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Schedule Management for Green Building Projects in Singapore: Schedule Delay, Causal Factors and Solutions

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***Abstract:** With the mounting concerns over environmental issues, green construction is gaining a place in the global construction industry. However, rare research has been conducted to analyze green construction projects, especially in the aspect of project schedule performance. As a result, this study aims to investigate the degree of project delay in green building construction, analyze the factors affecting schedule delay of green building projects, and finally provide recommendations to improve schedule performance of green building project. To achieve the objectives, a comprehensive literature review was carried out, followed by a survey conducted with 30 companies that provided data from 220 traditional and 96 green building projects. The analysis of the responses identified that 15.9% of the traditional building projects were delayed while 32.3% of the green building projects were completed behind schedule. Furthermore, the amount of the delays in green building projects was an average of 4.8% of their planned schedule. The top 5 critical factors that can cause delay in green building projects were identified as: (1) speed of decision-making by clients; (2) speed of decision-making involving all project teams; (3) communication/coordination between key parties; (4) level of experience of consultants; and (5) difficulties in contractors' project financing. Lastly, a list of recommendations was introduced, aiming to reduce schedule delay in green building construction projects based on the observations. This study will serve as s a base for further research on the enhancement of green building project schedule performance.*

***Keywords:** Green building, schedule, delay, causal factors, solutions*

I. INTRODUCTION

The building and construction industry greatly contributes to the increase in greenhouse gas (GHG) emissions, which leads to global climate change [1-4]. According to the World Green Building Council [5], buildings were responsible for one third of GHG emissions in the world, and thus sustainable building practices can substantially diminish energy consumption of resources and GHG emissions. In recent years, there has been an apparent shift towards green construction across the world [6].

The construction industry is a key economic growth sector in Singapore and plays a dominant role in providing employment to support the future development of Singapore [7]. According to the Building and Construction Authority [8], Singapore's construction demand reached a historical high of S$35.8 billion in 2013 and remains strong till 2030. With the mounting global concern on the environment, Singapore has also shifted its focus to making sustainable development a key national priority as well [9, 10]. Since the launch of the Green Mark Scheme in 2005, the number of green mark certified buildings have increased to over 2,000 in 2014 from the mere 17 in 2005 [11]. In order to intensify the efforts in speeding up the development of green buildings in Singapore, all new building developments and major renovations which are over 2000m^2 in size are required to achieve green mark certifications [12]. As such, construction of green buildings has gained greater foothold in the recent years in Singapore.

Schedule performance is critical for the successful project delivery [13]. The design and construction process of green building construction usually takes longer than traditional building construction [14, 15]. This is because project team members need more time to be familiar with and implement green building practices, and the design process is more complicated than that of a traditional building due to the evaluation of alternative materials and systems [16]. As green building construction continues to grow and gain popularity, it is necessary to ensure that green building projects are completed on time and delivered successfully. This study aims to: (1) investigate the degree of project delay in comparison between traditional and green projects in Singapore; (2) analyze the causal factors of delay for both green and traditional projects; and (3) discuss the possible solutions for the delay problems of green projects.

II. BACKGROUND

In terms of green construction, the green requirements should be well addressed and reflected in project schedule performance [17, 18, 19]. The design and construction of green buildings usually takes longer than traditional projects because project team members need more time to understand and implement green practices [14, 15] and more time is required to integrate green requirements into architectural and engineering designs [15].

In addition to the factors relating to green requirements, a number of studies have investigated the factors affecting schedule performance of construction projects [13, 20, 21, 22]. Despite the studies investigating the schedule performance of traditional construction projects, few have explored the factors relating to the delays of green building projects and the schedule performance of green building projects. In this study, 38

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factors were identified from the literature review, and grouped into eight major categories:

(1) Project Related Factors (PR), including the project delivery methods, project cost, the lack of communication between all the project team members, speed of decision-making involving all projects teams, and Disputes/conflicts between key parties [21, 23, 24].

(2) Client Related Factors (CL), including speed of decision-making by client, delay in payment by client, client's experience in the construction industry, and client initiated variation of works [21, 25-27].

(3) Design Team Related Factors (DT), including mistakes and delay in producing design documents, level of design team experience, complexity in project design, and misunderstanding of client's requirements by design team [25, 28-30].

(4) Consultant Related Factors (CS), including delay in performing inspection and testing; delay in approving major changes in the scope of works; time for reviewing and approval of design documents by consultants; conflict between consultants and design engineers; level of experience of consultants [24, 25, 31].

