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Investigating factors influencing construction waste management efforts in developing countries: an experience from Thailand

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Abstract

Rapid economic growth and urbanization in developing countries lead to extensive construction activities that generate a large amount of waste. A challenge is how to manage construction waste in the most sustainable way. In the developing world, research on construction waste management is scarce and such academic knowledge needs to be responsive to actual practices in the industry in order to be implemented. As construction projects involve a number of participants and stakeholders, their participation and commitment can have a major influence on the goals of green and sustainable construction for urban development. This study provides a significant step in conducting a very first research of this kind in Thailand by aiming to investigate the level of construction stakeholders' commitment as well as the achievement of construction waste management in order to improve short-term practices and to establish a long-term strategic construction waste management plan. In this study, a structural equation model was employed to investigate the influence of factors that are related to environmental aspects, social aspects, and economic aspect of construction waste management. Concern about health and safety was found to be the most significant and dominant influence on the achievement of sustainable construction waste management. Other factors affecting the successful management of construction waste in Thai construction projects were also identified. It is perceived that this study has potential to contribute useful guidelines for practitioners both in Thailand and other developing countries with similar contexts.

Keywords

Construction waste management, developing countries, structural equation modelling, sustainable construction, Thailand

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Introduction

Construction industry has been found to be a major generator of waste and pollution. Waste from construction activities significantly pollutes the environment (Shen et al. 2004). In developed countries, construction waste management (CWM) has already been an important aspect that is included in a project management plan. However, in developing countries such as Thailand, CWM practices are still found to be insufficient and inappropriate (PCD 2007). Construction waste has been largely disposed of at both public and private landfills. When the dumping sites become inadequate to accommodate a higher volume of construction waste, heavy and bulky waste from construction and demolition sites becomes a waste stream requiring further attention. As a consequence of a lack of landfill space, the amount of construction waste illegally dumped in public places has increased, causing social and environmental problems to the local communities.

In developing countries, research on the social, environmental, and economic impacts of construction waste management has not been widely conducted. Meanwhile, in developed countries, extensive research on construction waste has mainly focused on the types of construction waste and work practices, processes and technologies that

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contribute to the generation of waste (Yost & Lund 1997, Shen et al. 2004, Haggar 2007). However, the importance of people's willingness to change their attitudes and behaviour pertaining to waste generation, collection and disposal has not been researched to the same extent (Teo & Loosemore 2001). Hence, in the present study, the participation and commitment of construction stakeholders are regarded as important drivers for construction management. The challenges in managing construction waste are therefore to actively identify what, where, when, and how to do/deal with the generated waste. Furthermore, it is necessary to specify who needs to be engaged in the CWM process.

As there has been very little research on construction waste management in Thailand, this study aimed to take an important step to initiate this kind of research in order to raise awareness on waste management among construction stakeholders within the country. The results and findings of this research are targeted to reflect useful information and direct perspectives from construction operatives, which can be adapted and adopted for further improvement of construction waste management. It is also expected that this paper will contribute and integrate knowledge from academic research to practical implementations in the construction industry with specific interest in the achievement of green and sustainable construction. The influences of three sustainability aspects on the project stakeholders' efforts on construction waste management were investigated by using the structural equation modelling (SEM) technique. The finding of influential factors and their inter-relationships provide useful insights for establishing effective CWM strategies in Thailand and other developing countries with similar contexts.

Construction waste management and sustainable development

The construction industry can contribute to society by considering the needs of sustainable development from the planning to construction and finally dismantling of buildings. This includes initiating and implementing a construction waste management scheme, which leads to minimization of raw material consumption, waste reduction, less emission, and cost-savings from utilizing the by-products from waste materials generated during construction activities. By-products have to achieve good environmental quality requirements and, at the same time, should be suitable with regard to economic and technical requirements. The ideology of sustainable development calls for a balanced drive to achieve economic, social and environmental goals (WHO 2005). It aims to protect the environment, reduce pollution, conserve natural resources, and safeguard the quality of life of all people. As such, the concept of green and sustainable construction is attractive for creating a healthy built environment while balancing the economic, social, and environmental benefits. However, the promotion of co-benefits of CWM is affected by a lack of awareness, inadequate capacity to quantify co-benefits in CWM activities, and difference in priorities or interests of the construction sector (Goco 2008). As suggested by Chung & Lo (2003) the social acceptability and equity are crucial because they refer to how the local community is receptive and supportive to the waste management options currently in use.

Environmental sustainability, the ability to maintain the qualities valued in the physical environment (CES 2006), is an important issue for the management of the construction industry. This is a main reason why the sustainable development concept is increasingly recognized and why the general public became more concerned of environmental impacts related to construction activities (Cole 2000, Tam et al. 2006a) so that systematic management of construction waste and pollution is increasingly demanded from urban construction projects (Chen et al. 2000). Furthermore, consideration of the social sustainability that ensures a better quality of life for the people today and for future generations is also essential. Social acceptability and equity reflects how the community is receptive and supportive of the waste management options currently in use (Chung & Lo 2003). When considering the social impacts in construction industry, the issue of health and safety is largely associated with construction waste management procedures because construction workers and the general public are subject to risks caused by insufficient management of construction waste (Muller & Schienberg 1997, Cole 2000, Klang et al. 2003, Shen et al. 2004). Furthermore, in terms of economic sustainability, it is essential to understand the economic growth, which is only sustainable when the quality of life and the environment are simultaneously improved (NHS PASA 2008). As such, this requires a mechanism that balances the interests of gaining both economic and socio-environmental benefits for all stakeholders.

McDonald & Smithers (1998) suggested that the construction industry, as a main polluter, should take a role as major contributor in managing environmental pollution by bringing new ways of construction practices that are environmentally and economically efficient e.g. with the effective CWM plan. In regards of sustainable development, such CWM plan should also be socially-accepted. A concept of green and sustainable construction (GSC) then emerged. The GSC concept combines the ideas of green building and sustainable construction. Green building practices create structures by employing environmentally responsible and resource-efficient processes throughout the life-cycle (design, construction, operation, maintenance, renovation, and deconstruction) of a building (EPA 2010) while the sustainable construction concept addresses more comprehensively the sustainability issues (social, economic, environmental, and ecological concerns) as they are involved with not only the environmental concerns but also the health aspects (Kibert 2008). GSC is then believed to bring environmental, social, and economic benefits since it creates a healthy built environment based on resource-efficient, ecologically-based principles.

