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DEVELOPING A MATURITY MODEL TO EVALUATE THE HEALTH AND SAFETY OF SUSTAINABLE BUILDING PROJECTS

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Abstract: The health and safety (H&S) of sustainable building (SB) projects, which constitute a fundamental part of social sustainability has traditionally been ignored when evaluating the sustainability of the built environment in favour environmental and energy aspects. This has made SB more dangerous to build compared to non-SB buildings. In order to address the emerging safety risk associated with SB development, the application of a sustainable H&S concept is needed to move SB from prescriptive compliance with H&S requirements to high performance. A review of the literature reveals a lack of a comprehensive tool to aid companies in achieving a sustainable H&S performance on their projects. This paper presents a model developed to evaluate the maturity of H&S practices of SB projects in the Manitoba construction industry. This project is conducted by the University of Manitoba Construction Engineering and Management Group. The proposed model expands on existing H&S management models, the concept of process improvement and relies on safety maturity drivers of H&S performance at the project level related to people, process and the building. After the model is validated, it should help construction organisations evaluate H&S practices against best practices, assesses H&S performance and address areas needing improvement. The model should also help reduce and ultimately prevent accidents on SB projects while supporting continuous improvement. The model can also be used to provide strategic information to H&S regulators for auditing purposes and to enable them to improve existing H&S standards.

1. INTRODUCTION

Sustainable Building (SB) projects usually consider issues related to energy and water use but not Health and Safety (H&S) aspects, which is a fundamental part of social sustainability (Rajendran 2009, Hinze 2013, Gambatese et al. 2007, Surbeck and Hilger 2014). This is because the sustainable development and H&S movements have traditionally operated in their own separate spheres, with little synergies between them (Annie and Brain 2013). Schulte et al. (2010) argues that following the six fatalities on Mirage's City Centre SB project in Las Vegas, Nevada. The SB project received a Leadership in Environmental and Energy Design (LEED) gold certification which represented an endorsement that trivialised the importance of H&S in the sustainability evaluation of the built environment. (Annie and Brain, 2013, Gambatese et al. 2007, Hinze et al. 2013) submits that although, SB projects offer the potential for improved energy and environmental performance, they are ultimately unsustainable if they compromise the H&S of the project. Following an increasing interest in SB technologies, the number of SB been built in Canada has been growing at a significant pace (CaGBC 2015), however a growing body of evidence is suggesting that SB are more dangerous to build compared to non SB (Annie and Brian 2013, Rajendran, et al. 2009, Fortunato et al. 2012, Dewlaney et al. 2012). For example, Rajendran et al. (2009) compared 38 LEED SB projects and 48 non-LEED SB projects and found that the Recordable Injury Rate was 48% higher for LEED SB projects compared to non-LEED SB projects**.** This is because SB technologies and systems have been found to combine in unexpected ways to achieve new synergies such as the use of building envelope for additional functions like renewable power generation or landscaping (Annie and Brain, 2013). These synergies created produce unwanted exposures and conditions that put workers at risk during the project life-cycle phases (Annie and Brain, 2013). As new SB technologies continue to evolve and sustainable goals become more ambitious, the use of nano-materials in SB, as well as on-site water recovery, treatment, and reuse are increasingly been employed (Annie and Brain, 2013). These technologies have been shown to pose significant H&S risks which needs to be addressed to move SB from mere compliance with existing prescriptive H&S requirements to high performance. Addressing these risks from a holistic perspective, requires evaluating how people work on the project and utilise the process in the creating SB. There is the need for tools that take advantage of leverage points in the integrated project design process of SB development to address existing and emerging hazards. This paper focuses on the development of a Sustainable H&S Maturity Model (SHSMM) to evaluate the H&S practices of SB projects.

2. LITERATURE REVIEW

This section presents a review of the SB H&S and maturity modelling in the construction industry.

