Evaluation of Social Sustainability in Building Projects: Theoretical Framework and Impact Assessment Approach

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Abstract
Recognizing the importance of building-specific social impact assessment tools to the achievement of social sustainability of building projects, this study developed a methodological framework for life-cycle social sustainability assessment of building projects through stakeholder-based approach. The assessment framework was firstly proposed considering four stakeholders, including worker, occupant, local community and society, and impact subcategories associated with different social concerns. Indicators were then selected for each subcategory based on the assessment objective and data availability. They were categorized into three groups, including quantitative indicators in generic analysis, as well as quantitative and semi-quantitative indicators in site-specific analysis, and corresponding scoring method were provided. Finally, weights among impact subcategories were generated through questionnaire survey based on AHP method using consistent fuzzy preference relations (CFPR), and weights among life-cycle phases were determined considering the possibility to place control as well as level of concern of construction practitioners. In summary, the proposed method applies multi-stakeholder approach and includes several life-cycle phases which enables the investigation on potential transfer of impacts between life-cycle phases.

Keywords: social sustainability, social life cycle assessment (S-LCA), life cycle perspective; multi-stakeholder approach, AHP

Introduction

Buildings and their relevant processes have significant influence on three key dimensions of sustainability, i.e., environmental, economic and social dimensions, in both positive and negative manners (Kamali & Hewage, 2017). On one hand, building projects satisfy human being's basic needs and improve life quality, create employment opportunities, and further contribute to national economy (Love & Irani, 2004; Zuo & Zhao, 2014). On the other hand, building projects consume raw materials and energy to construct and operate, release greenhouse gases (GHG), generate solid waste, cause pollution and occupy land (Ding, 2008; Wong & Fan, 2013). In addition, building projects are responsible for some safety and health issues during construction process (Shen, Tam, Tam, & Ji, 2010; Zhang, Wu, & Shen, 2015). The quality of building products and indoor environment also have great effect on occupational health (Zuo et al., 2017).

With increasing awareness of above-mentioned issues, efforts have been made in construction industry, shifting from traditional focuses of time and cost only, towards much broader ones. However, these efforts are mainly directed at reducing negative environmental impacts while social sustainability has not been properly addressed (Gould, Missimer, & Mesquita, 2017; Hutchins & Sutherland, 2008). Social sustainability involves multi-faceted social values, which are sequentially influenced by plentiful stakeholders (Almahmoud & Doloi, 2015). A socially sustainable building project is supposed to respond to the different requirements of multiple stakeholders involved in the whole process of the building project development, including not only the final users but also construction personnel, suppliers and local communities (Hussin, Rahman, & Memon, 2013; Valdes-Vasquez & Klotz, 2012; Wong & Fan, 2013).

However, social impact assessments with a proper coverage of relevant stakeholders for building project evaluation is still lacking (Valdes-Vasquez & Klotz, 2012; Zhao, Zhao, Davidson, & Zuo, 2012). This study thus aims to develop a methodological framework for social sustainability assessment of building projects through stakeholder interest-based approach. In this work, social life cycle assessment (S-LCA) method was adopted as the basis to assess the potential positive and negative social impact of products, processes, services or systems throughout their life cycle. Such life-cycle perspective enables the consideration of potential transfer of impacts between different life cycle phases, impact categories and regions.

S-LCA is regarded as a parallel to the environmental life cycle assessment (E-LCA) (Ekener, Hansson, & Gustavsson, 2018). However, unlike E-LCA that is standardized by ISO 14040 and 14044, there is no consensus on the specific or consistent S-LCA method. One significant step towards its standardization is the publication of Guidelines for Social Life Cycle Assessment of Products (Benoît et al., 2009) (hereafter referred to as the Guideline), which provides a general framework with methodological sheets for 31 social impact subcategories regarding different aspects of social concerns. In the Guideline, social impacts are observed in five stakeholder categories, including workers, local community, consumer, society and value chain actors. Such stakeholder-based approach is consistent with our initial consideration for framework development.

The Guideline has been applied and tested in many case studies in various industrial contexts with different objectives, including some building-specific analyses, such as (Dong & Ng, 2015; Hosseinijou, Mansour, & Shirazi, 2014). While using the Guideline as the basis for their analysis, previous cases studies vary greatly regarding the detailed methodological choices to conduct S-LCA studies depending upon difference purposes and application scenarios (Macombe, Feschet, Garrabé, & Loeillet, 2011; Reitinger, Dumke, Barosevcic, & Hillerbrand, 2011). Several key issues regarding methodological choices are identified from previous studies. The fundamental one is the identification of relevant stakeholders and social issues. Although the Guideline identifies hundreds of social issues, not all of them are directly relevant to the analysis. Social issues can be identified differently under different regional and industrial scenario. Therefore, a set of social issues associated with various stakeholders related to different life cycle phases of building projects needs to be understood before conducting S-LCA. Sequentially, weights among the selected impact categories need to be determined properly.

