranks in that sequence**. Always consider the number of attributes in the category before ranking.

Where you believe two or more attributes should have equal or same rank, please indicate this in your ranking of the attributes.

****Median** is the value which occupies the **middle position** when all the values are arranged in an ascending order. For example, if the ranking of an attribute, X, by 7 experts is 1, 2, 3, **3**, 4, 5, 6, then the median rank for X is **3**.*

Question 1: People attributes - Please rank the following four attributes based on their level of importance to the practice of SHE management of a construction company. Please type the ranking in the "**My Round 3 Rank**" boxes provided.

People attributes	**Round 2 MEDIAN RANK**	**My Round 2 Rank**	**My Round 3 Rank**
ROLES AND RESPONSIBILITIES i.e. availability of dedicated SHE roles and responsibilities within organisational hierarchy	**2**		
TRAINING i.e. provision of suitable SHE training for personnel	**2**		
EMPLOYEE INVOLVEMENT i.e. consultation and involvement of workforce at all levels in SHE management and operations	**2**		
SHE COMPETENCE i.e. the skills, knowledge and experience of personnel to undertake responsibilities and perform SHE activities	**1**		

Question 2: Resources attributes: - Please rank the following two attributes based on their level of importance to the practice of SHE management of a construction company. Please type the ranking in the "**My Round 3 Rank**" boxes provided.

Resources attributes	**Round 2 MEDIAN RANK**	**My Round 2 Rank**	**My Round 3 Rank**

PHYSICAL RESOURCES i.e. Provision of physical resources for SHE implementation	**1**		
FINANCIAL RESOURCES i.e. Provision of financial resources for SHE implementation	**1**		

THE END

THANK YOU!!!

Appendix F: Capability maturity levels for each attribute and their sources

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					References
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
SENIOR MANAGEMENT COMMITMENT	*As maturity increases, senior management commitment to safety, health and environmental (SHE) management becomes unwavering, visible and well-articulated across the company.*	• Lack of senior management commitment to SHE management • There is no resource commitment (financial and human resources) for SHE related issues	• Limited commitment by company's senior management to SHE implementation • Limited resource commitment for SHE related issues	• Partial commitment by company's senior management to SHE implementation • Show of senior management commitment is reactive (e.g. when significant risks are anticipated or response to a major environmental impacts) • An adhoc implementation committee is established • SHE champion is identified • There is resources commitment for SHE related issues.	• Firm commitment by company's senior management to SHE implementation. • Senior management commitment is aligned to company's policy on integrated SHE management. • Senior management are amongst the SHE champions within the organisation. • Management commitment is well articulated across the company Sufficient resources commitment for SHE related issues.	• There is a full, unwavering and clearly visible commitment of company's senior management to SHE implementation • Senior management continuously and visibly demonstrate their commitment to SHE and show shared values directed at continually meeting SHE objectives safely • A cross functional SHE implementation committee is established including a SHE champion, and members from all key management functions of the company. • There is a ring-fenced resource commitment for SHE implementation and maintenance Company senior manager(s) are amongst SHE management champions within the industry and are recognised as industry thought-leaders in respect of SHE management	Pen state BIM tool p.1 (2013) Yeo *et al.* (2009) p. 16 Defence Aviation Safety Manual (DASM, 2015) p.10 Civil aviation authority New Zealand (CAAnz, 2016) p.8 -9 (SMS evaluation tool) Department of transport, Canada, (DOTc, 2005) p. 12

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					References
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
SHE POLICY	*As maturity increases, company SHE policy becomes explicitly stated, well-communicated within the organisation, and interpreted and applied consistently by all managers/supervisors and staff.*	• No policy statement on integrated SHE management	• SHE policy statement is basic and vaguely worded. • SHE policy does not meet the legal requirements and personnel are rarely involved. • Policy has not been communicated and documented	• Policy on SHE management is clear, setting out the intention(s) on how SHE is managed, tracked and reported. • Policy meets some of the legal requirement with some personnel actively involved • Policy is communicated across different levels of the company, but management/supervisors and personnel have inconsistent interpretations and applications of the policy. • Policy statements may not be displayed at workplace and not formally documented	• SHE policy is comprehensive, well-defined and presents a clear approach to managing SHE including the required accountability and responsibility for managing SHE. • SHE policy meets all the legal requirements and other requirements the company subscribes to. • SHE policy is actively communicated within the company and to other stakeholders. • Policy is accepted, understood and consistently interpreted and applied in the same way by all manager's /supervisors and employees • SHE policy is formally documented, displayed at the workplace and is available to all stakeholders.	• Clear policy on SHE management, setting out intention(s) on integrated SHE management and recognising that SHE implementation is not a separate task but an integral part of SHE management • Documented policy is consistent with other best-performing organisation's policies • SHE policy is periodically reviewed and optimised to ensure that it remains relevant to the company, reflect industry best practices and demonstrate effectiveness and continuous improvement	Pen state BIM tool p.1 Yeo *et al.*, (2009) p. 16 Defence Aviation Safety Manual (DASM, 2015) p.10 Civil aviation authority New Zealand (CAAnz, 2016) p.8 -9 (SMS evaluation tool) Department of transport, Canada, (DOTc, 2005) p. 12
SHE RISK MANAGEMENT				• Formal processes and procedures for SHE hazards identification and SHE risk assessment • SHE risks control measures are somewhat defined • More involvement of SHE personnel • Adequate records are maintained	• Formal, more detailed and proactive processes and procedures for SHE hazards identification and SHE risk assessment • Processes and plans for SHE risks management are modelled on best practice risks assessment standards • SHE risks control measures are well defined and comprehensive • All levels of SHE personnel and other stakeholders are involved • Appropriate records are accurately maintained	• Processes and procedures for SHE hazards identification and risk assessments are explicitly defined and embedded into company's SHE planning activities and routinely applied in decision making process in a consistent and pragmatic manner by all. • The approach to SHE risks assessment and management are applied consistently throughout the company to drive continual improvement in the SHE risks profile of the company. • SHE risks management processes, procedures and control measures are monitored, reviewed and improved on a regular basis to address changing circumstances and ensure continuing effectiveness.	AC2E model performance matrix (Carilion Plc., 2005) HSE, (2007) p. 98 ORR, 2017 RM[3] p.19- 20 DASM, (2015) p.10 DOTc, (2005) p.12

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					References
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
SHE OBJECTIVES AND TARGETS	*High maturity levels would be characterised by setting SHE objectives and targets that are 'specific, measurable, agreed with those who deliver them, realistic and to a suitable timescale' (SMART) and well communicated and understood within the company*	• No, SHE objectives and targets are set	• SHE objects and targets are not SMART or prioritised. They are basic, vaguely worded and not based on any baseline review of the company's SHE operations • SHE objects and targets has not been communicated to personnel and relevant stakeholders within the company	• Some SHE objects and targets may be SMART and prioritised. They are defined based on a baseline review and consistent with SHE policy and applicable legal and other regulatory requirements. • SHE objects and targets is communicated to personnel and relevant stakeholders within the company.	• SHE objectives and targets are defined and mostly SMART and consistent with SHE policy and applicable legal and other regulatory requirements • Objectives and targets are documented and well-communicated to all relevant functions across the company	• SHE objectives and targets are clear, well defined, SMART, prioritised and in line with each other to support the overall SHE policy and focused towards continually improving SHE performance. • SHE objectives and targets are monitored, routinely reviewed and updated to ensure continuous improvement.	AC2E model performance matrix Carillon Plc., 2005) Hillsong, 2003, p8. HSE, 2007 p. 102 Foster and Holt, (2013) p. 5 CAAnz (2016) p. 16-18 DASM (2015) p.17

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					References
		Level 1	Level 2	Level 3	Level 4	Level 5	
SHE MANAGEMENT PROGRAMME	*As maturity increases, SHE management programs becomes adequate to achieve company's SHE objective and targets*	• There are no SHE management program(s) for achieving objectives and targets.	• Basic SHE plans and program(s) are available but without a clear definition of specific responsibilities and the time frame. • Little involvement of employees in establishing SHE plans and program(s)	• Formal and detailed management plans and program(s) are available • Key responsibilities, tactical steps, resources need and schedules are clearly defined to achieve SHE objectives and targets. • More involvement of employees in establishing SHE programmes	• SHE management plans and programme(s) are adequate, more detailed and integrated with company objectives, strategies and budgets • Full involvement of employees and other stakeholders • SHE plans and program(s) are clearly communicated to all who needs to know.	• SHE management plans and programmes are dynamic and integrated with company's SHE planning strategies • SHE management programmes are continuously reviewed and modified to address changes to company's operations for continuous improvement of SHE programmes	Penstate BIM tool p.1 ORR, 2017 p. 44-45 DOTc, (2005) p. 14
PHYSICAL SHE RESOURCES	*Higher maturity levels would be characterised by the provision of adequate physical SHE resources informed on a resource plan*	• No physical resources that enable SHE employees to perform SHE related tasks. • Resource provision is not informed by any strategic resource plan	• Limited physical resources that enable employees to perform SHE related tasks. • Company is ill-equipped with physical resources. • Resource provision is rarely informed by any strategic resource plan	• Sufficient physical resources that enable employees to perform SHE related tasks. • Company has the appropriate physical SHE resources. • Resource provision is usually reactive and occasionally informed by strategic resource plan	• Sufficient and well-organised physical resources that enable employees to perform SHE related tasks. • Company has adequate physical SHE resources. • A strategic resource plan is available to inform timely resource provision of SHE physical resources to specific roles throughout the company	• Company's physical work resources are advanced and current, and considered to be integral to SHE performance and competitiveness • Resource plans for provision for SHE physical resources are documented and integrated into company's processes and systems to improve effectiveness and efficiency. • Resource plans are regularly reviewed to ensure the provision of adequate and current resources to meet planned and agreed targets and objectives	Hillsong, 2003, p.8
FINANCIAL RESOURCES FOR SHE	*Higher maturity levels would be characterised by the availability of adequate financial sources on a resource plan*	• No financial resources for SHE implementation. • Unstable or insecure funding	• Limited financial resources for SHE implementation and rarely informed by a strategic resource plan • No established sources of funding	• Company has sufficient financial resources for SHE implementation • Provision of financial resources is occasionally informed by strategic resource plan • Established source of funding	• Company has sufficient and well organised funding lines for SHE implementation. • A strategic resource plan is available to inform timely provision of financial resources for effective SE management • Stable sources of funding	• Dedicated and adequate financial resources for effective SHE implementation and considered to be an integral part of the company's finance plan. • Highly stable funding	Succar, (2009) p. 32
ROLES AND RESPONSIBILITIES FOR SHE	*Higher maturity levels would be characterised by well-defined SHE*	• SHE roles, and responsibilities are not defined	• SHE roles and responsibilities are somewhat defined	• SHE roles and responsibilities for SHE management are mostly defined and allocated and	• SHE roles and responsibilities at all levels are adequately defined and communicated to designated personnel who	• SHE roles, responsibilities and authorities at all levels of the company are well-defined, adequate and documented.	MacGillivray *et al.*, (2007) p.17

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		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
	roles and responsibilities		• Some roles are unclear with specific responsibilities and authorities not well developed. • SHE roles and responsibilities are not recorded in job descriptions	inconsistently recorded in job descriptions	accept them in order to meet SHE objectives • All SHE roles and responsibilities are consistently recorded in key documentation (e.g. job descriptions) and appropriate communication media	• SHE roles, responsibilities and authorities are continuously revisited, realigned to effort and tracked to ensure proper distribution and continuous improvement	Schuh and Leviton, (2006) p.5 Rapaccini *et al.*, (2013) p. 7
SHE COMPETENCE	*Higher maturity levels would be characterised by company's SHE personnel having expert knowledge, skills as well as vast experience in SHE management, while lower maturity levels would be characterised by basic, SHE knowledge, skills and limited experience.*	• Company's SHE personnel do not have the skills, knowledge and the experience necessary for SHE management.	• The spread of SHE knowledge and skills amongst company's personnel is highly skewed towards basic knowledge and skills • An overwhelming majority of company's SHE personnel have basic SHE knowledge and skills, with no staff having advanced or expert skills and knowledge • Company's personnel have limited experience in SHE management tasks	• The spread of SHE knowledge and skills amongst company's personnel is mainly concentrated around basic to intermediate knowledge and skills. • A majority of company's SHE personnel have basic to intermediate SHE skills and knowledge with very few having advanced and/or expert skills and knowledge • Company's personnel have some experience in SHE management tasks	• The spread of SHE knowledge and skills amongst company's personnel is mainly concentrated around intermediate to advanced knowledge and skills. • A majority of company's SHE personnel have intermediate to advanced SHE skills and knowledge with very few having basic or no SHE skills, knowledge and experience • Company's personnel have adequate experience in SHE management tasks	• The spread of SHE knowledge and skills amongst company's personnel is skewed towards advanced and expert SHE knowledge and skills • An overwhelming majority of company's SHE personnel have advanced to expert SHE skills, and knowledge with very few or none having basic or no SHE skills and knowledge • Company's personnel have vast experience in SHE management tasks • Company's employees feel competent and capable to perform their SHE tasks.	AC2E model performance matrix. (Carillon Plc, 2005) Foster and Hoult, 2013 p. 5 Penstate BIM tool p.1 Succar, (2009) p. 34 CAAnz, (2016) p. 30-31 DoTs, (2005), p. 19 MAA, 2015.p.9 ASMPM
MANAGEMENT OF OUTSOURCED PERSONNEL	*As maturity increases, a well-structured competence management system and procedures is available and used in appointing competent outsource personal and assessing their competence and performance in SHE tasks*	• No procedure is used in appointing competent outsourced personnel, subcontractors and suppliers with regards to the management of SHE • No monitoring and assessment of the performance of outsourced	• Rare use of a procedure in appointing competent outsourced SHE personnel, subcontractors and suppliers • Rare monitoring and assessment of the performance of outsourced personnel, subcontractors and suppliers	• Occasional and reactive use of a procedure in appointing competent outsource personnel, subcontractors and suppliers. • Occasional and reactive assessment of the performance of outsourced personnel, subcontractors and suppliers • Procedures are adequately	• Regular and proactive use of a structured system and procedures in appointing competent outsource personnel, subcontractors and suppliers. • Regular and proactive assessment of the performance of outsourced personnel, subcontractors and suppliers. • All competency definitions are explicitly defined and include industry recognised best practice	• A well-structured and clear competence management system and procedures exists and are integral to and embedded within the company's performance of SHE management. • Competence and performance assessment procedures are reviewed regularly to ensure their current suitability and continuous improvement.	HSE, 2007 p.45 (CDM, 2007)