2.1 Conceptualization of Sustainable Health and Safety

Sustainable H&S is a concept borne out of the need to improve H&S performance of organizations committed to sustainability values (Tom 2014). Rajendran (2009) described sustainable H&S as an effective, self-sustaining H&S, and risk management approach which is defined by sustained proactive control and elimination of hazards while reducing the potential for accidents. Cary (2013) submits that a sustainable H&S system should be characterized by a defined vision, strategy, goal planning, training, safety communication, risk management, active workers and leadership engagement and commitment to continuous improvement. Tom (2014) argues that sustainable H&S is the responsibility to ensure that the protection of human life, the H&S, well-being of workers, customers and neighbouring communities are the primary considerations in any business endeavours. The challenges to achieve sustainable H&S in the organisation and project environment are complex (ERM 2015). Many organisations aim to achieve zero harm but accidents still occur on their projects. These organisations strive to balance the priorities of personal and process safety management on their projects while managing the ability to identify signals of imminent equipment failure (ERM 2015). Sustainable H&S requires optimisation of the interaction between the priorities of people, process and plant to achieve a sustainable H&S performance (ERM 2015). Wojick (2015) submits that the sustainability of H&S systems should be evaluated based on understanding the psychological needs of people, their values and intrinsic motivation, because people would only sustain what they care about. Tom (2014) submits that H&S sustainability at the organization level should be assessed within three core areas of oversights and transparency, operational excellence, values and belief. A review of the literature shows that only two H&S evaluation tools (Integrated Value Model for Sustainability Assessment) IVMSA (Reyes 2014) and (Sustainable Construction Safety and Health) SCSH (Rajendran 2009) were developed for assessing H&S of SB. A major limitation of these tools are that they practice based and focuses on error prevention and normative compliances while ignoring complex social process such as values, attitude and behaviour which are core components of sustainable H&S standards in the construction industry (Guo et al. 2015). Moreover, vital sustainable H&S elements such as safety communication and hazard management are ignored in the tools. The tools also ignores the need for continuous safety input to facilitate changes in the event of a need to address uncertainty scenarios onsite.

2.2 Sustainable Buildings

SB have been defined differently by academic and industry practitioners. OECD (2006) defined SB as those buildings that have minimum impacts, in terms of the buildings themselves, their immediate surroundings, the broader regional and global setting. SB utilizes practices that strive for integral quality (including economic, social, and environmental performance) in a broad manner. Under (Agenda 21), SB is a building built using a holistic process that aspires to restore and maintain harmony between the natural and built environments, that ensure human dignity and encourage economic equity. In other to create SB, a number of practices are pertinent which keep evolving as SB goals become more ambitious. These practices aim to minimize resource use such as water, building raw materials, energy use, virgin site use, and the improvement of the indoor environmental quality (Kibert 2008).

2.3 Impact of Sustainable Building Practices on Health and safety

There is little empirical evidence about the actual risks associated with SB practices. Only five studies appear to have investigated such risks. Mulhern (2008) and Fortunato et al. (2012) investigated the safety risks of green roofs and found that covering a building's roof with plant life increased exposure to fall hazards during construction and maintenance. Chen (2010) and Gerhold (1999) explained how working on solar panels involved working on the power source itself, thus increasing the risk of electrical shocks and fall hazards. It was also found that the greater use of skylights, atria and more windows in SB increased fall hazards (Chen 2010, Gambatese et al. 2007, Fortunato et al. 2012, Gambatese 2009). Gambatese et al. (2007) found that the recycling of construction waste increased the risk of musculoskeletal injuries due to onsite material handling. Greg (2012) submitted that the glare from the white, reflective roofing used for some SB poses a visual hazard to workers especially in the summer. Fortunato et al. (2012) found that workers on LEED SB projects were exposed to work at heights, electrical currents, and heavy equipment for longer durations than workers on non-LEED SB projects. A research by National Institute for Occupational Safety and Health (2011) showed that 11 credit of LEED rating system affected H&S negatively. Similarly Dewlaney et al. (2012), found out that 12 LEED credits impacted the frequency, severity and exposure to hazards on SB practices compared to non-SB practices. For example it was shown that on-site renewable energy credit led to a 10.2% increase in falls hazards, innovative wastewater technologies led to 8.8% increase in exposures to harmful substances and a 12.5% increase in overexertion. Construction waste management credit led to a 26.2% increase in lacerations, strains, and sprains.