To meet the goals of voluntary corporate social responsibility (CSR), legislated environmental impact assessment (EIA), and the economic interests, it is necessary for the construction industry to recognize and initiate to overcome construction waste problems by bringing new ways of construction practices that are socially acceptable, economically viable, and environmentally sustainable (McDonald & Smithers 1998). However, sustainable construction can hardly be achieved without the construction stakeholders' strong efforts for CWM. Previous researches found that people's awareness, attitudes and perceptions towards CWM may have influence on their behaviour and decision making regarding waste handling (Lingard et al. 2000, Teo & Loosemore 2001, Kulatunga et al. 2006, Tam et al. 2006b). The construction stakeholders' awareness and efforts on CWM should therefore be investigated and organized to maximize the probability of achieving practical and effective CWM.

Research methodology

Theoretical framework, conceptual model and research hypotheses

As the sustainable construction essentially relies on the management of waste and pollution (EA 2008), the achievement of GSC was influenced by the measurement of CWM efforts. It is perceived that the CWM efforts are influenced by the environmental sustainability (Chen et al. 2000, Cole 2000, Tam et al. 2006a), social sustainability (Cole 2000, Chung & Lo 2003, Shen et al. 2004), and economic sustainability variables (Wong & Yip, 2004, Duran et al. 2006).

The main objectives of this research are to:

1. explore the current practices of construction waste management in Thailand;
2. investigate the influence of sustainability factors on the construction waste management efforts and the achievement of green and sustainable construction;
3. contribute research results and findings to the construction operatives and waste management practitioners in Thailand and, when applicable, in other developing countries.

Moreover, the studied literatures provided a theoretical framework for this research and a conceptual model for sustainable construction waste management was developed, as shown in Figure 1, comprising the constructs of sustainability cores and showing their hypothesized influences on construction waste management efforts towards the achievement of the prospective GSC practices.

The following research hypotheses were defined.

H1: The environmental sustainability concern has a direct causal effect on CWM efforts and indirect causal effects on green and sustainable construction as mediated by CWM efforts.

H2: The public health and safety has a direct causal effect on CWM efforts and indirect causal effects on green and sustainable construction as mediated by CWM efforts.

H3: The gender equality has a direct causal effect on CWM efforts and indirect causal effects on green and sustainable construction as mediated by CWM efforts.

H4: The economic incentives have a direct causal effect on CWM efforts and indirect causal effects on green and sustainable construction as mediated by CWM efforts.

H5: The CWM efforts have a direct causal effect on green and sustainable construction.

The structural equation modelling and research variables

The structural equation modelling (SEM) technique was employed to test the hypothesized model in order to analyse the influences and relationships of factors affecting the success of construction waste management practices. General SEM involves two inter-related procedural components; a measurement component and a structural component

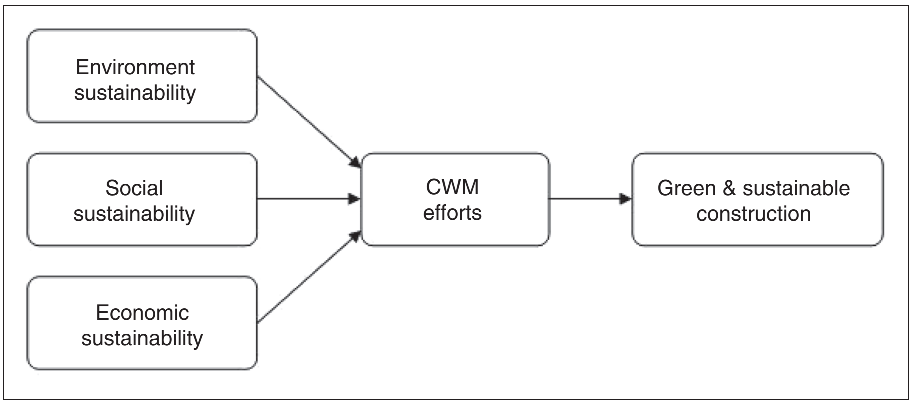

Figure 1. Conceptual model for sustainable construction waste management.

(Byrne 2001). The measurement component specifies how latent variables are measured in terms of observed variables. The structural component expresses relationship among the latent variables. The observed variables provided data that can be directly measured such as numeric responses to a rating scale item on a questionnaire. On the contrary, latent variables are under the researchers' interest but cannot be directly observed. To measure latent variables, it is necessary to construct a model to express latent variables in terms of the observed variables. Hence, the SEM technique enables the development of a causal indicator model in which a latent theoretical construct of interest is represented by measured variables.

The variables in the three constructs of sustainability are moderator variables that induce change in the relationship between the independent and dependent variables. Based on this, a model was constructed to investigate the influence of environmental, social, and economic sustainability on the CWM efforts towards the prospective GSC goals. The variables in each constructs measured in the study are listed in Table 1.

The factors in Table 1 were selected based on their theoretical relevance and practical potentials to reflect situational and technical problems of CWM in Thailand, where a standard CWM system is not yet established and construction waste recycling is not yet available (PCD 2007). These grouped factors are comprised of lower-level variables that represent actual problems occurred during field practices of CWM. The analysis results will reveal which of these factors are having high, moderate, or low influence on the stakeholders' effort on construction waste management as well as those facilitating Thailand's prospective achievement of sustainable construction.

Data collection and analysis

In this research, waste management practices in Thailand's construction industry were studied through site visits, interviews, and field questionnaire surveys at small, medium and large construction projects in major urban regions that were selected to represent a broad picture of CWM in Thailand. Nine projects from Bangkok metropolitan and peripheral provinces, ten projects from Chiang Mai and Pitsanulok provinces in the northern region, three projects from Udon Thani province in the north-eastern region, and twelve projects from the southern provinces (Phuket and Song Kla) were selected for the research. According to Thailand's National Economic and Social Development Board (NESDB 2006), these selected provinces were regarded as centres of urban development within their respective regions and showed a significant rate of economic development and expanded rate of gross productivity in the construction sector.