(5) Contractor Related Factors (CT), including poor site management and supervision, contractor's deficiencies in planning and updating schedule plans, difficulties in financing project by contractors, construction methods implemented by contractors, and rework due to defects during construction [25, 27, 28, 32].

(6) Labor Related Factors (LA): including shortage of labor; low labor productivity, and unskilled labor [13, 25, 29, 33, 34].

(7) Equipment and Material Related Factors (EM), including equipment breakdown, low productivity and efficiency of equipment, unskilled operators, lack of high technology mechanical equipment, availability of material, changes in materials during construction, and imported materials [21, 23, 24, 35].

(8) External Factors (EX), including unforeseen ground conditions, unfavorable weather condition on construction activities, accidents during construction, changes in government regulations and law, delay in final inspection and certification by third party, and delay in permits from political units/body of officials [21, 25, 36].

III. Research Method

To achieve the objectives of this study, a comprehensive literature review was first conducted, supporting the development of the questionnaire. In the survey, the respondents were asked to (1) provide their basic information; (2) assess the schedule performance of the traditional and green building projects they have performed in the period of 2005-2010, respectively; (3) rate the influence level of the potential factors that may cause delay using a five point scale (1=very low; 3=medium; 5=very high); and (4) select the five most relevant solutions among the 14 possible solutions. The percentage of schedule delay of green projects was reported and the causal factors were ranked based on their mean influence scores. A total of 100 questionnaires were sent out with reference to the list made available by the directories of the BCA registered contractors, BCA green mark architectural firms, and Singapore Institute of Surveyors and Valuers. As the BCA green mark scheme commenced in 2005, the target of the survey was the companies that had experience in both green and traditional projects performed in 2005-2010. The survey collected responses from 18 construction, 9 consulting and 3 development firms, which provided information of 220 traditional projects and 96 green building projects.

IV. Data Analysis and Discussions

A. Schedule delay

As shown in Table I, the overall percentages of the surveyed projects with delay were 15.91% and 32.29% for traditional and green building projects, respectively. It can be inferred that green building projects were more likely to experience delays than traditional projects. As green building construction projects require green technologies which were still relatively new to the industry, it required more time to understand and incorporate these technologies into the design. This was in line with Snell and Callahan [37] who pointed out that green building construction took much longer to complete and presented more challenges than anticipated even if builders were experienced in construction, design and creative problem-solving.

TABLE I
Delay of Traditional and Green Building Projects

Characteristics		Traditional			Green		
		Total No.	With delay		Total No.	With delay	
			N	%		N	%
Project type	Commercial	48	12	25.0%	28	16	57.1%
	Residential	91	9	9.9%	21	0	0.0%
	Educational	81	14	17.3%	47	15	31.9%
Project nature	New construction	184	32	17.4%	93	31	33.3%
	A&A	36	3	8.3%	3	0	0.0%
Project size	< S$5 mil.	32	4	12.5%	3	1	33.3%
	S$5-10 mil.	6	0	0.0%	8	2	25.0%
	S$10-20 mil.	35	5	14.3%	6	0	0.0%
	S$20-30 mil.	33	0	0.0%	13	3	23.1%
	S$30-40 mil.	15	1	6.7%	16	5	31.3%
	S$40-50 mil.	27	4	14.8%	18	7	38.9%
	> S$50 mil.	72	21	29.2%	32	13	40.6%
Sum		220	35	15.9%	96	31	32.3%

In terms of project type, commercial building projects represented the highest frequency of delay for both the traditional and green projects. This may be because commercial projects are relatively unique in nature and vary widely in terms of requirements, design and specifications, compared to residential or educational buildings that can be easily modelled based on past projects. With respect to the project nature, more new construction projects were delayed than addition and alteration (A&A) projects for both traditional and green projects. This was possibly because new projects have higher-level uncertainty than A&A projects. Furthermore, in terms of contract amount, large-sized projects were more likely to encounter delay. The projects costing over $50million reported the highest percentage of delay for

both traditional and green projects. With more project parties involved in large projects, relationships and information flows among project players become more complicated, and inadequate and ineffective coordination would increase the likelihood of communication breakdown and variations, leading to project delay [38].

