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Decision Making Of Carbon Reduction Strategies Adoption – A Case Study In Greater Melbourne Region

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ABSTRACT

Contractors convert design into reality. They are presumed as a major contributor of carbon emissions from the construction development. Carbon reduction strategies were proposed in previous studies. Nevertheless, contractors were often criticised for standing aloof to adopt them. Some argued that the contractors may not have contractual leverage to challenge the decisions made by the developers and the consultants. Nonetheless, there has been a lack of research that focuses on how different construction project organisations (CPOs) may be affecting carbon reduction strategies adoption. This paper presents a study that investigates the effect of the construction project organisations have on the contactors' adoption of carbon reduction strategies. An industry survey was conducted in Melbourne, Australia. 200 questionnaires were sent to the registered contractors. Monte Carlo simulations were conducted to examine how the priorities of strategies adoption may be affected by the CPOs. The results indicate that developers and the design consultants are influential to contractors' decision in adopting those carbon reduction strategies that may incur additional project cost. The results indicate that decisions towards the adoption of strategies may not be swayed towards their effectiveness of achieving carbon reduction. Instead, tightening planning and building regulations might affect decisions.

Keywords: carbon reduction, construction project organisations

1 Introduction

In Australia, construction related activities accounts for over 40 million metric tonnes, shares around one-fifth of the country's carbon emissions annually. Being the frontline of the construction operations, contractors have a significant role to play in carbon reduction. In recent years industry reports and research studies in relation to devising carbon reduction strategies have been published (ENCORD 2010; GRI 2011). However contractors are generally slow to adopt them in practice (Wong et al. 2015). In the public eye, contractors are responsible for all energy consumption in the construction process. Nevertheless, collectively bound by the project-based collaboration mechanism, contractors may be unable to change their ways of operations in isolation. However, scholars typically agreed that construction contractors are indeed capable of reducing carbon emissions in their operations (Lam et al. 2010, Wong and Zapantis 2013). The key is whether the contractors have sensible reasons not to stay passive in adopting carbon reduction strategies (Zuo et al. 2012, Ding 2008). Based on a literature review, Acquaye & Duffy (2010) pinpointed that it is difficult for contractors to change operational practice if the responding actions are in conflict with their core values. Wong et al. (2014) conducted a questionnaire survey in Australia to identify the obstacles that hinder contractors to change their carbon intensive operational practice. The findings indicated that the associated cost of introducing carbon reduction strategies may not be easily passed on to the developers due to competitive tendering. In similar context, they interviewed industry experts and found out that contractors rarely venture outside the given scope to reduce carbon emissions due to their contractually bound obligations for delivery of the projects (Wong et al. 2015). Moreover, the success of carbon reduction strategies adoption is also reliant on the cooperation from the sub-contractors and suppliers (Alhorr et a. 2014; Zuo et al. 2012). The above-mentioned studies indicate that contractors' decision to adopt carbon reduction strategies might be affected by the other construction project organisations (CPOs). Nonetheless, how different CPOs may be affecting carbon reduction strategies adoption was not investigated in a holistic manner. This paper presents a study that aims to investigate the influential powers of different CPOs on the contractor's decision of carbon reduction strategies adoption. CPOs in this paper refer to the organisations collaborating in a construction project. This includes the developers and their consultants, the main contractors and the sub-contractors.

This paper commences with a review of the carbon reduction strategies that are applicable to construction contractors. This is followed by a description of the research methodologies, with the research findings then discussed. Finally, concluding remarks and recommendations are made.

