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EVALUATION OF SUSTAINABILITY OF CONSTRUCTION OPERATIONS: A FRAMEWORK FOR THE NEW ZEALAND CONSTRUCTION INDUSTRY

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ABSTRACT: The concepts of 'sustainable development', 'sustainable construction' and 'green building' have been elevated to priority levels in all types and phases of construction project development worldwide. Consultants and contractors are now required to seriously consider the impact of their operations on the natural environment and the society, and consequently adopt sustainable construction practices in the development process to minimize and mitigate the negative impacts of their activities. However, existing sustainability rating tools apply to the design, post-construction and operation phases of a building; no tool exists for the rating of the performance of the contractor or the project team at the construction phase. This study aimed to develop a model for evaluating the sustainability of construction operations, drawing on the global best practice standards on sustainability. Practical applications of the model were carried out through case studies to evaluate the performances of fifteen construction firms in New Zealand. The developed model and the outcomes of the case studies were presented, including potential areas of weaknesses, strengths, constraints to achievement or adoption of sustainable construction practices and areas for improvement in the operations of the firms. The successful application of the developed model in practice shows its usefulness and ease of application. It is therefore recommended for adoption as a simple but effective system for measuring and reporting on sustainability performance or sustainability of construction operations of firms in New Zealand and elsewhere.

Keywords: Construction project management, Environmental Management Plan; Sustainability rating, Sustainable development, Sustainable construction.

1. INTRODUCTION

The global concerns about climate change and the need to minimize ecological footprint of human activities have elevated the concepts of 'sustainable development', 'sustainable construction' and 'green building' to priority levels for all types and phases of construction project development worldwide. Consultants and contractors are increasingly required to seriously consider the impact of their operations on the natural environment and the society, and consequently adopt sustainable construction practices in the development process to minimize and mitigate the negative impacts of their activities.

Though deemed to be more expensive in the short-term, adopting sustainable construction operations holds several strategic, financial and competitive benefits for a construction firm. For instance, The Sustainable Business Network of New Zealand (SBN) argues that developing strategies to take on sustainability is vital for the long-term survival of businesses [1]. 'Sustainability' means efficient and effective utilization of resources, which minimizes wastes and maximizes cost savings [2]. In New Zealand, construction firms may soon be required to demonstrate knowledge and provide records of sustainable construction operations if they must win government contracts in the near future. The revision of the New Zealand Building Act 2004 [9] to incorporate the principles of sustainable development is a signal for this.

The immediate and long-term social and environmental benefits of sustainable development are the drivers for its popularity and global agenda for action. Consequently, several government agencies and organizations are now recognizing sustainability as a top priority issue. For instance, the Building Research Association of New Zealand [3] identifies sustainability as one of the most important issues to challenge the construction industry, and which will continue to do so in years to come. The International Council for Research and Innovation in Building and Construction [4] also has identified sustainable construction as first of the four very high level priority themes for the work streams it coordinates. The Sustainable Business Network of New Zealand [1] aptly observes that, "We have reached the sustainability tipping point and it is now the imperative for business this century".

With the construction activity involving significant amount of resource use and pollution, the construction industry has a crucial role to play in combating global

warming and environmental degradation, hence the need for construction firms to adopt sustainable construction operations.

However, there is no agreed way of defining the extent to which sustainability is being achieved in any policy programme [5]. Though several tools have been devised, such as the green building rating tools, no assessment guidelines exist for benchmarking sustainable construction performance in the construction industry. The existing tools aim at evaluating the design and operational performance of the finished product. This study aims to develop a model for evaluating the sustainability of construction operations, drawing on the global best practice standards on sustainability.

2. CONCEPTS OF SUSTAINABLE DEVELOPMENT AND SUSTAINABLE CONSTRUCTION

The Brunddland Report [6] defines sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet own needs. Though criticized for its vagueness [7] and lack of measurability [5], this definition provides the most popular understanding of the concept. To give further insights into the operational definition of the concept, the United Nations Report of the World Summit on Sustainable Development (WSSD) [8]) identifies three pillars of sustainable development as economic development, social development and environmental protection. The three pillars are interdependent and mutually reinforcing and provide the best practice framework for understanding and evaluating sustainability of construction operation.

Sustainable construction should be seen as a subset of sustainable development, the latter encompassing sustainable design and sustainable use and management of the constructed facility. This is evident in the purpose statement of the New Zealand Building Act 2004 that 'buildings are designed, constructed and able to be used in ways that promote sustainable development' [9]. In the context of this study, the key criteria for the assessment of sustainable operations are provided by the Resource Management Act (RMA) 1991 – the New Zealand's main piece of environmental legislation – in its definition of 'sustainable management' as 'managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural wellbeing and for their health and safety, while sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonable foreseeable needs of future generations, and safeguarding the life-supporting capacity of air, water, soil and ecosystems, and avoiding, remedying or mitigating any adverse effects of activities on the environment' [10].

