Journal of Cleaner Production 232 (2019) 1348–1370

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Investigating associations among performance criteria in Green Building projects

Tayyab Ahmad [a, *], Ajibade Ayodeji Aibinu [a], André Stephan [a], Albert P.C. Chan [b]

[a] Faculty of Architecture Building and Planning, The University of Melbourne, Parkville, Victoria, 3010, Australia
[b] Building and Real Estate Department, Hong Kong Polytechnic University, Hong Kong

ARTICLE INFO

Article history:
Received 28 February 2019
Received in revised form
30 April 2019
Accepted 2 June 2019
Available online 6 June 2019

Keywords:
Performance criteria
Green buildings
Survey
Interviews
Sustainability performance

ABSTRACT

This study aims to identify the associations among performance criteria in the delivery of Green Building (GB) projects and their underlying conditions. The performance criteria included are social sustainability, economic sustainability, environmental sustainability, quality, schedule, and cost. A mixed methods approach is used, combining both qualitative and quantitative analysis. The findings from an online questionnaire survey (n = 104) are quantitatively and qualitatively analysed. Delphi method is used while conducting the survey. Semi-structured interviews (n = 30) are conducted to support, complement and help triangulate questionnaire survey findings and are also subjected to qualitative analysis.

For GB projects, cost and schedule performance have a positive association among each other while cost performance has a positive effect on economic sustainability. Social, economic, and environmental sustainability have a mutually positive effect on each other. Beside the mutually positive associations among most criteria, in some cases negative and even no associations are also identified. Different conditions that affect the associations among performance criteria are identified including project planning, quality of project development process, life-cycle perspective, project management, Project Delivery Method (PDM), client's vision and motivation, regional constraints, regional climate, compliance requirements, and innovation. These underlying conditions affect performance across multiple criteria. The existing literature is used to verify the significance of these conditions for successful GB project development.

This study has both theoretical and practical implications. In practice, project teams and decision-makers will be able to understand which conditions might result in a good performance in some criteria but underperformance in some other criteria. By controlling these conditions, across the project life-cycle, the desired performance on different criteria may be achieved. In theoretical terms, the identified associations and underlying conditions can lead to more holistic decision-making and multi-objective optimization models specifically designed for GB projects. The study is unique in its aim as well as the methodology used and the depth and breadth of the collected data. The study limitations include potential cognitive bias from the survey participants as well as a sole qualitative discussion of the effects of the key identified conditions on performance criteria associations.

1. Introduction

Although it is disputed whether project success can exclusively be determined using cost, time, and quality parameters, these performance criteria have received a significant attention in previous research studies. Whereas these criteria may not determine project success *per se*, they contribute significantly to determining project management success (Baccarini, 1999; Ika, 2009).

Sustainable design and construction adopt additional criteria which prioritize minimal resource consumption and environmental procedures to achieve a healthy built environment (Kibert, 1994). Vanegas, DuBose, and Pearce (1995) pointed to the paradigm shift in the construction industry with its emerging focus on environmental aspects of sustainability. This paradigm shift in the

Abbreviations: D&C, Design and Construct; GB, Green Building; LCC, Life-Cycle Cost; PDM, Project Delivery Method; VE, Value Engineering.

* Corresponding author. Room 447, Melbourne School of Design, University of Melbourne, VIC, 3010, Australia.
E-mail address: ahmadt@student.unimelb.edu.au (T. Ahmad).

https://doi.org/10.1016/j.jclepro.2019.06.013
0959-6526/

construction industry has sociocultural, and environmental implications in a global context (Bourdeau, 1999). Fig. 1 illustrates this new approach in the construction industry as originally developed by Vanegas et al. (1995), and expanded by (Bourdeau, 1999).

Green Buildings are important application of sustainable construction and are different from conventional buildings because they consider environmental, economic and social aspects (Nations, 1992), including among other things, higher energy performance, good Indoor Environment Quality (IEQ) and occupant health. For a building to completely fulfil sustainability criteria, it has to perform well in all three dimensions (Roulet et al., 2006). Hence, GBs can be seen as an important application of the new construction industry paradigm developed by Vanegas, DuBose [4] and Bourdeau [5]. A fundamental challenge for sustainable building practices is to find a balance among many and often conflicting building performance aspects and achieving trade-offs among multiple decision criteria (Pan et al., 2012). For instance, when affordability and environmental performance are considered together, the increase in the potential for carbon reductions results in relatively higher initial cost, and this is a concern for the clients and end-users, as well as builders and developers (Soetanto et al., 2014; Stephan and Stephan, 2016).

1.1. Research need

The complexity of project development increases with the number of performance criteria. This is particularly noticeable when a set of factors and conditions lead to good performance in one criterion but underperformance in another. For instance, in case the project budget is not well-planned (project condition/factor), the project might not be delivered within budget, and some features may have to eliminated, resulting in a reduced project quality.

The inquiry of associations among performance criteria is a complex problem, since a prediction of project performance in one criterion (i.e. sustainability) may not be possible based on the project's performance in another criterion (i.e. cost). For example, in a study by Korkmaz et al. (2010a) comprising of GB case study projects ($n = 11$), no clear associations among performance criteria are observed. The performance of these case study projects on different criteria is plotted in Fig. 2. The scale of project performance is divided into three levels i.e. below-target performance (-1), on-target performance (0), and above-target performance (1). From among 10 case study projects, performing on-target or above-target in sustainability criterion (i.e. GB certification metric), 5 projects have below-target performance in the cost criterion, 2 projects have below-target performance in the quality criterion, and 1 project has a below-target performance in the schedule criterion. From the overall 11 case study projects, there are only two pairs of projects having resemblance in their performance. P-1 and P-3 as well as P-4 and P-11 exhibit similar performance as shown in Fig. 2. This analysis brings to attention two important aspects. First, the assumption that sustainability performance is always realized at the expense of other performance criteria, seems to be incorrect. Second, the performance on a particular criterion may not be determined by observing project performance on a set of different criteria. This case study analysis of GB projects points to the possibility that the associations among performance criteria could be a function of some underlying conditions. Therefore, to optimize project performance among multiple criteria and to predict performance across different criteria, the key underlying conditions resulting in performance criteria associations need to be explored.

1.1.1. Research gap

As a GB project is developed, it has to perform well in meeting its long-term objectives (i.e. sustainability) and its short-term objective (i.e. project management success). In current GB project development, where the industry is beginning to accept sustainability as a project requirement, it is important to understand if sustainability performance relates to project management-related performance, and how. It is particularly important to address 'how' sustainability and project management-related performance interrelate, as this understanding can facilitate decision-making in projects and can lead to better performance prediction models. Although previous studies have considered multi-objective optimization and the effect of different factors on performance criteria of GBs, they have not exclusively addressed how performance criteria are interrelated in case of GBs. In light of the above, there is a need to characterise performance criteria associations and their underlying conditions in GB projects.

1.2. Research objectives

Based on the research need identified above, the research question posed in this study is as follows:

> 'How do the sustainability performance criteria and project management performance criteria interrelate in Green Building projects?'

The research question can be addressed by identifying the nature of associations (i.e. positive, negative, no relation) among

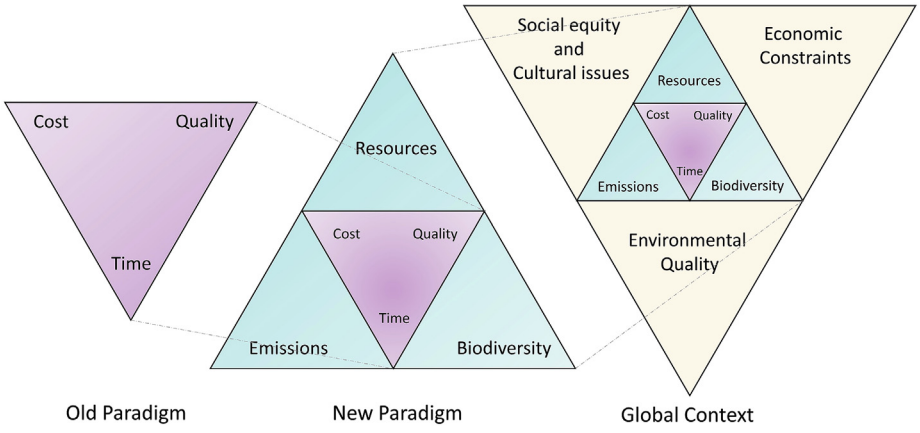
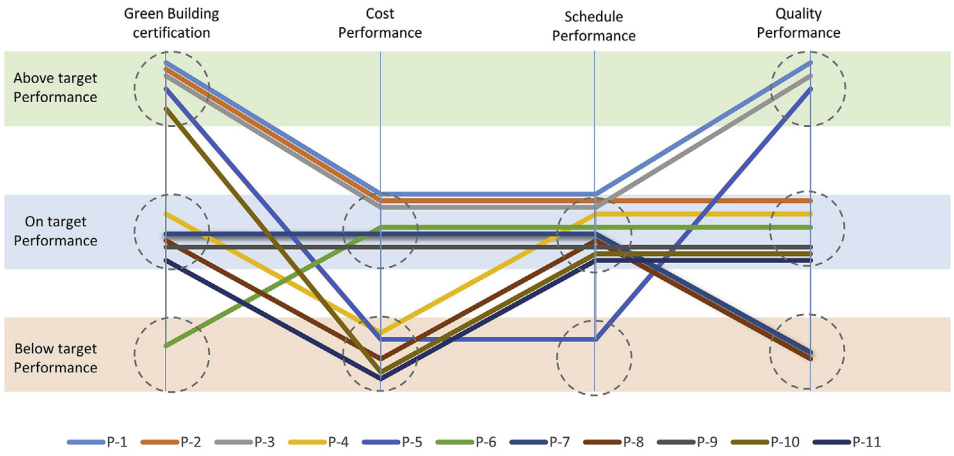


Fig. 1. Paradigm shift in construction industry (originally developed by Vanegas et al. (1995), expanded by Bourdeau (1999)).