2.4 Maturity Modelling

Maturity modelling was first developed in the software industry to improve the way software was built on US Department Defense projects (Paulk et al. 1995). It is premised on the idea of process Improvement defined as the Plan Do Check Act Cycle (Crosby 1979). Maturity modelling concept helps organizations to determine their current maturity level and areas in need of improvement and the steps needed to reach the next maturity level. The concept of maturity modelling was first popularized by researchers at Carnegie Mellon University (Paulk et al. 1995) who developed a Capability Maturity Model (CMM). CMM uses the concept of maturity modelling and defines five maturity levels for a given software development process (Paulk et al. 1995). At the first level, a process is chaotic, at the second level it repeatable, at the third level it is defined. At the fourth level, a process is usually controlled, before it is optimized at the fifth and highest level by subjecting it to continuous improvement cycles. Several attempts have been made to expand the use of maturity modelling to other domains such as human resources, Information technology, quality management and project management (Flemine et al. 2001, Klimko 2001). In the construction industry, maturity modelling concept has been applied to improve quality, costs and project performance (Ibbs and Kwak 2000). Vaidyanathan and Howell (2007) developed the Construction Supply Chain Maturity Model to improve the performance of construction supply chains. It was based on three dimensions and consisted of four maturity levels. Sarshar et al. (1998) developed the Standardized Process Improvement for Construction Enterprises Model (SPICE) to improve the management of construction processes by assessing an organization's key processes against five process elements. The model consists of five maturity levels. Willis and Rankin (2009) defined the Construction Industry Macro Maturity Model (CIM3) to assess management practices within the construction industry based on three maturity levels. The (CIM3) is based on the concept of process improvement used in the CMM. In construction H&S management, very few maturity models has been developed. Goggin and Rankin (2009) developed a H&S maturity model to evaluate an organization maturity with respect to H&S practices based on six key factors and three maturity levels. However, the model didn't adequately cover H&S practices at the project level. Fleming (2000) developed a model to help organizations identify their safety culture maturity based on 10 elements and five levels of maturity.

3. METHODOLOGY

This section provides an overview of the Sustainable Health and Safety Maturity Model (SHSMM) developed, its safety maturity drivers (SMD) at the process, people and building related H&S dimensions.