2 Identification Of The Carbon Reduction Strategies

In recent years industry reports and research studies in relation to introducing carbon reduction strategies to the construction developments have been published (ENCORD 2010; GRI 2011). Strategies related to advancing technologies to optimize energy efficiency and saving, adopting less carbon-intensive materials in buildings and advancing technologies to optimize energy efficiency and saving and developing mechanisms for evaluating the environmental impact driven by construction activities were proposed (Fieldson 2009; Li and Colombier 2009; Tsai et al. 2012). While researchers advocated that the proposed strategies are conducive to carbon reduction, there is no objective measure to access if the applied strategies have achieved the anticipated outcomes. In this regard, the United Nations Environment Programme (UNEP) suggested seven strategies to help the building sector reduce carbon in construction projects, these include: demonstrating technology on buildings and rented office, moving to holistic and systematic solutions to sustainable buildings, educating the supply chain, renovating buildings to maximize the reduction of emissions, working to introduce a carbon trade mechanism for buildings, working with governments to develop policies that make a difference in emissions behaviour and dedicating research and development to zero net buildings (UNEPSBCI 2009). Nevertheless, the proposed guidelines are not project-specific, implying that they may not be effective in evaluating contractors' performance in carbon reduction. Global Reporting

Initiatives (GRI) (2011) specifically developed guidelines for construction contractors to report their sustainability performances whereby their performance is assessed under three key aspects: management approach, strategy and profile and performance indicators. Similar, the developed guidelines have not proposed any project-specific measure to evaluate these strategies.

In this respect, the European Network of Construction Companies for Research and Development (ENCORD) developed an inventory that evaluates the carbon emitted by contractors in a construction project specifically. The inventory proposes evaluating carbon emission under twelve aspects as shown in Table 1. This study adopts the work of ENCORD (2010) as the proposed inventory is considered more suitable to evaluate contractors' carbon reduction practice.

3 Research Methodologies

3.1 The questionnaire design

To accomplish the research objectives, a questionnaire survey was conducted for data collection. The survey questionnaire contains three parts. Part 1 deals with demographic information about the respondents. Respondents were asked to specify a project they had been involved in for at least one year, and the questionnaires of those not having taken part in a specified project for more than one year were discarded. Part 2 seeks to solicit the degree of respondents' agreement (from 1 to 5 representing 'strongly disagree' to 'strongly agree' respectively) on whether the strategies were in place to reduce carbon emissions in their projects (refer to the operative statements of Table 1). In Part 3, respondents were asked to express their degree of agreement (from 1 to 5 representing 'strongly disagree' to 'strongly agree' respectively) on the impact of construction project organisations on the contractor's decision to adopt carbon reduction strategies. The impacts of 5 types of construction project organisations: developers [CPO_1], design consultants (architects/ engineers) [CPO_2], project management consultants (superintendent/ other equivalent project managers) [CPO_3], main contractors [CPO_4], and sub-contractors [CPO_5] on decision making were studied. This study received approval from the local university research ethics committee whose clearance standards are outlined in the Australia National Ethics Application Form (NEAF).

Carbon Reduction Strategies	**Respective Operational Statements**
Reducing fuel (project) [CRS1]	Reduce fuel for plants and machinery in use on site
Reducing fuel (premises) [CRS2]	Reduce fuel for use in premises which support the company's activities (i.e. offices and godowns)
Reducing process emissions [CRS3]	Reduce carbon emissions from physical and chemical processing involved in the production of mineral products (such and cements) and metal products (such as steel)
Reducing electricity (project) [CRS4]	Reduce electricity for plants and machinery in use on site
Reducing electricity (premises) [CRS5]	Reduce electricity for use in premises which support the company's activities (i.e. offices and godowns)

Reducing imported heat [CRS6]	Reduce heat purchased by the company for use at the company's project and premises
Reducing vehicle fuel [CRS7]	Reduce the use of vehicles travelling on public highways
Reducing the use of public transport [CRS8]	Reduce the use of public transports by the employees
Monitoring sub-contractors [CRS9]	Coordinate with sub-contractors at project level to achieve items 1 to 8
Reducing wastes [CRS10]	Reduce construction wastes and the associated transportation for disposal
Reducing high embodied CO2 materials [CRS11]	Reduce the use of materials with high embodies CO2 like structural steel concrete, reinforcement, cladding, aggregates and bituminous products
Reducing emissions from the facility [CRS12]	Reduce carbon emissions resulting from the built object through better design