Project	GB certification	Cost performance	Schedule performance	Quality performance	Sparkline
P-9	0	0	0	0	
P-1	1	0	0	1	
P-3	1	0	0	1	
P-5	1	-1	-1	1	
P-4	0	-1	0	0	
P-11	0	-1	0	0	
P-8	0	-1	0	-1	
P-10	1	-1	0	0	
P-2	1	0	0	0	
P-6	-1	0	0	0	
P-7	0	0	0	-1	

Note:
Above target Performance = 1
On target Performance = 0
Below target Performance = -1

Fig. 2. Performance of Green Building projects based on study by Korkmaz et al. (2010a). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

performance criteria. Furthermore, to address the research question the underlying conditions resulting in performance criteria associations need to be addressed. This is because the associations (i.e. positive, negative) among performance criteria (i.e. cost, sustainability) may vary under the influence of different underlying conditions (i.e. regional constraints, client's vision, etc.). The research objectives are as follows:

1. To identify the associations among sustainability-related and project management-related performance criteria in Green Building projects.
2. To identify the underlying conditions influencing the associations among the performance criteria.

The study considers project management performance criteria (i.e. cost, quality, and schedule performance) and sustainability performance criteria (i.e. environmental, economic, and social sustainability) for inquiry. The consideration of these two sets of criteria related to the old and new paradigms (as shown in Fig. 1), can help determine how the fulfilment of a project's long-term goals (i.e. sustainability) can affect the project's short-term goals (i.e. project management) and vice versa. In this study sustainability is divided into its three common dimensions (i.e. environmental, economic, and social sustainability) owing to the reason that these dimensions significantly help define sustainability, and also because previous studies have shown that good performance in one sustainability dimension may not necessarily imply good performance in others.

Since each building sector (i.e. residential and commercial sector) is unique in terms of its project development context, the performance criteria associations may not be the same for each sector. The scope of this study is limited to commercial office projects based on the rationale that commercial office development has received most attention in GB sector worldwide in terms of theory (Ahmad et al., 2019) and practice (Analytics, 2016) and in general GB professionals have more experience in the office sector compared to any other. Focussing on office projects can therefore result in more reliable findings which will also facilitate comparison to the existing literature.

Section 2 reviews the existing literature on GB development. Theoretically, the study relates to two construction industry related research streams. First, studies relating to multi-objective optimization are discussed. Then studies exploring Project Delivery Attributes (PDAs) are discussed. Section 3 explains the research method. Section 4 provides the results in two subsections. First, the findings relating associations among performance criteria are reported. Findings relating the conditions affecting performance criteria associations are provided afterwards. Section 5 provides a discussion regarding the conditions identified in Section 4 and Section 6 concludes this study. Survey data are provided in the Appendix section (Table C).

2. Literature review

The studies which have considered performance criteria lie within two main research streams. The first research stream titled 'multi-objective optimization', is focussed towards optimization of project performance among multiple criteria. The second research

stream titled 'project delivery attributes' is focussed on identifying correlations of different factors with performance criteria. Both research streams are briefly reviewed in this section.

2.1. Studies on the multi-objective optimization

'Multi-objective optimization' is a popular term used in research studies for balancing project performance across multiple criteria. Many research studies have been conducted to address multi-objective optimization in construction projects. A significant number of studies have discussed the associations of time and cost (Jiang and Zhu, 2010; Moselhi, 1993; Zhu et al., 2012). Many algorithms for studying time-cost trade-offs have been developed, including heuristic methods (e.g., Moselhi (1993)), mathematical programming (e.g., Jiang and Zhu (2010)) and evolutionary algorithms. Besides time-cost trade-off analysis, some studies have also incorporated quality as an objective. For time, cost, and quality optimization Khang and Myint (1999) used linear programming and network simulation approach, El-Rayes and Kandil (2005) used genetic algorithms method, Rahimi and Iranmanesh (2008) proposed multi-colony ant algorithms and particle swarm optimization technique, and Wang and Feng (2008) synthesized the weighted single-objective models.

Recently, some studies have also started to consider environmental sustainability as an objective in multi-objective optimization. Marzouk et al. (2008) applied genetic algorithms to the optimization of time, cost and pollution. Ozcan-Deniz et al. (2011) discussed an analytic framework for time, cost and carbon emission analysis of building and construction processes by using genetic algorithms. A tool known as SimulEICon, designed to support decision-making processes during design allows designers to select different design materials and products and produce optimal design options according to construction time, initial construction cost and greenhouse gas emissions (Zhu et al., 2012). The studies on multi-objective optimization are majorly limited in terms of the methodologies used because the analytical models developed in these studies (Fig. 3) majorly use construction activities and construction materials as the unit of analysis and optimization.

2.2. Studies on Green Building project delivery attributes

The studies within the Project Delivery Attributes (PDAs) research stream have typically considered the effects of different factors (i.e. PDAs) on the performance criteria in GB projects (Ahmad and Aibinu, 2017; Ahmad et al., 2019) as shown in Table 1. Unlike the studies on 'multi-objective optimization' which have majorly focussed on time, cost and quality, many studies in the PDA research stream as shown in Table 1 have considered sustainability performance (n = 13) along with cost (n = 10), schedule (n = 10), and quality performance (n = 8). While the studies within PDA research stream have been focussed on identifying correlations of PDAs with performance criteria (Fig. 3), they have not specifically identified the underlying conditions influencing the associations among performance criteria.

While the PDA-related studies may be similar to this study, a subtle difference sets them apart, as shown in Fig. 3. PDA-related studies establish correlations of factors with performance criteria to determine the importance of PDAs for project success. Further, these studies investigate the effects of PDAs on performance criteria by assuming PDAs as independent variables and performance criteria as dependent variables (Ahmad and Aibinu, 2017; Ahmad et al., 2019). However, this study considers that both the performance criteria and their underlying conditions can be dependent variables. This assumes that performance criteria are interrelated because of some underlying conditions implying that one criterion (i.e. cost performance as shown in Fig. 3) affects an underlying condition (i.e. A) which subsequently affects another performance criterion (i.e. quality performance). Moreover, unlike the PDA-related studies this study aims to identify performance criteria associations and will consider an underlying condition only if it directly or indirectly associates with multiple performance criteria instead of one criterion.

3. Research method

This study is based on the pragmatism research paradigm. Pragmatism is based on the assumption that "there are many

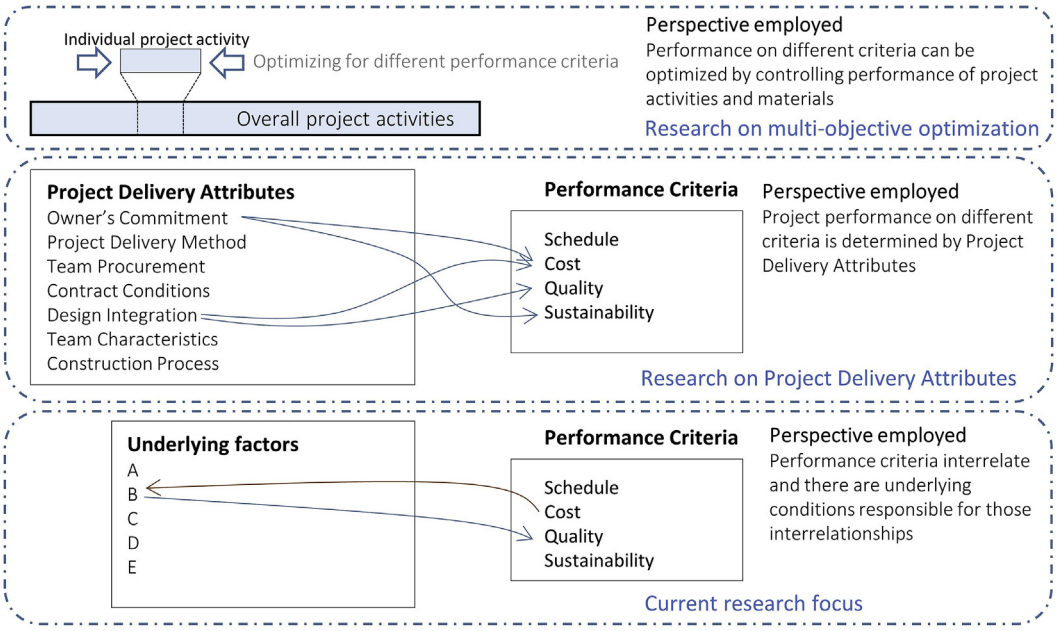


Fig. 3. Focus of current and previous research.