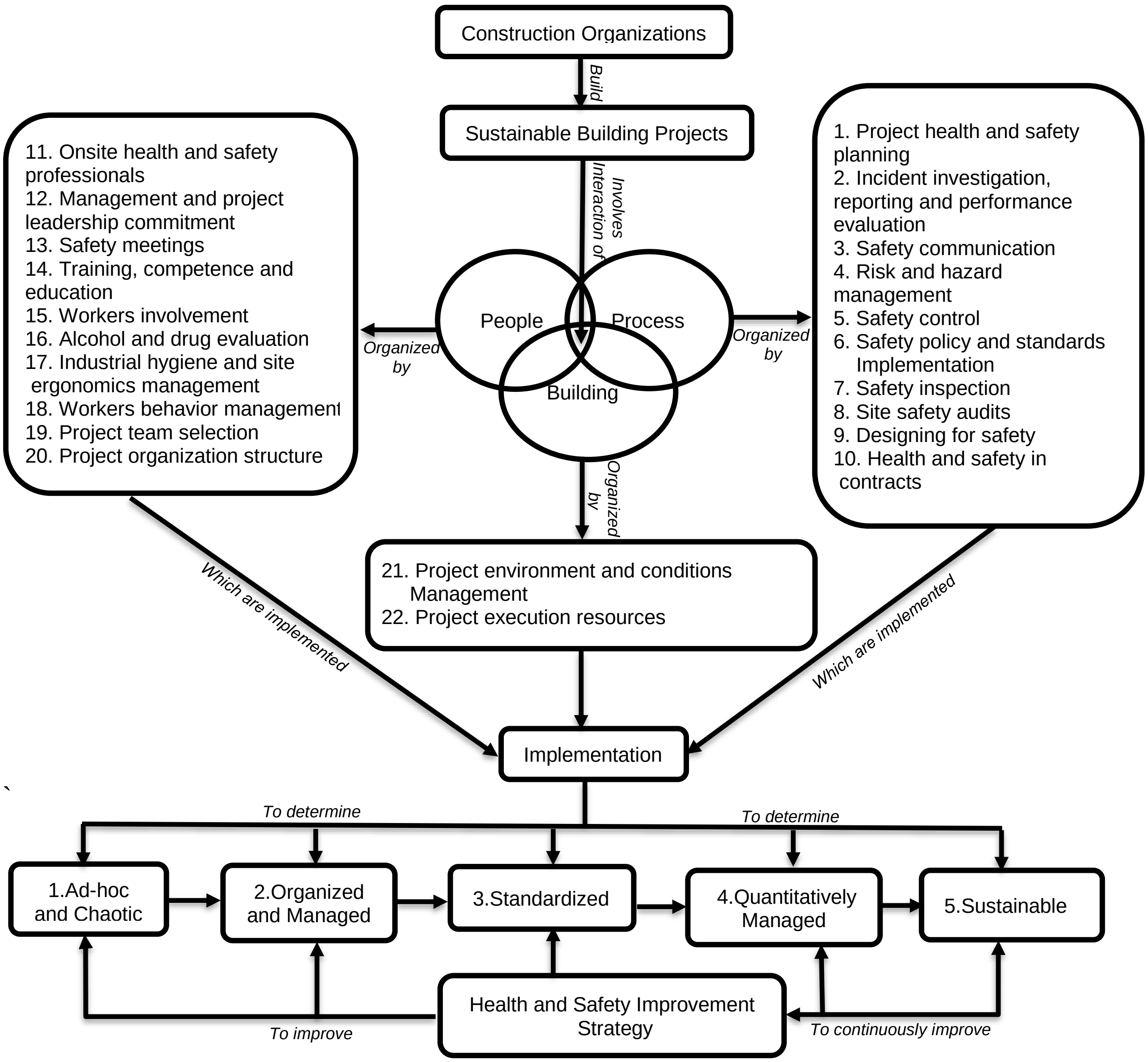

Figure 2: Schematic structure of the SHSMM

3.1 SHSMM Overview

The Sustainable Health and Safety Maturity Model (SHSMM) shown on Figure 2 aims to evaluate the expected daily management of H&S on SB projects. The model enables the identification of H&S practices implemented on a SB project and their comparison against industry's best practices to evaluate their maturity. The SHSMM adapts the idea of process improvement obtained from the process maturity framework taking into account vital H&S practices identified in the H&S literature and from Industry best practices documentation. The SHSMM consists of three different categorizations called H&S dimensions related to people, process and building, which are each organised by Safety Maturity Drivers (SMD). The SMD consists of critical to safety practices which reflects current best H&S practices. These best practices are used to determine the maturity levels of the H&S practices of a SB project and indicate the H&S sustainability gap. The SHSMM also provides recommendations for improving these H&S practices through a H&S improvement strategy. The basis for the three different dimensions is that H&S is considered to be a process that starts with people (Hinze 2012). People refer to a collection of skill to deliver the SB project, while building refers to non-human component such as tools, equipment, materials engaged to deliver the SB project.

3.2 Safety Maturity Drivers

The proposed SHSMM is multi-dimensional and constitutes a number of assessment drivers called SMD. SMD are essentially areas of concern and indicate H&S performance determinants for the SB project. The underlying assumption of the theoretical model is that higher practice maturity for each of the SMD will result in higher levels of H&S performance. The H&S dimensions are organised by the SMD which consists of industry current best H&S practices, which when performed should enable the achievement of sustainable H&S performance. The assessment of the SMD would enable the identification of areas in need of improvement on the SB project. The SMD cover H&S practices related to design and construction of SB.

3.2.1 Process Related Safety Maturity Drivers

1. Project Health and safety planning: Includes project specific H&S planning practices that aim to strategize for H&S performance. This includes the requirement for site safety planning, pretask planning. This also includes housekeeping planning, roof safety planning, construction and demolition waste planning, exposure control planning, safety training planning and pollution prevention planning.

2. Incident investigation, reporting and performance evaluation: Includes practices that identify root causes of accidents and develop methods to prevent them. This includes near misses and incident investigation, measuring H&S performance, continuous improvement commitments, developing, tracking and reporting of H&S metrics, leading and lagging indicators of performance to achieve project safety objectives.