Another issue is associated with the social indicators to characterize the social issues identified. In S-LCA studies, data can be collected from either generic or site-specific sources; impacts can be captured through quantitative, semi-quantitative or qualitative indicators. Both data source and indicator type, and even different policy or industrial requirement, may lead to different choices of indicator for a certain impact category. Hence, a specific set of indictors needs to be developed depending on the goal and scope definition as well as data accessibility. Besides, the choice of the reference performance for each indicator needs to be justified for quantitatively illustrating social performance. The reference performance could be determined based on the minimal legal requirements, sectorial standards and average performance, as well as the best expected practices within the industry (Revéret, Couture, & Parent, 2015).

This study contributes to the development of social sustainability assessment of building projects through addressing the above-mentioned issues regarding S-LCA and proposing a method to calculate social impact scores. The proposed theoretical framework for social sustainability assessment is presented in next section, with the definition of stakeholder and relevant impact subcategories. The methodology for social impact assessment is then elaborated, including indicators selection, weights determination, and calculation of social impact scores. This is followed by a case study comparing two building structures with different construction methods. Conclusion and future work are discussed in the last section.

Theoretical framework for social sustainability assessment

This section presents the selection and definition of social impact categories, which form the theoretical framework for social sustainability assessment of building projects. Consistent with the stakeholder-based approach in the Guideline, stakeholder categories were firstly identified to cover groups of people that are potentially affected by life-cycle activities, followed by the selection of social subcategories under each stakeholder category to illustrate different aspects of social concerns.

In this study, four main life cycle phases of building projects were considered, including raw material extraction, building material or products manufacturing, on-site construction, and operation and maintenance (O&M). Accordingly, four stakeholder categories were identified, including: a) workers, which refer to people working in manufacturing plant or on mining/construction site; b) occupants of the building; c) local communities, which refer to those who live in the close proximity to a production site or construction site, and thus directly affected by the production or construction activities; and d) society, which refers to the general public in the region where the building project is located and is indirectly affected regarding acknowledged social values (Manik et al., 2013; Siebert, Bezama, O'Keeffe, & Thrän, 2016).

Figure 1 illustrates how activities within different life cycle phases are linked to the stakeholder categories. For raw material extraction and manufacturing phase, many materials or products are required, and thus various organizations are involved and cause different impacts. Consequently, assessment should be performed separately by organizations. As for the construction and O&M phase, although several companies representing owners, contractors, designers, etc. are involved, only one integrated organization, i.e., project team, will be assessed. That is because building projects are delivered through a temporary and dynamic team. Stakeholder category "society" is not directly linked to any life cycle phase; it is how the development of a certain building project causes the change of industrial environment or society (specifically Singapore in this study) that will be examined.