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					References
		Level 1	Level 2	Level 3	Level 4	Level 5	
		personnel, subcontractors and suppliers	• Procedures are poorly documented and maintained	documented and maintained	• Procedures are accurately documented and maintained		
SHE COMMUNICATIONS	*As maturity increases, all information about SHE management issues and resultant actions are adequately communicated through appropriate communication channels to all personnel at the right time. In addition, all personnel would become fully aware of all critical SHE information*	• No communication of any SHE related issues to personnel • No formal communication channels for effective flow of SHE information internally and externally in the company	• Limited communication of SHE information to personnel. • Communication is ad hoc and restricted to those involved in a specific incident • Company's personnel are unaware of important SHE information since communication is on a need to know basis across the company • Some informal and formal communication channels are established for communicating SHE information to all personnel but poorly documented	• There is a communication strategy. • More SHE information is occasionally communicated to all personnel. Personnel are aware of relevant SHE information. • Specific informal and formal communication channels exist for communicating SHE issues to personnel and adequately documented.	• Sufficient SHE information is routinely and regularly communicated to all personnel. Personnel are aware of critical SHE information. • All levels of employees are involved, and there are robust mechanisms for them to feedback • Appropriate informal and formal communication channels are available for communicating critical SHE information and resultant actions and accurately documented	• All pertinent SHE information and resultant actions are well communicated to all personnel across the company. SHE communication is a strong, and consistent two-way process. • Good practice is communicated both externally and internally • Established communication channels and methods are fully adopted throughout the supply chain in the company and consistently used for efficient coordination of SHE activities. • Communication methods for SHE information flow internally and externally are continuously monitored and regularly reviewed against identified best practices in other sectors for potential continuous improvement.	HSE, (2007) p.101 ORR, (2017) RM3 p.39-40
EMPLOYEE INVOLVEMENT IN SHE	*As maturity increases, all personnel would be actively involved and full consulted on SHE issues on a regular basis.*	• No consultation and involvement of personnel on SHE related issues	• Limited consultation on SHE issues, but not carried out in a systematic way. • Minority of the personnel are involved/engaged in safety-related issues	• More consultation on SHE issues is carried out in a systematic way • Majority of the personnel are involved/engaged in safety-related issues	• Greater and regular consultation on SHE issues is carried out in a range of ways (e.g. surveys, workshops, site meetings and committees) • Overwhelming majority of the personnel are involved/engaged in safety-related issues • Personnel involvement and consultation arrangements are documented and interested parties informed.	• All personnel are fully consulted and actively engaged in SHE related issues at all company's levels. • Company's uses personnel involvement to gather ideas for improvement on SHE issues • Company makes full use of personnel potential to develop shared values and a culture of trust, openness and empowerment	AC2E model performance matrix, Carilion Plc, (2005) DASM (2015) p.22 CAAnz (2016) p. 32 ORR, (2017) p. 29

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		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
SHE DOCUMENTATION AND CONTROL	*As maturity increases, documentations of all elements of the SHE management system and other SHE related records would become well organised, identifiable, traceable and accessible to all personnel and other interested parties*	• No documentations and records that describes company's SHE system elements and their interrelationships are available	• Documentations of some elements of a company's SHE system and other related SHE records are available to personnel • SHE documentations and records are not organised at all and easily not traceable and accessible	• Documentations and records of more elements a company's SHE system and other related SHE records are available to personnel • SHE documentations and records are minimally organised in file folders, somewhat traceable and accessible	• Documentations and records of all elements of the company's SHE system and other related SHE records are available to all personnel • All SHE documentations are mostly organised using appropriate software, and are traceable and accessible	• SHE documentations including other related SHE records are well organised identifiable, legible, traceable and readily accessible to all. • SHE documentations is integrated with other organisational documentations (such as human resource plans) for continuous improvement of company's functions. • SHE documentations are regularly reviewed and updated with appropriate version control in place, based on system improvements, to drive efficiency and effectiveness of the management system.	ORR, (2017) RM[3] p.37-38 Filho *et al.*, (2010) p. 7

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					References
		Level 1	Level 2	Level 3	Level 4	Level 5	
SHE OPERATIONAL CONTROL	*Higher maturity levels, would be characterised by adequate and documented procedures for identifying SHE operations and activities that are associated with identified risks. In addition, there would be adequate control measures for mitigating those SHE risks*	• No procedures for identification of SHE operations and activities that need to be controlled to ensure risk associated with them are minimised or eliminated. • SHE risks control measures are not in place	• Informal procedures are available for identification of SHE operations and activities that need to be controlled to ensure risk associated with them are minimised or eliminated • SHE controls measures, are unclear and poorly documented	• Formal procedures are available for identification of SHE operations and activities that need to be controlled. • Control measures for identified SHE risks are more detailed and clearly stated • Operation control procedures and measures are adequately documented	• Formal and comprehensive procedures are available for identification of SHE operations and activities that need to be controlled. • Control measures for identified SHE risks are comprehensive and well defined • Identified SHE operations that needs to be controlled and their associated control measures are appropriately documented and well communicated to relevant personnel (e.g. suppliers, contractors and other interested parties)	• Well-structured procedures for identification of those SHE operations and activities that are associated with identified risks where control measures need to be applied, exists, to ensure compliance and to achieve objectives. • Documented procedures and control measures are regularly reviewed and updated	MacGillivray *et al.*, (2007) p. 17 Koehler *et al.*, (2015) BSI, (2012) p.9 DOTc (2005) p.15 CAAnz (2016) p. 15 DASM, (2015) p.13-14 MAA Air Safety Management Performance Matrix, (2015) p.6 ASMPM

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SHE EMERGENCY PREPAREDNESS AND RESPONSE	*High maturity levels would be characterised by establishing appropriate and comprehensive emergency preparedness and response (EPAR) procedures and measures to mitigate possible emergencies*	• No EPAR procedures and measures for identification of possible emergencies and SHE accidents, and how to respond if they arise	• Basic EPAR procedures and measures are available for identification of possible emergencies and SHE accidents, and how to respond if they arise • EPAR procedures and measures are poorly documented and accessible • Personnel involved are rarely trained in basic emergency responses	• Formal EPAR procedures and measures are available for identification of possible emergencies and SHE accidents, and how to respond if they arise • EPAR procedures and measures are adequately documented but not easily accessible • Personnel are trained in formal emergency responses.	• Formal EPAR procedures and measures are sufficiently detailed and focused to address the specific emergency situations • EPAR procedures and measures are appropriately and accurately documented and integrated with company objectives, strategies and budgets. • EPAR procedures and measures are communicated and accessible to all personnel involve • Personnel are adequately trained in emergency responses	• Appropriate and comprehensive EPAR procedures and measures are available at all relevant levels of the company and are fully integrated with other control measures and benchmarked consistently against best practices. • EPAR plans are an integral part of the SHE management system and used when and where necessary to prevent or reduce the harmful effects of major SHE accidents and emergencies • EPAR plans are periodically tested for the adequacy of the plan and the results reviewed to improve its effectiveness for continuous improvement.	Hillson, 2003 p. 8 BSI, (2012) p. 10 Dababneh, (2007) p.12-13

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SHE PERFORMANCE MONITORING AND MEASUREMENT(MaM)	*Higher maturity would be characterised by establishing and maintaining well designed procedures and measures to monitor and measure safety performance on a regular basis. As maturity increases procedures and measures would be fully documented and effectively co-ordinated throughout the company to facilitate subsequent corrective and preventive actions analysis.*	• SHE performance procedures and measures for monitoring and measurement (MaM) are not established	• Basic procedures and measures are established for monitoring and measurement of SHE performance on an adhoc basis. • Some personnel are aware of the SHE performance measures in their areas of responsibility	• Formal and detailed MaM procedures and measures are established for monitoring and measurement of SHE performance occasionally • Monitoring is reactive • More personnel are aware of the SHE performance measures in the areas of responsibilities	• Formal and proactive procedures and measures are established for monitoring and measurement of SHE performance regularly within the company, with the purpose of improving the SHE system • monitoring and measurement procedures and measures are compliance led and used to track SHE performance • Monitoring is proactive • monitoring and measurement procedures and measures are adequately documented and communicated to all personnel • Personnel at all levels are aware of the critical SHE performance measures in their areas of responsibility.	• Well-designed and defined procedures and measures for monitoring, measuring and recording of SHE performance on a regular basis are institutionalised within the company, focusing on operational excellence and continuous improvement • Results of SHE performance monitoring and measurement are continuously used to improve the SHE management system. The results are fully documented and effectively co-ordinated throughout the company to facilitate subsequent corrective and preventive actions analysis. Best practice is shared across the entire company. • SHE performance monitoring and measurement procedures are periodically reviewed and improved to make sure they remain relevant to the company's risk profile.	Hillson, 2003 p.8 Health and safety culture maturity model, p. 3 ORR, 2017 p.53-54 DASM (2015) CAAnz (2016) p. 14 MAA Air Safety Management Performance Matrix, (2015) p.6 Dababneh, (2001) p. 13-14
SHE INCIDENTS INVESTIGATIONS	*Highest maturity levels would be characterised by structured processes and procedures for investigating SHE incidents. As maturity increases records of, SHE investigation process and required actions would be monitored, reviewed and documented*	• No processes and procedures for SHE incidents investigations • No evidence of SHE investigations	• Generic processes and procedures for SHE incidents investigations • The range of incidents investigated is limited to immediate causes of accidents and negative environmental impacts • Limited personnel involvement • SHE investigations processes and	• Formal processes and procedures for SHE incidents investigations • Investigations tend to focus on the direct and root causes of SHE incidents and near miss incidents • More personnel involvement in SHE investigations. • SHE investigations processes and procedures are somewhat documented	• Comprehensive and standard processes and procedures for SHE incidents investigations • Investigations probe more deeply to identify direct and indirect causes of SHE incidents that result in significant SHE risks • All personnel are involved in SHE incidents investigations • SHE incidents investigations procedures are communicated to relevant committees for appropriate recommendations and actions • SHE investigations processes and procedures are well documented and corrective	• Structured processes and procedures for proactive, consistently high quality SHE incidents investigations are evident and institutionalised within the company. • SHE incidents investigations procedures are clearly documented and linked to SHE hazards identification and risk mitigation process, and routinely reviewed and updated to drive continuous improvement. • Outcomes of investigations are documented, recommended, monitored and used in the design of the SHE processes and shared with industry	AC2E model performance matrix Carillon Plc, (2005) Hillson, 2003 p.8 Foster and Hoult, (2013) p. 10 ORR, (2017) p. 55-56 DOTc, (2005) p. 14 DASP (2015) ORR, (2017) p.55-57