3. Safety communication: Includes practices that pertain to the exchange of H&S information to the right people at the right time. This include provision and use of onsite safety communication gadgets and new technology, employing visual management techniques, proactive safety hazard warnings through material labelling. This also includes updating contractors with relevant H&S information and opening up of communications channel between project participants independent of contractual relationship.

4. Risk and Hazard management: Includes practices related to managing risk on the SB project. This includes all practicable steps that involves identification of hazards, assessment, controls and hazard abatement verification. This also includes Job Safety Analysis (JSA) for each construction activity, evaluating construction safety and sequence issues, and hazards identification from group dynamic processes and interface between trades and individual workers.

5. Safety control: Includes practices that aim to ensure the use of control mechanisms to improve a project site safety condition. This also includes the use of engineering controls, administrative controls and Personal Protective Equipment’s (PPE) use.

6. Safety policy and standards implementation: Includes practices that ensure implementation of a H&S guidance, policy and standards on the project. This also includes daily running of safety routines, rituals and huddles, the documentation of specific activities to carry out or avoid to complete a task safely.

7. Safety inspection: Includes practices that indicate how safety inspection is carried out on the SB project. Safety inspection should be carried out before construction, during construction to identify and address safety violations which is a precondition for incidents. This also includes identification, reporting, documentation and discussion of safety violations between project team, the use of a checklist as a guide to the inspection team or personnel to ensure certain processes and equipment’s are evaluated.

8. Site safety audits: Includes practices that show how site safety audits is carried out. Site safety audit is an essential practice and it provides managers with information with compliance on defined H&S standards and goals to enable the identification of safety violation. This includes periodic participation in independent and unscheduled site safety audit by management and tracking project safety audit by management.

9. Designing for safety: Includes practices that show measures during the design phase aimed to achieve safety during construction. Designing for safety involves "designing out" hazards in the design phase to reduce and eliminate H&S hazards as early as possible in the life cycle of a building. This also includes the evaluation of design alternatives based on H&S criteria, performing safety design reviews before completion of SB schematic design, utilizing prevention through design checklist to guide designers.

10. Health and safety in contracts: Includes practices that show the extent to which H&S requirement are part of the construction documents (e.g. plans and project specifications) and finalized project contract**.** It ensures H&S hazards of material specification regarding the SB project are defined in construction documents. This also includes definition of comprehensive safety method statements and extent of owners involvement in safety.

3.2.1 People Related Safety Maturity Drivers

11. Onsite health and safety professionals: Includes practices pertaining to the appointment of H&S professionals such as H&S representatives and supervisors to a building project. These professionals should become part of the integrated design process of SB projects to advice on the safety implications of sustainable design decisions. This also includes the allocation of safety representatives of owners, contractors and subcontractors to perform safety supervision onsite.

12. Management commitment and project leadership commitment: Includes practices that reflect the extent of support for safety and commitment at the managerial level. This commitment should manifest itself in the involvement of all levels of management and project leadership in activities such as planning, participation in safety committees, safety meetings, risk and hazard management, training and controlling job related H&S project activities.

13. Safety Meetings: Includes practices that evaluate how project safety meetings are carried out during project execution. Safety meetings improve safety motivation and allow for the discussion of H&S issues and guidance. Safety meetings have different dimensions such as pretask meetings, tool box meetings and mitigation meetings. This also includes the extent of interactiveness in the communicating of safety issues and safety rules to workers and other project participants.

14. Training, competence and education: Includes practices that evaluate the extent to which project workers are equipped with the skills and knowledge needed to carry out their tasks safely. Training should be relevant to the people taking it and address their specific skill deficiencies. This also includes project task specific and H&S manual training, safety hands-on training, coaching by experienced workers, risk management based training as well as proactive site orientation for new and inexperienced workers.

15. Workers involvement: Includes practices that evaluate how workers are engaged on the project in achieving a sustainable H&S performance. This includes engaging workers in H&S related decision making, involvement in identifying H&S issues, and consultation with workers about H&S matters. This also includes accommodating workers safety initiatives, engaging them in mitigating safety problems, planning and implementation and empowering them to take responsibility for safety.

