Building Tomorrow's Society
Bâtir la Société de Demain

Fredericton, Canada
June 13 – June 16, 2018/ *Juin 13 – Juin 16, 2018*

VALIDATING AND WEIGHTING THE IMPORTANCE OF THE SAFETY MATURITY DRIVERS OF THE SUSTAINABLE HEALTH AND SAFETY MATURITY MODEL

Orogun, Bezalel[1, 2], Mohamed H Issa
[2] University of Manitoba, Canada
[3] University of Manitoba, Canada
[4] orogunb@myumanitoba.ca

Abstract: The occupational health and safety(OHS) performance of sustainable building(SB) projects has often been deemphasized when evaluating the sustainability of these projects in favour of aspects such as energy, water and indoor environmental quality. This has made some SB more risky to build compared to non SB, thus the need for adequate tools to evaluate them. This paper builds on the Sustainable Health and Safety Maturity Model previously developed to evaluate the maturity of the OHS practices implemented on SB. The model is constituted by 22 safety maturity drivers(SMD) which reflects main OHS aspect to evaluate. Before implementing the maturity model, it is important to validate and determine the extent of importance of the SMDs through an analytic hierarchy process (AHP). This paper presents the methods used to validate and weigh the importance of each SMD. By engaging the expert judgment of OHS experts and researchers, the SMDs were subjected to a validation and AHP process. It was found that project OHS planning was the most important SMD, followed by Incident investigation reporting, performance and workers involvement respectively. The three least important SMD were alcohol and drug evaluation, health and safety in contracts and project organization structure. In validating the SMD using the criteria of appropriateness and comprehensiveness, safety control received the highest average score, followed by project OHS planning, training, competence and education, safety communication and safety inspection. The least average validation scores were obtained for alcohol and drug evaluation, project organization structure and project environment and conditions management.

1 INTRODUCTION

The occupational health and safety(OHS) performance of sustainable building(SB) projects has often been deemphasised when evaluating the sustainability of these projects in favour of other aspects such as energy, water and indoor environmental quality (Rajendran et al. 2009, Hinze et al. 2013, Chen 2010, Greg 2012). Little has been done to evaluate the OHS of SB projects despite OHS being a fundamental component of social sustainability and directly linked to economic sustainability because of its financial implications (Tom 2014). A review of the literature reveals that there is a growing body of evidence that suggest some SB usually have more complex design elements than traditional buildings and may therefore be riskier to build from a OHS perspective compared to non-SB (Annie and Brian 2013, Rajendran et al. 2009, Fortunato et al. 2012 and Dewlaney et al. 2012). This is because tools developed to evaluate the sustainability of building projects such as the Leadership in Energy and Environmental Design (LEED) Rating System do not adequately address OHS, rather it promotes the implementation of sustainable practices that potentially impact OHS performance negatively(Fortunato et al. 2012, Dewlaney et al. 2012). Rajendran et al. (2009) found that the recordable injury rate (RIR) of 38 LEED SB projects was 48% higher than that of 48 non-LEED SB projects. SB technologies and systems have also been found to combine more than one function such as using the building envelope for additional functions like power generation or landscaping (Annie and Brian 2013). The synergies between these different functions produce unwanted hazards and conditions that put workers at a higher risk during construction (Annie and Brian 2013). Similarly, Omar et al. (2013) evaluated the OHS impact of five green features such as geothermal well, storm-water design, renewable energy, green roofs, and daylights on workers of a SB project and found that some SB had greater safety hazards to workers when compared to non SB projects. Therefore, although SB projects offer the potential for improved environmental and energy performance, they are ultimately unsustainable if they don't adequately consider the OHS of the workers who build, operate and maintain them (Rajendran et al. 2009, Hinze et al. 2013, Gambatese et al. 2007, Fortunato III et al. 2011). Given the unique OHS risks of SB projects, there is a need to move from mere compliance with existing prescriptive OHS requirements to high performance as is the case with other SB aspects such as water and energy use. There is also a need to develop new methodologies and tools that evaluate and improve the OHS performance of SB projects from a holistic perspective. These tools would need to identify best practices for sustainable OHS and take advantage of the integrated design process used on these projects and of the people involved in it. Against this background, a maturity model called the Sustainable health and Safety Maturity Model (SHSMM) was developed as shown in Figure 1 to evaluate the maturity of the OHS practices of SB projects and benchmark them against the industry's best OHS practices (Orogun and Mohamed 2017). The SHSMM consists of the three different health and safety (H&S) dimensions of people, process and building, which are each organized by safety maturity drivers (SMD). Each SMD contains a number of critical to safety practices (CTSP). These CTSP reflect current best OHS practices and are used to determine the OHS maturity levels of a project. Before implementing the SHSMM to evaluate selected SB projects, it is important to determine the extent of importance of the selected SMDs in daily onsite OHS management through an analytic hierarchy process (AHP). Also prior to implementing the SHSMM, Its important to determine how reliable the SMDs are in evaluating the OHS of SB projects via a validation process carried out by industry and academic OHS professionals. This paper aims to describe the methods used to validate and weigh the importance of these SMDs.