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					References
		Level 1	Level 2	Level 3	Level 4	Level 5	
			procedures are not documented		actions well communicated to best utilise any lessons to be learned	• Corrective and preventive actions progress is reviewed regularly and updated as and when to ensure actions taken are effective.	
SHE SYSTEM AUDITS	*As maturity increases, there would be a well-defined audit plan and procedures, covering all aspects of the SHE system on a regular basis, to assess compliance, and SHE management system effectiveness*	• No clear SHE audits plan and procedures • No auditing of SHE system	• SHE audits plans and procedures are not well defined • Adhoc audit with no follow up. Company rarely undertake planned SHE system audits • Procedures for assessing SHE compliance is limited • Legal and regulatory obligations noncompliance • SHE audits plans are undocumented.	• SHE audits plan and procedures are somewhat defined and poorly documented • Company occasionally undertake planned SHE system audits • Most aspects of SHE system audited with some follow-up • SHE audits procedures and plans are focused on achieving compliance with legal and regulatory obligations. Minimal legal and regulatory compliance	• SHE audits plans and procedures are well defined and designed, modelled on best practice of audits • Company regularly undertake planned SHE audits. • All aspects of SHE system audited with some follow-up • Total legal and regulatory obligations compliance • Written recommendations, (e.g. non-compliances) are well documented and communicated to form the basis of SHE improvement and innovation.	• SHE audits plans and procedures are planned and prioritised, and covers all aspects of the SHE system • There is a company-wide audit scheme connected to review of annual plan • Regular SHE audits exist to demonstrate compliance with required standards, legal and regulatory obligations • Documented procedures for planned SHE audits are institutionalised within the company, and best practice shared internally with other functions of a company. • SHE audits plans and procedures are regularly maintained for periodic audits, and routinely updated to ensure continuous improvement that is in line with industry best performing companies	AC2E model performance matrix, Carillon Plc, (2005); Hillson, 2003 p.8 ORR, 2017 p. 58

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LESSONS LEARNED AND KNOWLEDGE ENT	*Higher maturity levels would be characterised by company using advanced digital technologies to routinely record consistent quality information in a well-structured manner. In addition, lessons learned would be consistently relied upon for continuous SHE improvement and innovation.*	• Company has no processes and procedures for capturing lessons in order to facilitate future improvement of the SHE management system. • No records of lessons learned. There is highly reliance on individual memory.	• Company's processes and procedures for capturing and disseminating lessons learned are characterised by poor/unstructured records keeping and inconsistent data. • Heavy reliance on manual record keeping of lessons • Lesson learned are rarely used for SHE management system continuous improvement and innovation	• Company's processes and procedures for capturing and disseminating lessons learned are characterised by well-structured record keeping and good information • Little reliance on manual record keeping and greater uses of digital technologies for record keeping • Records of lessons learned are sometimes relied on for SHE management system continuous improvement and innovation	• Company's processes and procedures for capturing and disseminating lessons learned are characterised by routinely well-structured record keeping and consistent high-quality information • Heavy reliance on advanced digital technologies for capturing and disseminating lessons • Records of lessons are consistently relied on for SHE decision making, continuous improvement and innovation • Processes and procedures for capturing and disseminating lessons learned are modelled on best practice knowledge management standards e.g. ISO 30401 Knowledge management system.	• Company's processes and procedures for capturing and disseminating lessons learned are well structured and institutionalised within the company and are considered a key measure of operational excellence. • Processes and procedures for capturing and disseminating lessons learned are routinely reviewed and updated to drive continuous improvement and innovation. • Well established SHE Knowledge Management system in place	HSE, (2007) p.100, Health and safety culture maturity model, p. 3 ORR, 2017 P,56-57 Foster and Hoult, (2013) CAAnz, (2016) p. 27 MAA, (2015)

Appendix G: Conceptual model for expert refinement

Instructions
(Please read all instructions carefully)

The objective of this stage is to have the SHE management capability maturity framework refined before it is validated.

1. The general capability level definitions are as follows:

Level 1	There are no structured processes and procedures in place. Resources and expertise are non-existent. Performance is consistently poor
Level 2	Organisational processes and procedures may exist but are usually ad-hoc and unstructured. Procedures and processes are not defined. Resources and expertise exist but inadequate. Performance is fair
Level 3	Organisational processes and procedures are formal and defined. Process and procedures are reactive. Resources and expertise exist but inconsistently applied. Performance is mostly good
Level 4	Organisational procedures and processes are planned, well-defined, proactive and generally, conform to best practices. Resources and expertise strategically allocated and effective. Performance is very good and consistently repeated
Level 5	Organisational processes and procedures are standardised, fully integrated throughout the organisation, and continually monitored, reviewed for continuous improvement. Performance is exemplary and comparable to best in the industry

This provides a clearer understanding of the peculiarity of each capability maturity level characteristics (i.e**. Level 1- low maturity to Level 5- high maturity).**

1. The capability attributes presented in this model relates to strategies, processes, people, resources and information, which guides a construction company to manage its SHE issues effectively to achieve better SHE outcomes. The capabilities attributes have been found to have influence on integrated SHE management in construction.

2. Through a review of literature related to SHE management capability attributes, best practice guides and existing capability maturity models, the underlying notion of maturity of each of the SHE management capability attribute was obtained and then used in formulating the five level descriptors of each of the twenty capability attributes.

3. The SHE management capability maturity framework (i.e. Document A) was developed consisting of capability attributes for integrated SHE management in construction and capability level descriptors of each attribute.

4. Carefully read the SHE management capability maturity framework (i.e. Document A.) While reading the document, **take note of the column to the right of maturity level.**

5. **On document A,** *kindly indicate your satisfaction with the quality and adequacy of each capability attribute, the characteristics describing each capability level for each capability attribute*. Do this by writing in the column to the right of maturity level 5 (Comments column)***. Please provide robust comments.***

6. **Please provide other comments that can <u>improve the model</u>**

7. Kindly return Documents A via email by Wednesday, 28th September 2018

Thank you for your time.

Conceptual safety, health and environmental capability maturity model (SHEM-CMM).

Below is a capability maturity model containing twenty (20) integrated SHE management capability attributes mapped against five (5) levels of SHE maturity described on a maturity scale of 1-5**. Kindly review and comment on your satisfaction with the key capability attributes and level definitions.**