Table 1
Performance criteria and Project Delivery Attributes investigated by different studies.

		Olanipekun et al. (2018)	Carpenter (2005)	Bilec (2008)	Molenaar et al. (2009)	Enache-Pommer & Horman (2009)	(Korkmaz et al., 2010a)	(Korkmaz et al., 2010b)	Sinem Korkmaz et al. (2011)	Swarup et al. (2011)	Mollaoglu-Korkmaz et al. (2011)	Gultekin et al. (2013)	El Asmar et al. (2013)	Hanks et al. (2015)	Aggregate
Performance Criteria	Schedule	×				×	×	×	×	×	×	×	×	×	10
	Cost	×				×	×	×	×	×	×	×	×	×	10
	Quality	×				×	×	×		×	×		×	×	8
	Sustainability	×	×	×	×	×	×	×	×	×	×	×	×	×	13
Project Delivery Attributes	Owner's	×		×	×	×	×	×	×	×		×			9
	Commitment	×													
	PDM		×	×	×		×	×	×	×	×	×	×	×	11
	Team				×		×	×	×	×		×			6
	Procurement														
	Contract				×		×	×	×	×		×		×	7
	Conditions														
	Design			×	×	×	×	×	×	×	×	×		×	10
	Integration														
	Team			×	×	×	×	×	×	×	×	×		×	10
	Characteristics														
	Construction					×		×	×		×	×			5
	Process														

different ways of interpreting the world and undertaking research, that no single point of view can ever give the entire picture and that there may be multiple realities" (Saunders, 2011). Pragmatism as a research philosophy allows the use of both the positivist and interpretivist approaches within the scope of a single research. Furthermore, it allows the use of multiple research methods including quantitative and qualitative method (Johnson and Onwuegbuzie, 2004).

While using the pragmatic paradigm, this study induces a subjectivist approach which incorporates stakeholder's perceptions regarding project success. An important aspect of this approach is the collection of opinions of stakeholders from in-depth interviews, relying on the "richness" of words instead of just preferences in terms of numbers (Ika, 2009). The pragmatic research paradigm used in this study contrasts with the largely positivist research paradigm used by previous PDA-related studies. While using quantitative methodologies, the PDA-related research usually relied on empirical data obtained from case study projects. Although such an approach can be useful in verification of a phenomenon, it cannot be used to discover underlying phenomena and therefore cannot be used to achieve the aims of this study which is to identify underlying conditions affecting performance criteria associations. By using a mixed methods approach and employing an online survey and interviews, this study highlights the performance criteria associations and identifies the underlying conditions which can be verified using positivist research approach, in future research.

3.1. Research design

The study used a mixed method research approach to explore the associations among performance criteria and the underlying conditions associated with those associations. In terms of the data collection methods, an online questionnaire survey was primarily used. Semi-structured interviews were also conducted to support and complement survey findings. The research roadmap of this study is shown in Fig. 4.

This study relies on two aspects of inquiry (see Table 2). Firstly, determining the performance criteria associations, and secondly determining the underlying conditions influencing those associations. For the first aspect of inquiry, it was necessary to collect data from a significantly large sample of GB experts and to have this as a close-ended question enabling statistical analysis. An internet survey was used as this approach enables collecting responses from regionally distributed experts within a relatively short duration of time and with minimum resource expenditure (AKBAYRAK, 2000). The second aspect of inquiry which was about identifying the underlying conditions responsible for performance criteria associations, was addressed by both the questionnaire survey and in-depth interviews. Survey respondents were strategically directed through the online questionnaire to first respond to the close-ended question (i.e. type of criteria associations) and then to open-ended questions (i.e. reasons behind the associations).

Besides the merits of the questionnaire survey method for efficiently inquiring the first aspect (Question-1), it is a limiting approach when the open-ended questions are part of the inquiry. This is particularly because the researcher cannot actively assist the thought process of a respondent to transform mental constructs into explicitly stated information (AKBAYRAK, 2000). To compensate for this limitation, in-depth interviews were conducted to support and complement the findings from the open-ended questions in the questionnaire survey. The online survey was conducted prior to the interviews.

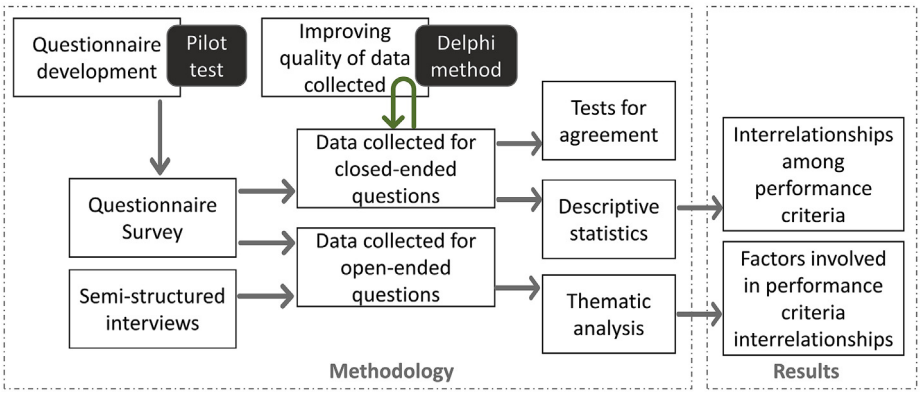


Fig. 4. The research roadmap.

Table 2
Aspects of inquiry considered in online survey and interviews.

Aspect of inquiry	Question/Theme	Method	Respondents
Performance criteria associations	Question-1: In a close-ended question, the respondents were asked to relate the performance criteria of green office buildings. Respondents could select the effect of good performance in a criterion on other criteria as '*Highly Positive*', '*Moderately Positive*', '*Not related*', '*Moderately Negative*', or '*Highly Negative*'. The survey respondents were asked to provide their opinion for the potential associations between 6 different performance criteria. Therefore, each respondent had to establish 30 different associations.	Online survey	104
Underlying conditions responsible for performance criteria associations	Question-2: In an open-ended question, the respondents were asked to highlight the conditions behind the associations between performance criteria of green office projects.	Online survey Semi-structured interviews	83 30

3.2. Questionnaire survey

A project's performance on project management-related and sustainability criteria can potentially be construed in many ways. To ensure consistency in responses, facilitate responses from a unified viewpoint, and help reduce the cognitive bias, the good performance of a GB project on different criteria was explained in the online survey questionnaire (shown in Table A - Appendix).

3.2.1. Pilot testing the online questionnaire

The questionnaire was tested to examine how respondents perceived the questions and to examine the viability of survey administration. First, a preliminary review of the questionnaire was conducted by two academic scholars. Afterwards, two industry experts acting as pilot study participants were asked to comment on the content and scope of the survey questionnaire. Some minor amendments related to some of the questions were suggested by the participants based on which the questionnaire was revised and its final version is available online (Tayyab, 2019).[1]

3.2.2. Sampling

The expert sampling approach, a form of purposive sampling technique was used in conducting the online survey. GB experts in Asia and Australia were contacted to participate in the survey. For this study, the professionals who had an understanding of GB projects and who had actually been involved in GB development were considered as 'experts'. The contact details of experts were obtained from different online GB professional databases. Overall 980 survey requests were sent through emails and the responses from 105 GB experts were obtained, resulting in a 10.7% response rate. Owing to incomplete information from one respondent, 104 responses were considered for detailed analysis. The sample size was deemed adequate upon comparing with similar survey-based studies involving GB experts. For instance, while conducting an international survey of experts, Darko et al. (2017) used a sample set of 104 participants to identify major drivers of GB technologies. In a survey-based study of drivers and barriers related to sustainable design and construction, Ahn et al. (2013) used a sample size of 100 participants. Some studies based in specific-regional contexts have been limited to smaller sample sizes. For instance, Hwang and Tan (2012) conducted a survey of 31 experts in Singapore for identifying management-related barriers in green construction projects.