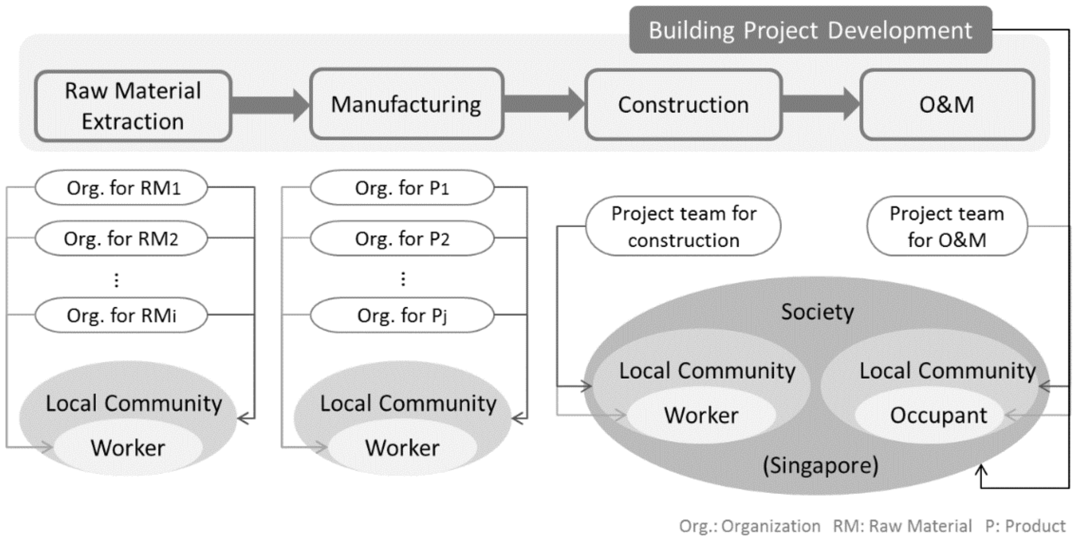

Figure 1: Relationship between life cycle phases and stakeholder categories

The selection of social impact subcategories was based on the Guideline and 15 previous studies that developed building-specific criteria for social impact assessment (Ali & Al Nsairat, 2009; Almahmoud & Doloi, 2015; Alwaer & Clements-Croome, 2010; Andrade & Bragança, 2011; Bragança, Mateus, & Koukkari, 2010; Chan & Lee, 2008; Y. Chen, Okudan, & Riley, 2010; Dave, 2011; Kamali & Hewage, 2015; Nguyen & Altan, 2011; Pan, Dainty, & Gibb, 2012; L.-y. Shen et al., 2010; L. Y. Shen, Li Hao, Tam, & Yao, 2007; Valdes-Vasquez & Klotz, 2012; Yunus & Yang, 2011). It is worth mentioning that previous building-specific studies usually only focus on construction and O&M phases, while enlarged boundary in this study, i.e., including four main life-cycle phases, leads to a broader set of impact categories. Social impact categories included in this study are summarized in Table 1.

Table 1: Selection of stakeholder categories and subcategories

Social Impact Category		Source	
Stakeholder Category	Subcategory	the Guideline (original expression if any change)	Papers (count of papers mentioning a certain subcategory)
Worker	Health and safety of workers	√	√ (8)
	Fair Salary	√	×
	Working Hours	√	×
	Discrimination	√	×
	Forced Labour	√	×
	Child Labour	√	×
Occupant	Functionality and Usability	√ (safety & health)	√ (8)
	Health and Comfort	√ (safety & health)	√ (14)
	Accessibility	×	√ (6)
	Feedback Mechanism	√	×
Local Community	Safety and Health	√ (safe, healthy and secure living conditions)	√ (9)
	Accessibility	√ (access to material resources)	√ (6)
	Integration and Interaction	√ (local engagement; cultural heritage)	√ (7)
	Local Employment	√	√ (6)
Society	Technology development	√	√ (3)
	Public commitments to sustainability issues	√	×

For category "workers", *safety and health* is the only aspect discussed in previous papers. It evaluates the quality and efficiency of safety management within an organization, mainly including the provision of necessary and enough safety measures, equipment, facilities, information and trainings to the workers. Apart from safety and health protection, the Guideline also highlights the importance of protecting human rights, particularly workers' rights here, which is seldom included in previous building-specific criteria. Therefore, five subcategories, including *fair salary*, *working hours*, *discrimination*, *forced labour*, *child labour*, are added to consider human rights including right to free choice of employment, right to equal pay for equal work without any discrimination, right to just remuneration and right to rest brought by reasonable working hours and periodic holidays with pay.

Category "occupants", named "consumer" in the Guideline, is mostly discussed in building-specific studies as it is about the core function of buildings. *Safety and health* in the Guidelines is divided into two subcategories, *functionality and usability*, and *health and comfort*. *Functionality and usability* assesses how well the project meets its functional needs and provides building facilities and features depending on different usage purposes. Particularly, it focuses on the provision of essential amenities such as drinking water, toilet, first aid, etc., as well as safety and security issues, including building's ability to protect the residents from external harm events, provide safe internal installations and security measures to avoid risk of harm due to intentional criminal acts such as assault, burglary or vandalism. *Health and comfort* basically assesses indoor environmental quality (IEQ). IEQ is regarded to directly influence the health, comfort and well-being of occupants (De Giuli et al., 2012), which is illustrated by several aspects such as indoor air quality, hydrothermal comfort, acoustic comfort and visual comfort.

Accessibility is another essential factor in improving social sustainability through increasing occupants' satisfaction. People are always willing to have proper and convenient access to certain places in their daily lives (Chan and Lee, 2008); thus they care about how building is linked to places such as public transport nodes, daily use shops, health facilities, etc. The last subcategory is *feedback mechanism*, which is tightly related to the occupants' satisfaction related to building services. Efficient feedback mechanism should at least make sure any complaints concerning the building normal operation can be solved within a reasonable time.