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	**CAPABILITY LEVELS**					**Kindly review and comment on your satisfaction with the key capability areas and level definitions here**
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
SENIOR MANAGEMENT COMMITMENT	*As maturity increases, senior management commitment to safety, health and environmental (SHE) management becomes unwavering, visible and well-articulated across the company.*	• Commitment by company’s senior management to SHE management does not exists • No or minimal SHE resources commitment from senior management	• Limited commitment by company’s senior management to SHE implementation • Limited resource commitment for SHE related issues • Limited commitment is given to very basic controls for the purposes of tracking progress	• Partial commitment by company's senior management to SHE implementation • An adhoc implementation committee is established • SHE champion is identified • Some resources commitment for SHE related issues.	• Firm commitment by company's senior management to SHE implementation. • SHE champion is appointed with adequate skills and motivation to SHE implementation • Management commitment is well articulated across the company • Adequate resources (financial and human resources) commitment for SHE related issues.	• There is a full, unwavering and clearly visible commitment of company's senior management to SHE implementation (SHE policy, objectives). • Show of commitment is aligned to company’s’ SHE policy. • Senior management continuously and visibly demonstrate their commitment to SHE and show shared values directed at continually meeting SHE objectives safely • A cross functional SHE implementation committee is established including a SHE champion, and members from all key management functions of the company • There is a ring-fenced and sufficient resource commitment for SHE implementation and maintenance	
SHE POLICY	*As maturity increases, company SHE policy becomes explicitly stated, well-communicated within the organisation, and interpreted and applied consistently by all*	• No policy statement on integrated SHE management	• SHE policy statement is basic and vaguely worded. • SHE policy does not meet the legal requirements and personnel are rarely involved. • Policy has not been communicated and documented	• Policy on SHE management is clear, setting out the intention(s) on how SHE is managed, tracked and reported. • Policy meets some of the legal requirement with some personnel actively involved	• SHE policy is comprehensive, well-defined and presents a clear approach to managing SHE including the required accountability and responsibility for managing SHE. • SHE policy meets all the legal requirements and	• Clear policy on SHE management, setting out intention(s) on integrated SHE management and recognising that SHE implementation is not a separate task but an integral part of SHE management • Documented policy is consistent with other best-	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	Level 2	Level 3	Level 4	Level 5	
	managers/supervisors and staff.			• Policy is communicated across different levels of the company, but management/supervisors and personnel have inconsistent interpretations and applications of the policy. • Policy statements may not be displayed at workplace and not formally documented	other requirements the company subscribes to. • SHE policy is actively communicated within the company and to other stakeholders. • Policy is accepted, understood and consistently interpreted and applied in the same way by all manager's /supervisors and employees • SHE policy is formally documented, displayed at the workplace and is available to all stakeholders.	performing organisation's policies • SHE policy is periodically reviewed and optimised to ensure that it remains relevant to the company, reflect industry best practices and demonstrate effectiveness and continuous improvement	
SHE RISK MANAGEMENT	*High maturity levels would be characterised by well-defined and documented processes and procedures for SHE hazards identification and risks assessment applied in a consistent manner throughout the company*	• No processes and procedures for SHE hazards identification and SHE risk assessments	• Informal processes and procedures for SHE hazards identification and SHE risk assessments • Risk control measures are poorly defined • Limited involvement of SHE personnel • Poor records are maintained	• Formal processes and procedures for SHE hazards identification and SHE risk assessment • SHE risks control measures are somewhat defined • More involvement of SHE personnel • Adequate records are maintained	• Formal, more detailed and proactive processes and procedures for SHE hazards identification and SHE risk assessment • Processes and plans for SHE risks management are modelled on best practice risks assessment standards • SHE risks control measures are well defined and comprehensive • All levels of SHE personnel and other stakeholders are involved • Appropriate records are accurately maintained	• Processes and procedures for SHE hazards identification and risk assessments are explicitly defined and embedded into company's SHE planning activities and routinely applied in decision making process in a consistent and pragmatic manner by all. • The approach to SHE risks assessment and management are applied consistently throughout the company to drive continual improvement in the SHE risks profile of the company. • SHE risks management processes, procedures and control measures are monitored, reviewed and improved on a regular basis to address changing circumstances and ensure continuing effectiveness.	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	Level 2	Level 3	Level 4	Level 5	
SHE OBJECTIVES AND TARGETS	*High maturity levels would be characterised by setting SHE objectives and targets that are 'specific, measurable, agreed with those who deliver them, realistic and to a suitable timescale' (SMART) and well communicated and understood within the company*	• Few or no SHE objectives and targets are set	• SHE objects and targets are not SMART or prioritised. They are basic, vaguely worded and not based on any baseline review of the company's SHE operations • SHE objects and targets has not been communicated to personnel and relevant stakeholders within the company.	• Some SHE objects and targets may be SMART and prioritised. They are defined based on a baseline review and consistent with SHE policy and applicable legal and other regulatory requirements • SHE objects and targets is communicated to personnel and relevant stakeholders within the company.	• SHE objectives and targets are defined and mostly SMART and consistent with SHE policy and applicable legal and other regulatory requirements • Objectives and targets are documented and well-communicated to all relevant functions across the company	• SHE objectives and targets are clear, well defined, SMART, prioritised and in line with each other to support the overall SHE policy and focused towards continually improving SHE performance. • SHE objectives and targets are monitored, routinely reviewed and updated to ensure continuous improvement.	
SHE MANAGEMENT PROGRAMME	*As maturity increases, SHE management programs becomes adequate to achieve company's SHE objective and targets*	• There are no SHE management program(s) for achieving objectives and targets.	• Basic SHE plans and program(s) are available but without a clear definition of specific responsibilities and the time frame. • Little involvement of employees in establishing SHE plans and program(s)	• Formal and detailed management plans and program(s) are available • Key responsibilities, tactical steps, resources need and schedules are clearly defined to achieve SHE objectives and targets. • More involvement of employees in establishing SHE programmes	• SHE management plans and programme(s) are adequate, more detailed and integrated with company objectives, strategies and budgets • Full involvement of employees and other stakeholders • SHE plans and program(s) are clearly communicated to all who needs to know.	• SHE management plans and programmes are dynamic and integrated with company's SHE planning strategies • SHE management programmes are continuously reviewed and modified to address changes to company's operations for continuous improvement of SHE programmes	
PHYSICAL SHE RESOURCES	*Higher maturity levels would be characterised by the provision of adequate physical SHE resources*	• No physical resources that enable SHE employees to perform SHE related tasks.	• Limited physical resources that enable employees to perform SHE related tasks. • Company is ill-equipped with physical resources.	• Sufficient physical resources that enable employees to perform SHE related tasks. • Company has the appropriate physical SHE resources.	• Sufficient and well-organised physical resources that enable employees to perform SHE related tasks. • Company has adequate physical SHE resources.	• Company's physical work resources are advanced and current, and considered to be integral to SHE performance and competitiveness	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	Level 2	Level 3	Level 4	Level 5	
	informed on a resource plan	• Resource provision is not informed by any strategic resource plan	• Resource provision is rarely informed by any strategic resource plan	• Resource provision is usually reactive and occasionally informed by strategic resource plan	• A strategic resource plan is available to inform timely resource provision of SHE physical resources to specific roles throughout the company	• Resource plans for provision for SHE physical resources are documented and integrated into company's processes and systems to improve effectiveness and efficiency. • Resource plans are regularly reviewed to ensure the provision of adequate and current resources to meet planned and agreed targets and objectives	
FINANCIAL RESOURCES FOR SHE	*Higher maturity levels would be characterised by the availability of adequate financial sources on a resource plan*	• No financial resources for SHE implementation. • Unstable or insecure funding	• Limited financial resources for SHE implementation and rarely informed by a strategic resource plan • No established sources of funding	• Company has sufficient financial resources for SHE implementation • Provision of financial resources is occasionally informed by strategic resource plan • Established source of funding	• Company has sufficient and well organised funding lines for SHE implementation. • A strategic resource plan is available to inform timely provision of financial resources for effective SE management • Stable sources of funding	• Dedicated and adequate financial resources for effective SHE implementation and considered to be an integral part of the company's finance plan. • Highly stable funding	
ROLES AND RESPONSIBILITIES FOR SHE	*Higher maturity levels would be characterised by well-defined SHE roles and responsibilities*	• SHE roles, and responsibilities are not defined	• SHE roles and responsibilities are somewhat defined • Some roles are unclear with specific responsibilities and authorities not well developed. • SHE roles and responsibilities are not recorded in job descriptions	• SHE roles and responsibilities for SHE management are mostly defined and allocated and inconsistently recorded in job descriptions	• SHE roles and responsibilities at all levels are adequately defined and communicated to designated personnel who accept them in order to meet SHE objectives • All SHE roles and responsibilities are consistently recorded in key documentation (e.g. job descriptions) and appropriate communication media	• SHE roles, responsibilities and authorities at all levels of the company are well-defined, adequate and documented. • SHE roles, responsibilities and authorities are continuously revisited, realigned to effort and tracked to ensure proper distribution and continuous improvement	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
SHE TRAINING	*Higher maturity levels would be characterised by the regular provision of appropriate and adequate SHE training for personnel informed by a well-defined SHE training needs analysis*	• No provision of SHE related training for personnel • No formal training needs analysis undertaken	• Limited or minimal provision of SHE related training for personnel • Provision of SHE training is rarely informed by a formal training needs analysis • Identified training needs are not well defined and poorly documented	• Provision of SHE related training is reactive and typically provided only when needed, and occasionally informed by a formal training needs analysis • Identified training needs are somewhat defined and based on broad competency and performance objectives • Training needs adequately documented	• Regular provision of adequate SHE related training for personnel, informed by a formal and objective training needs analysis undertaken on a regular basis. • Training is usually proactive, tracked and evaluated to ensure its effectiveness • Training needs are well defined and accurately documented (e.g. in the employees' personal files) • Training is typically based on personnel SHE roles and respective competency objectives	• Appropriate and timely SHE training is delivered and integral to the company's human resource strategy to improve SHE performance • SHE related training programme is monitored for its effectiveness, periodically reviewed to ensure their current suitability and updated to also reflect organisational, regulatory changes and any other changes in technology and techniques, to allow continuous learning and improvement • Training needs analysis is regularly reviewed	
SHE COMPETENCE	*Higher maturity levels would be characterised by company's SHE personnel having expert knowledge, skills as well as vast experience in SHE management, while lower maturity levels would be characterised by basic, SHE knowledge, skills and limited experience.*	• Company's SHE personnel do not have the skills, knowledge and the experience necessary for SHE management.	• The spread of SHE knowledge and skills amongst company's personnel is highly skewed towards basic knowledge and skills • An overwhelming majority of company's SHE personnel have basic SHE knowledge and skills, with no staff having advanced or expert skills and knowledge • Company's personnel have limited experience in SHE management tasks	• The spread of SHE knowledge and skills amongst company's personnel is mainly concentrated around basic to intermediate knowledge and skills. • A majority of company's SHE personnel have basic to intermediate SHE skills and knowledge with very few having advanced and/or expert skills and knowledge • Company's personnel have some experience in SHE management tasks	• The spread of SHE knowledge and skills amongst company's personnel is mainly concentrated around intermediate to advanced knowledge and skills. • A majority of company's SHE personnel have intermediate to advanced SHE skills and knowledge with very few having basic or no SHE skills, knowledge and experience • Company's personnel have adequate experience in SHE management tasks	• The spread of SHE knowledge and skills amongst company's personnel is skewed towards advanced and expert SHE knowledge and skills • An overwhelming majority of company's SHE personnel have advanced to expert SHE skills, and knowledge with very few or none having basic or no SHE skills and knowledge • Company's personnel have vast experience in SHE management tasks • Company's employees feel competent and capable to perform their SHE tasks.	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					**Kindly review and comment on your satisfaction with the key capability areas and level definitions here**
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
MANAGEMENT OF OUTSOURCED PERSONNEL	*As maturity increases, a well-structured competence management system and procedures is available and used in appointing competent outsource personal and assessing their competence and performance in SHE tasks*	• No procedure is used in appointing competent outsourced personnel, subcontractors and suppliers with regards to the management of SHE • No monitoring and assessment of the performance of outsourced personnel, subcontractors and suppliers	• Rare use of a procedure in appointing competent outsourced SHE personnel, subcontractors and suppliers • Rare monitoring and assessment of the performance of outsourced personnel, subcontractors and suppliers • Procedures are poorly documented and maintained	• Occasional and reactive use of a procedure in appointing competent outsource personnel, subcontractors and suppliers. • Occasional and reactive assessment of the performance of outsourced personnel, subcontractors and suppliers • Procedures are adequately documented and maintained	• Regular and proactive use of a structured system and procedures in appointing competent outsource personnel, subcontractors and suppliers. • Regular and proactive assessment of the performance of outsourced personnel, subcontractors and suppliers. • All competency definitions are explicitly defined and include industry recognised best practice • Procedures are accurately documented and maintained	• A well-structured and clear competence management system and procedures exists and are integral to and embedded within the company's performance of SHE management. • Competence and performance assessment procedures are reviewed regularly to ensure their current suitability and continuous improvement.	
SHE COMMUNICATIONS	*As maturity increases, all information about SHE management issues and resultant actions are adequately communicated through appropriate communication channels to all personnel at the right time. In addition, all personnel would become fully aware of all critical SHE information*	• No communication of any SHE related issues to personnel • No formal communication channels for effective flow of SHE information internally and externally in the company	• Limited communication of SHE information to personnel. • Communication is ad hoc and restricted to those involved in a specific incident • Company's personnel are unaware of important SHE information since communication is on a need to know basis across the company • Some informal and formal communication channels are established for communicating SHE information to all personnel but poorly documented	• There is a communication strategy. • More SHE information is occasionally communicated to all personnel. Personnel are aware of relevant SHE information. • Specific informal and formal communication channels exist for communicating SHE issues to personnel and adequately documented.	• Sufficient SHE information is routinely and regularly communicated to all personnel. Personnel are aware of critical SHE information. • All levels of employees are involved, and there are robust mechanisms for them to feedback • Appropriate informal and formal communication channels are available for communicating critical SHE information and resultant actions and accurately documented	• All pertinent SHE information and resultant actions are well communicated to all personnel across the company. SHE communication is a strong, and consistent two-way process. • Good practice is communicated both externally and internally • Established communication channels and methods are fully adopted throughout the supply chain in the company and consistently used for efficient coordination of SHE activities. • Communication methods for SHE information flow internally and externally are continuously monitored and regularly	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	Level 2	Level 3	Level 4	Level 5	
						reviewed against identified best practices in other sectors for potential continuous improvement.	
EMPLOYEE INVOLVEMENT IN SHE	*As maturity increases, all personnel would be actively involved and full consulted on SHE issues on a regular basis.*	• No consultation and involvement of personnel on SHE related issues	• Limited consultation on SHE issues, but not carried out in a systematic way. • Minority of the personnel are involved/engaged in safety-related issues	• More consultation on SHE issues is carried out in a systematic way • Majority of the personnel are involved/engaged in safety-related issues	• Greater and regular consultation on SHE issues is carried out in a range of ways (e.g. surveys, workshops, site meetings and committees) • Overwhelming majority of the personnel are involved/engaged in safety-related issues • Personnel involvement and consultation arrangements are documented and interested parties informed.	• All personnel are fully consulted and actively engaged in SHE related issues at all company's levels. • Company's uses personnel involvement to gather ideas for improvement on SHE issues • Company makes full use of personnel potential to develop shared values and a culture of trust, openness and empowerment	
SHE DOCUMENTATION AND CONTROL	*As maturity increases, documentations of all elements of the SHE management system and other SHE related records would become well organised, identifiable, traceable and accessible to all personnel and other interested parties*	• No documentations and records that describes company's SHE system elements and their interrelationships are available	• Documentations of some elements of a company's SHE system and other related SHE records are available to personnel • SHE documentations and records are not organised at all and easily not traceable and accessible	• Documentations and records of more elements a company's SHE system and other related SHE records are available to personnel • SHE documentations and records are minimally organised in file folders, somewhat traceable and accessible	• Documentations and records of all elements of the company's SHE system and other related SHE records are available to all personnel • All SHE documentations are mostly organised using appropriate software, and are traceable and accessible	• SHE documentations including other related SHE records are well organised identifiable, legible, traceable and readily accessible to all. • SHE documentations is integrated with other organisational documentations (such as human resource plans) for continuous improvement of company's functions. • SHE documentations are regularly reviewed and updated with appropriate version control in place, based on system improvements, to drive efficiency and effectiveness of the management system.	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
SHE OPERATIONAL CONTROL	*Higher maturity levels, would be characterised by adequate and documented procedures for identifying SHE operations and activities that are associated with identified risks. In addition, there would be adequate control measures for mitigating those SHE risks*	• No procedures for identification of SHE operations and activities that need to be controlled to ensure risk associated with them are minimised or eliminated. • SHE risks control measures are not in place	• Informal procedures are available for identification of SHE operations and activities that need to be controlled to ensure risk associated with them are minimised or eliminated • SHE controls measures, are unclear and poorly documented	• Formal procedures are available for identification of SHE operations and activities that need to be controlled. • Control measures for identified SHE risks are more detailed and clearly stated • Operation control procedures and measures are adequately documented	• Formal and comprehensive procedures are available for identification of SHE operations and activities that need to be controlled. • Control measures for identified SHE risks are comprehensive and well defined • Identified SHE operations that needs to be controlled and their associated control measures are appropriately documented and well communicated to relevant personnel (e.g. suppliers, contractors and other interested parties)	• Well-structured procedures for identification of those SHE operations and activities that are associated with identified risks where control measures need to be applied, exists, to ensure compliance and to achieve objectives. • Documented procedures and control measures are regularly reviewed and updated	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
SHE EMERGENCY PREPAREDNESS AND RESPONSE	*High maturity levels would be characterised by establishing appropriate and comprehensive emergency preparedness and response (EPAR) procedures and measures to mitigate possible emergencies*	• No EPAR procedures and measures for identification of possible emergencies and SHE accidents, and how to respond if they arise	• Basic EPAR procedures and measures are available for identification of possible emergencies and SHE accidents, and how to respond if they arise • EPAR procedures and measures are poorly documented and accessible • Personnel involved are rarely trained in basic emergency responses	• Formal EPAR procedures and measures are available for identification of possible emergencies and SHE accidents, and how to respond if they arise • EPAR procedures and measures are adequately documented but not easily accessible • Personnel are trained in formal emergency responses.	• Formal EPAR procedures and measures are sufficiently detailed and focused to address the specific emergency situations • EPAR procedures and measures are appropriately and accurately documented and integrated with company objectives, strategies and budgets. • EPAR procedures and measures are communicated and accessible to all personnel involve • Personnel are adequately trained in emergency responses	• Appropriate and comprehensive EPAR procedures and measures are available at all relevant levels of the company and are fully integrated with other control measures and benchmarked consistently against best practices. • EPAR plans are an integral part of the SHE management system and used when and where necessary to prevent or reduce the harmful effects of major SHE accidents and emergencies • EPAR plans are periodically tested for the adequacy of the plan and the results reviewed to improve its effectiveness for continuous improvement.	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	Level 2	Level 3	Level 4	Level 5	
SHE PERFORMANCE MONITORING AND MEASUREMENT(MaM)	*Higher maturity would be characterised by establishing and maintaining well designed procedures and measures to monitor and measure safety performance on a regular basis. As maturity increases procedures and measures would be fully documented and effectively co-ordinated throughout the company to facilitate subsequent corrective and preventive actions analysis.*	• SHE performance procedures and measures for monitoring and measurement (MaM) are not established	• Basic procedures and measures are established for monitoring and measurement of SHE performance on an adhoc basis. • Some personnel are aware of the SHE performance measures in their areas of responsibility	• Formal and detailed MaM procedures and measures are established for monitoring and measurement of SHE performance occasionally • Monitoring is reactive • More personnel are aware of the SHE performance measures in the areas of responsibilities	• Formal and proactive procedures and measures are established for monitoring and measurement of SHE performance regularly within the company, with the purpose of improving the SHE system • monitoring and measurement procedures and measures are compliance led and used to track SHE performance • Monitoring is proactive • monitoring and measurement procedures and measures are adequately documented and communicated to all personnel • Personnel at all levels are aware of the critical SHE performance measures in their areas of responsibility.	• Well-designed and defined procedures and measures for monitoring, measuring and recording of SHE performance on a regular basis are institutionalised within the company, focusing on operational excellence and continuous improvement • Results of SHE performance monitoring and measurement are continuously used to improve the SHE management system. The results are fully documented and effectively co-ordinated throughout the company to facilitate subsequent corrective and preventive actions analysis. Best practice is shared across the entire company. • SHE performance monitoring and measurement procedures are periodically reviewed and improved to make sure they remain relevant to the company's risk profile.	
SHE INCIDENTS INVESTIGATIONS	*Highest maturity levels would be characterised by structured processes and procedures for investigating SHE incidents. As maturity increases records of, SHE investigation process and required actions would be monitored,*	• No processes and procedures for SHE incidents investigations • No evidence of SHE investigations	• Generic processes and procedures for SHE incidents investigations • The range of incidents investigated is limited to immediate causes of accidents and negative environmental impacts • Limited personnel involvement	• Formal processes and procedures for SHE incidents investigations • Investigations tend to focus on the direct and root causes of SHE incidents and near miss incidents • More personnel involvement in SHE investigations. • SHE investigations processes and	• Comprehensive and standard processes and procedures for SHE incidents investigations • Investigations probe more deeply to identify direct and indirect causes of SHE incidents that result in significant SHE risks • All personnel are involved in SHE incidents investigations	• Structured processes and procedures for proactive, consistently high quality SHE incidents investigations are evident and institutionalised within the company. • SHE incidents investigations procedures are clearly documented and linked to SHE hazards identification and risk mitigation process, and routinely reviewed and	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
	reviewed and documented		• SHE investigations processes and procedures are not documented	procedures are somewhat documented	• SHE incidents investigations procedures are communicated to relevant committees for appropriate recommendations and actions • SHE investigations processes and procedures are well documented and corrective actions well communicated to best utilise any lessons to be learned.	updated to drive continuous improvement. • Outcomes of investigations are documented, recommended, monitored and used in the design of the SHE processes and shared with industry • Corrective and preventive actions progress is reviewed regularly and updated as and when to ensure actions taken are effective.	
SHE SYSTEM AUDITS	*As maturity increases, there would be a well-defined audit plan and procedures, covering all aspects of the SHE system on a regular basis, to assess compliance, and SHE management system effectiveness*	• No clear SHE audits plan and procedures • No auditing of SHE system	• SHE audits plans and procedures are not well defined • Adhoc audit with no follow up. Company rarely undertake planned SHE system audits • Procedures for assessing SHE compliance is limited • Legal and regulatory obligations noncompliance • SHE audits plans are undocumented.	• SHE audits plan and procedures are somewhat defined and poorly documented • Company occasionally undertake planned SHE system audits • Most aspects of SHE system audited with some follow-up • SHE audits procedures and plans are focused on achieving compliance with legal and regulatory obligations. Minimal legal and regulatory compliance	• SHE audits plans and procedures are well defined and designed, modelled on best practice of audits • Company regularly undertake planned SHE audits. • All aspects of SHE system audited with some follow-up • Total legal and regulatory obligations compliance • Written recommendations, (e.g. non-compliances) are well documented and communicated to form the basis of SHE improvement and innovation.	• SHE audits plans and procedures are planned and prioritised, and covers all aspects of the SHE system • There is a company-wide audit scheme connected to review of annual plan • Regular SHE audits exist to demonstrate compliance with required standards, legal and regulatory obligations • Documented procedures for planned SHE audits are institutionalised within the company, and best practice shared internally with other functions of a company. • SHE audits plans and procedures are regularly maintained for periodic audits, and routinely updated to ensure continuous improvement that is in line with industry best performing companies	