Thus, the management of construction operations can be adjudged sustainable if it does not only support economic development through providing infrastructure as the end-product, but also encourages social development by contributing to the economic well being of the community, while taking steps to mitigate adverse impact on the society and the natural environment.

3. CRITERIA FOR ASSESSMENT OF SUSTAINABILITY OF CONSTRUCTION OPERATION

A review of the current thinking on the subject of sustainability provides five sets of criteria or stages which underlie sustainability of construction operations: Long-term commitment to sustainable operations, clearly documented environmental management plan or system, efficient and effective implementation of the project environmental management plan and the required degree of monitoring and control, performance measurement and reporting, and organizational learning. These interdependent and mutually reinforcing criteria or stages provide a complete cycle of best practice standards for sustainable operations.

3.1 Long-term commitment

Evidence of organization-wide commitment to long-term implementation of sustainable operations can be communicated through clearly documented mission, value or vision statements, as well as well-formulated goals, strategies, and policies for the realization of the commitment. This is because strong vision for sustainability conveys total management devotion and therefore encourages employees to continuously look at ways they can be involved in the overall sustainability process. Without embedding the commitment to sustainability in the vision or value statements and in the formulation of the strategies and policies, organizations can only adopt ad-hoc and half-haphazard approach to sustainable operations with abysmal results. It is argued [11] that mission or vision statement or credo is essentially a statement of the organisation's values or a philosophy of business, within which every other activity revolves; the corollary is that anything that is not part of the credo is seen as a distraction, no matter the sham put up in downstream operations to give a misleading impression to the public. A company that aims at long-term commitment to sustainable operations must have a well-crafted Environmental Policy to guide its operations.

3.2 Environmental management plan (EMP)

The Auckland Regional Council [12] defines the EMP as "a document created by companies to provide a framework for dealing with the pollution risks associated with their site and activities", adding that it helps companies know the legal requirements for the project and how to manage pollution risks according to best practice, which can result in increased efficiencies cost reduction. A well-articulated EMP provides the basis for

effective and efficient implementation of sustainable construction. For large-size projects that have significant impact on the environment, submission of the EMP is legally required. For instance, in New Zealand, an EMP is required for sites that undertake moderate and high risk industrial or trade activities as well as sites that have on-going pollution issues [12]. Project-specific

EMP should be produced by construction companies that seek long-term commitment to sustainable construction even in situations where it is not legally required. The EMP should embody the outcomes of a comprehensive assessment of the environmental impact of the project development process and the optimized ways of minimizing or eliminating identified adverse effects.

During the environmental management planning, the resource requirements for meeting obligations for environmental responsibility should be comprehensively estimated and provided for. The focus here is the selection of safer or greener materials for the project, efficient and effective resource utilization and the minimization or elimination of adverse socio-ecological impact by mitigating and minimizing pollutions to water, air and the soil. In the EMP responsibilities for environmental impact monitoring and control must be assigned and the officers involved should be adequately trained and empowered to do their job. Timelines should be clearly set for periodic review and reporting of performance against the benchmarks set at the onset.

3.3 Effective and efficient implementation, monitoring and control

At the heart of sustainable construction operation is the effective and efficient implementation of the EMP and the associated monitoring and control processes required to ensure the achievement of the set targets. The focus should be on the following key issues:

- Legislative compliance; e.g. applicable provisions of the Resource Management Act 1991, the Building Act 2004, Hazardous Substance and New Organisms Act 1996, Health & Safety in the Employment Act 1992, Waste Minimisation Act 2008, Building Regulations and council byelaws for the protection of the environment. Threshold performance in this regard is achievement of zero-fine record.
- Efficient and effective management of the use of resources especially as it relates to energy, water and materials. Energy efficiency implies not only minimization of the rate of energy consumption but also promotion of the use of renewable sources such as solar and wind. Sustainable use of materials will entail choosing from alternatives the material that has the least embodied energy (i.e. the material that requires lowest amount of energy in its production, transportation, handling and disposal), and that exerts the least impact on the environment, as well as that which has the highest potentials for recycling and re-use. . Efficiency in these areas results in the reduction of operational costs and the maximization of profits.
- Pollution control over and above the thresholds for legislative compliance as it relates to water, soil and air. The emphasis should be on the reduction of the quantity of wastes to landfill and the discharge of contaminants to the sea, as well as minimization of noise and gaseous emissions. An example of the criterion for assessing performance in this area is the amount paid for waste disposal to landfills.
- Social responsibility: The focus here should be on taking responsibility not just within the defects liability period but for the whole of the life cycle impact of operations on the community at large. Sustainable construction operations are those that promote engagement or participation of the community in making decisions that affect them, in showing respect to the culture, historic places and people in the community, and in making significant investments for improving the lot of the local community. Typical instances of this include active engagement in the tree-planting - especially the endangered species - to compensate for the uprooted trees, financial donations and offering of job opportunities to the locals.