As for category "local community", *safety and health* assesses whether production activities in factories or on-site construction work have a good control of noise generation, pollution and dust emission as well as a good waste management to avoid harming neighbors' health and comfort. It also evaluates whether there is any safety risk around construction site, such as falling objects, uncovered holes in the road or pavement, poor lighting and uneven surfaces, etc. *Accessibility* for the surroundings means differently for different phases. During construction phase, accessibility assesses how construction works affect people's daily travel time and distance and decrease the mobility of daily life (Andersson and Johansson, 2012); while during O&M phase, surrounding residents see accessibility as whether the project respects, protects, provides or improves community access to infrastructures, such as roads, facilities, drainage, and even open spaces, parking areas, green areas, etc.

Integration and Interaction is to assess how a project is integrated into the local community, and how it interacts with community stakeholders. This subcategory requires a project to respect the social value of a community, to preserve the local characteristics, to engage community stakeholders in relevant decision-making processes and listen to their voices, to respond to communities' concerns and perceptions effectively, as well as to establish a communication path to encourage such interaction and integration. The last subcategory, *local employment*, investigates both direct and indirect influence of a project on local employment. Local hiring preferences provide important income and training opportunities to community members. Furthermore, developing relationships with locally-based suppliers will further encourage local employment and development.

For category "society", *technology development* examines technology development strategies of an organization. It may include involvement in technology transfer program, partnerships in research and development, or investments in technology development/technology transfer regarding building products, systems, construction methods, services, techniques, or management models. Another category, *public commitments to sustainability issues*, is related to the broader meaning of organizational social responsibility. It assesses whether an organization prepare publicly available documents as promises or agreements on sustainability issues to its customers, shareholders, local community or the public.

Methodology for social impact assessment

This section addresses the issues related to social impact assessment, which are illustrated by Figure 2. One or more social indicators were selected to characterize each impact subcategory (as listed in Table 1). Three groups of indicators were used in this methodology and they applied different scoring methods, which are explained separately in the subsections. To integrate these social performance scores (SPS), weights among life-cycle phases and impact categories were generated.

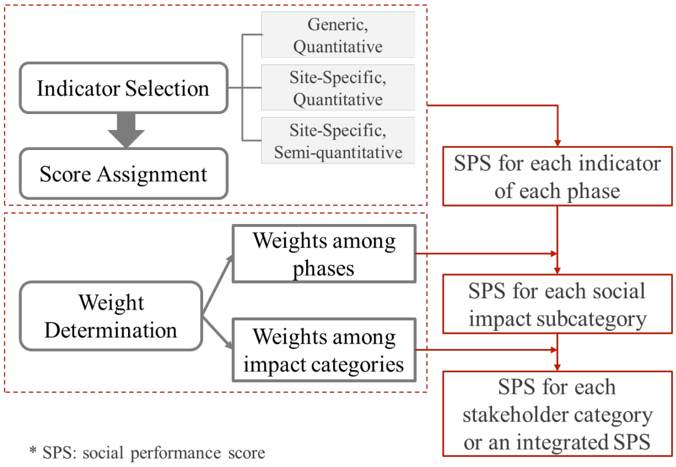

Figure 2: methodological framework for social impact assessment

Indicators Selection

Indicator selection is influenced by the nature of the assessment objective and data availability. Site-specific data obtained by investigating organizational operation are generally more favorable to evaluate social impact compared with generic statistical data(L. Dreyer, Hauschild, & Schierbeck, 2006; Jørgensen, Le Bocq, Nazarkina, & Hauschild, 2008; Kruse, Flysjö, Kasperczyk, & Scholz, 2009). However, such information is not always available. From life cycle perspective, main activities of a project team lie in construction and O&M phases, and the building evaluation is always conducted during the design phase, or before buildings being put into operation. The availability of detailed information will be lower if the activities are located farther from the center, as indicated in Figure 3. Therefore, this study uses both generic and site-specific data, as shown in Figure 3.