The targeted respondents were both direct and indirect stakeholders of construction projects. That is, they benefit and/or were affected by construction activities. The group of respondents included project participants (e.g. project owner, managers, designers, site engineers, foremen, workers, waste removing and recycling operators etc.), government officials (e.g. in the Department of Environment & Construction Works), and members of the local community (e.g. people living/working near construction sites). A total of 384 responses were finally considered valid for data analysis. Details of respondents are shown in Table 2.

In addition to general statistics, which were applied for a presentation of descriptive analysis as well as correlation coefficients and level of statistical significance, the SEM part measured and tested the measurement model by confirmatory factor analysis (CFA) whereas the structural model was assessed according to the goodness of fit indices. As suggested by Molenaar et al. (2000), the model that performed well with regard to both goodness of fit and the theoretical expectations, after refinements, was selected as the best fitted final SEM model.

In this study, the structural equation model was analysed by using a SEM computer program called AMOS (Analysis of MOment Structures) version 16.0. The latent constructs were incorporated with their corresponding measured variables into an initial causal model. The SEM technique was used to refine and confirm the causal relationships among variables. Model modification indices and theoretical justifications were used until a final satisfactory model was identified. The model was revised through several iterations in order to improve the fitness of the model. Four indices were used to examine the goodness of fit of the analysed model. They are the relative chi-square (CMIN/DF; $\leqslant 2.0$), the comparative fit index [CFI; $\geqslant 0.90$), the root mean square error of approximation (RMSEA; $\leqslant 0.08$ (acceptable fit) or $\leqslant 0.05$ (good fit)], and the incremental fit index (IFI; $\geqslant 0.90$). These indices were selected because they are relatively independent (least affected) of sample size.

Results

Statistical results

Descriptive statistics results show that a majority of respondents (30%) were from Bangkok whereas the numbers of respondents from other locations ranged from 10 to 15%. As for the number of construction projects in Bangkok outnumbered that of other regions in the country, this proportion was reasonable. In terms of occupation, the large groups of respondents were personnel in construction sites (total 41%), local residents (31%), and government officials (24%). The survey was also carried out in such a manner as to avoid gender biases so that the female respondents were 30% of the total number of respondents. As construction is a male-dominated industry, this proportion is normal for research in construction and this number also conformed to findings by the Women-Core Consortium (2008) which

Table 1. Research Latent Constructs and Observed Variables

Latent constructs	Code	Variables	Description	References
Environmental sustainability (ES)	ES1	Awareness	Raising awareness on environmental impact	Dixon et al. (2007)
	ES2	Waste	Waste generation and management (minimization, generation, source evaluation, collection, storage, separation, treatment, transportation, and disposal)	Donatiello (2001)
	ES3	Air	Air quality and management (provision and density of air pollutant monitoring devices)	Donatiello (2001)
	ES4	Water	Water consumption and wastewater treatment. Water quality and water contamination	Donatiello (2001); UNCSD (2005)
	ES5	Land	Land degradation due to construction activities	UNEP RRC.AP (2007)
	ES6	Noise	Noise control (monitoring device & noise barriers)	Donatiello (2001)
	ES7	Energy	Rate of energy (fuel/gas/electricity) consumption	Donatiello (2001)
	ES8	Green areas	Availability and density of public green area	Donatiello (2001)
	ES9	Resource recovery	Policy and rate of recoverable natural resources	Phillips (2006)
Health & safety (HS)	HS1	Awareness	Activities for raising awareness on H&S issues	Dixon et al. (2007)
	HS2	Accident	Rigorous safety measures & procedures to prevent occurrence of the accidents	HSE (2007)
	HS3	Casualty	Rigorous safety measures & procedures to prevent site deaths and casualties	HSE (2007)
	HS4	Health condition	Frequency of illness related to construction activities	ILO (2003)
	HS5	Waste handling	Procedures for safely handling construction waste	Shen et al. (2004)
	HS6	Training	Safety training provided	HSE (2007)
	HS7	Health risks	Exposure to risks from construction waste	Cooper (2008)
	HS8	Quality of life	On-site welfare, community wellbeing, and access to healthcare	Dixon et al. (2007); HSE (2007)
	HS9	Mental health	Relationship within family & relationship among groups of project stakeholders	Ageton et al. 2007
Gender equality (GE)	GE1	Gender awareness	Emphasis on gender equality in waste management	Hemmati & Gardiner (2002)
	GE2	Respect	Respect among gender of the workforce exists	Miles & Niethammer (2009)
	GE3	Diversity	Diversity and biological differences in workplace and society is understood	Dixon et al. (2007); WEF (2006)
	GE4	Fairness	Provided with equality/fairness to receive consideration, to express opinion, and to decide	Dixon et al. (2007)
	GE5	Employment	Rate of employment in the working sector	Russell (2002)
	GE6	Participation	Rate of participation in CWM activities	Russell (2002)
	GE7	Susceptibility	Susceptibility on waste handling	Cooper (2008)

(continued)

Table 1. Continued

Latent constructs	Code	Variables	Description	References
Economic incentives (EC)	EC1	Cost-effectiveness	Cost-effectiveness of CWM implementation	PCD (2007)
	EC2	Expenditures	Project cost reduction (financial incentives)	PCD (2007)
	EC3	Revenue	Revenue generation from construction waste with good quality for reuse & recycle	Klundert & Anschutz (1999)
	EC4	Recycling interests	Regulatory incentives that attract and encourage using recycled material and making CWM efforts for environmentally sustainable construction	PCD (2007); Kulatunga et al. (2006)
	EC5	Willingness	Willingness to initiate CWM plan and providing budget to carry out CWM scheme	PCD (2007)
Waste management efforts (WME)	WME1	Awareness	Level of awareness on CWM's importance, effects and potential for 3Rs	PCD (2007); Klundert & Anschutz (1999)
	WME2	Attitude	Attitude & perception of stakeholders have effects on their behaviour in CWM implementation. High demand of good quality waste can change consumers' attitude	Kulatunga (2006); Teo & Loosemore (2001)
	WME3	Knowledge	Adequate knowledge, understanding and education on CWM's benefits and practices	PCD (2007); Kulatunga et al. (2006)
	WME4	Communication	Development of channels for communication	Kulatunga et al. (2006); HSE (2007)
	WME5	CWM guidelines	Availability of instruction & procedures & training for 3Rs operations	PCD (2007); Kulatunga et al. (2006)
	WME6	Participation channels	Availability & encouragement of participation channels in CWM activities	PCD (2007); Kulatunga et al. (2006)
	WME7	CWM policy	Available CWM strategic policy & plan that drive CWM efforts	PCD (2007); Kulatunga et al. (2006)
	WME8	CWM system	Availability and compatibility of CWM system that facilitate CWM efforts	PCD (2007)
	WME9	Satisfaction	Stakeholders' satisfaction with availability of CWM plan	
	WME10	Encouragement	Level of encouragement induced by the established CWM plan	PCD (2007)
	WME11	Alertness	Relevant stakeholders' alertness and adaptation for changes in their working behaviour	PCD (2007)
	WME12	Legislation	Law & regulation supporting CWM enforcement	PCD (2007)
	WME13	Waste reduction	Level of construction operatives' effort to reduce waste	PCD (2007)
	WME14	Waste storage	Availability of storage area for construction waste	PCD (2007)
	WME15	Waste transportation	Transportation of construction waste	PCD (2007)
	WME16	Waste separation	Efficiency of construction waste sorting and separation	PCD (2007)
	WME17	Waste disposal	Appropriateness of management/disposal process for construction waste	PCD (2007)