Furthermore, 53.3% of the respondents reported that the average schedule overrun of their projects ranged from 4 to 6% of the as-planned schedule (Table II). The overall average schedule overrun in green building projects was 4.8% of the planned schedule and it was of paramount concern of clients and contractors, as such delay would reduce chances of producing successful projects.

TABLE II
SCHEDULE OVERRUN OF GREEN BUILDING PROJECTS

Schedule overrun (% of planned schedule)	N	%	Mean
0%	3	10.0%	4.8%
1-3%	5	16.7%	
4-6%	16	53.3%	
7-9%	3	10.0%	
≥ 10%	3	10.0%	

B. Causal factors of delay

The causal factors were ranked according to their mean scores, as indicated in Table III. For green building projects, "speed of decision-making by client" obtained the highest score, suggesting that the green building project delay was greatly attributed to the slow decision-making by client. The slowness of decision-making made contractors waste resources waiting for clients to decide on specialty contractors, decorative materials and suppliers, and provision of adequate information on the changes required [32]. This result was in line with the findings of Sullivan and Harris [39] and Faridi and El-Sayegh [40], who found that slowness of the owner's decision-making greatly caused delay in the UK and the United Arab Emirates, respectively.

"Speed of decision-making involving all project teams" occupied the second position, indicating that decisions should be made timely and slow decision-making would make project teams work inefficiently. It is essential that effective decisions should be made at the right time. To achieve a successful project, the flow of information between all project team members should be systematic and timely, reaching the appropriate personnel. The delay in the contractors' reception of decisions would slow down their construction activities. If the activities were in the critical path, delay would occur.

There were three factors receiving the third rank, with the same scores. "Communication/coordination between key parties" was found to influence the green building projects' schedule. Successful completion of construction projects involves the interconnected collaboration of various parties, which requires effective tools and processes to coordinate parties in order to ensure the project's success. Green building construction projects requires a more holistic and integrated approach as the design process is more complex and much of the design phases overlap with the construction phases [41]. As such, green building projects requires more effort in communicating amongst the various team members [42]. In addition, "level of experience of consultants" was ranked third, implying inadequate experience of consultants may result in late issuance of construction drawing, delay in work approval, poor communication and change orders, which are likely to cause construction delay [13]. In green building projects, the level of design

TABLE III
RANKING OF THE CAUSAL FACTORS OF DELAY

Causal factors of delay		Traditional		Green	
		Mean	Rank	Mean	Rank
PR	Project delivery methods	4.03	18	4.30	16
	Project cost	4.03	18	4.30	16
	Speed of decision-making involving all project teams	4.53	**3**	4.77	**2**
	Communication/coordination between key parties	4.57	**2**	4.70	**3**
	Disputes/conflicts between key parties	3.17	39	3.47	35
CL	Speed of decision-making by client	4.53	**3**	5.00	**1**
	Delay in progress payment by client	4.07	17	4.17	20
	Client's experience in the construction industry	4.43	7	4.67	6
	Client initiated variation of works	3.80	26	4.13	23
DT	Mistakes and delay in producing design documents	4.47	**5**	4.27	18
	Level of design team experience	4.03	18	4.63	7
	Complexity in project design	4.13	14	4.53	10
	Misunderstanding of client's requirements by design team	4.00	22	4.17	20
CS	Delay in performing inspection and testing	4.13	14	4.00	27
	Delay in approving major changes in the scope of works	4.47	**5**	4.57	9
	Time for reviewing and approval of design documents by consultants	4.60	**1**	4.63	7
	Conflict between consultants and design engineers	4.17	13	4.43	14
	Level of experience of consultants	4.43	7	4.70	**3**
CT	Poor site management and supervision	4.20	11	4.53	10
	Contractor's deficiencies in planning and updating schedule plans	4.20	11	4.47	12
	Difficulties in financing project by contractors	4.40	9	4.70	**3**
	Construction methods implemented by contractors	3.93	24	4.27	18
	Rework due to defects during construction	3.27	37	3.43	36
LA	Shortage of labor	4.13	14	4.10	25
	Low labor productivity	3.63	30	3.67	30
	Unskilled labor	3.50	34	3.57	31
EM	Equipment breakdown	3.40	36	3.37	37
	Unskilled operators	3.27	37	3.53	32
	Low productivity and efficiency of equipment	3.57	33	3.50	34
	Lack of high technology mechanical equipment	3.60	32	3.37	37
	Availability of material	3.63	30	4.17	20
	Changes in materials during construction	3.83	25	4.07	26
	Imported materials	4.03	18	4.33	15
EX	Unforeseen ground conditions	3.67	29	3.53	32
	Unfavorable weather condition on construction activities	3.50	34	3.37	37
	Accidents during construction	3.97	23	4.13	23
	Changes in government regulations and law	3.73	28	3.90	28
	Delay in final inspection and certification by third party	3.80	26	3.87	29
	Delay in permits from political units/body of officials	4.40	9	4.47	12
Spearman's rank correlation = 0.913 (p-value = 0.000)					