2 LITERATURE REVIEW

This section presents a brief review of the AHP used to determine the weighting of importance of the SMD and how the AHP is carried out and evaluated for consistency.

2.1 Analytic Hierarchy Process

The AHP introduced by Thomas Saaty (1980), is one of the most widely used effective tool for dealing with multiple criteria and complex decision making to set priorities. The AHP enables the reduction of complex decisions to a series of pairwise comparisons, and then synthesizing the results (Vaidya and Kumar 2006). The AHP helps to capture both subjective and objective aspects of a decision. The AHP is a method of measurement based on a priority scales that involves pairwise comparisons as determined by expert judgment (Rosaria and Roberto 2015). The hierarchical structure of AHP methodology is able to measure and synthetize a variety of factors of a complex decision making process in a hierarchical manner and making it simple to combine the parts in a whole. The AHP basically has three main methodology functions which are: structuring complexity, measurement, and synthesis (Forman and Gass 2001). For the first function, Saaty submits that to deal with the complexity of a decision making process we need to identify all the different factors that affect the decision and organize them in a hierarchical structure of homogenous clusters of factors (Forman and Gass 2001). The second function, measurement is obtained by comparing those factors in pairs in a process called absolute comparison. The weight of each factor in the hierarchy is then found by comparing each factor with a defined parent factor. The third function, synthesis of the priorities (weights) throughout the hierarchy is found by multiplying the priority of one factor in each level by the priority of the factor with which the first is linked (parent factor). The AHP has analytic in its name, because it separates the abstract entity into its constituent elements. The AHP also has the ability to measure and synthesize the multitude of factors in a hierarchy (Forman and Gass 2001). The AHP is a very flexible and powerful tool because the final ranking are obtained on the basis of the pairwise relative evaluations of both the criteria and the options provided by the user. The computations made by the AHP are always guided by the decision maker's experience, and the AHP can thus be considered as a tool that is able to translate the evaluations (both qualitative and quantitative) made by the decision maker into a multicriteria ranking.

2.1.1 How the AHP Works

The AHP can be implemented in four simple consecutive steps (Forman and Gass 2001): computing the vector of criteria weights, computing the matrix of option scores, ranking the options and checking the consistency. In the first step, the AHP considers a set of evaluation criteria and a set of alternative options. The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria (Rosaria and Roberto 2015). The higher the weight, the more important the corresponding criterion. In the second step, for a fixed criterion, the AHP assigns a score to each option according to the decision maker's pairwise comparisons of the options based on that criterion to generate a matrix of option scores (Saaty 1987). The higher the score, the better the performance of the option with respect to the considered criterion. In the third step, the AHP combines the criteria weights and the options scores to determine a score for each option, and a consequent ranking (Saaty 1987). The score for a given option is a weighted sum of the scores it obtained with respect to all the criteria. In the final step, The AHP deploys an effective technique for checking the consistency of the decision maker's evaluations when building the pairwise comparison matrix, thus reducing the bias in the decision making process. Checking the consistency is important because when many pairwise comparisons are performed based on the judgement of experts, some inconsistencies may arise. For instance, assume that three criteria are considered, and the decision maker evaluates that the first criterion is slightly more important than the second criterion, while the second criterion is slightly more important than the third criterion. An evident inconsistency arises if the decision maker evaluates by mistake that the third criterion is equally or more important than the first criterion. A consistent evaluation would be, for instance, that the first criterion is more important than the third criterion. The consistency checking technique relies on the computation of a suitable consistency ratio which must be less than 0.1 if the results from the AHP is to be considered valid (Saaty 1980). The AHP is often used by decision makers and researchers, because it is a simple and powerful tool (Rosaria and Roberto 2015). For instance, in OHS research, Goggin and Rankin (2009) applied the AHP to rank the six key factors constituting the OHS maturity model they developed to evaluate an organization OHS maturity. Reyes et al. (2014) applied the AHP to rank a set of OHS criteria elements constituting the integrated value model for sustainability assessment based on their importance to determine the global OHS sustainability index for a building project throughout its life-cycle.