	WME18	Technology readiness	Readiness to employ technology for CWM	PCD (2007)
	WME19	Budget	Financial support from government and relevant organizations	PCD (2007)
	WME20	Co-operation	Co-operation/co-ordination between government and private sectors	PCD (2007)
Green & sustainable construction (GSC)	GSC1	Awareness	Society becomes more aware of green/sustainable construction to increases construction efficiency	BERR (2007)
	GSC2	Stakeholders development	Stakeholders attain career development through capacity building	Dixon et al. (2007)
	GSC3	Energy efficiency	Improvement of energy consumption during on-site, off-site and operational activities	Dixon et al. (2007)
	GSC4	Material consumption	Improved efficiency of building materials and components via new technology	BERR(2007)
	GSC5	Water consumption	Reduction of wastewater and increased usage of recycled water	BERR (2007)
	GSC6	Building standards	Design of buildings meet environmental standards, satisfy the occupants, and adaptable to new uses	Dixon et al. (2007); Haggar (2007)
	GSC7	Site waste generation	Improved on-site, off-site and operational activities that prevent/minimize CW generation	BERR (2007)
	GSC8	Site planning	Improved site planning to reduce waste	BERR (2007)
	GSC9	Manufacturing	Improve manufacturing process for construction materials manufacturing to reduce environmental impacts	Dixon et al. (2007); Haggar (2007)
	GSC10	Procurement & logistics	Improved procedures of construction materials supplies and transportation	BERR (2007)
	GSC11	Air quality	Air pollution prevention and control	BERR (2007)
	GSC12	Water quality	Control and remedy of problems related to water pollution	BERR (2007)
	GSC13	Land use	Land degradation problems caused by construction activities	Dixon et al. (2007)
	GSC14	Workers' health and safety	Health insurance provided to workers	HSE (2007)
	GSC15	Public health & safety	Provision of healthcare and safety precautions	HSE (2007)
	GSC16	CESR	Organization's practices on corporate environmental & social responsibility (CESR)	HSE (2007)
	GSC17	Corporate governance	Regular monitoring and reports on the status and performance of construction industry's initiatives towards sustainability	BERR (2007)
	GSC18	Traffic problems	Traffic problems caused by the physical presence and uses of the built facilities leading to health problems as well as wasteful energy consumption	Uher (1999)
	GSC19	Profitability	Profitable construction procedures	BERR (2007)

Table 2. Status of survey respondents

Involvement with construction projects	Respondents					
	Male		Female		Overall	
	Count	%	Count	%	Count	%
Owner	2	100.0	0	0.0	2	0.5
Manager	12	85.7	2	14.3	14	3.6
Engineer	32	94.1	2	5.9	34	8.9
Supervisor/foreman	56	96.6	2	3.4	58	15.1
Worker	20	54.1	17	45.9	37	9.6
Local residents	65	54.2	55	45.8	120	31.3
Government officials (construction)	27	87.1	4	12.9	31	8.1
Government officials (health & environment)	21	58.3	15	41.7	36	9.4
Government officials (other departments)	16	61.5	10	38.5	26	6.8
Recycling company	1	50.0	1	50.0	2	0.5
Others (e.g. architect/safety engineer/contractor/procurement officer)	13	54.2	11	45.8	24	6.3
Total	265	69.0	119	31.0	384	100.0

Table 3. Analysis of variance (ANOVA) of the recognition on importance of CWM

Issues under consideration	Type of analysis	Sum of squares	df	Mean square	F	Sig.
Recognition of importance of CWM	Between groups	36.119	8	4.515	2.484	0.012*
	Within groups	681.621	375	1.818		
	Total	717.740	383			
CWM is equally important compared with other works in construction management	Between groups	45.136	8	5.642	2.790	0.005**
	Within groups	758.278	375	2.022		
	Total	803.414	383			

Note: * $p < 0.05$; ** $p < 0.01$.

indicated that women's participation in construction research was between 25 and 44%.

Descriptive statistics also show that the respondents could have similar or different opinions on particular issues. For example, the ranking of important factors to be concerned in construction project were differently recognized by different groups of respondents or by gender. The project owners and managers ranked profits and expenses as the most important factors whereas construction workers ranked health and safety as their most important concerns (Manowong & Perera 2008). As such, in order to prevent biased SEM analysis due to the different backgrounds of the respondents, it was essential to examine the significant difference in their attitudes and perceptions of the respondents towards the importance of construction waste management. As presented in Table 3, the analysis of variance (ANOVA) indicated that the difference in their attitudes and perceptions was not statistically significant (Sig. = 0.012 at the 0.05 level of confidence). Furthermore, the respondents similarly recognized that CWM is as important as other issues in construction project management (Sig. = 0.005; $p < 0.01$).

However, project owners still consider CWM to be less important than profits and indicate that the cost of CWM has a high effect on the project expenses. From correlation analysis, it was found that CWM's importance level has a moderately significant correlation with the CWM costs ($r = 0.36$; $p < 0.01$). As pointed out by Wong & Yip (2004), the recycling approach for construction waste material is not widely practised because it is not cost-effective. Thus, cost-effectiveness remains an important decision-making factor for CWM practices, particularly in developing countries such as Thailand where financial resources are limited.