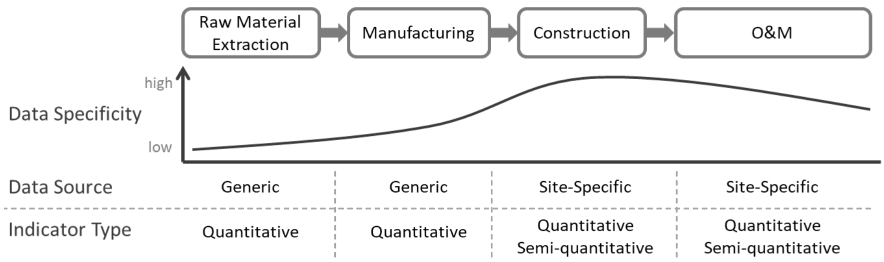

Figure 3: Data specificity change along life cycle phases and their corresponding data sources and indicator types

To obtained quantitative results, indicators can be quantitative or semi-quantitative. Quantitative indicators describe assessed issues using specific values, for instance, number of work accidents. Semi-quantitative indicators are quantification of qualitative indicators which usually use a scoring system or a yes/no form, for example, giving score for company performance regarding human rights protection using a scale of 1 to 5. As shown in Figure 3, for the analyses based on the generic data, indicators are all quantitative since statistical data at the country and industry level are used. As for site-specific analyses, both quantitative and semi-quantitative indicators are involved, since quantitative indicators sometimes cannot properly describe the real case situation (L. C. Dreyer, Hauschild, & Schierbeck, 2010).

Based on the previous discussion, indicators were selected separately for generic analysis and site-specific analysis involving both quantitative and semi-quantitative indicators. The selection of indicators and their corresponding data sources, as summarized in Table 2 (for generic analysis) and Table 3 (for site-specific analysis), were on the basic of methodological sheets of *the Guideline* (Benoît et al., 2009); further selection was based on the relevancy to construction sector context or Singapore context and data availability.

Table 2: Selection of indicators for generic analysis

Subcategory	Indicators for generic analysis	Sources
Health and safety (worker)	Non-fatal and fatal occupational injuries per 100,000 workers	(Hämäläinen, Takala, & Saarela, 2006)
Fair Salary	Ratio between average sector wage and living wage	(Communities, 2009; ILO, 2017)
Working Hours	Excessive weekly working hours per employed person compared with 48 hours	(ILO, 2017)
Discrimination	Gender inequality index	(Selim Jahan, Eva Jespersen, & Mukherjee, 2016)
Forced Labor	Proportion of population in modern slavery	(WalkFree, 2016)
Child Labor	Percentage of children 5-14 years old involved in child labor	(UNICEF, 2017)
Safety and Health (Local community)	Reliability of police services Burden of disease Dealing with construction permits	(Klaus Schwab, Xavier Sala-i-Martín, & Samans, 2018) (WHO, 2015) (WorldBank, 2017)
Accessibility (Local community)	Percentage of population with access to improved water source and improved sanitation facilities Quality of road	(WorldBank, 2016) (Klaus Schwab et al., 2018)
Integration and Interaction	Transparency of government Policymaking Public trust in politicians	(Klaus Schwab et al., 2018)
Local Employment	Unemployment rate Local supplier quantity	(WorldBank, 2016) (Klaus Schwab et al., 2018)

Table 3: Selection of indicators for site-specific analysis

Subcategory	Indicators
Health and safety (worker)	Status of managerial practices; Accident frequency rate
Fair Salary	Status of managerial practices; Percentage of workers whose wages meet at least legal minimum wage or sectorial standard; Percentage of workers who are paid a living wage.
Working Hours	Status of managerial practices; Contractual working hours; Management of overtime
Discrimination	Status of managerial practices; Numbers of incidents of discrimination
Forced Labor	Status of managerial practices; Numbers of forced labor
Child Labor	Status of managerial practices; Numbers of child labor
Functionality and Usability	Status of design consideration; Performance regarding meeting functionality needs and provision of essential amenities and building equipment
Health and Comfort	Status of design consideration; Performance regarding indoor air quality, acoustic comfort, hydrothermal comfort and visual comfort
Accessibility (occupants)	Status of design consideration; Performance regarding proximity to public transportations and amenities
Feedback Mechanism	Status of managerial practices; Performance regarding efficiency of dealing with fault reporting and general enquiries
Safety and Health (Local community)	Status of managerial practices; Performance regarding controlling disturbance to surroundings regarding dust emission, noise emission, and preventing safety issues
Accessibility (Local community)	Status of managerial practices; Performance regarding preventing mobility disturbance (construction phase); Status of design consideration; Performance regarding proving open places, paths and facility for public (O&M phase)
Integration and Interaction	Status of managerial practices; Performance regarding the preservation of local characteristics, and involvement of neighbourhoods into project-related activities, such as design and construction process planning, knowledge sharing and skill transfer
Local Employment	Status of managerial practices; Percentage of workforce hired locally; Percentage of spending on locally-based suppliers.
Technology development	Status of managerial practices; Performance regarding technology development strategies
Public Commitment to Sustainability Issues	Status of managerial practices; Performance regarding public sustainability reporting

Scoring of indicators

As listed in Table 2, three groups of indictors are involved, including quantitative indicators in generic analysis, as well as quantitative and semi-quantitative indicators in site-specific analysis. Indicators need to be scored and normalized to a range of -2 to +2 in order to be further integrated to single social performance scores.