complexity is higher than that in traditional building projects. Specialist consultants should be involved in the design process earlier to incorporate their suggestions and requirements in the design so that their contributions are taken into account to safeguard maximum efficiency [43]. Therefore, without the required level of knowledge and experience by the consultants, the harmonization of the systems would not be possible and conflicts would occur. In addition, a delay in reviewing and approving the design would further impede the project schedule.

"Difficulties in financing project by contractors" were also ranked third, indicating that the financial difficulties would cease construction activities and result in delay of material supply, thus leading to schedule delay. This result confirmed the previous studies that reported financial difficulties of contractors as the most significant cause of delay [44, 45, 46].

The Spearman's rank correlation was performed and the coefficient was 0.913 with a p-value of 0.000, indicating strong agreement between the rankings of delay causes in traditional and green building projects. Thus, both groups of projects shared similar causal factors of delay.

C. Solutions for improving schedule performance

A total of 14 possible solutions for improving schedule performance were identified from the literature review and presented in the questionnaire and the respondents were asked to select the five most relevant solutions. The top three solutions are discussed as follows:

(1) "Ensure that the actual construction schedule and resources are seriously monitored and reviewed so that the performance is in line with as planned to avoid chances of cost overrun and disputes": Project managers should check that the green building construction planning and scheduling are in perpetual processes during construction and that the schedule plans correspond with the time to develop the work and resources to prevent cost overrun and disputes [47]. To ensure that the project schedule and resources are constantly monitored and reviewed, owners may deploy certain tools and techniques for schedule control. A schedule control system may be set up to define the procedures when changes occur in the project schedule, and performance measurements should be carried out to assess the degree of variations that took place [48].

(2) "Check for mistakes and discrepancies in design documents to avoid redoing of designs and drawing before submission for approval to avoid variations or necessary corrections": It is better to detect mistakes and discrepancies as early as possible. During construction, mistakes and discrepancies discovered in design documents would result in redoing of designs and drawing, which requires extra time beyond the as-planned schedule and leads to poor time performance [23].

(3) "Alternative procurement method should be analyzed to ensure it meets the project requirements and complexity": Every procurement method has a different course of project development and involves different relationships between all the project team members [49]. As such, clients should analyze the project characteristics with care to select the appropriate procurement method as misinterpretation of project characteristics would probably lead to poor project performance and resulting in cost growth [50]. Due to the higher complexity of technical systems used in green building construction projects, the projects requires high levels of interdependency, communications and close partnerships with all the project participants during design stages [42].

V. CONCLUSIONS AND RECOMMENDATIONS

The BCA has decided to have at least 80% of Singapore's buildings certified Green Mark by 2030. Since all new building projects are obliged to comply with Green Mark Scheme standards, it is therefore essential to look into how green building project performance can be managed more effectively. The analysis results established that 15.9% of the traditional building projects and 32.3% of the green building projects experienced delay. In addition, the overall average schedule overrun in green building projects was 4.8% of planned schedule. Furthermore, the top five critical factors that caused delay in green building projects were reported as (1) speed of decision-making by client; (2) speed of decision-making involving all project teams; (3) communication/ coordination between key parties; (4) level of experience of consultants; and (5) difficulties in financing project by contractors. The delay statistics in this study can offer a benchmark for the industry to gauge the overall time required by green building projects as compared to traditional building projects. Similarly, clients should consider the additional time when setting out the overall schedule for green building projects. In addition, the main factors influencing schedule performance of green building projects bring forth a focal point for project managers to enhance its performance for the project.

For future studies, construction time prediction models can be developed for green building projects of which the types can include residential, commercial, and industrial projects. In addition, assessment and comparison of schedule performance between green and traditional building construction projects can be done to set up a norm that can be used at the planning stage of green construction. Finally, it is also recommended to establish entire processes of project planning and feasibility studies for green projects as the processes directly affect schedule performance of green building projects.

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