3.2.3. Demographics of survey respondents

The respondent's experience of working on GBs shows the reliability and credibility of survey findings. Although all participants had an experience of developing GBs in general, up to 5% participants had no experience of working on commercial office GBs (shown in Fig. 5). Approximately 81% of participants had at least 5 years' experience related to Green office projects and about 61% of participants had been involved in 6 or more number of such projects.

While most respondents (n = 78) belonged to design and sustainability consultancy role (Fig. 6), the sample set also had respondents belonging to six other roles in the construction industry. In terms of regional belonging, the respondents majorly belonged to Australia (n = 42), Singapore (n = 18), India (n = 16), and the United Arab Emirates (UAE) (n = 15). The demographics of the sample set played an important role in data analysis as it enabled a comparison of the agreement among survey responses (section

[1] https://melbourne.figshare.com/articles/A_Survey_of_Performance_Criteria_associations_in_Green_Building_Projects/7623833.

[2] Correlations listed in the descending order of the pattern strength.

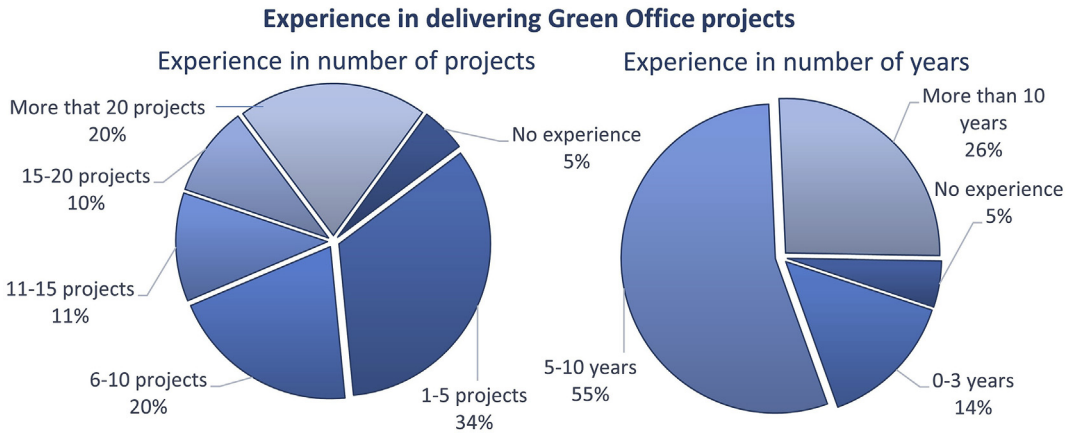


Fig. 5. Green Building-related experience of survey participants. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

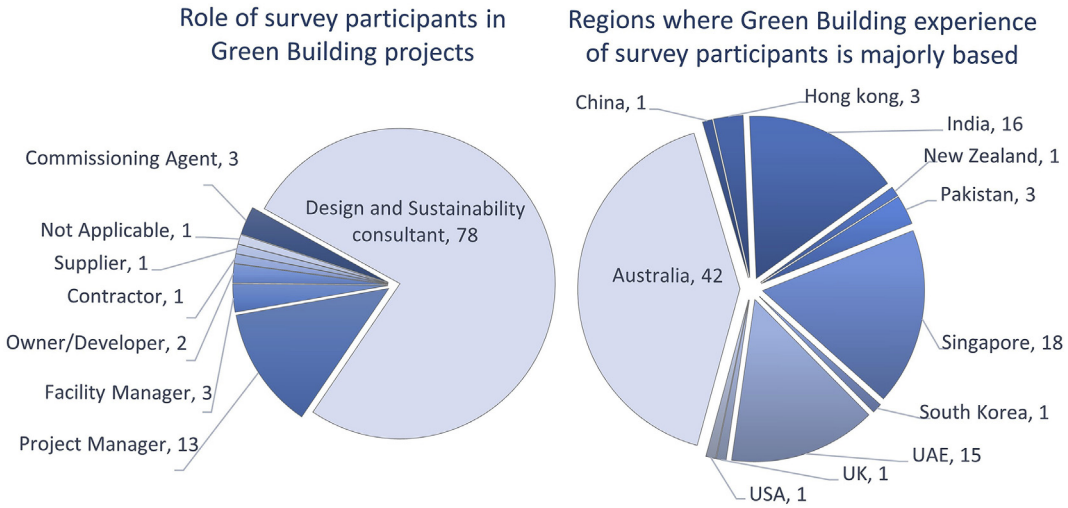


Fig. 6. Green Building-related regional belonging and role of survey participants. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3.4.2.) based on geographical locations, professional roles, and experience. Furthermore, since the survey also included an exploratory open-ended question for identifying underlying conditions resulting in associations among performance criteria, a variety in participants' demographics was found useful. This is because, some conditions being inquired may have a strong role in some regional contexts than others. Furthermore, professionals with different role and experience of GBs can have a varying focus towards the conditions being inquired. Hence, the identification of these conditions benefitted from the variety in the professional and regional background of participants.

3.2.4. Use of delphi technique

While conducting a preliminary analysis of the questionnaire survey dataset, some outliers and dispersions in the data were identified. For these issues, the application of Delphi technique was considered which is a structured process of collecting and distilling knowledge from a group of experts using multiple rounds of feedback (Brady, 2015; David Botterill, 2012). The respondents who had high variance in their responses ($n = 38$) were contacted and some of them ($n = 10$) consented to engage in the Delphi process. They were provided with the trends in the data and were asked to reconsider their response. The revised responses from the survey participants were incorporated in the dataset, which was deemed adequate for analysis.

3.3. Interviews

Interviewees were asked to interrelate GB performance criteria and to provide reasons for those associations. The questions and theme areas to be used in interviews were thoroughly scrutinized for research ethics and clarity by an academic committee. The interviews were digitally recorded. They were transcribed and coded thematically using both the inductive and deductive approaches. After transcription, the Interviewee Transcript Review (ITR) process was conducted. ITR is a process in which transcripts are sent to interviewees for review to support research ethics and validate the interview discourse (Hagens et al., 2009). While realizing ITR as a time-sensitive matter, the transcripts were sent for review, in a duration of 1–30 days after each interview was conducted.

Face-to-face interviews were preferred in this study as they provide the interviewer with more control to access and discuss

information. Apart from 7 telephone-based interviews, the rest of 23 interviews were conducted face-to-face. The convenience sample of interview participants (n = 30) used in this study originate from Australia (n = 12), Hong Kong (n = 1), Pakistan (n = 2), Singapore (n = 3), the UK (n = 10), and the UAE (n = 2). Other than Pakistan, all these regions are on the track of increased development of GBs and these also have a significant number of professionals with extensive-experience of developing GBs. Another reason for selecting different geological regions was to consider potential regional variations. The interview participants were highly experienced building professionals as most of them (n = 25) have a minimum of 6 years of experience in developing GB projects. This supports the reliability and credibility of the interview findings. A large number of these professionals have acted in the role of sustainability consultants (n = 14) and design consultants (n = 11) in GB projects. In terms of sampling, the interview participants did not participate in the survey. Hence their input could be used for supporting and complementing responses from survey participants. When reporting on the interview findings in results section (4.2), a unique ID for each interview participant is provided based on information about each participant's experience, professional role, and regional belonging as shown in Table B (Appendix).

3.4. Data analysis

3.4.1. Data consistency check

The survey responses obtained for the performance criteria associations were subjected to an internal consistency test. The Cronbach alpha (α) value for the results of Question-1 (highlighted in section 3.1) was 0.9183. Since $\alpha \geq 0.9$ means 'excellent' internal consistency, the data from survey results can be regarded as internally consistent.

3.4.2. Tests for agreement among survey respondents

Determining agreement in case of this study is necessary to highlight the level of unanimity in the interpretation of performance criteria associations by survey participants and for this purpose tests of agreement are conducted. Besides, a wide demographical distribution in the sample set (explained in section 3.2.3.), in case some level of agreement is observed among survey findings, then it can highlight that GB professionals are unanimous in their interpretation to some extent.

Three tests including Fleiss' kappa (κ), Kendall's coefficient of concordance (W), and Chi-square are used to measure the agreement and consistency of responses given by GB experts (n = 104). While measuring the agreement among the overall sample, these tests also helped measure the agreement in responses from participants with different experience (Group 1–3), regional origins (Group 4–7), professional roles (Group 8–11), and response to open-ended questions (Group 12–13). The results relating these tests are provided in Table 3.