SHE CAPABILITY ATTRIBUTES	Underlying notion of maturity (i.e. what represent maturity of each process area)	CAPABILITY LEVELS					Kindly review and comment on your satisfaction with the key capability areas and level definitions here
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	
LESSONS LEARNED AND KNOWLEDGE ENT	*Higher maturity levels would be characterised by company using advanced digital technologies to routinely record consistent quality information in a well-structured manner. In addition, lessons learned would be consistently relied upon* for *continuous SHE improvement and innovation.*	• Company has no processes and procedures for capturing lessons in order to facilitate future improvement of the SHE management system. • No records of lessons learned. There is highly reliance on individual memory.	• Company's processes and procedures for capturing and disseminating lessons learned are characterised by poor/unstructured records keeping and inconsistent data. • Heavy reliance on manual record keeping of lessons • Lesson learned are rarely used for SHE management system continuous improvement and innovation	• Company's processes and procedures for capturing and disseminating lessons learned are characterised by well-structured record keeping and good information • Little reliance on manual record keeping and greater uses of digital technologies for record keeping • Records of lessons learned are sometimes relied on for SHE management system continuous improvement and innovation	• Company's processes and procedures for capturing and disseminating lessons learned are characterised by routinely well-structured record keeping and consistent high-quality information • Heavy reliance on advanced digital technologies for capturing and disseminating lessons • Records of lessons are consistently relied on for SHE decision making, continuous improvement and innovation • Processes and procedures for capturing and disseminating lessons learned are modelled on best practice knowledge management standards e.g. ISO 30401 Knowledge management system.	• Company's processes and procedures for capturing and disseminating lessons learned are well structured and institutionalised within the company and are considered a key measure of operational excellence. • Processes and procedures for capturing and disseminating lessons learned are routinely reviewed and updated to drive continuous improvement and innovation. • Well established SHE Knowledge Management system in place	

Appendix H: Capability maturity model (after expert review)

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	Level 2	Level 3	Level 4	Level 5
1	**SENIOR MANAGEMENT COMMITMENT**	• Lack of senior management commitment to SHE management • There is no resource commitment (financial and human resources) for SHE related issues	• Limited commitment by company's senior management to SHE implementation • Limited resource commitment for SHE related issues	• Partial commitment by company's senior management to SHE implementation • Show of senior management commitment is reactive (e.g. when significant risks are anticipated or response to a major environmental impacts) • An adhoc implementation committee is established • SHE champion is identified • There is resources commitment for SHE related issues.	• Firm commitment by company's senior management to SHE implementation. • Senior management commitment is aligned to company's policy on SHE management. • Senior management are amongst the SHE champions within the organisation. • Management commitment is well articulated across the company • Sufficient resources commitment for SHE related issues.	• There is a full, unwavering and clearly visible commitment of company's senior management to SHE implementation • Senior management continuously and visibly demonstrate their commitment to SHE and show shared values directed at continually meeting SHE objectives safely • A cross functional SHE implementation committee is established including a SHE champion, and members from all key management functions of the company. There is a ring-fenced resource commitment for SHE implementation and maintenance Company senior manager(s) are amongst SHE management champions within the industry and are recognised as industry thought-leaders in respect of SHE management
	SHE POLICY	• No policy statement on SHE management	• SHE policy statement is outdated and vaguely worded. • SHE policy does not meet legal requirements and employees are rarely involved in its development. • Policy has not been communicated within the company and documented	• SHE policy statement is clear, setting out the intention(s) on how SHE is managed, tracked and reported. • Policy meets majority of legal requirement with some employees actively involved in its development • Policy is communicated across different levels of the company, but management or supervisors and employees have inconsistent interpretations and applications of the policy. • 3Policy statements are poorly documented and not displayed at workplace	• SHE policy is clear, comprehensive and well-defined, setting out the intention on SHE • SHE policy presents a clear approach to managing SHE including the required accountability and responsibility for managing SHE. • SHE policy meets all the legal requirements and other requirements the company subscribes to. • More relevant employees are actively involved in SHE policy formation and strategy formulation • SHE policy is actively communicated within the company and to other stakeholders.	• There is a clear policy on SHE management, setting out intention(s) on SHE management and recognising that SHE implementation is not a separate task but an integral part of the organisation SHE activities • All relevant people are engaged in SHE policy formation as wells as SHE strategy formulation, with clear actions, and accountabilities and targets. • Documented policy is in place, consistent with other best-performing organisation's policies, communicated and readily available to all stakeholders • SHE policy is periodically reviewed to ensure that it remains relevant to the company, reflect industry best practices and

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	Level 2	Level 3	Level 4	Level 5
					• Policy is accepted, understood and consistently interpreted and applied in the same way by all manager's or supervisors and employees • SHE policy is formally documented, displayed at the workplace and is available to all stakeholders.	demonstrate effectiveness and continuous improvement.
3	**SHE RISK MANAGEMENT**	• No processes and procedures for SHE hazards identification, risk assessment and control	• Informal processes and procedures for SHE hazards identification and risk assessments are in place • Risk control measures are poorly defined, understood and have limited application • SHE risks assessments and management are poorly documented	• Formal processes and procedures for SHE hazards identification and risk assessment are in place • Processes and procedures for identification and management of SHE risks, focuses on the most significant and obvious SHE risks • SHE risks assessments are carried out in isolation • Risk control measures are somewhat defined and used to reactively managed identified SHE risks • Most important SHE risks assessment activities and plans are documented	• Formal, more detailed and proactive processes and procedures for SHE hazards identification and risk assessment • Processes and procedures for identification and management focusses on specific, hazards and risks, including less obvious and immediate risks • Processes and procedures are consistently applied to identify and manage SHE risks. • SHE risks control measures are well defined, understood and implemented in a consistent manner. • All levels of SHE employees and other stakeholders can contribute to risks assessments • Appropriate SHE risks assessment records are accurately documented and maintained • Processes and plans for SHE risks management are modelled on best practice risks assessment standards e.g. ISO 31000	• Well-defined processes and procedures for SHE risks management are in place and practicable. • SHE risks management processes and procedures are embedded into company's SHE planning activities and considered as a core measure of operational excellence. • The approach to SHE risks assessment are routinely applied consistently throughout the company in a pragmatic manner to drive continual improvement in the SHE risks profile of the company. • SHE risks management processes, procedures and control measures are monitored, reviewed and improved on a regular basis to address changing circumstances and ensure continuing success.
4	**SHE OBJECTIVES AND TARGETS**	• No formal SHE objectives and targets identified and documented	• SHE objectives and targets are vaguely worded and not based on any baseline review of the company's SHE operations. They are not 'specific, measurable, attainable, relevant and timely (SMART) and prioritised. • People in relevant functional area(s)are not involved in setting SHE objectives and targets	• SHE objectives and targets are defined, formal, based on a baseline review and consistent with SHE policy and applicable legal and other regulatory requirements • Some SHE objectives and targets may be SMART and prioritised. • Some people in relevant functional areas(s) are involved in setting objectives and targets	• SHE objectives and targets are formal, well defined, mostly SMART, and consistent with SHE policy and applicable legal and other regulatory requirements • More people in relevant functional areas (s)are involved in setting SHE objectives and targets	• SHE objectives and targets are clear, SMART, prioritised and aligned to the overall SHE policy and focused towards continually improving SHE performance. • All relevant people are involved in setting SHE objectives and targets • Objectives and target are included in critical tasks or role descriptions of employees

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	Level 2	Level 3	Level 4	Level 5
			• Objectives and targets not included in critical tasks or role descriptions of employees • SHE objectives and targets are poorly documented and not communicated to employees and other stakeholders	• Objectives and targets are rarely included role descriptions of employees • SHE objectives and targets are somewhat documented and informally communicated to employees and relevant stakeholders within the company.	• Objectives and targets are included role descriptions of employees • Objectives and targets are properly documented and formally communicated to all relevant functions across the company	• SHE objectives and targets are adequately documented, monitored, routinely reviewed and updated to ensure continuous improvement.
5	**SHE MANAGEMENT PROGRAMME**	• There are no clearer or well defined SHE management programme(s) for achieving objectives and targets.	• SHE plans and programme(s) are available but without a clear definition of specific responsibilities and the time frame. • Little involvement of employees in establishing SHE plans and programme(s)	• Formal and detailed management plans and programme(s) are available • Key responsibilities, tactical steps, resources needed and schedules are clearly defined to achieve SHE objectives and targets. • More involvement of employees in establishing SHE programmes	• SHE management plans and programme(s) are adequate, more detailed and integrated with company objectives, strategies and budgets • Greater number of employees' involvement in establishing SHE programmes • SHE plans and programme(s) are clearly communicated to all who needs to know.	• SHE management plans and programmes are dynamic and integrated with company's SHE planning strategies • Full involvement of employees and other stakeholders in establishing SHE programmes • SHE management programmes are continuously reviewed and modified to address changes to company's operations for continuous improvement of SHE programmes
6	**PHYSICAL SHE RESOURCES**	• No physical resources available to enable SHE employees to perform SHE related tasks.	• Company is ill-equipped with physical resources for employees to perform SHE related tasks. Physical SHE resources are limited • Resource provision is not or rarely informed by any strategic resource plan	• Company is equipped with adequate physical SHE resources to enable employees to perform SHE related tasks. • Resource provision is usually reactive and occasionally informed by strategic resource plan	• Company is well equipped with sufficient physical resources for employees to perform SHE related tasks. • A strategic resource plan is available to inform timely provision of physical resources to enable employees to perform SHE related tasks	• Company is fully equipped with sufficient resources in quality and quantity for employees to perform SHE related tasks • Company's SHE physical resources are considered to be integral to SHE performance and competitiveness • Physical resources are continuously tested, upgraded and deployed. • Resource plans for provision of physical resources are documented and integrated into company's processes and systems to improve effectiveness and efficiency. • Resource plans are regularly reviewed to ensure the provision of adequate and current resources to meet planned and agreed targets and objectives