Table 1: Carbon reduction strategies proposed by the ENCORD (modified from (ENCORD 2010)

3.2 Data collection and analysis

The targeted respondents for this study were identified from the registered contractors list maintained by the Masters Builders Association of Victoria. Master Builders is a major building and construction industry association in Australia, and its members represent 95% of all sectors of the Australian building industry. 200 respondents were randomly selected from the registered contractors list. They were invited to participate in the survey via either an online platform supported by Qualtrics or hardcopies delivered by our research team. To avoid disruption to selected hardcopies recipients, the research team initially sought permission via telephone before visiting the respective companies in person. Concerning data analysis, firstly the mean scores of the respondents' degree of agreement on the adoption of carbon reduction strategies and the impact of construction project organisations on the contractor's decision were compared. Furthermore, Monte Carlo simulations were conducted to examine how the priorities of strategies adoption may be affected by the construction project organisations. Monte Carlo simulation is a computerized mathematical technique that uses the Multiple Regression data set to provide an array of possible outcomes and probabilities based on sensitivity analysis. This simulation allows easy identifiable visuals on what inputs have the biggest effects on the dependent variable. The same approach had been successfully adopted by Hong et al. (2016) who adopted Monte Carlo simulation to identifying parameters for measuring greenhouse gas emissions in construction projects. In this study, five multiple regression analyses were conducted to investigate how the impact of the CPOs (as an dependent variable) may affect contractors decision of carbon reduction strategies adoption (as an independent variables). The broad equation of multiple regressions is shown as below:

$$CRS_x = a + b_1CPO_1 + b_2CPO_2 + b_3CPO_3 + b_4CPO_4 + b_5CPO_5 + \varepsilon$$

Where:

CRS_x = *Dependent variable (i.e. the adoption of one out of twelve carbon reduction strategies* CRS_1 to CRS_{13}*)*

CPO = *Independent variables (i.e. impact of a particular construction project organisations on carbon reduction strategies adoption)*

a, b1, b2……b5 = *Unknown constant*

ε = *Random error for any given set of values for* CPO_1 *to* CPO_5

The Multiple Regression results were then further analysed through Monte Carlo simulation to examine the influential powers of the construction project organisations on the decision of carbon reduction strategy adoption.

4 Response Rate and Sample Profile

A total of 200 questionnaires were dispatched. 46 respondents returned the questionnaires with 2 replies excluded due to being incomplete. 44 valid responses were used representing a 22% response rate. The study has attracted a reasonable response rate in comparison to other questionnaire surveys in the construction field normally ranging from 25% to 30% (Wong et al. 2012). Likewise, the response rate of the current research is similar to that of the study related to carbon emissions conducted by Lam et al. (2010) that received 100 responses while 652 questionnaires being sent out (equivalent to 15% response rate). Among the respondents' backgrounds, 29 out of 46 (i.e over 70% of the) respondents have had more than 10 years' project management experience. The creditability of the respondents is indicative of their service to the industry thus their responses are considered to be reflective to the industry's views in the greater Melbourne region.

5 Findings and Discussions

5.1 Adoption of carbon reductions strategies

Participants were asked whether they agreed with CRS1 to CRS12 were adopted to reduce carbon emissions in their projects on a 5 point likert scale from 1 "Strongly Disagree" to 5 "Strongly Agree". The mean scores **and standard deviations (S.D.) are presented in Table 2.**