Kappa which ranges from −1 to +1, measures the degree of agreement of the nominal or ordinal assessments made by multiple appraisers when assessing the same samples. Kappa value '1' means the existence of a perfect agreement and its value '0' means an agreement as expected by chance. For the ordinal data, Kendall's coefficient of concordance is often used in addition to kappa statistics. Since the data in case of the online survey is of ordinal nature Kendall's coefficient of concordance is also measured. An aspect which differentiates the two tests is that Kappa statistics represent an absolute agreement between ratings while Kendall's coefficients measure the associations between ratings. Kendall's concordance (W) is a non-parametric statistic measuring the agreement among several judges that are assessing a set of n objects of interest ("Encyclopedia of Research Design," 2010). The value of W ranges from 0 to +1. A high level of agreement among respondents results in a W value closer to +1; a lack of agreement, however, means a W value closer to 0. While conducting this test the null hypothesis (Ho) is that no agreement exists among the responses given by respondents. With W value at low significance ($p \leq 0.001$) the null hypothesis can be rejected, implying that a degree of consensus exists among the responses from respondents (Siegel and Castellan, 1988). In determining the significance of observed W value, Chi-square provides approximate distribution with (N-1) degrees of freedom. Since Kendall's coefficient of concordance and Kappa value of +1 responds to a perfect agreement, while using a relative scale in this study the agreement is considered 'slight' for W = 0.118–0.192 and κ = 0.027–0.055, and the agreement is considered 'fair' for W = 0.193–0.258 and κ = 0.056–0.085.

Based on Kendall's W and Fleiss' kappa (κ) tests, the highest agreement among the respondents exist in case of Group-7 comprised of GB experts from Australia (W = 0.258; κ = 0.085); Group-11 comprised of sustainability consultants (W = 0.222; κ = 0.076); and Group-3 comprised of high-level experience (W = 0.214; κ = 0.058). Hence, it can be concluded that participants who are sustainability consultants (Group-11), have high-level experience (Group-3), or are based in Australia (Group-7) have a high level of agreement in their interpretation of performance criteria associations. The least agreement exists among Group-4 comprised of GB experts from Pakistan and India (W = 0.126; κ = 0.027). For Group-10 (i.e. Project Managers) as shown in Table 3, the P value is 0.0305 and therefore the null hypothesis is accepted that an agreement does not exist among the respondents.

In case of Groups 1 to 3, it can be observed that there is a stronger agreement among Group-3 participants (W = 0.214; κ = 0.058) with high experience compared to Group-2 participants (W = 0.145; κ = 0.047) with medium experience. Group-2 itself has a stronger agreement compared to Group-1 participants (W = 0.118; κ = 0.041) with low experience. This implies that with the increase in experience of developing GBs, the perception of different GB experts relating performance criteria associations begins to converge.

In case of Groups 4 to 7, it can be observed that participants from Asian countries (i.e. UAE, Singapore, Pakistan and India) have a significantly lower level of agreement compared to Australia-based participants. This points to the possibility that the perception of GB experts relating performance criteria associations is a function of the regional context. Many regional aspects such as industrial norms, GB-related awareness, etc. can influence the perception of GB experts. Yet, a detailed discussion on this matter is beyond the scope of this study.

In case of Groups 8 to 11, sustainability consultants have a relatively stronger level of internal agreement compared to other professionals. This can be due to the fact that the professional role of sustainability consultants always requires a focus on sustainability, while design consultants and project managers work on a diverse set of projects which include GBs as well as non-GBs.

The comparison of the level of agreement of participants from Group-12 (W = 0.142; κ = 0.054) and Group-13 (W = 0.139; κ = 0.055) showed that the participants responding to only close-ended questions and the participants responding to both the open-ended and close-ended questions in the survey had a similar level of agreement among themselves.

3.4.3. Descriptive statistics

A descriptive statistical analysis using Mean, Mode, Standard Deviation (SD), Inter Quartile Range (IQR), and Skewness functions

Table 3
Results relating Fleiss' kappa test, Kendall's coefficient of concordance, and Chi-square.

		Kendall's W	Chi-Square	P value (Chi Square Test)	Fleiss' kappa (κ)	Standard Error Kappa	P value (Kappa test)	Outcome
	Total Sample (n = 104)	0.134	404	0	0.054	0.001	0	Slight
Sample segregation based on experience	Group-1: Low level experience (n = 40)	0.118	137	0	0.041	0.004	0	Slight
	Group-2: Medium level experience (n = 33)	0.145	139	0	0.047	0.004	0	Slight
	Group-3: High level experience (n = 31)	0.214	193	0	0.058	0.005	0	Fair
Sample segregation based on origin	Group-4: Pakistan and India (n = 19)	0.126	70	0	0.027	0.008	0.0006	Slight
	Group-5: UAE (n = 16)	0.17	79	0	0.035	0.01	0.0001	Slight
	Group-6: Singapore (n = 18)	0.139	72	0	0.046	0.008	0	Slight
	Group-7: Australia (n = 43)	0.258	322	0	0.085	0.003	0	Fair
Sample segregation based on role	Group-8: Design and Sustainability Consultants (n = 42)	0.173	211	0	0.05	0.004	0	Slight
	Group-9: Design Consultants (n = 11)	0.192	61	0.0004	0.034	0.016	0.0181	Slight
	Group-10: Project Managers (n = 12)	0.129	45	0.0305	0.005	0.013	0	No agreement
	Group-11: Sustainability Consultants (n = 25)	0.222	161	0	0.076	0.006	0	Fair
Sample segregation based on response to open-ended question	Group-12: Participants responding to open-ended question (n = 83)	0.142	342	0	0.054	0.001	0	Slight
	Group-13: Participants not responding to open-ended question (n = 21)	0.139	84.5	0	0.055	0.007	0	Slight

Note: 'Outcome' in the last column is the level of agreement based on Kendall's W and Fleiss' kappa (κ) test.
For chi-square statistic Degree of freedom (Df) is 29.

Table 4
Results relating descriptive statistical analysis.

Cases	Mean	Mode	SD	IQR	Skewness	Outcome
'Environmental Sustainability' affecting 'Economic Sustainability'	0.394	1	0.84	1	−0.86	Positive
'Environmental Sustainability' affecting 'Social Sustainability'	0.76	1	0.6	0	−2.34	Positive
'Environmental Sustainability' affecting 'Quality'	0.462	1	0.77	1	−1.02	Positive
'Environmental Sustainability' affecting 'Cost'	0.154	1	0.89	2	−0.31	Positive
'Social Sustainability' affecting 'Environmental Sustainability'	0.683	1	0.63	0	−1.81	Positive
'Social Sustainability' affecting 'Economic Sustainability'	0.596	1	0.7	1	−1.46	Positive
'Social Sustainability' affecting 'Quality'	0.692	1	0.5	1	−1.3	Positive
'Social Sustainability' affecting 'Cost'	0.115	1	0.86	2	−0.23	Positive
'Economic Sustainability' affecting 'Environmental Sustainability'	0.721	1	0.57	0	−1.93	Positive
'Economic Sustainability' affecting 'Social Sustainability'	0.519	1	0.67	1	−1.07	Positive
'Economic Sustainability' affecting 'Quality'	0.5	1	0.7	1	−1.05	Positive
'Economic Sustainability' affecting 'Cost'	0.442	1	0.79	1	−0.97	Positive
'Cost' affecting 'Schedule'	0.202	1	0.81	1	−0.39	Positive
'Cost' affecting 'Economic Sustainability'	0.26	1	0.87	2	−0.53	Positive
'Schedule' affecting 'Cost'	0.404	1	0.82	1	−0.87	Positive
'Quality' affecting 'Social Sustainability'	0.577	1	0.62	1	−1.18	Positive
'Quality' affecting 'Economic Sustainability'	0.519	1	0.7	1	−1.12	Positive
'Quality' affecting 'Environmental Sustainability'	0.702	1	0.57	0	−1.8	Positive
'Social Sustainability' affecting 'Schedule'	0.019	0	0.65	0	−0.02	No effect
'Economic Sustainability' affecting 'Schedule'	0.096	0	0.7	1	−0.14	No effect
'Schedule' affecting 'Social Sustainability'	0.077	0	0.66	1	−0.09	No effect
'Schedule' affecting 'Environmental Sustainability'	0.039	0	0.74	1.75	−0.06	No effect
'Environmental Sustainability' affecting 'Schedule'	0.25	1	0.77	1	−0.47	Unclear
'Cost' affecting 'Quality'	0.096	1	0.91	2	−0.19	Unclear
'Cost' affecting 'Social Sustainability'	−0.048	−1	0.82	2	0.09	Unclear
'Cost' affecting 'Environmental Sustainability'	0.077	1	0.84	2	−0.15	Unclear
'Schedule' affecting 'Quality'	0.039	0, 1	0.81	2	−0.07	Unclear
'Schedule' affecting 'Economic Sustainability'	0.24	0, 1	0.73	1	−0.41	Unclear
'Quality' affecting 'Schedule'	−0.087	−1	0.83	2	0.16	Unclear
'Quality' affecting 'Cost'	−0.077	−1	0.89	2	0.15	Unclear

Note: SD=Standard Deviation; IQR=Interquartile Range.

is conducted (shown in Table 4) to identify the trends in survey data. In essence, it helped determine the prevalent associations (i.e. positive, negative, non-existent) among performance criteria (reported in section 4.1). The positive and negative association implies that the higher level of performance in a criterion is likely to be associated with higher and lower level of performance in another criterion respectively. Since the data were originally of the ordinal nature, for conducting the statistical analysis, they were converted into numerical values. To avoid the issues related with potential misinterpretation of data while converting them from ordinal to numerical values, positive associations are given the same value (i.e. Highly positive = 1, Moderately positive = 1), and negative associations are also treated equally (i.e. Moderately negative = −1, and Highly negative = −1). 'No effect' is assigned a '0' value. Assigning these values is useful as the objective is to determine the types of associations instead of the intensity of associations.