3.5 Performance measurement and reporting

Rather than adopt post-construction phase approach, sustainability performance measurement and reporting should be ongoing at regular intervals that could warrant early detection and correction of any significant variations from the targets set in the EMP. The environmental reports should document reasons for any discrepancies between the targets and actual outcomes. Companies that are committed to long-term sustainable operations involve outside experts to assess their sustainability performance, seek ISO 14001 certification or make submissions for sustainability awards.

3.6 Organizational learning

Lessons from the efforts made towards achieving sustainable operations could be lost if there are no debriefing sessions at the project close-out stage held to review overall performance, analyze sources of variations from initial plans and document innovative ways employed in the current project for addressing sustainability issues. These lessons could be valuable for future sustainability efforts and are basis for continuous improvement of the sustainable operations.

4. THE CONCEPTUAL FRAMEWORK

4.1 Sustainable construction operation cycle

To give effect to the application of the above underpinnings of sustainable construction operation, a framework was developed. The framework incorporates the above criteria as a basis for the assessment of performance of construction firms in their sustainable construction operation efforts. Figure 1 presents the framework as a flow chart, highlighting the key criteria or

stages as interdependent components of a sustainable construction operation cycle.

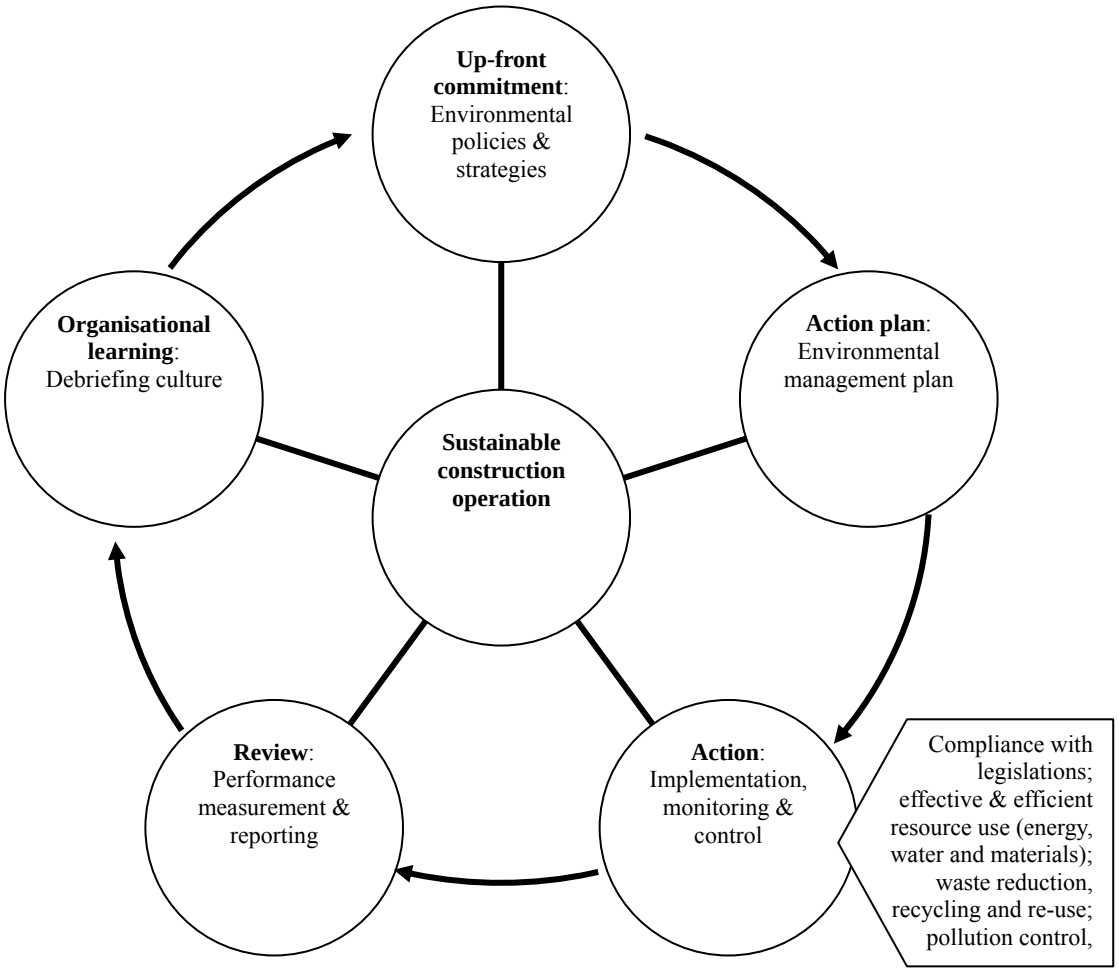

Figure 1. Conceptual model of the cycle of sustainable construction operations

4.2 Assessment model

For a given project, the management overall performance (OP) of sustainable construction operations could be assessed as the sum of performance in each of the five stages of up-front commitment (C), action plan (P), action implementation (I), performance review (R) and organizational learning (L). Equation 1.1 provides the model of assessment for the overall, stage and subcomponent performance.

2 Assessment model

$$OP = a\sum_{i=1}^{k} C_i + b\sum_{i=1}^{n} P_i + c\sum_{i=1}^{x} I_i + d\sum_{i=1}^{y} R_i + e\sum_{i=1}^{z} L_i \quad \text{..... (1.1)}$$

Where:

- a', 'b', 'c', and 'd' are relative weightings of the various stages in contributing to sustainability;
- k, n, x, y, and z are the number of attributes or subcomponents, 'i', of the various stages that count towards achievement of sustainability.