(a) Quantitative Indicators in Generic Analysis

Before conducting generic analysis, country-level performance scores regarding each impact indicator need to be prepared using national statistical data. Statistical data were collected from several online databases or international reports, as indicated in Table 2, and were normalized to a range of -2 to +2. Positive values represent above-average or favorable social performance, while negative ones show poor social performance or negative impact. For example, country-level statistics regarding non-fatal occupational injuries rate (Hämäläinen et al., 2006) were normalized between -2 to +2 where country with lowest injuries rate was assigned a score of 2, and country with the highest injuries rate was assigned a score of -2. As mentioned, the normalization rule is based on the actual social meaning of the indicator, rather than all being normalized according to maximum and minimum values. For example, most of the countries do not have issues of child labor according to statics (UNICEF, 2017); thus countries with 0% were scored as 2, while others are normalized to -2~0.

With country-level performance scores, data collection for generic analysis focuses on the identification of main countries involved in certain phases (particularly raw material extraction and production phase), and the activity contribution of these countries. In this study, weight proportions of building materials serve as the basis for calculation, as adopted in previous studies (Ekener-Petersen & Finnveden, 2013; Gould et al., 2017); while activity contributions of countries are connected to these materials through worldwide extraction statistics and export or import data.

For raw material extraction phase, weights of raw materials are estimated based on the quantity of building materials that can be identified using Bill of Quantity or other project records. These materials can be split into raw materials based on general production information of a certain material. For example, integrated steelmaking route requires 1.4 kg of iron ore, 0.8 kg of coal, 0.3 kg of limestone and 0.12 kg of recycled steel to produce 1 kg of crude steel (Worldsteel, 2018). Such information indicates the extraction forms of raw materials and allows the conversion to percentage composition of all the raw materials involved. For each raw material, main extraction locations and percentage of extraction from each country can be obtained from the statistics. In this study, Mineral Commodity Statistics (USGS, 2017) and World Mineral Production (Brown et al., 2014) were used to identify dominant countries that contribute around 90% of total world extraction, which are then used to represent all contributing countries for simplification.

For manufacturing phase, indicators are scored following the similar process. Differently, the activity contribution of each country could be calculated based on more specific and accurate information, such as project purchasing or supplier records, showing actual origins of a certain building material or product. Alternatively, for building materials or products that are directly related to assembly or construction activities in Singapore, country activity distribution can be determined using Singapore-specific statistical data, such as import statistics (COMTRADE, 2017; Simoes, 2017), instead of using worldwide statistical data. For example, considering sand usage in Singapore relies greatly on import, country activity contribution for sand was estimated using import data, according to which Malaysia (65.3%), Vietnam (20.4%) and Cambodia (14.3%) are the top three contributors for sand mining.

Accordingly, the contribution of activities in jth country (activity contribution, AC_j) involved in a certain life cycle stage can be obtained through integrating quantity proportion of kth material (quantity proportion, QP_k) and country activity contributions regarding individual materials (AC_{jk}), as indicated by Equation (1).

$$AC_j = \sum QP_k \times AC_{jk} \tag{1}$$

With the normalized social performance score of jth country for ith indicator (country-level performance score, CPS_{ij}), and the activities contribution occurred in each country (AC_j), the integrated normalized social performance score of ith indicator (social performance score, SPS_i) can be obtained by,

$$SPS_i = \sum CPS_{ij} \times AC_j \tag{2}$$

(b) Quantitative Indicators in Site-specific Analysis

Scores for quantitative indicators are obtained using performance reference values (PRVs), which can be country and/or sector average performance values. Specific calculation depends highly on the actual meaning of the indicators. For instance, to score performance regarding local employment, percentage of local workforce in a project is selected as indicator, and both sector and country statistical data were used as PRVs, being 14% and 63% respectively. 63%, rather than 100%, is given the score of +2, considering 63% is seen as the optimistic (best) performance in the context of Singapore; 14% is given the score of 0, indicating the standard and average performance level. Accordingly, performance score is obtained through normalizing project-specific percentage of local workforce, e.g. project with 20% being local workforce obtains the score of 0.24 (= $(20\% - 14\%)/(63\% - 14\%)$).