While responding to Question-1 in the online survey, each participant opted for 30 associations among 6 performance criteria. Table 4 presents the statistical data analysis for each case. The arithmetic mean values for the survey data suggest that the cases in which the mean values are closer to 0, either a majority of respondents have opted for the 'no effect' option (i.e. '0') or the majority had a similar distribution for both the positive and the negative associations. For instance, for "Schedule Performance affecting Quality Performance", the low mean value (i.e. 0.039) is because a similar number of respondents opted for both the positive (n = 34%) and negative associations (n = 31%). Similarly, for "Social Sustainability Performance affecting Schedule Performance", the low mean value (i.e. 0.019) means a high number of participants (n = 58%) opted for the 'no effect' option (i.e. '0'), while the number of participants opting for positive (n = 22%) and negative associations (n = 20%) is both relatively small (n = 44%) and similar.

In Table 4, a negative skewness value suggests a relatively higher number of respondents opting for 'no effect' or positive associations. While a positive skewness value suggests a relatively higher number of respondents opting for 'no effect' or negative associations. Within the survey data, only 3 cases of positive skewness are identified while the remaining 27 cases reveal negative skewness which means that most participants have indicated positive associations among performance criteria. For the survey data, the mode value of 1, -1, and 0 indicates that the most appearing associations in a case are positive, negative, and non-existing respectively. Within the overall 30 associations studied, some cases (n = 3) have −1 value, some (n = 4) have 0 value, and some (n = 2) have both the 0 and 1 value. Most number of cases (n = 21) have 1 value which indicates that most number of associations assigned are positive in nature.

For the survey data, a low SD value indicates that a large number of respondents have opted for 'no effect' along with one of the two associations 'i.e. positive or negative'. A high SD value indicates that a similar number of participants have opted for both the positive and the negative associations. In terms of IQR, three values majorly occurring in the survey dataset are 0 (n = 5), 1 (n = 15), and 2 (n = 9). The '0' IQR value means that at least 50% of respondents in a case have opted for a positive association. The '1' IQR value means that at least 50% of respondents in a case have opted for a positive association or no association. The '2' IQR value means that many respondents have opted both the positive as well as negative association, which means that the results in such cases are inconclusive.

4. Results

4.1. Associations among performance criteria

This section addresses the first objective of this study, which is to identify the associations among sustainability-related and project management-related performance criteria in GB projects. Fig. 7 and Table C (Appendix) present the overall findings of the survey question related to the 'performance criteria associations. From the overall participants (n = 104), 83 participants (Group-A) responded to both open-ended and close-ended questions while 21 participants (Group-B) responded to only the close-ended questions. The response of both these groups of participants for the close-ended question is shown in Fig. 7. A significant difference in responses of these two groups is observed in case of 8 associations including the effect of quality on cost; effect of schedule on quality; effect of cost on quality and social sustainability; effect of environmental sustainability on schedule and economic sustainability; and effect of economic sustainability and social sustainability on quality.

Upon conducting the descriptive statistical analysis (shown in Table 4), the identified trends are shown in Fig. 8, which is divided into Part-1 and 2 to exhibit the cases of positive and no associations among the performance criteria, respectively.

Positive associations: Positive associations imply that good performance in one criterion leads to a good performance in another criterion. As shown in Part-1 (Fig. 8), sustainability performance has a positive influence on quality performance and vice versa. Interview participants (PK-M-2; UK-M-5; UK-F-1) also corroborated that sustainability and quality performance go hand in hand. The mutually positive associations of quality performance with cost and schedule performance have not been reported in the survey. Cost and schedule performance are reported to be positively associated. Further, cost performance is identified to have a positive effect on economic sustainability. As an interviewee (UK—F-6) mentioned, "schedule and cost are like siblings, if you increase one the other also increases." It is important to note that the positive effects of cost and schedule performance on social and environmental sustainability have not been identified as trends.

All three sustainability dimensions are reported in the survey to have a mutually positive association among each other. While it may appear that environmental sustainability is realized at a higher cost, it has a positive effect on economic sustainability. According to an interviewee (AU-M-7), "in the short-term achieving sustainability may seem to cost more as the technology is better and complex. The client, however, will benefit in the long term from the savings. Generally, as the cost goes up, the quality also gets better."

No associations: No associations imply that good performance in one criterion do not lead to a good or bad performance in another criterion. As shown in Part-2 (Fig. 8), survey participants are of the view that the associations between schedule and sustainability performance criteria do not exist. Although a direct association between sustainability and schedule performance is not highlighted, the existence of indirect associations between these performance criteria is indicated by interview participants. According to interviewees *UK-F-1* and *AU-F-4* only in adequately managed and well-planned projects can sustainability performance be achieved without affecting schedule performance. Interviewee *UK-M-1* flagged that schedule performance affects sustainability performance when project schedules are not developed in consultation with sustainability consultants. This highlights that even though direct associations may not seem to exist among some performance criteria, these associations may become prominent in case of unsuitable project conditions.

Unclear associations: It is necessary to also provide an account of unclear trends in performance criteria associations. All three types of associations (i.e. positive, negative, and not effect) have been highlighted in case of some performance criteria. For instance.

- 'Cost performance' may either have a positive, negative, or no effect on 'environmental sustainability' and 'social sustainability'.
- 'Quality performance' may either have a positive, negative, or no effect on 'schedule performance' and vice versa.

Both the positive and negative associations have been highlighted in case of cost and quality performance.

- 'Quality performance' may either have a positive or a negative association with 'cost performance' and vice versa.

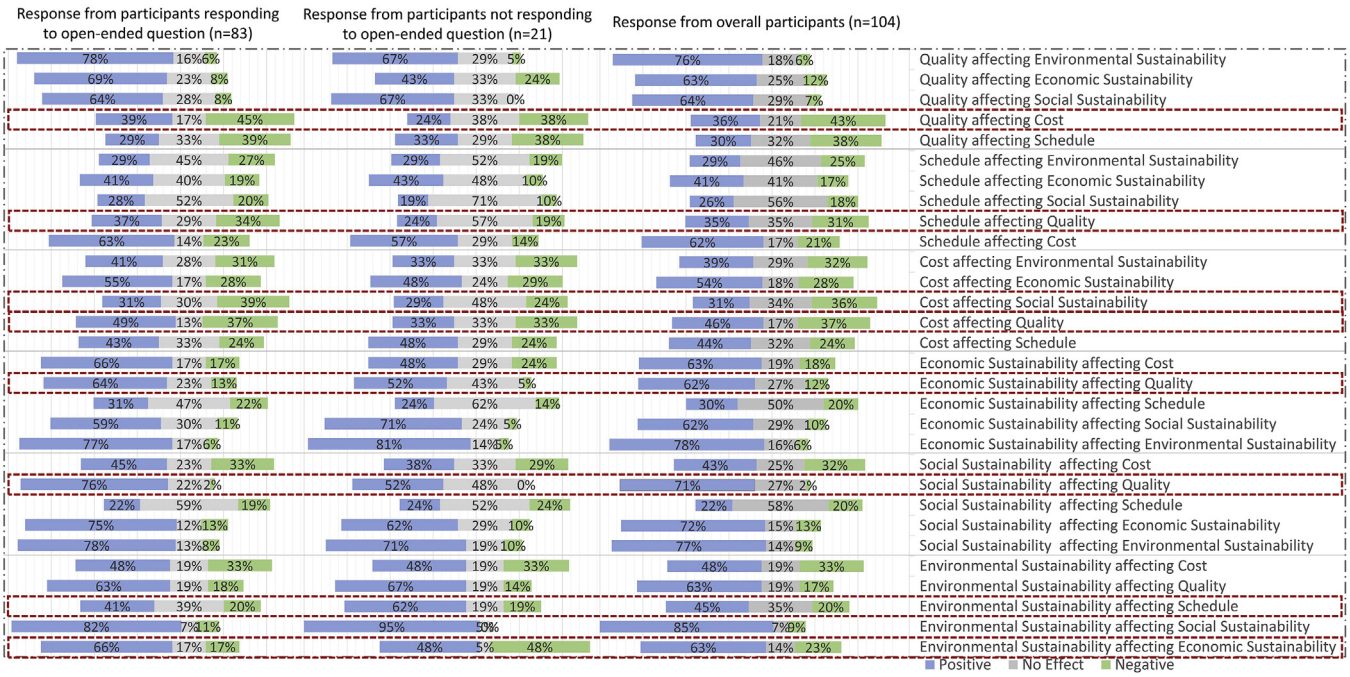


Fig. 7. Associations between GB performance criteria based on survey findings.