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
7	**FINANCIAL RESOURCES FOR SHE**	• No financial resources for SHE implementation. • Unstable or uncertain funding	• Limited financial resources for SHE implementation and rarely informed by a strategic resource plan • No established sources of funding	• Company has adequate financial resources for SHE implementation • Provision of financial resources is occasionally informed by strategic resource plan • Established source of funding	• Company has sufficient and well organised funding lines for SHE implementation. • A strategic resource plan is available to inform timely provision of financial resources for effective SHE management • Stable sources of funding	• Dedicated and adequate financial resources in place for effective SHE implementation and considered to be an integral part of the company's finance plan. • Highly stable funding. Resource plans are regularly reviewed to ensure the provision of adequate and current resources to meet planned and agreed targets and objectives
8	**ROLES AND RESPONSIBILITIES FOR SHE**	• No clear SHE roles, and responsibilities (i.e. there are no roles, tasks and objectives given to people and teams to meet the organisation's SHE objectives)	• SHE roles and responsibilities are are unclear with some specific RESPONSIBILITES and authorities somewhat defined and developed. • SHE roles and responsibilities are not recorded in job descriptions	• SHE roles and responsibilities are mostly defined and assigned to employees • SHE roles and responsibilities are inconsistently recorded in job descriptions	• SHE roles and responsibilities are well defined, sufficiently comprehensive and well communicated to designated employees at all levels • All SHE roles and responsibilities are consistently recorded in key documentation (e.g. job descriptions) and appropriate communication media	• Clearly defined SHE roles, responsibilities and authorities at all levels of the company • SHE roles and responsibilities are unambiguous, clearly understood and accurately documented • SHE roles, responsibilities and authorities are continuously reviewed, realigned to effort and tracked to ensure proper distribution and continuous improvement
9	**SHE TRAINING**	• No provision of SHE related training for employees • No formal training needs analysis undertaken	• Provision of SHE related training for employees is very low and unplanned. Provision of SHE training is rarely informed by a formal training needs analysis • Training needs are not well defined and documented	• Provision of SHE related training is reactive. • Provision of SHE training is occasionally informed by a formal training needs analysis • Identified training needs are somewhat defined and based on the wider competency and performance objectives • Training needs adequately documented	• Regular provision of adequate SHE related training for employees, informed by a formal and objective training needs analysis undertaken on a regular basis. • Training is typically based on employees SHE roles and respective competency objectives • Training needs are well defined and accurately documented (e.g. in the employees' personal files) • Training is usually proactive, tracked and evaluated to be improved upon	• Appropriate and timely SHE training is in place and integral to company's human resource strategy to improve SHE performance • SHE training strategies are incorporated into the company's overall, SHE management strategies and policies • SHE related training programmes or plans are reviewed for its effectiveness and periodically reviewed to ensure their current suitability. • SHE related training programme and training are continuously assessed and updated to reflect organisational, regulatory changes

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
						and any other changes in technology and techniques, to allow continuous learning and improvement • The various training methods are incorporated into the knowledge and communication channels of the company • Training needs analysis procedures are regularly reviewed
10	**SHE COMPETENCE**	• Company's employees do not have the skills, knowledge and the experience necessary for SHE management.	• An overwhelming majority of company's employees have basic SHE knowledge and skills, with no employees having advanced or expert skills and knowledge • Company's employees have limited experience in SHE management tasks	• A majority of company's SHE employees have intermediate SHE skills and knowledge with very few having advanced and/or expert skills and knowledge • Company's employees have some experience in SHE management tasks	• A majority of company's employees have sufficient and advanced SHE skills, and knowledge with very few having basic or no SHE skills and knowledge • Company's employees have appropriate experience in SHE management tasks	• An overwhelming majority of company's employees have expert SHE skills and knowledge with very few or none having basic or no SHE skills and knowledge • Company's employees have vast and experience in SHE management tasks • Company's employees feel competent and capable to perform their SHE tasks.
11	**MANAGEMENT OF OUTSOURCED PERSONNEL**	• No structured procedure is used in appointing competent outsourced employees, subcontractors and suppliers with regards to the management of SHE • No structured monitoring and assessment of the performance of outsourced employees, subcontractors and suppliers	• Informal procedure in place but rarely used in appointing competent outsourced SHE employees, subcontractors and suppliers. • Rare monitoring and assessment of the performance of outsourced employees, subcontractors and suppliers in respect of SHE management • Procedures are poorly documented and maintained	• Formal procedures in place and used occasionally and reactively appointing competent outsource employees, subcontractors and suppliers. • Occasional and reactive assessment of the performance of outsourced employees, subcontractors and suppliers in respect of SHE management • Procedures are adequately documented and maintained	• Regular and proactive procedures are in place for appointing competent outsource employees, subcontractors in a consistent manner • Regular and proactive assessment of the performance of outsourced employees, subcontractors and suppliers in respect of SHE management • All competency definitions are explicitly defined and include industry recognised best practice • Procedures are accurately documented and maintained	• There is a well-structured procedure for appointing, monitoring and assessing the performance of outsourced personnel, subcontractors and suppliers • The well-structured and clear competence management system is integrated within the company's performance of SHE management. • Competence and performance assessment procedures are reviewed regularly to ensure their current suitability and continuous improvement.
12	**SHE COMMUNICATIONS**	• No formal communication of any SHE related issues to employees • No formal communication channels for effective flow of SHE information internally and externally in the company	• Limited communication of SHE information to employees. • Communication is ad hoc and restricted to those involved in specific incidents.	• Some communication of SHE information to employees on a need to know basis • There is a communication strategy for SHE information flow internally and externally occasionally to all employees. • Employees are aware of pertinent SHE information.	• Adequate SHE information is routinely and regularly communicated to all employees. Employees are aware of critical SHE information. • There are established, good and appropriate informal and formal communication channels for	• There is an open, proactive and effective SHE communication between the company and its employees and stakeholders. • SHE communication is a strong, and consistent two-way process. Good practice is communicated both externally and internally

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
			• Company's employees are unaware of important SHE information • Some informal and formal communication channels are established for information flow internally to all employees.	• Specific informal and formal communication channels are in place for communicating SHE issues to employees	communicating critical SHE information and resultant actions • All levels of employees are involved, and there are robust mechanisms for them to feedback	• The company communicates to its employees on all the SHE-related issues and aspects of the company. • Established communication channels and methods are fully adopted throughout the supply chain in the company and consistently used for efficient coordination of SHE activities. • All pertinent SHE information and resultant actions are well communicated to all employees across the company. • Communication methods for SHE information flow internally and externally are continuously monitored and regularly reviewed against identified best practices in other sectors for potential continuous improvement.
13	**EMPLOYEE INVOLVEMENT IN SHE**	• No consultation of employees on SHE related issues • Employees are not involved and have no interested in participating in SHE related issues	• Limited consultation on SHE related issues, but not carried out in a systematic way. • Minority of the employees are involved and interested in participating in SHE-related issues	• More consultation on SHE issues is carried out in a systematic way • Majority of the employees are involved and interested in participating SHE related issues	• All employees are regularly consulted on SHE related issues and carried out in a range of ways (e.g. surveys, workshops, site meetings and committees) • Overwhelming majority of the employees are involved and interested in participating in SHE-related issues • Employees' involvement and consultation arrangements are documented and interested parties informed.	• All employees are fully consulted and actively engaged in SHE related issues at all company's levels. • All employees are interested in participating SHE related issues • Company's uses employees' involvement to gather ideas for improvement on SHE issues • Company makes full use of employees' potential to develop shared values and a culture of trust, openness and empowerment
14	**SHE DOCUMENTATION AND CONTROL**	• No organised documentations (e.g. SHE policy, SHE manual, emergency plans and work instructions etc.) and records that describes company's SHE system elements and their interrelationships	• Documentations of some elements of a company's SHE system and other related SHE records are available to employees • SHE documentations and records are not organise, easily not traceable and accessible	• Documentations and records of more elements of a company's SHE system and other related SHE records are available to employees • SHE documentations and records are compiled and organised in a format that is somewhat traceable and accessible	• Documentations and records of all elements of the company's SHE system and other related SHE records are available to all employees • All SHE documentations are compiled and mostly organised in an appropriate format, traceable and accessible.	• SHE documentations including other related SHE records are compiled and well organised in a clear, concise and functional format, traceable and readily accessible to all. • SHE documentations and records are integrated with other organisational documentations (such as human resource plans) for

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	Level 2	Level 3	Level 4	Level 5
						continuous improvement of company's functions. • SHE reports and SHE documentations are systematically maintained regularly reviewed and updated with appropriate version control in place, based on system improvements, to drive efficiency and effectiveness of the management system.
15	**SHE OPERATIONAL CONTROL**	• No procedures for identification of SHE operations that need to be controlled to ensure risk associated with them are minimised or eliminated. • SHE risks control measures are not in place	• Informal procedures are in place for identification of SHE operations and activities that need to be controlled to ensure risk associated with them are minimised or eliminated • SHE controls measures, are unclear and poorly documented	• Formal procedures are in place for identification of SHE operations and activities that need to be controlled. • Control measures for identified SHE risks are more detailed and clearly stated • Operation control procedures and measures are adequately documented	• Formal and comprehensive procedures are in place for identification of SHE operations and activities that need to be controlled. • Control measures for identified SHE risks are comprehensive and well defined • Identified SHE operations that needs to be controlled and their associated control measures are appropriately documented and well communicated to relevant employees (e.g. suppliers, contractors and other interested parties)	• Well-structured procedures are in place for identification of SHE operations and activities that need to be controlled to ensure compliance, and to achieve objectives. • Documented SHE control procedures and measures are continually reviewed and improved
16	**SHE EMERGENCY PREPAREDNESS AND RESPONSE**	• No emergency preparedness and response *(*EPAR) procedures • No measures for identification of possible emergencies and SHE accidents, and how to respond if they arise	• Undefined and inappropriate EPAR procedures and measures for identification of possible emergencies and SHE accidents, and how to respond if they arise • EPAR procedures and measures are poorly documented and not accessible • Employees are rarely trained in emergency responses	• Defined procedures and measures are available for identification of possible emergencies and SHE accidents, and how to respond if they arise • EPAR procedures and measures are adequately documented but not easily accessible • Employees are trained in formal emergency responses.	• Well-defined and sufficient EPAR procedures and measures for identification of possible emergencies with focus on specific emergency situations • EPAR procedures and measures are appropriately and accurately documented • EPAR procedures and measures are communicated and accessible to all employees involve • Employees are adequately trained in emergency responses	• Appropriate and comprehensive EPAR plans, procedures and measures are in place to effectively respond to emergency situations. • EPAR plans and procedures are fully integrated with other control measures and benchmarked consistently against best practices. • EPAR plans are periodically tested for the adequacy of the plan and the results reviewed to improve its effectiveness for continuous improvement.
17	**SHE PERFORMANCE MONITORING AND MEASUREMENT**	• No performance measuring and monitoring system in place.	• There are vague procedures for MaM of SHE performance.	• SHE performance MaM procedures and performance	• Well-defined and appropriate performance procedures, key SHE performance indicators and	• Well-designed and defined proactive procedures and measures for monitoring, measuring and