Carbon Reduction Strategies	**Mean**	**S.D.**
Reducing fuel (project) [CRS1]	2.80	0.85
Reducing fuel (premises) [CRS2]	2.66	0.89
Reducing process emissions [CRS3]	2.48	0.98
Reducing electricity (project) [CRS4]	3.06	0.90
Reducing electricity (premises) [CRS5]	3.43	0.98
Reducing imported heat [CRS6]	2.84	0.99
Reducing vehicle fuel [CRS7]	2.95	0.94
Reducing the use of public transport [CRS8]	2.95	1.10
Monitoring sub-contractors [CRS9]	2.45	0.98
Reducing wastes [CRS10]	3.08	0.97
Reducing high embodied CO2 materials [CRS11]	2.30	1.02
Reducing emissions from the facility [CRS12]	2.37	1.02

Table 2: Respondents' opinions of carbon reduction strategies adoption in projects

The respondents showed neutral or slight agreement towards the adoption of 8 out of 12 strategies throughout their projects. These statements generally received scores around the mid-point of the five-point scale. Mean scores of CRS 4 "Reducing electricity (project)", CRS 5 "Reducing electricity (premises)" and CRS10 "Reducing wastes [CRS10]" are greater than three in the five-point scale, indicating respondents tend to agree that these strategies were adopted onsite. Interestingly, CRS4, CRS 5, CRS 10 are strategies that are contributive to cost savings. Moreover, adoption of these strategies may not necessarily rely on the collaboration of the other construction project organisations. Conversely, strategies that implies higher operational cost or require collaborative efforts among construction project organisations might not be as popular. For examples, means score of CRS 11 "Reducing high embodied CO2 materials" and CRS 12 "Reducing emissions from the facility" are among the lowest of the 12 strategies. Successful adoption of these strategies requires preplanning of the project design and alternative construction methodologies. Decisions on designs are heavily reflected on the construction operations. Carbon reduction strategies may affect the conventional approach of estimating profit margin in projects might not be easily accepted by the contractors. Despite developers, consultants as well as the subcontractors might be willing to help, the industry practice to award construction project to the lowest bidder may not encourage new ways of construction operations that enable carbon reduction.

5.2 Impact of project organisations on strategies adoption

Multiple linear regression analyses were used to examine the impact of construction project organisations on the contractors' adoption of carbon reduction strategies. The results were further analysed through Monte Carlo Simulation in order to articulate the impact (in terms of the Contributions to Variance (CV) and normalised contributions to variance (NV)) of each of the CPOs on the adoption of a particular CRS.

The outputs of the Monte Carlo simulations indicated that the design consultants have the greatest impact on the contractors' decision made on CRS3 Reducing process emissions (CV= 55.06; NV= 0.52), CRS11 Reducing high embodied CO2 materials (CV= 65.58; NV= 0.42) and CRS12 Reducing emissions from the facility (CV= 80.39; NV= 0.42). The results reveals that some carbon reduction strategies may not likely be adopted without the support of the design consultants. In particular, the respective strategies are all related to building design. Some scholars describe construction contractor as merely an executor of the designers' instructions that may have long term consequences in carbon emissions (Acquaye & Duffy 2010, Wong et al. 2015). Without endorsement, contractors may not initialise any change to foster carbon reduction

The means scores indicated that contractors generally disagree that CRS 11 "Reducing high embodied CO2 materials" and CRS 12 "Reducing emissions from the facility" were adopted. In this aspect, the Monte Carlo simulations results further suggest that the developers and design consultants are most influential to the adoption of these strategies. The results indicate that developers and the design consultants are influential to contactors' decision in adopting those carbon reduction strategies that may incur additional project cost. The results looks contradictory to previous studies that reported the industry's enthusiasm towards adoption of greener and more energy efficient designs in construction projects (Zuo et al. 2012). However, this may be linked to the fact that the related carbon reduction strategies have to be adopted at some point in order to comply with the stringent planning and construction regulations. In Australia, Green Stars and National Australian Built Environmental Ratings Scheme (NABERS) were introduced which serves to establish a common-ground for rating building energy efficiency (Iyer-Raniga and Wong 2012). Some State Governments in Australia such as Victoria have tightened their regulations to disapprove new construction or alteration works that don't reach a certain level of Green Star or NABERS standards (Iyer-Raniga and Wong 2012). The introduction of these regulations has been viewed as the motives toward forcing behavioural changes into the construction sector (Iyer-Raniga and Wong 2012)