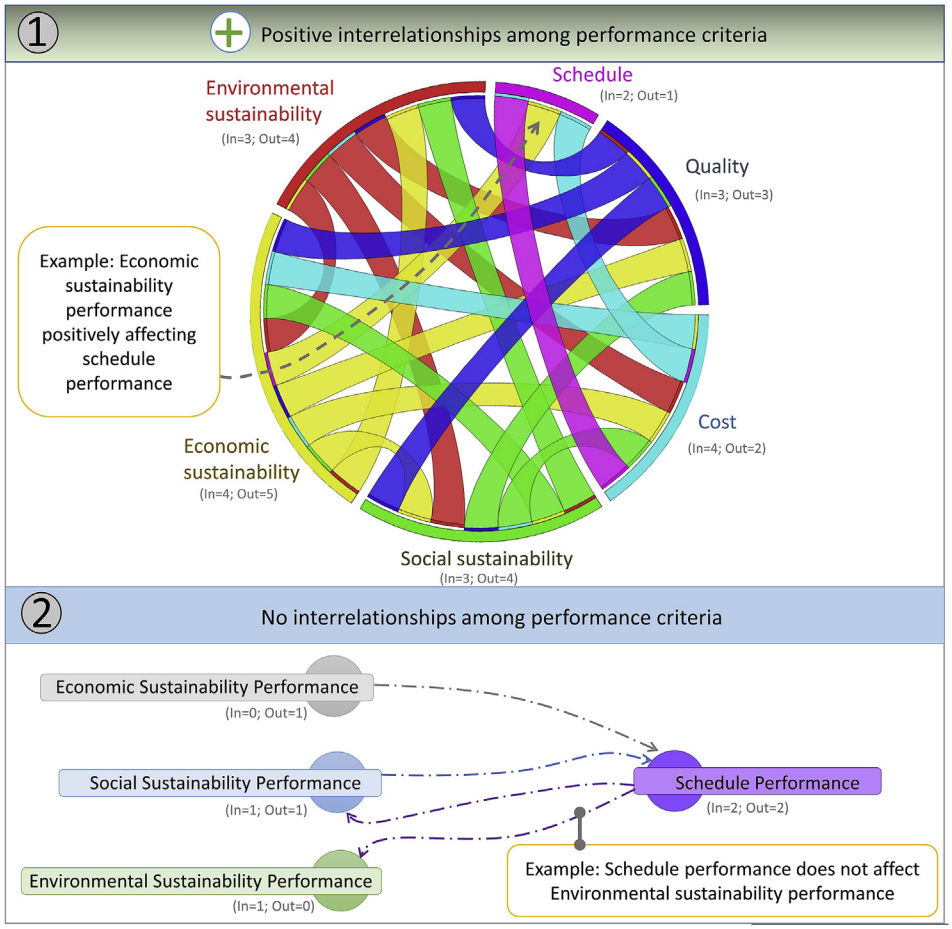


Fig. 8. Clear trends of associations between performance criteria.

Both the positive and no effect have been highlighted as associations in case of economic sustainability, environmental sustainability, and schedule performance.

- 'Schedule performance' may either have a positive effect or no effect on 'economic sustainability'.
- 'Environmental sustainability' may either have a positive effect or no effect on 'schedule performance'.

The mixed responses and associated unclear trends exist mostly in the case of project management-related performance criteria but not for sustainability performance criteria.

4.2. Conditions resulting in performance criteria associations

This section responds to the second objective of this study, which is to identify the underlying conditions resulting in associations among performance criteria. Upon conducting a qualitative analysis of the survey responses to open-ended question (i.e. Question-2), 56 underlying conditions resulting in associations among performance criteria were identified. In conceptual terms some of the closely related conditions were grouped together and represented by 37 conditions shown in Table 5. The originally identified conditions and their representative conditions are shown in Appendix (Table D). These 37 representative conditions have been further grouped in 11 theme areas (Table 5). Effects of conditions on each other and on performance criteria are shown in Table 5. The order is such that the conditions occurring in rows affect conditions or performance criteria occurring in columns. The associations among performance criteria and the underlying conditions are provided in a network diagram (Fig. 9). The network not only shows the associations of different underlying conditions with performance criteria but also the mutual associations among different conditions.

Some of the identified conditions are directly linked with the performance criteria. However, other conditions such as 'Focus on capital cost of project' have a direct as well as indirect association with performance criteria. The indirect association occurs as 'focus on capital cost of project' results in 'reworking because of poor workmanship', 'system and material selection', and 'inappropriately conducted value engineering exercises'. These conditions inturn affect performance criteria, therefore carrying the indirect effect of 'focus on capital cost of project'. The underlying conditions having indirect along with direct effects on performance criteria are as follows:

- 'Adequate time allocation for project development' and 'early incorporation of sustainability in project' affects 'use of integrated design approach'.
- 'Use of integrated design approach', 'involvement of project team in defining project requirements', 'use of clearly defined and standardized approaches for GB development', and 'early incorporation of sustainability in project' affects 'project team's understanding of project goals and aspirations'.
- 'Setting of a detailed sustainability charter or brief' and 'using appropriate project delivery method' affects 'adequate time allocation for project development'
- 'Using appropriate PDM' affects 'adequate allocation of project budget'
- 'Monitoring of project development' affects 'Execution of sustainable design during construction'.
- 'Rigor of project design development' can affect 'Use of energy-oriented design methodology'. Rigor implies that the fundamentals are considered as a project is developed. In case the fundamental design aspects are correctly executed in a project, an energy efficient design can be realized with ease. According to an interviewee (SN-M-11), "to us the design of such [GB] projects appears very natural. When we are doing the building design we are already considering the orientation and the context of the building. We are definitely working on the concept designs which can reduce the building's energy consumption, and all of this is very fundamental."
- 'Complexity in design' affects 'Suitability of project design for execution'. This is because a simplistic design is relatively easier to execute.
- 'Considerations towards potential building occupants' can result in 'Life-cycle based project development approach'. In case the Facility Management professionals are involved in project development process they can guide design consultant about building systems and materials which may require low maintenance.
- 'Focus on capital cost of project' affects 'Value Engineering exercise'. For GB projects a high focus on reducing project costs can result in a value engineering exercise which may adversely affect the incorporation of sustainable features.
- 'Preferences in contractor's engagement' affects 'access to sustainable building materials'. In case an experienced contractor is brought on-board early in a project, s/he can suggest the design consultants about easily accessible building materials.

'System and material selection' is an underlying condition which affects all six performance criteria. Some conditions affecting all three sustainability criteria include 'monitoring and controlling operational performance of building', 'life-cycle based project development approach', and 'value engineering exercise'. There are some conditions ($n = 21$) which directly associate with only multiple performance criteria and some other conditions ($n = 15$) are highlighted to have a direct association with only one out of six performance criteria. There are 11 conditions highlighted which affect the overall project performance. Most conditions have been associated with economic sustainability ($n = 18$) and schedule ($n = 15$) while least have been associated with cost performance ($n = 7$). It is important to flag that the six performance criteria used in this study contribute towards overall project performance, but the overall project performance is not limited to the six performance criteria only.

Survey participants have emphasized some underlying conditions by providing detailed discussions to contextualise these conditions. These findings are also verified by the semi-structured interviews. Important conditions are discussed in detail in this section.

4.2.1. Regional constraints

Some conditions specific to the regional contexts of the GB projects can determine the performance criteria associations in GBs. According to survey participants, these conditions include 'limited tenders on sustainable materials', 'local sourcing of materials', and 'non-standard materials, practices, and requirements'. These conditions highlight that the ease of developing GBs can vary from region to region.

4.2.1.1. Regional climate. Regional climatic constraints can pose limits for sustainability performance of building projects and can affect the associations among sustainability performance criteria. According to some survey participants, high indoor air quality requires high ventilation rates. Increases in outside air rates over the

Table 5
Associations of underlying conditions with performance criteria.