Structural equation modelling results

By using the confirmatory factor analysis (CFA) technique, in order to examine whether the observed variables were well factorized into the respective factors, it was initially found that the conceptual model consisted of five latent variables (or factors) altogether. The environmental sustainability comprised two factors (CFI = 0.951); environmental impact and resource consumption. The social sustainability comprised two factors (CFI = 0.955); health and safety and gender equality. Finally, the economic sustainability construct was found to consist only one factor; the economic incentives (CFI = 0.976).

Each of the CFA model was examined by the Kaiser–Meyer–Olkin (KMO) statistics in order to check both predictability of sampling adequacy and wellness of data factorizing. KMO values vary from 0 to 1.0. Overall, KMO should be 0.60 or higher. The result shows that the KMO for CFAs of latent variables in the starter model ranged from 0.63 to 0.94, indicating that the observed variables were well factorized into the respective factors. Regarding the goodness-of-fit of the CFA models, the RMSEA index indicated that all CFA models were adequately fitted (RMSEA < 0.08) whereas the IFI, TLI and CFI indices indicated that these CFA models were a very good fit (fit indices > 0.09). Hence, the CFA models were taken to establish the SEM starter model.

By means of the SEM program AMOS 16.0, the good-fitted starter model was analysed and further revised until the final model with best fit was achieved. Revisions of the analysed model included deletion and relocation of variables; rearrangement of directions of influence; exclusion of insignificant paths; and addition of covariance; which were recommended by modification indices. In the final model, the influences of variables resource consumption construct were found to be not significant in the model's path analysis. Hence, their paths are not illustrated in the simplified final structural model. Table 4 shows the fit indices of the analysed structural model. It was found that the final model had a very good fit (IFI, TLI, and CFI indices were all greater than 0.90; RMSEA < 0.05; and CMIN/DF < 2.0).

In the final model, the GSC latent variable was represented in the form of two sub-constructs: preventive/correction measures and resource utilization. The model's parsimony comparative fit index (PCFI) was 0.85 while its parsimony ratio (PRATIO) was 0.94, indicating that the final model had a better fit.

Tables 5 and 6 present detailed results of all standardized path coefficients of the final best-fitted model, along with the squared multiple correlations (R^2) values. Path coefficients in the final model were statistically significant at the 0.001 level of confidence. Paths from the constructs of environmental sustainability to the constructs of construction waste management efforts were not statistically significant. Hence, at this stage, the model data did not support the hypothesis H1 while remaining hypotheses H2, H3, H4, and H5 were supported.

In the SEM model, it can be seen that the environmental sustainability construct was measured by the environmental impact and resource consumption variables. Results from Table 5 indicate that construction activities (ES1) generated highly adverse environmental impacts, especially the air pollution (ES3) and construction waste (ES2). Meanwhile, the wastewater from construction site (ES4) had moderate impact (standardized loading = 0.62) on the environment conditions. These SEM results conformed to the survey results which indicated that a large volume of construction waste was mostly generated during the construction stage. Some wasted construction materials such as concrete and bricks were largely dumped in landfill sites. The resource consumption (ES5, ES6) variables had no significant influence on the environmental sustainability. This reflects the fact that the resources of natural construction materials in Thailand are plentiful and so it is not yet perceived that current consumption of natural materials would adversely affect the environment.

Concerning the construction of social sustainability, the most influential factors in characterizing the health impact was the risk from construction waste and pollution (HS7) and the mental health impact (HS9). Meanwhile, public health policy and practice were most influenced by the availability of training for construction waste management (HS6) and measures for construction waste management available (HS5). This SEM results support the surveyed responses indicating that health and safety issues are very significant issues, particularly for construction workers who are directly exposed to construction waste. It is suggested that, based on this finding, the protection of stakeholders' health and safety are the first priority that must be considered by those who have power to make decisions in construction

Table 4. Goodness of fit measures of the analysed structural model

Model	Goodness of fit measures					
	CMIN	CMIN/DF	RMSEA	IFI	TLI	CFI
Starter model	4272.822	2.234	0.057	0.831	0.821	0.830
Revised 1	4118.631	2.153	0.055	0.842	0.832	0.841
Revised 2	3991.453	2.091	0.053	0.851	0.841	0.850
Revised 3	3826.822	2.062	0.053	0.858	0.849	0.857
Revised 4	3647.662	2.031	0.052	0.865	0.857	0.864
Revised 5	3460.110	1.927	0.049	0.879	0.872	0.878
Final model	2740.815	1.771	0.045	0.907	0.900	0.906

Table 5. Path coefficients in the measurement model (sustainability constructs)

Path of model	Causal relations	Standardized loading	Squared multiple correlation (R^2)
Environmental sustainability (ES)	Environmental impact		
	→ ES1 (Awareness)	0.82	0.68
	→ ES2 (Waste generation)	0.72	0.52
	→ ES3 (Air quality)	0.74	0.55
	→ ES4 (Water quality)	0.62	0.39
	Resource consumption		
	→ ES5 (Land degradation)	0.62	0.39
	→ ES7 (Energy consumption)	0.67	0.45
Social sustainability (SS)	Health impact		
	→ HS2 (Accident prevention)	0.65	0.43
	→ HS3 (Casualty prevention)	0.62	0.39
	→ HS4 (Health condition)	0.61	0.38
	→ HS7 (Exposure to risks)	0.80	0.64
	→ HS9 (Mental health)	0.74	0.55
	Health policy & practice		
	→ HS1 (Health awareness)	0.43	0.19
	→ HS5 (Waste handling)	0.76	0.57
	→ HS6 (Safety training)	0.80	0.65
	Gender equality		
	→ GE1 (Gender equality)	0.48	0.23
	→ GE2 (Gender respect)	0.22	0.05
	→ GE3 (Workplace diversity)	0.65	0.42
	→ GE4 (Fairness)	0.56	0.31
	→ GE6 (Stakeholder participation)	0.52	0.27
	→ GE7 (Susceptibility)	0.47	0.22
Economic sustainability (EC)	Economic incentives		
	→ EC1 (Cost effectiveness)	0.31	0.09
	→ EC2 (Expenditures)	0.30	0.09
	→ EC3 (Revenues)	0.35	0.12
	→ EC4 (Recycling interests)	0.58	0.34
	→ EC5 (Willingness)	0.84	0.70

projects. Findings also suggest that, in order to increase gender equality in the management of waste in the construction industry, women should be assigned to construction waste management duties because it was found that women are more sensible in managing construction waste. Furthermore, the SEM analysis shows that the success of such works weare most influenced by the acceptance of women's working ability (GE3), the number of women working at management level (GE4), and women's participation in management of construction waste (GE6).