3. METHODOLOGY

This section provides an overview of the safety maturity drivers (SMD) defined in the SHSMM and how the AHP and validation process for the SMDs were carried out.

3.1 Conceptualizing the Sustainable Health and Safety Maturity Model

The Sustainable Health and Safety Maturity Model (SHSMM) aims to evaluate the daily management of OHS on SB projects. The SHSMM shown in Figure 1 was developed based on the expected daily implementation of OHS practices on the SB project (Orogun and Mohamed 2017). The SHSMM uses the idea of process improvement obtained from the process maturity framework, taking into account vital OHS practices identified in the literature and from industry best OHS practices documentation. The model consists of three different categorizations called health and safety dimensions related to people, process and building, which are each organised by assessment drivers called Safety Maturity Drivers (SMD) which consists of critical to safety practices which reflects current best OHS practices. The underlying assumption of the theoretical model is that higher practice maturity for each of the SMD will translate to higher levels of OHS performance. The assessment of the SMDs would enable the identification of areas of concern that needs to be improved on the SB project through the implementation of a OHS improvement strategy. The 22 SMDs defined in the SHSMM cover OHS practices related to design and construction of SB as described below.

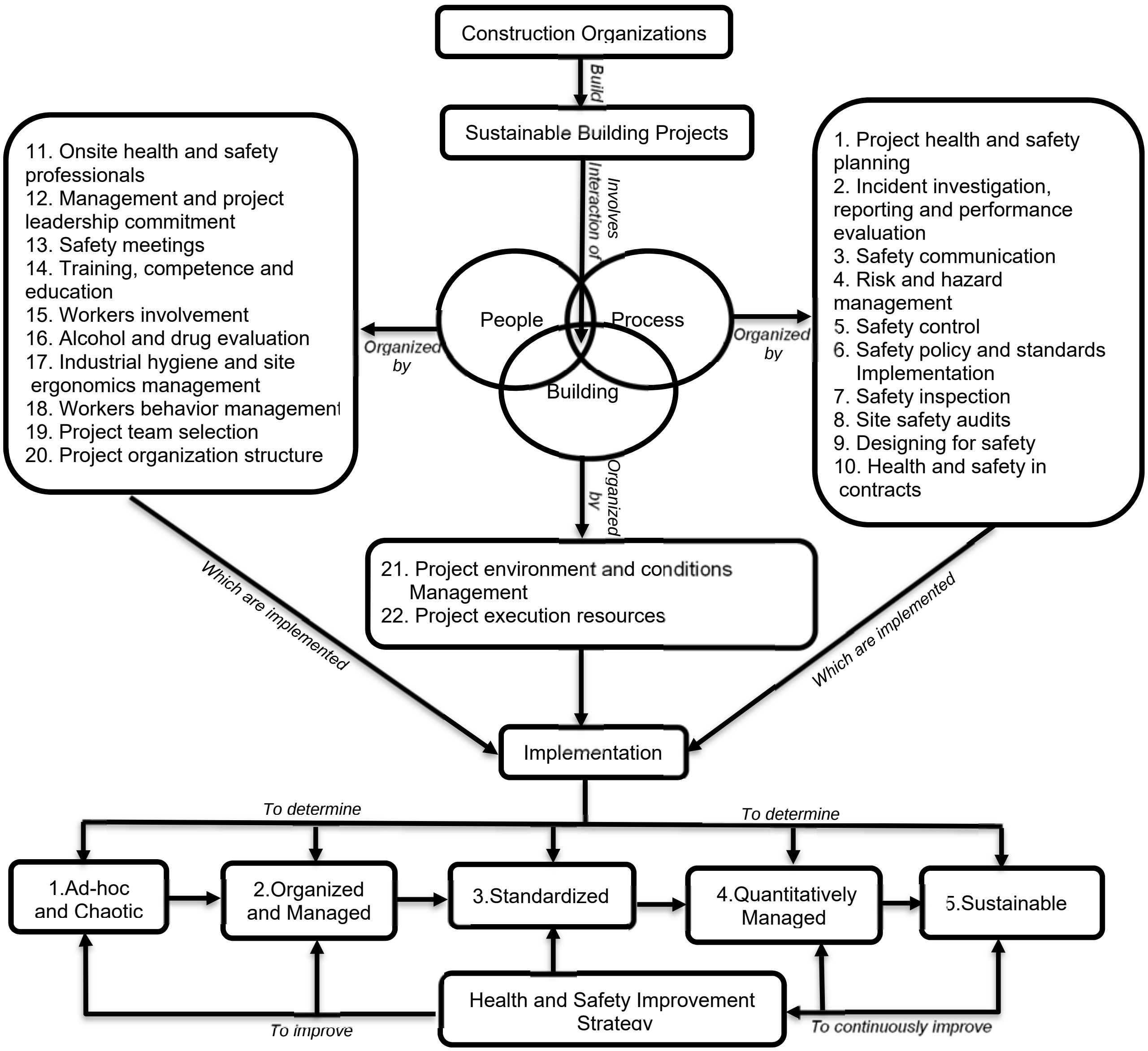

Figure 1 Schematic view of the SHSMM

3.1.1 Process Related Safety Maturity Drivers

1. Project Health and safety planning: Includes practices that indicate how the building project is planned and includes 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 and develop methods to prevent incidents from re-occurring while monitoring onsite safety condition. This also includes near misses and incident investigation, measuring OHS performance, continuous improvement commitment, developing, tracking and reporting of safety metrics and leading indicators.

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

4. Risk and Hazard management: Includes practices about the approach of managing risk on the SB project. These includes all practicable steps that involves identification of hazards, assessment, controls and hazard abatement verification. This include 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 indicate how safety is controlled, managed and improved onsite to achieve a safe condition during SB project execution. This include the use of engineering controls, administrative controls and Personal Protective Equipment's (PPE) use.

6. Safety policy and standards implementation: Includes practices that show the extent of implementation of a OHS policy and standards on SB projects. 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, facilities 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 with defined OHS standards to enable the identification of safety violation. This also includes periodic participation in independent and unscheduled site safety audit by management, carrying out and tracking project safety audit by management.