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	Level 2	Level 3	Level 4	Level 5
		• SHE procedures for performance monitoring and measurement (MaM) are not well developed • SHE performance indicators and measures are not established • SHE system performance is poor	• Some SHE performance indicators and measures are in place but not well defined • Performance MaM are rarely undertaken • Some employees are aware of the SHE performance measures in their areas of responsibilities • SHE system performance is fair	indicators and other measures are in place and defined. • Performance MaM are undertaken occasionally. • Monitoring is reactive • More employees are aware of the SHE performance measures in the areas of responsibilities • SHE system performance is mostly good	other measures are in place to monitor SHE performance • Performance monitoring and measurement are undertaken regularly with the purpose of improving the SHE system • Performance MaM procedures and measures are compliance led and used to track SHE performance • MaM procedures and measures are adequately documented and communicated to all employees • Employees at all levels are aware of the critical SHE performance measures in their areas of responsibility. • SHE system performance is very good and constantly repeated.	recording of SHE performance on a regular basis are in place and institutionalised within the company, focusing on operational excellence and continuous improvement • Results of SHE performance MaM are documented and effectively communicated throughout the company, to facilitate subsequent corrective and preventive actions analysis • SHE performance MaM procedures and measures are continuously used to improve the SHE management system. Best practice is shared across the entire company. • SHE performance MaM system is periodically reviewed and improved to make sure they remain relevant to the company's risk profile • SHE system performance is exemplary and comparable to best in the industry
18	**SHE INCIDENTS INVESTIGATIONS**	• No structured processes and procedures for SHE incidents investigations • No organised evidence of SHE investigations	• Vague processes and procedures for SHE incidents investigations are in place • The range of incidents investigated is limited to immediate causes of accidents and environmental aspects • Limited employees' involvement • SHE investigations processes and procedures are not documented	• Formal processes and procedures for SHE incidents investigations are in place • Investigations tend to focus on the immediate and root causes of SHE incidents, near misses and environmental aspects and their impacts • Incident investigations tend to be reactive • More employees' involvement in SHE investigations. • SHE incident investigations processes and procedures are somewhat documented	• Formal comprehensive and standard processes and procedures for SHE incidents investigations • Incidents investigations are proactive and probe more deeply to identify direct and indirect causes of SHE incidents and environmental aspects that result in significant SHE risks • Greater employees' involvement in SHE incidents investigations • SHE incidents investigations procedures are communicated to relevant committees for appropriate recommendations and actions • SHE investigations processes and procedures are well documented	• There are documented structured processes and procedures in place for consistently high quality SHE incidents investigations • SHE incidents investigations procedures are linked to SHE hazards identification and risk mitigation process and institutionalised within the company • Outcomes of SHE incidents investigations are seen as opportunities for improvement, and are documented, monitored and shared with industry. SHE incident trends are used to identify and help manage SHE risks

SN	SHE CAPABILITY ATTRIBUTES	CAPABILITY LEVELS				
		Level 1	Level 2	Level 3	Level 4	Level 5
					and corrective actions well communicated to best utilise any lessons to be learned.	• Lessons learned from incidents investigations are shared and implemented across the company. • Corrective and preventive actions are reviewed regularly and updated to ensure actions taken are effective. • SHE incidents investigations procedures are routinely reviewed and updated to drive continuous improvement
19	**SHE SYSTEM AUDITS**	• No auditing of SHE system • No clear SHE audits processes and procedures	• Company rarely undertake planned SHE system audits. Adhoc audit with no follow up. • SHE audits processes and procedures are not defined and may not be documented. • Procedures for assessing SHE compliance is limited • Legal and regulatory obligations noncompliance	• Company occasionally undertake planned SHE system audits • SHE audits processes and procedures are somewhat defined and poorly documented • Most aspects of SHE system is audited with some follow-up • Minimal legal and regulatory compliance. • SHE audits processes and procedures are focused on achieving compliance with legal and regulatory obligations	• Company regularly undertake planned SHE audits. • SHE audits processes and procedures are well defined and designed, and modelled on best practice of audits • All aspects of SHE system audited with some follow-up • Total legal and regulatory obligations compliance Written recommendations, (e.g. non-compliances) are well documented and communicated to form the basis of SHE improvement and innovation. • SHE audits processes and procedures are modelled on best practice standards for auditing management system e.g. ISO 19011:2018 guidelines for auditing management systems, OHSAS 18001 :2007	• There is a company-wide standardised audit system in place and institutionalised within the company, with best practice shared internally with other functions of the company. • SHE audits are undertaken regularly by competent employees to demonstrate compliance with required standards, legal and regulatory obligations. • SHE audits processes and procedures are planned and prioritised, and covers all aspects of the SHE system. • SHE audits process and procedures are reviewed periodically to ensure they are current and consistent with leading internal audit practice and standard requirements in order to ensure continuous improvement in audit processes

<table>
<tr><th rowspan="2">SN</th><th rowspan="2">SHE CAPABILITY ATTRIBUTES</th><th colspan="5">CAPABILITY LEVELS</th></tr>
<tr><th>Level 1</th><th>Level 2</th><th>Level 3</th><th>Level 4</th><th>Level 5</th></tr>
<tr><td>20</td><td>LESSONS LEARNED AND KNOWLEDGE MANAGEMENT</td>
<td>• Company has no structured system for capturing lessons in order to facilitate future improvement of the SHE management system
• No promotion of knowledge sharing and lessons learned across the company
• No records of lessons learned. There is highly reliance on individual memory.</td>
<td>• Company’s processes and procedures for capturing and disseminating lessons learned are characterised by poor or unstructured records keeping and inconsistent data
• Limited promotion of knowledge sharing and lessons learned across the company
• Reliance on manual record keeping of lessons
• Lesson learned are rarely used for SHE management system continuous improvement and innovation</td>
<td>• Company's processes and procedures for capturing and disseminating lessons learned are characterised by well-structured record keeping and good information
• Knowledge sharing and lessons learned is promoted across the company
• Little reliance on manual record keeping and greater usage of digital technologies for record keeping
• Records of lessons learned are sometimes relied on for SHE management system continuous improvement and innovation</td>
<td>• Company's processes and procedures for capturing and disseminating lessons learned are characterised by routinely well-structured record keeping and consistent high-quality information
• Knowledge sharing and lesson learned is promoted systematic ally across the company
• Reliance on advanced digital technologies for capturing and disseminating lessons
• Records of lessons are consistently relied on for SHE decision making, continuous improvement and innovation
• Processes and procedures for capturing and disseminating lessons learned are modelled on best practice knowledge management standards e.g. ISO 30401 - 2018, ISO 9001: 2015.</td>
<td>• There is well structured system for capturing and disseminating lessons learned and knowledge gained across the whole company. Heavy reliance on technological innovations for capturing and disseminating lessons
• The processes are institutionalised within the company and are considered a key measure of operational excellence.
• Knowledge and lessons learned are continuously shared and consistently relied upon across the company to continuously improve SHE
• Processes and procedures for capturing and disseminating lessons learned are routinely reviewed and updated to drive continuous improvement and innovation.</td></tr>
</table>

Appendix I: Validation questionnaire

Safety, Health and Environmental Management Capability Maturity Model (SHEM-CMM) Research

INFORMATION SHEET

Thank you once again for your interest in this research project. The previous phase of the research involved three rounds of a survey. The survey results have been incorporated into the development of the safety, health and environmental capability maturity model (SHEM-CMM).

This phase of the research involves the evaluation of the SHEM-CMM. This questionnaire survey aims to validate the comprehensiveness, applicability and practicality of the maturity model for uptake by construction companies in Ghana.

As it would be useful for the model evaluation to be based on real organisational capability assessments, I kindly ask **you to please complete the following evaluation form after using the capability maturity model to assess the organisational SHE management capability of your construction company or any construction company you have worked closely with.** This would take about 10-15 minutes to complete. Please return your completed form to the researcher.

The evaluation form consists of two sections.
Section One: Solicits for general background information of the company.
Section Two: Asks you to rate your level of agreement for each statement on a 5-point agreement scale after using the integrated SHE management capability maturity model as well as making general comments.

All information collected will be stored securely. You will not be identified at any point in this research. Participation in this research is voluntary and you may withdraw your responses from the research at any time prior to when all the responses from the evaluation form have been analysed. You can withdraw by emailing the research team using the contact information below. The research is granted ethical approval by the University of the West of England ethics committee. If you have any ethical queries that you want to be addressed by an independent person, you may contact the ethics committee at UWE by email.

Thank you very much for your time.

Millicent Asah-Kissiedu (Doctoral Researcher)

CONSENT SHEET

I confirm that I have read the Information Sheet (above) for this project and understood the information provided therein *(please tick the check box)*	☐
I agree to participate in the research *(please tick the check box)*	☐

Section One: Background Information

Please answer the questions below to provide details about your professional role. For each question please select the most appropriate response using tick box.

1. What is your professional role? Please choose one option.
   - ☐ Health and safety manager ☐ Civil/Structural Engineer ☐ Environmental Manager
   - ☐ Site manager ☐ Safety and health/ Environmental Management consultant
   - ☐ Project manager/construction manager ☐ Quantity surveyor
   - ☐ Architect
   - ☐ Other (please specify)

   ………………………………………………………………………………………………………

2. How many years of experience do you have in your professional role? Please specify…………………………….

3. How many years of experience do you have in safety, health and environmental (SHE) management practice (e.g. 2 years in health and safety and 1 year in environmental management). Please specify…………………………………….

Please answer the questions below to provide details about the background of the company you are assessing. For each question please select the most appropriate response using tick box.

4. In what way are you associated with the company you are assessing? Please choose one option

- ☐ I am an employee of the company.
- ☐ I am currently working with the company on a project as a consultant on the project.
- ☐ Within the past 6 months I have worked with the company on a project as a consultant on the project.
- ☐ I provide external consultancy advice to the company
- ☐ Other (please specify)

  ………………………………………………………………………………………………

5. Type of company being assessed.
   Please tick the applicable options that best describe(s) the company's main activities:
   - ☐ Building construction works ☐ Civil engineering construction works
   - ☐ Mechanical installation works ☐ Electrical installation works
   - ☐ Construction works within the mining sector
   - ☐ Other (please specify)

   ……………………………………………………………………………………

6. Approximately, how many employees (directly employed) does the company have? Please choose one option.

☐ up to 10 ☐ 11 - 50 ☐ 51 - 100 ☐ 101 – 150 ☐ 151 - 250 ☐ Over 250

7. Company's classification? Please choose one option.

☐ D1K1/A1B1 ☐ D2K2/A2B2 ☐ D3K3/A3B3 ☐ D4K4/A4B4

Other ……………………………………………………………………………………………………

8. What is the typical size of projects the company undertakes? Choose all applicable options.
   - ☐ Below GHC 50,000
   - ☐ GHC 50,000 to GHC100,000
   - ☐ GHC 100,001 to GHC250,0000
   - ☐ GHC 250,001 to GHC500,0000
   - ☐ Above GHC 500,000

9. In which of the following sectors does the company work? Choose all applicable options.

   ☐ Public ☐ Private
   ☐ International construction market

.

10. In which of the 10 regions of Ghana does the company operate? Please specify:

    ……………………………………………………………………………….

11. Which of the following systems do you implement in your company?
    - ☐ Environmental management system (EMS) only
    - ☐ Safety and health management systems (SHMS) only
    - ☐ Both EMS and SHMS ☐ Others……………………………………

12. Which of the following health, safety and environmental management certification does the company have? Please tick the applicable box or boxes that best describe(s) the company's main activities:

    - ☐ ISO Health and Safety management certification
    - ☐ ISO Environmental management certification
    - ☐ Other (please specify)

    ..…...
    - ☐ No certification

Section Two: Validation Questions

Please read and rate your level of agreement for each statement on a 5-point Likert scale: 5= Strongly agree, 4=agree, 3= Neither agree nor disagree, 2= disagree, 1= Strongly disagree

Assessment Criteria	Level of Agreement				
	Strongly agree 5	Agree 4	Neither agree nor disagree 3	disagree 2	Strongly disagree 1
Attributes used in the SHEM-CMM Worksheet					
Attributes are relevant to SHE management capability.	☐	☐	☐	☐	☐
Attributes cover all aspects of SHE management capability.	☐	☐	☐	☐	☐
Attributes are correctly assigned to their respective maturity level.	☐	☐	☐	☐	☐
Attributes are clearly distinct.	☐	☐	☐	☐	☐
Capability Maturity Levels					
The maturity levels sufficiently represent maturation in the attributes.	☐	☐	☐	☐	☐
There is no overlap detected between descriptions of maturity levels.	☐	☐	☐	☐	☐
Ease of Understanding					
The maturity levels are understandable	☐	☐	☐	☐	☐
The documentations (i.e. assessment instructions) are easy to understand	☐	☐	☐	☐	☐
The results are understandable	☐	☐	☐	☐	☐

Assessment Criteria	Level of Agreement				
	Strongly agree 5	Agree 4	Neither agree nor disagree 3	disagree 2	Strongly disagree 1
Ease of Use					
The scoring scheme [i.e. drop-down options for maturity levels (1-5)] is easy to use	☐	☐	☐	☐	☐
The SHEM-CMM is easy to use	☐	☐	☐	☐	☐

Usefulness and Practicality					
SHEM-CMM is useful for assessing SHE management capability	☐	☐	☐	☐	☐
SHEM-CMM is practical for use in industry	☐	☐	☐	☐	☐
Further comments					

Please do you have any further comments?