When considering factors of the economic sustainability, willingness of construction operators (EC5) and motivation to implement 3Rs (EC4) had high influence on construction waste management efforts while the remaining factors had moderate influence. Hence, economic incentives and a wide range of CWM alternatives should be initiated.

Table 6 shows path coefficients for measures of the construction waste management efforts and sustainable construction factors. From the CFA result, the four major latent constructs of the CWM efforts included CWM recognition, CWM policy and planning (P&P) enforcement, the effectiveness of CWM P&P implementation, and CWM managerial practices. The final structural model shows that the CWM recognition was highly influenced by the availability of CWM procedures and guidelines (WME5), followed by the availability of channels for CWM information exchange (WME4), people's knowledge and understanding of CWM (WME3). Meanwhile, intention to initiate and implement a CWM plan (WME2) had a moderate influence on CWM recognition. These SEM results reflect that the CWM initiatives would be recognized if the CWM information and detailed process was widely available to the relevant stakeholders in the construction industry. Recognition and improvement of CWM skills and techniques would gradually develop if supports from governing authorities and professional bodies were provided.

Table 6. Estimates of path coefficients in the measurement model (construction waste management efforts and GSC constructs)

Path of model	Causal relations	Standardized loading	Squared multiple correlation (R^2)
Construction waste management efforts (WME)	Recognition		
	→ WME1 (Awareness)	0.36	0.13
	→ WME2 (Attitudes)	0.66	0.43
	→ WME3 (Knowledge)	0.73	0.53
	→ WME4 (Communication)	0.78	0.61
	→ WME5 (CWM guidelines)	0.83	0.69
	Policy & planning enforcement		
	→ WME6 (Participation channels)	0.76	0.58
	→ WME7 (CWM policy)	0.82	0.66
	→ WME8 (CWM system)	0.82	0.68
	Policy & planning effectiveness		
	→ WME10 (Encouragement)	0.80	0.65
	→ WME11 (Alertness)	0.84	0.71
	→ WME12 (Legislation)	0.66	0.43
	Management		
	→ WME13 (Waste reduction)	0.61	0.37
	→ WME14 (Waste storage)	0.77	0.59
	→ WME15 (Waste transportation)	0.79	0.63
	→ WME16 (Waste separation)	0.81	0.66
	→ WME17 (Waste disposal)	0.81	0.66
	→ WME18 (Technology readiness)	0.66	0.44
	→ WME19 (Budget)	0.69	0.48
	→ WME20 (Co-operation)	0.63	0.40
Green & sustainable construction (GSC)	Preventive/Correction measures		
	→ GSC11 (Air quality)	0.83	0.69
	→ GSC12 (Water quality)	0.89	0.79
	→ GSC13 (Land use)	0.82	0.68
	→ GSC14 (Workers' health & safety)	0.72	0.52
	→ GSC15 (Public's health & safety)	0.78	0.61
	→ GSC16 (Corporate E&S responsibility)	0.71	0.51
	→ GSC17 (Corporate governance)	0.68	0.47
	Resource utilization		
	→ GSC1 (Awareness)	0.72	0.52
	→ GSC2 (Human resource development)	0.76	0.57
	→ GSC3 (Energy efficiency)	0.89	0.79
	→ GSC4 (Material consumption)	0.90	0.80
	→ GSC5 (Water consumption)	0.85	0.72
	→ GSC19 (Profitability)	0.26	0.07

Effective enforcement of CWM policies and plans was most influenced by the compatibility of CWM plan and actual situation (WME8). Clarity of CWM policies (WME7) and consultations among government/private/citizen sectors (WME6) also had high influences on the enforcement of CWM policies and plans. Hence, CWM policies should be clear and they must be carried out with participation from the concerned groups of project stakeholders. Further, the relevant stakeholders' alertness and adaptation for changes in their working behaviour (WME11), particularly the foremen and the on-site construction workers, and the level of encouragement induced by the established CWM plan (WME10), were found to have most influence on the effectiveness of CWM policies and plans. Therefore, construction stakeholders need to be highly motivated and continuously encouraged through all possible means to obtain their co-operation and co-ordination in order to run the introduced CWM plan.

Furthermore, the appropriateness of management/disposal process for construction waste (WME17), the efficiency of construction waste sorting and separation (WME16), transportation of construction waste (WME15), and the availability of storage area for construction waste (WME14) were found to have high influence on the success of CWM efforts. However, high influences from these factors could not be meaningful without the availability of budget (WME19), readiness to employ new CWM technology (WME18), and co-operation/co-ordination between government and private sectors (WME20), which have moderate influence on CWM efforts.

The prospects of Green and Sustainable Construction were measured in the SEM model through the status of resource utilization, and preventive/correction measures for the resolution of social and environmental problems, which was highly influenced by measures for prevention, control and remedy of problems related to water pollution (GSC12), air pollution (GSC11), and land degradation (GSC13). In addition, provision of healthcare and safety precautions (GSC15), worker's health insurance (GSC14), corporate social responsibility (GSC16), and regular monitoring and reports on the status of construction industry's initiatives towards sustainability (GSC17) were found to have moderate influence on the GSC status.

Meanwhile, the resource utilization was found to be most influenced by an effective use of material in construction activities (GSC4), energy (GSC3), and water (GSC5). Further, resource utilization was also moderately influenced by development and improvement of workers' skills (GSC2) and recognition on worthiness of CWM plan (GSC1). It is reflected, in this study, that GSC is regarded as being dependent upon not only the success in prevention/solution of these environmental problems but also a balanced achievement of the goals of social and economic sustainability.

For better visualization and clarity, a simplified final structural model is shown in Figure 2 presenting only significant influences (i.e. path coefficients) of sustainability issues upon the construction waste management efforts and on GSC.

The final model in Figure 2 briefly indicates that concerns of economic incentives have the highest influence on the efforts to recognize and manage construction waste problems.