9. Designing for safety: Includes practices that show measures during the design phase aimed at preventing accident. Designing for safety means explicitly considering the OHS of the project in its design. This concept builds on the principle that, in the hierarchy of controls "designing out" hazards are superior to adopting safe work practices and procedures and using PPE. This also includes the evaluation of design alternatives based on OHS criteria, performing safety design reviews before completion of schematic design, utilizing prevention through design checklist to guide designers.

10. Health and safety in contracts: Includes practices that show the extent to which OHS requirement are captured in the bidding process and finalised project contract. It ensures OHS hazards of material specification regarding the SB project are defined in construction documents. This also includes definition of comprehensive safety method statements, extent of owners involvement in safety.

3.1.2 People Related Safety Maturity Drivers

11. Onsite health and safety professionals: Includes practices that show how OHS professionals are assigned to the project during design and construction phases. It's important that for OHS to improve on SB the integrated design team should include OHS experts. 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 quality and extent of management commitment and project leadership commitment to OHS. This commitment can 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 OHS project activities.

13. Safety Meetings: Includes practices that evaluate how project safety meetings are carried out during project execution. Safety meetings provide opportunities to discuss safety problems and improve safety motivation. 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 how training, competence and education is managed during project execution. Training and competence evaluation is vital because they help to ensure project workers are equipped with the required skills and knowledge to carry out their task safely. Training activities would start by determining training needs. This also includes project task specific and OHS 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 OHS performance. This also includes engaging workers in OHS related decision making, involvement in identifying safety problems, and consultation with workers about OHS matters. This also includes mitigating safety problems, involvement in planning and implementation, empowering workers to take responsibility for safety and accommodating workers safety initiatives.

16. Workers Behavior Management: Includes practices that evaluates how workers behaviour, values and attitude are expressed and managed. Workers behaviour can be assessed based workers disposition towards rewards for safety behaviour, their values, 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, continuous reminders of the severity implications of safety violations

17. Alcohol and Drug Evaluation: Includes practices that evaluates the extent of use of alcohol and drug onsite. This would involve 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 how industrial hygiene and site ergonomics is managed onsite. 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 off 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 taking OHS criteria into account. This also includes selecting subcontractors who would follow established and defined OHS standards, selecting project team members considering OHS conscious attitudes and ensuring contractors and subcontractors adhere to same OHS standard and values to work with them.