(c) Semi-quantitative Indicators in Site-specific Analysis

Scores for semi-quantitative indicators are obtained based on experts' verbal and qualitative assessments and their further conversion to numbers. The assessment is based on the performance reference scales (PRS), including five performance levels, namely, very poor (VP), poor (P), fair (F), good (G), very good (VG), and corresponding performance descriptions of each level. Project team members (such as engineers and project managers) or multi-stakeholder (which may include occupants, local community, workers) are required to carefully check the descriptions provided and select the suitable performance level based on their opinion.

Assessment results are then converted into triangular fuzzy numbers $\tilde{x}_i^m = (a, b, c)$ using Figure 4 to represent mth evaluator's assessment regarding ith indicator, where a, b, and c are the membership function parameters. Adoption of fuzzy numbers can address the imprecision and uncertainty that is inherent to the human judgments in the decision-making process (Ren, Manzardo, Mazzi, Zuliani, & Scipioni, 2015). Later, all the assessment results are aggregated into group evaluation results by applying the fuzzy averaging operator, which is defined by:

$$\tilde{x}_{ik} = \frac{1}{\mathrm{M}}[\tilde{x}_i^1(+)\tilde{x}_i^2(+)\dots(+)\tilde{x}_i^M], \tag{3}$$

where M is the number of experts.

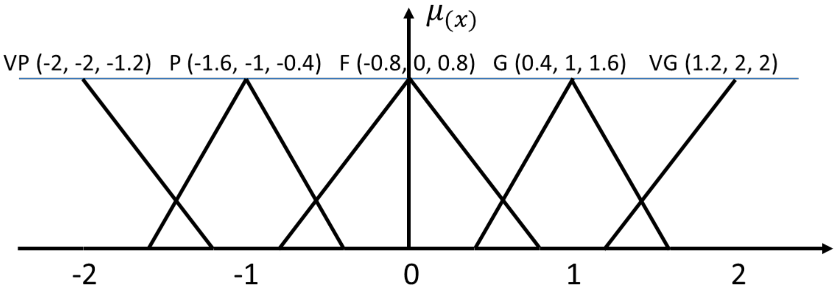

Figure 4: Membership function of linguistic terms

Note: Linguitic scales and their corresponding fuzzy numbers adopt the definition of (Hsieh, Lu, & Tzeng, 2004) which is propotionally transformed between -2 and 2.

Finally, fuzzy evaluation results are then defuzzified based on centroid of area (COA) method, as indicated by Eq. (4), which are the scores for semi-quantitative indicators.

$$x_i' = \frac{\mathrm{a+b+c}}{3} \tag{4}$$

Weight Generation

Weights among social impact subcategories were obtained through questionnaire survey. The main part of the questionnaire was designed in a pairwise comparison manner, which was based on AHP method using consistent fuzzy preference relations (CFPR). Linguistic terms are used to describe the relevant importance and are converted into corresponding numbers for further calculation. CFPR-based AHP can be seen as the deviation of the traditional AHP process. Traditional AHP process involves $n(n-1)/2$ pairs of comparison in a group of n criteria, which brings some issues when there are too many criteria involved. Faced with a quite long questionnaire, experts usually do not have enough time or patience to complete it. Furthermore, too many pairs of comparison may cause experts' mental confusion, resulting in inconsistent responses, in which case, the questionnaire needs to be checked and re-answered, leading to inefficiency (Y.-H. Chen & Chao, 2012). However, in CFPR-based AHP, ith criterion is only compared with $(i+1)$th criterion, which means only $(n-1)$ judgments are involved, and consistency can also be guaranteed. For detailed methodology of CFPR-based AHP, please refer to previous studies, such as (Herrera-Viedma, Herrera, Chiclana, & Luque, 2004) and (Wang et al., 2016).

Questionnaires, including respondents' basic information, main pairwise comparison part and corresponding explanations, were delivered via face-to-face distribution or e-mail to local construction experts. In total 67 feedbacks were received with a response rate of 72.3%. The respondents covered various stakeholders as shown in Figure 5. Based on the questionnaire survey results, weights were derived as showed in Table 4.