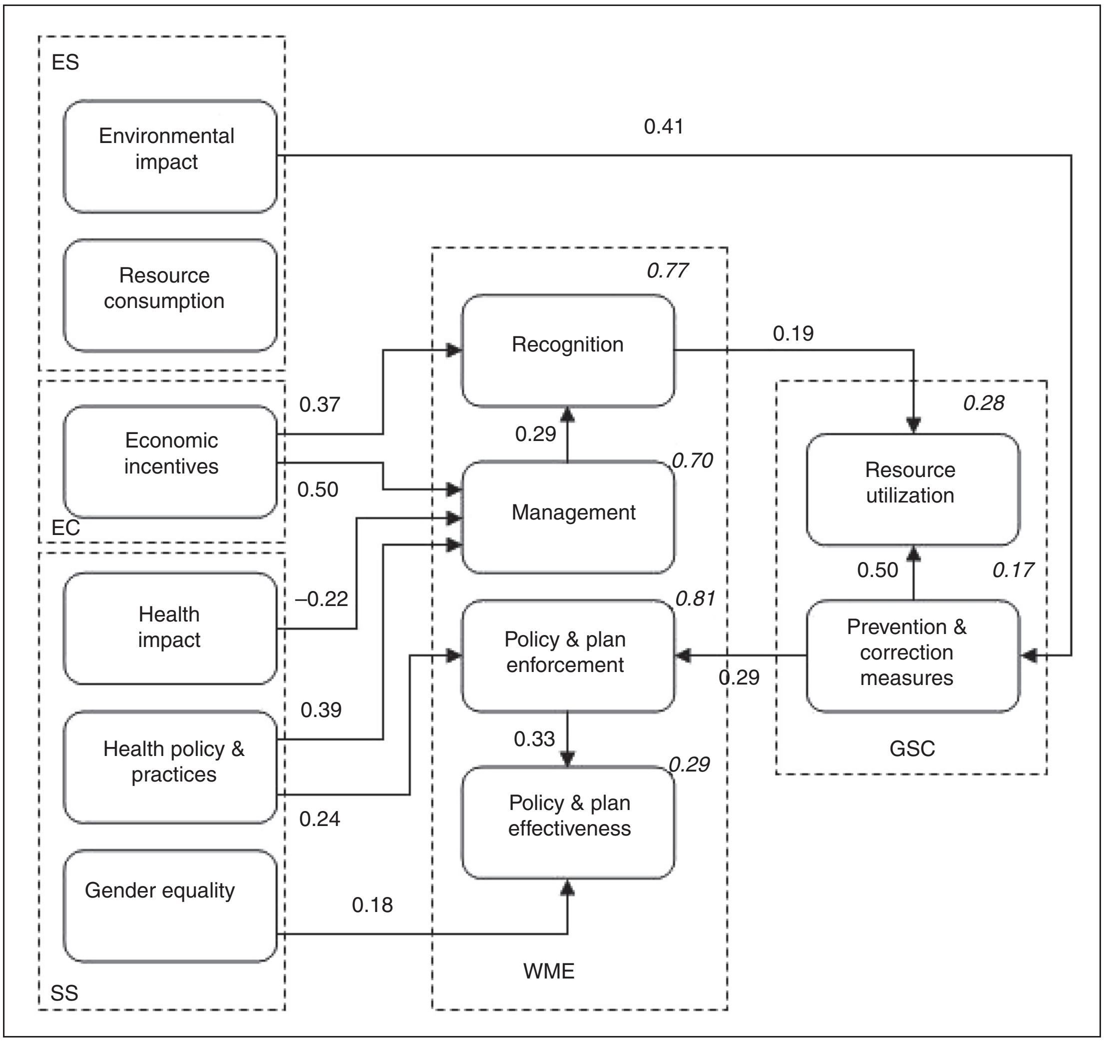

Figure 2. Final structural model.

When considering the path coefficients in Table 5, as previously discussed, it was found that stakeholders' willingness to attain economic incentives and their interests in recycling waste are main factors that drive their efforts to implement CWM practices. As such, these two factors should seriously be taken into account when trying to encourage the construction operatives to participate in CWM programmes or initiatives.

Similarly, the social sustainability issues also have significant influence on CWM efforts. Health impact was found to have significant negative impact on management, meaning that the higher rate of stakeholders' suffering health problems reflects lower effectiveness of the management in exerting the CWM efforts. The path coefficients in Table 5 suggest that attention must be paid to significant factors such as stakeholders' exposure to risks when handling construction waste and this can be done by firstly providing CWM training to construction operatives.

Figure 2 also indicates that concerns on environmental sustainability have no direct significant influence on CWM efforts. Rather, the concerns on environmental impacts have direct influence GSC achievement, through provision of measures to prevent and correct environmental impacts. These initiatives significantly influence enforcement of CWM policy and plan, which is supported by clear health policy and practical guidelines, leading to the effective implementation of CWM policies and plans.

Factors influencing construction waste management efforts

This study has found a few major factors having influence on CWM efforts. The findings are summarized in the following list.

- Availability of management procedures (collection, separation, transportation, and disposal). This requires allocated budget, standardized CWM guidelines, and enhanced communication channels to increased recognition on CWM.
- Enforcement of CWM policies and plans. The CWM system needs to be clearly planned and strongly established with stakeholders' participation in order to alert and encourage their willingness, possibly through legislation.
- Economic incentives. Provision of economic incentives brings stakeholders' willingness to better manage and interest to recycle construction wastes.
- Health assurances. Healthcare and waste handling training are essential to prevent risks from being exposed to wastes on-site and off-site. When this is provided, stakeholders feel more motivated to voluntarily deal with wastes.
- Gender diversity recognition. When the construction industry better recognizes gender differences such as female workers' physical sensitivity or female employees' managerial capability there can be more CWM efforts.

The aforementioned factors are only those having moderately and highly significant influence on CWM efforts. Other factors having significant influence, but at a lower level, can be observed based on their path coefficients in Table 5 and 6.

Case study examples

To provide a clearer picture of the situation of CWM problems in Thailand, two studied cases have been selected to briefly reflect similarities and differences of practices in a big city such as Bangkok and a smaller provincial city in the southern region.

The mass transit infrastructure project of in Bangkok is larger and located in a highly populated area. This project has a better CWM system on-site where waste materials are collected and stored in a designated place. The construction contractor company also has its own special stockpile for construction waste. The company can allocate reusable waste for its own use in other projects in Bangkok and the company can save material costs. Furthermore, the environmental and pollution control law and regulations in Bangkok are more strict so that the construction company has to be careful with its waste-related operations.