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

3.1.3 Building Related Safety Maturity Drivers

21. Project environment and conditions management: Includes practices that evaluates how the project site environment is managed. This include 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 how project execution resources is managed on the site. This evaluate how project resources are maintained and managed to facilitate project execution in a safe way. This includes maintenance, inspection and management of equipment and tools, materials evaluation for safety.

Table 1: Fundamental scale for AHP pairwise comparisons (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	An SMD strongly favored over another and its dominance demonstrated in practice.
9	Extreme importance	The evidence favoring one SMD over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between adjacent judgments	When compromise is needed
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	

3.2 Analytic Hierarchy Process Evaluation of the Safety Maturity Drivers

This research adopted the AHP to rank the 22 SMDs making up the SHSMM based on their relative importance. Eight construction OHS experts from the industry were recruited to conduct pairwise comparison of the 22 SMDs to determine their relative weights of importance in daily onsite OHS management of SB projects. These experts whose profile are shown in Table 3 were identified using convenience and snowball sampling (Bryant and Charmaz 2010), and recruited based on their extensive industry and research experience in construction OHS. The AHP was conducted by face to face meetings with the OHS experts in which the experts were presented with the 22 SMD's in a matrix table and were requested to relatively compare the SMD based on their perception of relative importance via a quantitative ranking scale defined by (Saaty 1987) as shown in Table 1. The scale was selected because it has been used and validated by many studies (Goggin et al. 2010, Reyes et al. 2014) and found to produce consistent results. During the AHP exercise, the pairwise comparisons of the SMDs were conducted by each OHS expert and a pairwise comparison matrix was created. The aggregated pairwise comparison values obtained were then normalized by dividing the value of each column value (i.e. each SMD) by the sum of values for each column in the pairwise comparison matrix such that the sum of each column's values was 1. The obtained values were then normalized to determine ratio scales called eigenvectors which represents the weights of importance (Saaty 1987). The final set of weights of importance of the SMDs as shown in Table 2, were then determined based on the consensus of the participating experts. A consistency check of the AHP results was done by calculating a consistency ratio to assess the consistency of the ratings of the various SMDs by the participating OHS experts (Saaty 1987).

3.3 Validation of the Safety Maturity Drivers

The 22 SMDs of the SHSMM were validated conceptually to determine their content validity before they would be used to evaluate SB projects. This entails determining the extent to which each SMD is able to provide reliable and valid information about a SB project's OHS maturity level. Two criteria were used to validate the SMDs: appropriateness and comprehensiveness as recommended by Carlucci (2010) and

Brain (2016). Appropriateness refers to the extent to which each SMD can be used to evaluate the OHS practices of SB projects (Ferzon 2015). This is to determine the relevance and applicability of the SMD in evaluating a project OHS maturity. Comprehensiveness refers to the completeness of the SMDs making up the SHSMM (Brian 2016). Comprehensiveness aims to determine if there are other SMDs that need to be considered in addition to the 22 SMDs that have already been identified. Expert judgement has been found to be a reliable means of carrying out conceptual validation (Brian et al. 2015). Eight of the 22 OHS experts contacted participated in the AHP and validation exercise and five out of the 10 OHS researchers contacted participated in the validation. The validation involved administering a questionnaire survey worksheet to the participants. The participants were requested to use a five-point Likert-scale (Strongly Agree(5), Agree(4), Neutral(3), Disagree(2), Strongly Disagree(1)) defined in the validation worksheet to rate the appropriateness of each SMD. To rate the comprehensiveness of the SMDs, each participate was requested to answer an open-ended question at the end of the validation worksheet enquiring about potential additional SMDs to be considered to assess the maturity of a project's OHS practices. A detailed description of each SMD was attached to help ensure participants understanding of the SMD been validated. The average validation score for each SMD was determined based on the average of the rating given by the eight participating expert and the five OHS researchers respectively. In revising SMD after the validation, only new SMDs proposed by more than 50% of the participants was needed to be added to the model to improve the comprehensiveness of the model, with the appropriate CTSPs also proposed.