16. Workers Behavior Management: Includes practices that evaluates how workers behaviour, values and attitude are monitored, expressed and managed. Workers behaviour can be assessed based on workers disposition towards rewards for safety behaviour and the influences on behaviour to comply with project safety rules and procedures. This includes coaching by experienced workers, inter-worker one-one observation, giving feedback on risky behaviour and continuous reminders of the severity implications of safety violations.

17. Alcohol and Drug Evaluation: Includes practices that evaluates the extent of alcohol use and substance onsite. This also includes random testing before and during project execution and testing after an injury, enforcement of zero tolerance policy and carrying out impaired judgement test on selected workers.

18. Industrial Hygiene and Site Ergonomics Management: Includes practices that evaluates the extent to which workers are physically and mentally able to carry out assigned tasks safely. This evaluates the extent of suitability of the project task to the physical and mental ability of the workers assigned. This also include ergonomic task analysis, ensuring the design of work processes that minimize injuries and use of project customised ergonomics controls.

19. Project team selection: Includes practices that evaluates how designers, workers, subcontractors, contractors are selected for the project. This evaluates the quality of the selection process for the project while taking H&S consideration into account. This includes selecting subcontractors who would follow established and defined H&S standards, selecting project team members considering H&S conscious attitudes and ensuring contractors and subcontractors adhere to same H&S standard and values to work with them.

20. Project organization structure: Includes practices that evaluate how the contractor and subcontractor project organization structure is set up for the project. The type of project organization impacts H&S on the project. This also includes the extent of line responsibility for safety, mitigation responsibility on the project.

3.2.1 Building Related Safety Maturity Drivers

21. Project environment and conditions management: Includes practices that evaluates the management of the project site to ensure positive H&S outcomes. This includes site layout, human, vehicular and equipment interaction, site topography, soil condition, lighting, proximity to power utilities, wind management and weather conditions.

22. Management of project execution resources: Includes practices that evaluates the management of a project's resources to ensure its safe execution. This evaluate how project resources are maintained and managed to facilitate project execution in a safe way. This also includes maintenance, inspection and management of equipment and tools and materials evaluation for safety**.**

3.3 SHSMM Measurement

The SHSMM has been developed to help SB projects determine the maturity of their H&S practices based on 22 SMD. Participating projects would be evaluated to determine their level of implementation of defined SMD using a five point Likert scale, that ranges from (Strongly Disagree)-1 to (Strongly agree)-5.

3.3.1 Measurement Maturity Levels

The research develops the SHSMM by adopting similar maturity scales used by the CMMI and SPICE**.** The SHSMM has five maturity levels to enable the attainment of the sustainable H&S practices at the highest level of the process maturity. The five maturity level scale provides a comprehensive breakdown of the maturity evolution. The different maturity levels, represent a well-defined stage as shown on Figure 1 are described below:

At Maturity level 1 (Chaotic and ad-hoc): At this level, the project H&S practices are usually ad-hoc and chaotic. There is no H&S procedure initiated and implemented. The project team members carry out project activities based on personal discretion, and competence without the application of specific H&S practices.

At Maturity level 2 (Organized and managed): At this level the project H&S practices are organized, planned and controlled to a degree. At this level, H&S requirements, H&S controlling and measurement mechanisms can be observed but not integrated together on the project. The results are visible to project leadership.

At Maturity level 3 (Standardized): At this level a set of defined H&S practices and procedure are clearly spelt out, implemented, managed and enforced throughout the duration of the project execution activities.

At Maturity level 4 (Quantitatively managed). At this level, H&S practices are implemented accurately and efficiently on the project, the quality of H&S is measured. Performance data is collected at regular intervals on the project and evaluated against benchmarks to identify areas needing improvement and address them.

At Maturity level 5 (Sustainable). At this level H&S practices are continually improved upon through implementation of innovative ideas and technologies to prevent complacency. New objectives and targets are set out in the project. At this level, H&S practice exceed regulatory requirement. H&S consideration becomes an integral part of every project activity. Management demonstrates the importance of H&S consistently. H&S is frequently discussed and workers exhibit strong commitment and knowledge of it.