In comparison, CWM in the construction of the government's university building in southern Thailand is less practiced. Only steel is being collected for recycling because its value and recycling potential is already recognized. Other on-site waste materials are mixed together and it is impossible to reuse or recycle. The contractor has no interest in recycling waste materials because fresh materials are locally available with lower prices. Furthermore, there is no clear requirement in local government administration concerning CWM.

It can be seen that both projects have different motives in managing their wastes. The main considerations are involved with local law and regulations and construction operators' attitudes towards the benefits of implementing CWM in their project management.

Discussion

Existing situations

Waste materials from construction projects in Thailand are handled differently depending on their perceived current economic values. Currently, construction waste management practices are not widely familiar to Thai construction stakeholders. They do not know any particular policy or procedures to handle waste materials properly. Bulk and decomposable wastes such as concrete, bricks, and asbestos have not been properly managed. At the construction site's waste collecting point, construction wastes are left and mixed together so that their quality is worsened.

Therefore, they are not taken for reuse or recycling because the processing cost is higher than buying fresh raw materials.

Currently, mixed construction wastes is buried on-site, disposed at landfill sites, or illegally dumped into empty areas, causing environmental and social problems. Only construction wastes with perceived quality and economic value are collected on-site. There are no problems for metal wastes because they can be easily sorted and sold to the existing domestic market. Some type of recyclable wastes from construction such as papers and plastics are less frequently brought to recycling because most of them are normally mixed with other wastes at construction sites. As a result of the unavailability or inadequacy of a sorting process, such waste materials are contaminated and unsuitable for recycling. In fact, the salvage of construction materials and building parts has already been in practice when buildings are demolished. However, a standardized salvage system is needed to promote a wider market for reused/recycled materials. The enhanced salvage system facilitates the assessment of the quality of salvageable building materials and the resources required for the salvaging process. By this approach, the overall value of a building can be evaluated throughout its whole life-cycle. The relevant impacts on sustainability are assessed and proper CWM actions can then be applied. As such, the value of construction waste is maximized while minimizing the costs of waste reuse and recycling.

Attitudinal and regulatory problems

The SEM analysis provides insights into the attitudes and perceptions of stakeholders concerning how to successfully achieve the purpose of GSC in Thailand through exertion of waste management efforts. Lack of construction waste management facilities and economic incentives have caused the Thai construction operatives to have little interest in segregating and storing waste materials for recycling or proper disposal process. In the general view of project owners or managers, additional efforts or resources used for management of waste (such as sorting, storing, and transporting) imposed additional costs to their project. Although they realize that waste management is a good practice, it was considered to be a much less important issue compared with the financial benefits and time consumption. Then, the waste management plan had hardly been integrated into the project management plan. Lack of motivation and encouragement in implementing '3R' practices results in a high rate of landfilling and little presence of a market for recycled material. In addition, there is no specific law to deal with construction and demolition waste and the enforcement of related environmental law and regulations is ineffective. As such, construction activities in those areas with fewer restrictions continue to generate waste and pollution.

Improving construction waste management and achieving sustainable construction

This study recommends that the significance of waste management need to be firstly recognized in order to encourage stakeholders to exert their efforts in waste management. Such recognition has significant influence on the achievement of sustainable construction by focusing on effective utilization of a project's resources. Successful building of stakeholders' recognition relies on effective management process. Inclusion of economic incentives and the stakeholders concern about the issue of health impact play a significant role in increasing recognition and waste management effort. Policies and practices on people's health also significantly push the enforcement of waste management policy and plan. Strong enforcement of construction waste management policies and plans, in combination with emphasis on gender equality issues which strengthens women's roles and decision-making power in managing construction waste, finally leads waste management initiatives and implementation to be effectively carried out.

An implication of the findings of the study is that, the issues of environmental impact and depletion of resources due to high consumption have no influence on the waste management effort. Rather, the concern on environmental impact significantly influences the improvement of construction practices. Various measures for prevention and correction of bad practices must be implemented in order to attain GSC. Such measures significantly motivate better resource utilization, which is regarded as the most significant factor for GSC achievement. Although the issue of gender equality has no influence on sustainable construction, it has significant influence on stimulating the effectiveness of policies and planning for management of construction waste and pollution. Accepting the ability of women at the management level and encouraging their participation in construction projects can play a noticeable role in driving the success of construction waste management.

Conclusion

The influence of sustainability factors on the efforts on construction waste management and the achievement of GSC practices in Thailand's construction projects were investigated through field observations and surveys. Collected data was quantitatively analysed by means of statistical packages and the SEM techniques. The result indicates that the management of construction and demolition waste is generally regarded as an important emerging issue. However, the Thai construction owners and managers still consider project profits and related economic benefits as the most important concerns. On the contrary, Thai construction workers and members of the public are most concerned with the issues of health and safety. When there is no agreed position to adequately utilize a project's budget on waste management scheme initiatives, the efforts on waste management are not actively exerted.

By testing the research hypotheses, it was revealed that the economic and social sustainability factors had significant direct causal effect on the waste management effort. This is not the case for the environmental sustainability factors because they have significant direct causal effect only on the achievement of GSC where preventive and correction measures for environmental problems are applied focusing on effective resource utilization. Hence, in order to initiate and implement construction and demolition waste management policies and practices in Thailand, recognition of the waste problems should be firstly adopted. Moreover, the issues on economic incentives and social concerns such as health and safety or empowerment of women should be emphasized more because these lead to higher recognition of construction waste problems and stronger enforcement of waste management policies and plans in order to achieve effective implementation of construction waste management countrywide.

For developing countries with limited financial resources and construction waste management initiatives, in order to avoid subsequent costly process for managing construction waste, there should be strategies established aiming to take proactive steps and pay attention to both existing and anticipated conditions for construction waste. Sustainable construction in developing countries can be achieved in an affordable manner through effective utilization of resources in construction, material recovery, an improved system for waste management, and energy savings. However, the first objective to be achieved is a change of the stakeholders' norms. To achieve the goals of GSC in Thailand, as well as other developing countries with similar context, strong regulatory initiatives such as specific laws and policies for construction waste management are as important as the stakeholders' awareness and willingness to participate.

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