Table 2 AHP Weighing and Validation for safety maturity drivers

S/N	SMD's evaluated	AHP evaluation		Validation	
		Eigenvalues	Ranking	Average score	Percentage of response higher than 3
1	Project health and safety planning	0.059941898	4	4.5	92.3%
2	Incident investigation reporting, performance	0.068732975	2	4.3	100%
3	Safety communication	0.048191525	11	4.5	100%
4	Risk and hazard management	0.070851749	1	4.2	92.3%
5	Safety control	0.051418601	7	4.7	100%
6	Safety policy and standards implementation	0.050086184	9	4.2	100%
7	Safety inspection	0.048604496	10	4.5	92.3%
8	Site safety audits	0.045059524	13	4.2	92.3%
9	Designing for safety	0.053094513	6	4	84.6%
10	Health and safety in contracts	0.028907881	20	3.8	84.6%
11	Onsite health and safety professionals	0.051000513	8	3.8	76.9%
12	Management commitment and project leadership commitment	0.048146088	12	4.3	100%
13	Safety meetings	0.030435004	18	4.2	92.3%
14	Training, competence and education	0.057086308	5	4.5	100%
15	Workers involvement	0.064091669	3	4.3	100%
16	Workers behavior management	0.036001763	15	4.3	100%
17	Alcohol and drug evaluation	0.024082676	22	3.8	92.3%
18	Industrial hygiene and site ergonomic management	0.038155958	14	3.8	76.9%
19	Project team selection	0.030406021	19	3.8	76.9%
20	Project organization structure	0.027523218	21	3.5	76.9%
21	Project environment and conditions management	0.034697603	16	3.5	76.9%
22	Management of project execution resources	0.033483841	17	3.8	84.6%

4 RESULTS

The AHP consistency ratio was 0.085 which is less than 0.1 indicating a good consistency of the response of the AHP participants. Based on relative importance and ranking of the SMDs, risk and hazard management was found to be the most important SMD, this was followed by incident investigation reporting, performance and then workers involvement. Alcohol and drug evaluation was the least importance, then followed by project organization structure and health and safety in contracts**.** In interpreting participant's validation ratings, two criteria were developed. The first criterion is a threshold value of 3.50 for all mean values for the SMD based on the likert scale (1 = lowest level; 5 = highest level), in which ratings of 1–1.99, 2-3.49, 3.5-3.99 and 4–5 were considered "highly invalid," "invalid," "valid," and "highly valid," respectively. The second criterion is comparing the percentage of the number of responses of the experts higher than 3 based on the likert scale with 75%, which means if the percentage is higher than 75%, then more than 75% of the experts agree that the SMD is a valid and reliable basis for determining a SB projects OHS maturity.

Table 3 AHP and Validation Experts Profile

Experts	Position	Experience in Health and Safety Field
1	District Health and Safety Manager	22 years
2	Senior District Health and Safety Manager	20 years
3	Health and Safety Administrator	10 years
4	Health and Safety Consultant	10 years
5	Senior Health and Safety Advisor	15 years
6	Health and Safety Advisor	8 year
7	Senior Health and Safety Manager	17 years
8	Health and Safety Consultant	16 years

5 DISCUSSIONS

For the appropriateness validation criteria, the SMDs validated had a mean value of above 3.5 and an expert agreement percentage of above 75% suggesting that the SMDs provide a reliable basis for evaluating SB projects OHS maturity level. The average validation score for the 22 SMDs was 4.1. Also, 14 of the total 22 SMDs were rated highly valid, while the remaining eight SMDs were rated valid suggesting that the SMDs are appropriate enough to evaluate a SB OHS maturity level. It was found that project H&S planning was the most important SMD, this is because H&S planning sets the pace for daily onsite H&S management. This was in agreement with (Rajendran 2009) who found that after a series of reviewing 13 safety elements by expert judgment, Safety planning was found to be the most important safety element onsite. Project H&S planning was also validated with a highly valid score of 4.5 and an expert agreement percentage of 92.3 % suggesting the high extent of its importance. Alcohol and drug evaluation was found to be the least important SMD affecting onsite OHS performance with an average score of 3.5 with a relatively high expert agreement percentage of 92.3%. This is probably because alcohol and drugs evaluation is not done by a number of construction companies due to provincial regulations hence the strongly diverging opinion among participating experts during the AHP on its importance with respect other SMD. However its importance with respect to onsite OHS management was strongly recognised by the experts as shown by an expert agreement percentage of 92.3%. For the comprehensiveness criteria, there was no additional comment put down by the participants, thus suggesting that the identified 22 SMD are adequate enough to evaluate the maturity of the OHS practices implemented on SB projects.