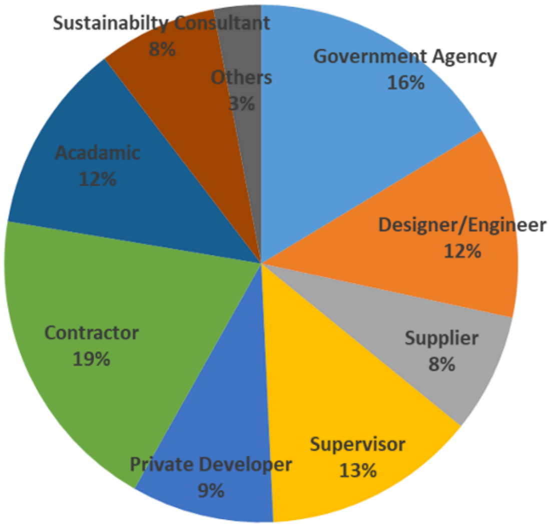

Figure 5: Distribution of responses of questionnaire survey

Table 4: Weights of Social Impact Categories

Stakeholder Category	Subcategory	Local weights	Global weights
Worker		***0.273***	
	Health and Safety	0.254	0.069
	Fair Salary	0.233	0.064
	Working Hours	0.186	0.051
	Discrimination	0.175	0.048
	Forced Labour	0.085	0.023
	Child Labour	0.067	0.018
Occupant		***0.283***	
	Functionality and Usability	0.312	0.088
	Health and Comfort	0.307	0.087
	Accessibility	0.209	0.059
	Feedback Mechanism	0.172	0.049
Local Community		***0.243***	
	Safety and Health	0.343	0.083
	Accessibility	0.191	0.046
	Integration and Interaction	0.170	0.041
	Local Employment	0.296	0.072
Society		***0.201***	
	Technology development	0.621	0.125
	Public Commitment to Sustainability Issues	0.379	0.076

Another set of weights are weights among life cycle phases. Previous studies usually use activity variables to “reflect the share of a given activity associated with each unit process” and to describe the relevance of impacts caused by a process in a life cycle. Currently, the most common activity variable is worker hours, i.e. the time workers spend to produce certain amount of products in the given process or sector. However, strictly speaking, worker hours are only related to the stakeholder workers (Ciroth & Eisfeldt, 2016), which is very relevant in previous studies that only discuss topics regarding labor conditions. In this study, worker hours, however, may not be a suitable activity variable as it includes multiple stakeholders.

This study indicatively estimated the relative importance of each phase based on two considerations, as shown in Table 5. One is the degree of possibility to place control. As indicated in Figure 3, data specificity is lower if the activities are located farther from the center phases; so is the control possibility. Therefore, the possibility to control is ranked from high to low as follows: construction phase, use phase, production phase, and raw material extraction phase. Use phase is weaker than construction phase due to its longer time span (around 50 years). Another aspect is level of concern of construction practitioners, whose focus is on construction and use phase; raw material extraction was given a relatively higher score, since mining industry is believed to have much severer negative social impact compared with manufacturing industry. A total score of 100 was allocated to four phases for each aspect of consideration, and for each phase mean of two scores was calculated and converted to weight.

Table 5: Weights of life cycle phases

	Raw Material Extraction	Production	Construction	Use
Control	5	15	50	30
Concern	25	5	30	40
Weight	0.15	0.10	0.40	0.35

Conclusion

This study proposed a methodological framework for social sustainability assessment of building projects. It applies multi-stakeholder approach and includes several life-cycle phases in the analysis which enables the investigation on potential transfer of impacts between life-cycle phases.

A theoretical framework for social sustainability assessment was firstly constructed through the identification of relevant stakeholders (in this study, worker, occupant, local community and society) and impact subcategories associated with each stakeholder category. Weights among these impact subcategories were then generated through questionnaire survey based on CFPR-based AHP method. As for weights among life-cycle phases, they were determined considering the degree of possibility to place control as well as level of concern of construction practitioners. Indicators were selected for each impact subcategory based on the assessment objective and data availability, which were categorized into three groups by data source and indicator type, including quantitative indicators in generic analysis, as well as quantitative and semi-quantitative indicators in site-specific analysis. For generic analysis, SPS were obtained by integrating country activity contribution and normalized country-level performance scores, which were calculated from different sources of statistics. For site-specific analysis, scores for semi-quantitative indicators were obtained based on PRS, while score for quantitative indicators were calculated using actual performance data and PRVs, which can be country and/or sector average performance values.

This study proposed an extensive methodology for social sustainability assessment of building projects. However, there are still methodological issues that require further attention. Indicators selected to characterize impact categories need continuous improvement through investigation of cause-effect relationships. Furthermore, data availability for social assessment also restricts the selection of indicators, which highlights the need to establish relevant database. Accordingly, the analysis scope could be broadened to include maintenance and end-of-life phases, which were excluded in this study due to data unavailability.

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