If, through factor analysis, an equal number of subcomponents, 'n', could be identified to sufficiently address sustainability issues at each stage of the operation cycle, Equation 1.1 could be simplified to the form shown in Equation 1.2. A matrix 'A_{ij}' of the form represented in Equation 2.0 could be developed for the analysis:

$$OP = Ai_j = \sum_{i=1}^{5}\sum_{j=1}^{n} ai_j \quad \text{..... (1.2)}$$

$$Aij = \begin{bmatrix} a11 & a12 & .. & a1j \\ a21 & a22 & .. & a2j \\ : & : & : & : \\ ai1 & a12 & .. & aij \end{bmatrix} \quad \text{.....(2.0)}$$

5. RESEARCH

To demonstrate practical application of the developed conceptual model, directors and project managers of fifteen medium sized construction firms were surveyed. The principal aim was to evaluate, using the model, their companies' performance of sustainable construction operation at each stage of the cycle of the projects they were implementing at the time. To simplify the assessment, each stage was weighted equally, i.e. each of the coefficients, a, b, c, d and e in Equation 1.1 was assigned the value of 1 or unity. A ten-point Likert rating scale was used for each stage assessment, ranging from 1 (i.e. 'Extremely Poor') to the maximum value of 10 ('Extremely High'). The mean rating score (MR) achieved for each stage was computed as the average of the rating points achieved in the subcomponents as follows:

$$MR = \frac{\sum_{I=1}^{n} I_r}{n} \quad \text{..... (3.1)}$$

Where: I_r is the rating of subcomponent I, and n is the identified number subcomponents for the assessment of sustainable operation at each stage.

Overall performance (OP) for all stages was computed as the average of the MR values for each stage as given in Equation 3.2.

$$OP = \frac{\sum_{i=1}^{5} MR_i}{5} \quad \text{..... (3.2)}$$

Poor performance was evident where:

- $1 \leq Ir \leq 5$ (for a subcomponent) or
- $1 \leq MR \leq 5$ (for each stage).

The Ir and MR values therefore served as indicators of areas of poor performance and became the basis for recommending improvement in the given subcomponent or at a particular stage.

6. RESULTS

Typical analysis of the performance assessment for one of the firms was presented in Table 1 in the Appendix. The identified subcomponents for each stage are also shown in the table.

Results showed that out of the fifteen companies surveyed, only three achieved above average ratings in their overall sustainability performance. As for the firm used for the illustration, majority of the firms appeared to show commitment to sustainability through their value statements and environmental policies, but failed to follow this through in their action plans, implementation, performance review and organizational learning. In fact none of the firms undertook or had plans for debriefing sessions to review the performance and document lessons for future projects.