6 CONCLUSION

The potentially lower OHS performance of some SB projects reinforces the need for tools that would improve their performance through improving the maturity of the OHS practices implemented on them and addressing the risks that would undermine them. In this light, a Sustainable Health and Safety Maturity

Model comprising 22 SMD was developed and subjected to an AHP and validation process by expert judgment to determine the SMDs relative importance and the extent to which they could provide valid and reliable information about a SB project OHS maturity level. It was found that project health and safety planning was the most important SMD, followed by Incident investigation reporting, performance and workers involvement respectively. The three least important SMDs were health and safety in contracts, project organization structure and alcohol and drug evaluation. After the validation process using the criteria of appropriateness and comprehensiveness, it was found that safety control received the highest average score, followed by project health and safety planning, training, competence and education, safety communication and safety inspection. The least average validation score was obtained for project organization structure, project environment and conditions management and alcohol and drug evaluation. The implementation of the SHSMM will require the use of an assessment questionnaire based on each SMD to evaluate a minimum of 15 SB and 15 non-SB projects within Manitoba. The maturity level for each project will be obtained by multiplying the weights of importance derived from the AHP and the scores from the assessment sheet for each SMD. The research is part of an ongoing research initiative led by the Construction Engineering and Management Group at the University of Manitoba.

References

Annie, R. and Brian, M. 2013. A Systematic Review of the Literature and Green Construction Rating System *Analysis*, VirginiaTech, USA

Chen, H. 2010. Green and Healthy Jobs. Labor Occupational Health Program, University of California, Berkley, USA.

Dewlaney, K. S. Hallowell, M. R. and Fortunato, B. 2011. Safety risk quantification for high performance sustainable building construction. *Journal of Construction Engineering and Management*, ASCE, 138(8): 964-971

Forman, E. and Gass, S. 2001.The Analytic Hierarchy Process. *Operational Research*, 49:469-86.

Fortunato, B. Hallowell, R. and Dewlaney, K. 2011. Identification of safety risks for high performance sustainable construction projects. *Journal of Construction Engineering and Management* ASCE, 138(4): 499-508

Gambatese, J. A. Rajendran, S. and Behn, M. G. 2007. Green Design and Construction: Understanding the Effects On Construction Worker Safety and Health. *Professional Safety*, ASSE, 52(5):

Greg, B. 2012. Safety Goes Green Occupational Health and Safety Canada. Available: http://www.ohscanada.com/features/safety-goes-green/

Goggin, A. Willis, C. and Rankin, J. 2010. The relationship between the maturity of safety management practices and performance. *Construction Research Congress*, ASCE, Banff, Canada, 1047- 1056

Hinze, J. Godfrey, R. and Sullivan, J. 2012 Integration of Construction Worker Safety and Health in Assessment of Sustainable Construction. *Journal of Construction Engineering and Management,* ASCE, 139(6): 594-600

Rajendran, S. and Gambatese, J. 2009. Development and validation of sustainable construction safety and health rating system. *Journal of Construction Engineering and Management*, ASCE, 135(10): 1067-1075.

Rajendran, S. Gambatese, J. A. and Behm, M. G. 2009. Impact of green building design and construction on worker safety and health. *Journal of Construction Engineering and Management*, 135(10): 1058-1066

Reyes, J. P. San-José, J. T. Cuadrado, J. and Sancibrian, R. 2014. Health & Safety criteria for determining the sustainable value of construction projects. *Safety Science*, 62: 221- 232.

Rosaria, F. and Roberto, C. 2015. Criteria in AHP: A Systematic Review of Literature, Criteria in AHP: a Systematic Review of Literature, *Information Technology and Quantitative Management* 55: 1123-1132.

Saaty, R. W. 1980. The Analytic Hierarchy Process." McGraw-Hill, New York.

Saaty, R. W. 1987. The analytic hierarchy process, What it is and how it is used. *Mathematical Modelling*, 9(3): 161-176.

Tom, C. 2014. If Corporations Are Sustainable, Why Are So Many Workers Dying, Centre for safety and Health Sustainability, Illinois, USA

Vaidya. O.S. and Kumar S. 2006 Analytic hierarchy process: An overview of applications. *European Journal of Operational Research*, 169:1–29.