Table 1: Fundamental scale for pairwise comparison (Saaty, 1987)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two SMD contribute equally to the objective/goal
3	Moderate importance	Experience and judgment slightly favor one SMD over another
5	Essential or strong importance	Experience and judgment strongly favor one SMD over another
7	Very strong importance	A SMD strongly favored over another and its dominance demonstrated
9	Extreme importance	The evidence favoring one SMD over another is of the highest possible order of affirmation
Reciprocal	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	

3.3.2 AHP Implementation and SHSMM Evaluation

SB H&S practices measurement will be carried out by applying the concept of absolute comparison in analytical hierarchy proceeds (AHP) (Islam and Rasad 2006). The AHP enables the use of a systematic way to determine the relative weights of importance of the 22 SMD as they impact H&S performance of SB. The SMD will be ranked by determining the relative weights of the 22 SMD using pairwise comparison (Saaty 1987). A team of five construction H&S experts will be engaged to determine the weights for each of the 22 SMD. At least four pairwise comparisons will be completed for each SMD and aggregated quantitatively and geometrically (Yee-Ching and Elea 1991). The comparisons of SMD will be carried out using a nine point fundamental scale of values as shown on Table 1. During the AHP exercise, the SMD would be compared, based on the relative importance of a SMD to another as it affects the H&S performance of SB. The aggregated pairwise comparison values obtained will be normalized by dividing each column value (i.e each SMD) by the sum of column values, such that the sum of each column's values will be 1. Each construction H&S expert will evaluate the SMD as shown in the SHSMM in Figure 1 with respect to the criteria's defined in Table 1. For each SMD assessed, the pairwise comparisons carried out by the construction H&S experts will generate a pairwise comparison matrix (Yee-Ching and Elea, 1991). The obtained values of the pairwise comparison matrix are known as pairwise comparison judgments which would be normalized to produce ratio scales called eigenvectors (Saaty 1987). These developed eigenvectors reflects the relative weights of importance of the SMD as considered by an expert. The study uses the scale developed by (Saaty 1987) because it is been widely used and validated by many studies**.**

A consistency check will be carried to determine the consistency of the ratings of the SMD (Saaty 1987). In determining the consistency, a consistency ratio will be used, whose value must be less than 0.1. If the consistency ratio is greater than or equal to 0.1, the pairwise comparison will be repeated. After the AHP exercise, the SHSMM will be validated by academic and industry H&S professionals for appropriateness, comprehensiveness and relevance. The second part of the SHSMM implementation involves the development of an evaluation worksheet based on close ended questionnaire. This questionnaire will assess each SMD using a 5-point Likert rating which ranges from "Strongly Disagree" -1 to "Strongly Agree"-5 response. Evaluating a project quantitatively with the evaluation worksheet is a direct approach and has been widely used in the assessment of many maturity models. When the questionnaires are answered, the response column is assessed to determine the level of maturity while taking into consideration the ranking of the SMD based on the eigenvectors obtained from the AHP exercise. The questionnaires aim to determine the implementation of specific SMD practices on a SB project. The SHSMM requires that the evaluation worksheet be administered for each participating SB project to selected project participants by the researchers. In other to determine the accuracy of the responses, random verification would be conducted through a review of project documents and follow up interviews with selected participants. In obtaining the maturity scores for each participating project, the weights of importance reflected as eigenvectors for each SMD obtained from the AHP will be multiplied by the scores from the evaluation worksheet for each SMD.

4. CONCLUSION

The paper presents the development of the Sustainable Health and Safety Maturity Model (SHSMM) and describes its mode of implementation. The SHSMM was developed to provide a framework for benchmarking H&S practices and performance on SB projects in the construction industry and to improve H&S of SB. The SHSMM can be used as a tool to supports continuous improvement, assesses H&S performance and addresses areas needing improvement in order to reduce and ultimately prevent accidents and injuries on SB projects. The tool expands on previous H&S models on the interactions between the elements and practices as shown to affect H&S performance of SB projects. The research extends the application of CMMI to H&S Maturity modelling in the construction industry. It also integrates a framework that defines the advancement of the maturity of H&S practices on SB projects from a chaotic maturity level to a sustainable maturity level. It also integrates a H&S improvement strategy to facilitate the improvement of the H&S maturity level of the SB project, to enable practitioners implement a sustainable H&S tool on their projects. After the AHP exercise, the model will be validated by academic and industry H&S experts and implemented in practice by applying it to at least twenty SB projects.

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