Another survey question sought to establish the factors constraining the companies' sustainability performance or their good intentions for implementing sustainable construction operations. The recurring feedback included the following factors: limitations imposed by costs, design and timeframe; relatively new concept that was not featured in the contract clauses and specifications and that lacked client leadership and encouragement, ostensibly due to client penchant for lowest tender, as well as preference of speed to 'greenness'; resistance to change as the concept was foreign to organizational culture and staff lacked training on the issue; lack of alternative methods, materials and products on sustainability; tediousness of the certification process and lack of incentive to 'go green'.

7. CONCLUSIONS

A model for evaluating the sustainability of construction operations has been developed, drawing on the global best practice standards on sustainability. Practical applications of the model were carried out through case studies to evaluate the performances of fifteen construction firms in New Zealand. Results showed that out of the fifteen companies surveyed, only three achieved above average ratings in their overall sustainability performance. Majority of the firms appeared to show commitment to sustainability through their value statements and environmental policies, but failed to follow this through in their action plans, implementation, performance review and organizational learning. Recurring factors constraining sustainability performance by the companies included limitations imposed by costs, design and timeframe; client related issues such as strong penchant for lowest tender and preference of speed to sustainability; resistance to change , lack of training, lack of alternative methods, materials and products on sustainability; and lack of incentive to 'go green'. The successful application of the developed

model in practice shows its usefulness and ease of application. It is therefore recommended for adoption as a simple but effective system for measuring and reporting on sustainability performance or sustainability of construction operations of firms in New Zealand and elsewhere.

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APPENDIX

Table 1. Assessment of performance of sustainable construction practice

	Company ID:	A12
	Annual turnover: ($m)	
	Size:	Medium
		Commercial
	Specialty or main type of development projects engaged in:	/ office

(PR = Performance Rating: 1= "Extremely Poor"; 10 = "Extremely High"; AI = "Area for Improvement": 1 ≤ PR ≤ 5)

	Criteria for sustainability	**PR**	**AI**
1	**Evidence of up-front commitment (C) to long-term sustainable construction operation**		
a	Documented evidence of organisation-wide mission and value statements on sustainable construction practices	**8**	
b	Well-articulated Environmental Policy and strategies for sustainable operations of projects and communication of same to staff	**6**	
c	Evidence of organisation-wide culture of sustainability and employee awareness and commitments to sustainable operations	**2**	**X**
	Mean rating (MRc) for up-front commitment (C) = (average)	**5.3**	
2	**Evidence of effective and efficient action plan (P):**		
a	Documented environmental management plan (EMP) for project with clearly established benchmarks for resource utilization	**2**	**X**
b	Identification of environmental legislative requirements for the project	**5**	**X**
c	Documented procedure for environmental risk identification and mitigation	**10**	
d	Estimation and provision of adequate resources for achieving environmental obligations; assignment of responsibilities	**1**	**X**
	Mean rating (MRp) for action plan (C) = (average)	**4.5**	**X**
3	**Effectiveness and efficiency of the implementation process, monitoring and control (I):**		
a	Level of efficiency of resource management: Evidence of quantification and benchmarking of resource consumption levels against targets set for water, energy and materials in the EMP	**2**	**X**
b	Level of efforts directed towards minimization of water, energy and material consumption levels and minimisation of pollution through recycling, re-use and safe disposal of waste	**10**	
c	Level of staff training on and awareness for sustainability, hierarchy of designations and staff empowerment for achievement of sustainable operations	**3**	**X**
d	Level of compliance with the environmental regulations through records of fines for violations or absence of such	**10**	
e	Level of investment in the local community through evidence of social responsibility (donations, jobs for the locals, etc)	**2**	**X**
	Mean rating (MRi) for action implementation (I) = (average)	**5.4**	

4 Evidence of transparency and performance review and reporting (R):

a	ISO 14001 certification or awards for sustainability performance achieved or applied for.	**1**	**X**
b	Clearly documented external and internal environmental audit processes;	**1**	**X**
c	Periodic reports on sustainability performance available for public scrutiny.	**10**	
	Mean rating (MRr) for performance review & reporting (R) =	**4**	**X**

5 Evidence of organisational learning (L)

a	Records or plans for briefing sessions at the project close-out stage for reviewing performance, analysing reasons for deviations from targets and documenting lessons for future sustainability plans	**1**	**X**
b	Evidence of continuous improvement in the sustainability efforts	**1**	**X**
c	Evidence of clearly documented innovations for dealing with sustainability issues in the current project	**1**	**X**
	Mean rating (MRl) for organisational learning (L) =	**1**	**X**

6 OVERALL PERFORMANCE ACHIEVEMENT (OP)

Average values of MRc, MRp, MRi, MRr and MRl =	**4.1**	**X**

Remarks: Poor performance; company's operations are unstainable