END OF EVALUATION FORM. PLEASE RETURN THE FORM VIA EMAIL

THANK YOU!!

Appendix J: Examples of maturity models

Name	Abbreviation	Developed by	Subject area	Industry	Maturity levels	Maturity level descriptors
Capability maturity model	CMM	Paulk, *et al*, (1993)	Software engineering	Information Technology (IT)	5	Adhoc, repeatable, defined, manged and optimise
Safety culture maturity model	SCMM	Fleming, (1999/2000) Keil Centre	Safety culture	Oil and gas	5	Emerging, managing, involving, cooperating, and continually improving
Structured process improvement framework for construction Environments – Facilities Management	**SPICE FM**	Construct IT, (2001)	**Facilities Management**	**Construction**	**5**	**Initial, planned and tracked, well defined, quantitatively controlled and continuously improving**
Benchmarking and readiness assessment for concurrent engineering in construction	**BEACON**	Khalfan *et al.*, (2002)	**Concurrent Engineering**	**Construction**	**5**	**Adhoc, repeatable, characterised and managed**
Organisational project management maturity model	**OPM3**	PMI, Rayner and Reiss, (2002)	**Project Management**	**Construction**	**4**	**Standardize, measure, control continuous and improvement**
Project management process maturity model	(PM)2	Kwak and Ibbs, (2002)	Project Management	NIS	5	initial, planned, managed at project level, managed at corporate level and continuous learning
International association of contract and commercial management-business risk management maturity model	IACCM-BRM3	Hillson, (2003)	Risk management	NIS	4	Novice, Competent, Proficient and Expert
Portfolio, programme and project management maturity model	P3M3	IACCM, (2003)	Project Management	NIS	5	Awareness, repeatable, defined, managed and optimized
Supply chain management maturity model	SCMM	OGC, (2003)	Supply chain	NIS	5	Adhoc, defined, linked, integrated and extended
Standardised process improvement for construction enterprises	**SPICE 3**	Lockamy III and McCormack, (2004)	**NS**	**Construction**	**5**	**Initial/chaotic, planned & tracked, well defined, quantitatively controlled, and continuously improving**
Capital project portfolio management model	CPPM	SCRI, (2005)	Real estate	NIS	5	Adhoc, plan, managed, integrated and leveraged
Project management maturity model	PM3	Dettbarn Jr. *et al*, (2005)	Project management	IT	5	Initial process, structured process and standards, Organisational Standards and Institutionalized Process, managed process and optimized process
Capability maturity model integration (staged representation)	CMMI	SEI, (2006b)	Software engineering	IT	5	Initial, Managed, Defined Quantitatively, managed and Optimising
Construction supply chain management model	**CSCMM**	Vaidyanathan and Howell, (2007)	**Supply chain management**	**Construction**	**4**	**Ad hoc, defined, managed and controlled**
Design safety capability maturity model	DSCMM	Strut *et al.*, (2006)	Safety	Offshore	5	Adhoc, repeatable, defined managed and optimized

A framework for understanding the development of organisational safety culture	**NS**	**Parker *et al.*, (2006)**	**Safety culture**	**Oil and gas**	**5**	**Pathological, reactive, calculative, proactive generative**
Interactive capability maturity model	**I-CMM**	NIBS, (2007)	**Building information modelling**	**Construction**	**10**	**NAV**
Stakeholder relationship management	SRMM	Bourne, (2008)	Stakeholders relationship mgt.	NIS	5	Adhoc, procedural, relational, integrated and predictive
People capability maturity model	PCMM	SEI, (2008d)	Human resource mgt. in organisations	NIS	5	Initial, managed, defined, predictable and optimising
Knowledge retention maturity model	KRMM	Arif *et al.*, (2009)	Knowledge management	NIS	4	Knowledge is shared between employees, shared knowledge is documented, documented is stored, stored knowledge is accessible and easily retrievable
Change Management Maturity Model	**CM3**	Sung *et al.*, (2009)	**Change management**	**Construction**	**5**	**Adhoc, informal, systematic, integrated and continuous improvement**
System dynamics modelling of construction safety culture	**NS**	**Mohamed and Chinda, (2010)**	**Safety culture**	**Construction**	**5**	**Uncommitted winners, drifters, improvers, award and world class**
Supply chain capability maturity model	$S(CM)^2$	Reyes and Gaichetti, (2010)	Supply chain	NIS	5	Undefined, defined, manageable, collaborative and leading
Risk management model	**RM3**	Zou *et al.,* (2010)	**Risk Management**	**Construction**	**4**	**Initial and Adhoc, repeatable, managed an optimize**
E-government maturity model	EGMM	Kim and Grant, (2010)	E-Government	NIS	4	Web presence, Interaction Transaction, Integration, Continuous improvement
A Safety Culture Maturity Model for the Construction Industry	**NS**	**McGeorge *et al.* (2011)**	**Safety culture**	**Construction**	**5**	**Emerging, managing, involving, cooperating and continually improve**
The project risk maturity model	PRMM	Hopkinson, (2011)	Risk management	NIS	4	Naïve, Novice, Normalised, Natural
Supply Chain Relationship Maturity Model	**SCRMM**	Meng *et al.*, (2011)	**Supply chain relationships**	**Construction**	**4**	**Price competition, quality, project partnering, strategic partnering**
Program management organisation maturity integrated model for MCPs	**PMOMIM-MCPs**	Jia *et al*, (2011)	**Project mgt.**	**Construction**	**4**	**Standardize, measure, control and continuously improve**
Railway maturity model	RM^3	ORR, (2011)	Rail sector	Railway	4	Adhoc, managed, standardized and predictable
Built environment management maturity model	**BEM3**	Madritsh and Ebinger, (2011)	**NS**	**Built environment**	**5**	**Adhoc, repeatable, defined, measured and self-Optimising**
Open government maturity model	OGMM	Lee and Kwak, (2012)	Public engagement (US)	NIS	5	Initial conditions, data transparency, open participation, open collaboration and ubiquitous engagement
Construction industry macro maturity model	**CIM3**	Willis and Rankin (Canada) 2012	**NS**	**Construction industry**	**3**	**Immature, transitional mature and mature**
Safety culture maturity and risk	**NS**	**Goncalves *et al.* (2012)**	**Safety culture**	**Oil and Gas**	**5**	**Pathological reactive bureaucratic, proactive and generative**

management maturity in Industrial organisations				**Manufacturing and infrastructure**		
Business intelligence maturity model	BIMM	Raber *et al.,* (2012)	Business information systems	NIS	5	Initiate, harmonize, integrate, optimize and perpetuate
Project management capability maturity model	P2CMM	Lianyin *et al.*, 2012	Project management	NIS	5	Cognitive, repeatable, management, integration and continuous
Research on the maturity of real estate enterprises safety culture		Zhang *et al.*, (2013)	Safety culture		5	Emerging, managing, involving, cooperating and continually improving
Digital investigations capability maturity model	DI-CMM	Kerrigan, (2013)	Organisation digital investigations	NIS	5	Informally performed processes, Planned and tracked processes, Well-defined processes, quantitatively controlled processes and Continuously improving processes
Conceptual maturity model for sustainable construction	**MMSC**	**Goh, 2013**	**Sustainable construction**	**Construction**	**5**	**Initial, repeatable, defined, managed and optimising**
UK Coal maturity model (UK coal journey model)	UKCMM	Foster and Hault, (2013)	NS	Coal industry	5	Basic, Reactive Planned Proactive and Resilient
Maturity model for service systems in heavy equipment manufacturing enterprises	MMSS-HEME	Neff *et al.,* (2014)	Heavy equipment	Manufacturing	5	Service system prepared, engaged, established, and managed and optimised
Maturity model for a sustainable construction industry	**NS**	**Dahabra, (2014)**	**Sustainable construction**	**Construction**	**5**	**Unsustainable, poor sustainable, satisfactory, sustainable, mature sustainable**
Energy management maturity model	EMMM	Antunes et al, 2014	Energy mg. for all organisations	NIS	5	Initial, implementation, monitoring, and improvement
Business Sustainability Maturity Model	BSMM	Cagnin *et al.*, (2014)	Sustainability	NIS	5	Adhoc, planned in isolation, Managed with No Integration, Excellence at Corporate Level and *High-*Performance Sustainability Net
Integrated information maturity model	**IIMM**	Kang *et al.,* (2014)	**Capital projects**	**Construction**	**3**	**Business efficiency, Business effectiveness and Business transformation**
Lean maturity framework	**LMF**	Nesensohnn, (2014)	**Lean**	**Construction**	**5**	**Uncertain, awakening, systematic, integrated and challenging**
Public commissioning maturity model for construction clients	**PCMM**	Herman's *et al.,* 2014		**Construction**		**Ad hoc, Repeatable, Standard, Managed Optimised**
Collaboration maturity model	CoMM	Boughzala and de Vreede, (2015)	Management information system	IT	4	Adhoc exploring, managing and optimising
Collaborative innovation capability maturity model	**CICMM**	**Knoke, (2015).**	**Innovation management**	**Construction**	**5**	**Initial, managed, defined, quantitively managed and optimising**
Maturity model for IT-based case management	C3M	Koehler, (2015)	case management	IT	5	Individualistic, supported, managed standardised and transformative
Construction E-Business Capability Maturity Model	**CeB-CMM**	**Rodrogo, (2016)**	**E-Business**	**Construction**	**5**	**Initial level, Repeatable level, Defined level, Managed level and Optimising**
Maturity model for design automation	MMDA	Wilner *et al.,* (2016)	Automation in engineering	Automotive	5	Ultimate freedom, product standardisation, automation of tendering, automation of order execution and full automation

Demand driven supply chain maturity model	DDSC-MM	Mendes Jr. *et al.,* (2016)	Supply chain	Retail markets	5	Basic push operation, Optimized push, Hybrid push-pull, Advanced demand driven (pull); and Optimized demand-driven (pull)
Project management maturity model	**ProMMM**	**Backlund, 2016**	**Project Mgt**	**Engineering and construction**	**4**	**Naive, Novice, Normalised and Natural**
Engineering change management maturity model	**ECMMM**	**Storbjerg *et al,* (2016)**	**Change management**	**Engineering**	**5**	**Initial, repeated, define, managed and optimised**
A maturity model for the involvement of stakeholders in the city resilience building process	**NAV**	**Gimenez, R. *et al.,* (2016)**	**Resilient cities**	**Building**	**5**	**Unrecognized, initial, formalized, supportive, and proactive**
Portfolio management maturity model	Elena	Nikkhou *et al.,* (2016)	Portfolio management	NIS	5	Recognition, Forming, Dynamism, Wisdom and Property
ISO 50001 standard-based energy management maturity	EMMM50001	Jovanovi and Filipovi, (2016)	Energy management	Manufacturing /services	5	Initial. managed, defined, quantitively managed and optimised
An OHS management maturity model and assessment tool.	**NAV**	**Chen (2016)**	**Safety culture**	**NS**	**5**	**Pathological, reactive, bureaucratic, proactive and generative**
Environmental management maturity model	EMMM-IC	Ormazabel, 2017	Environmental management	Industrial companies	6	Legal requirements, responsibility assignment and training, systematization, ECO2, eco-innovative products and services, and leading green company.
Management maturity model	**MMM**	**Langston and Ghanbaripour, (2016)**	**Project Management**	**Construction**	**5**	**Core objectives, standalone projects, multiple aligned projects, and project/program collection**
DfOSH capability maturity model	**DfOSH-CMM**	**Manu *et al.,* 2018**	**Occupational safety and health design**	**Construction**	**5**	**Level 1, level 2, level 3, level 4 and level 5**
Built environment flood resilience capability maturity model	**NS**	**Adeniyi *et al.*, (2018)**	**Flood resilience**	**Built environment**	**5**	**Initial, repeatable, defined, managed and optimizing**
Environmental management maturity model of construction programs	**EMMMCP**	**Bai *et al.,* (2018)**	**Environmental management**	**Construction**	**5**	**Disordered level, simple level, standard level, improved level and lean level**
Construction disability management maturity model	**(CDM3)**	**Quaigrain, 2019**	**Disability management**	**Construction**	**5**	**Adhoc and chaotic, Planned & managed, standardised practices, quantitatively measured, continuously refining practices**

Note:

NAV- not available, NIS- non-industry specific, NS- not specified.

Appendix K: Authors publications

Conference

Asah-Kissiedu, M., Manu, P., Booth, C., and Mahamadu, A. (2018) Organisational attributes that determine integrated safety, health and environmental management capability. *The 9th International conference on Engineering Project and Production Management (EPPM)*. 24 -26 September 2018, Cape town, South Africa.

Book Chapter

Asah-Kissiedu, M., Manu, P., Booth, C., and Mahamadu, A. (2019) *Towards the development of an integrated safety, health and environmental management capability maturity model (SHEM-CMM) for uptake by construction companies in Ghana.* In Construction and health and safety in developing countries by Routledge, Taylor & Francis Group.