Strategies	Developers		Design Consultants		Project Management Consultants		Main Contractor		Sub-contractor	
	CV	NV	CV	NV	CV	NV	CV	NV	CV	NV
CRS1	45.50	0.32	33.60	0.24	25.60	0.18	25.70	0.18	11.00	0.08
CRS2	9.40	0.05	22.23	0.12	16.49	0.09	90.15	0.48	47.62	0.26
CRS3	30.72	0.29	55.06	0.52	7.50	0.07	4.90	0.05	7.50	0.07
CRS4	6.79	0.06	19.77	0.16	3.82	0.03	79.63	0.66	11.24	0.09
CRS5	16.70	0.13	4.14	0.03	83.80	0.64	14.05	0.11	11.83	0.09
CRS6	3.82	0.01	70.67	0.23	64.01	0.21	96.92	0.32	65.42	0.22
CRS7	11.70	0.07	17.03	0.11	48.57	0.31	65.98	0.42	14.41	0.09
CRS8	2.53	0.02	8.60	0.08	6.80	0.07	65.30	0.64	18.60	0.18
CRS9	15.48	0.11	36.71	0.25	20.62	0.14	41.26	0.28	33.00	0.22
CRS10	25.44	0.13	60.48	0.32	0.42	0.00	58.95	0.31	43.68	0.23
CRS11	34.47	0.22	65.58	0.42	21.43	0.14	25.49	0.16	8.36	0.05
CRS12	67.51	0.35	80.39	0.42	1.14	0.01	30.39	0.16	13.75	0.07

Table 3: Influential power of the construction project organisations on carbon reduction strategies adoption

Main contractors have the greatest impact on their decision made on CRS2 Reducing fuel (premises) (CV=90.50; NV= 0.48), CRS4 Reducing electricity (project) (CV= 79.63; NV= 0.66), CRS8 Reducing the use of public transport (CV= 65.30; NV= 0.64), and CRS10 Reducing wastes (CV=58.95; NV=0.31). The results can be explained by the cost to be undertaken by the main contractors. Main contractors prefer to adopt carbon reduction strategies that can foster cost savings. Main contractors are charged on a variable amount dependent on the wastes they dispose to the landfill. Unless the strategies adoption involve design change, main contractors are more likely to change operational behaviour in order to save energy consumption from the construction operations. As such, the contractors' decisions towards the adoption of strategies may not be swayed towards their effectiveness of achieving carbon reduction, but their financial interests.

6 The Concluding Remarks

There is a candid need to determine why the construction contractors has been criticised as slow and not motivated to adopt carbon reduction adoption. This study aims to investigate the impact of construction project organisations on the main contractor's decision on adopting carbon reduction strategies. Data collected from a questionnaire survey suggest that contractors resist adopting carbon reduction strategies that may involve endorsement of the developers or those strategies that may erode their profits. The results of the Monte Carlo simulations indicate that design consultants and the developers may have influential power on the contractors' decision made on carbon reduction. However, the results also indicate that contractors don't always adopt strategies with the interest of carbon reduction. Instead, it is suggested that the motives of strategies adopted are driven by the financial interest of the individual construction project organisations and the tightening government regulations.

This study contributes to identifying the role played by construction project organisations on the contractors' adoption of carbon reduction strategies. However, this information should be taken into consideration with limitation. The comparison of mean scores reported in the discussion section should be read with due caveats on the limitations of the working sample and the constraint on the scope of research. It should be noted that the respondents of this survey were randomly selected from the contractors list registered in the State of Victoria, Australia. The results of this study can be viewed as a case study conducted in the greater Melbourne region. As a further study this survey can be extended to collecting data in other Australian states and territories as well as other countries.

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