Theme	Identified conditions	Adequate allocation of project budget	Access to sustainable building materials	Life-cycle based project development approach	Suitability of project design for execution	Use of energy-oriented design methodology	Execution of sustainable design during construction	Adequate time allocation for project development
Building maintenance	Monitoring and controlling operational performance of building							
	Quality of maintenance							
Constraints	Access to sustainable building materials							
	Material delivery time							
	Regional climate							
	Innovation in building industry							
Preferences towards different objectives in project development	Preferences in contractor's engagement		×					
	Focus on capital cost of project							
	Focus on reducing operational costs							
	Team working on project with value management mind-set							
	Considerations towards potential building occupants			×				
Project design approach	Complexity in design				×			
	Life-cycle based project development approach							
	Rigor of project design development					×		
	Suitability of project design for execution							
	System and material selection							
	Use of energy-oriented design methodology							
	Use of integrated design approach							
Project planning approach	Adequate allocation of project budget							
	Adequate time allocation for project development							
	Early incorporation of sustainability in project							
	Attention towards details							
	Use of buffers and contingencies in project planning							
Realization of design intent during construction and hand-over	Execution of commissioning and fine-tuning							
	Execution of sustainable design during construction							
	Monitoring of project development						×	
Defining and understanding project aspirations	Setting of a detailed sustainability charter or brief							×
	Sustainability brief aligned with project budget							
	Involvement of project team in defining project requirements							
	Project team's understanding of project goals and aspirations							
	Use of clearly defined and standardized approaches for GB development							
Project control and management	Value Engineering exercise							
	Rework because of poor workmanship							
	Proficiency of Project Management team							
Project delivery method	Using appropriate project delivery method	×			×			×
Client's vision and motivation	Client's commitment towards sustainable outcomes							
Project requirements	High consultation requirements							
Sum		1	1	1	2	1	1	2

required statutory regulations because of sustainability requirements leads to an increase in plant capacity to treat the additional fresh air volumes. Whilst heat exchange may be used to reduce this impact it is not always efficient at treating latent heat energy. In case the climate allows economy cycle operation for substantial periods of the year, the increase in ventilation rates do not result in increased Life-Cycle Cost (LCC) or environmental degradation. On the contrary, for climates unsuitable for ventilation, high indoor air quality costs more to operate and becomes a hindrance in achieving low emissions target and therefore results in a higher LCC. This explains that the regional climatic conditions can have a significant effect on the associations among sustainability performance criteria.

4.2.2. Life-cycle perspective

Life-cycle perspective is an important aspect as a GB project is being developed. According to survey participants both the economic and environmental sustainability highly rely on the life-cycle approach which resultantly benefits a project in terms of other performance criteria as well. Economic sustainability requires a holistic life-cycle approach and long term thinking in the design process which also leads to stronger environmental results, subsequently affecting social sustainability performance in a positive way. Furthermore, a focus on environmental sustainability also brings about long-term consideration with effective solutions for a project, therefore increasing the performance of other criteria as well. Whether the project sustainability is driven by economic or

Project team's understanding of project goals and aspirations	Rework because of poor workmanship	System and material selection	Use of integrated design approach	Value Engineering exercise	Cost performance	Quality performance	Schedule performance	Economic sustainability performance	Environmental sustainability performance	Social sustainability performance	Overall project performance
								×	×	×	
								×			
							×				×
							×				
								×	×	×	
								×	×	×	
						×					×
	×	×		×			×		×		
									×	×	
							×				×
										×	
					×		×				
								×	×	×	
								×		×	×
											×
					×	×	×	×	×	×	
								×			
×										×	×
					×	×					
			×				×				×
×			×				×	×			
							×				
					×	×	×	×	×	×	
						×					
						×		×			
								×	×	×	
								×	×	×	
					×						
					×	×	×	×	×	×	
×			×				×	×			×
						×			×	×	
							×	×			×
5	1	1	3	1	7	10	15	18	14	14	12

environmental aspirations, the holistic life-cycle approach is an outcome, which positively affects both the sustainability and the quality performance.

4.2.3. Client's vision and motivation

Since the performance of a project across different criteria is mainly achieved by meeting pre-set goals, the vision of clients about these goals and their motivation to pursue them can be very important in determining performance criteria associations. Projects in which clients are willing to pay for sustainability may also perform well in other performance criteria. According to survey participants, owners opting for higher environmental sustainability targets and mandates, generally "spend more effort in getting things right", which automatically improves the quality due to "greater scrutiny and ownership". In case the project clients have clear goals, visions and priorities, the project team can easily follow these. However, when lacking clear goals, the team may not know which criteria to focus on and this can subsequently result in conflicts among performance criteria.

4.2.4. Rigor of project development process

Compared to traditional building projects, the different project development processes in GBs are given more attention and more rigorously performed, which results in increased performance on different criteria. According to survey participants, because of the better design, installation, commissioning and tuning resulting

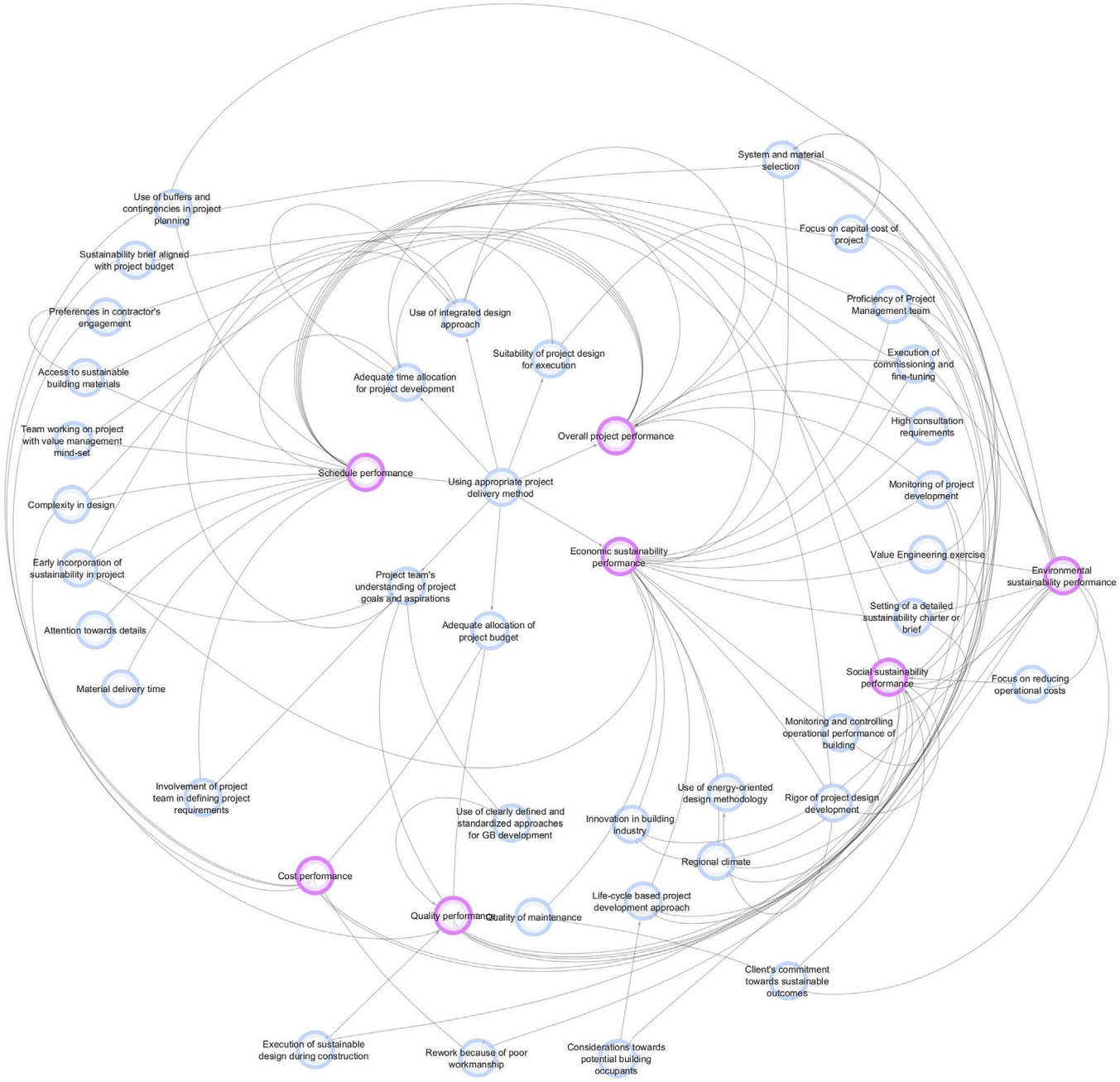


Fig. 9. Associations among Green Building performance criteria and the associated underlying conditions. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

from environmentally sustainable development, social sustainability performance is also positively affected in GBs.

4.2.4.1. Integrated design approach. The integrated design results in more value for individual building features. Consequently, an integrated and holistic design approach can significantly affect the associations among performance criteria by helping achieve different performance goals in an optimized way. While each design component will have multiple functions, it will become difficult to eliminate design features in a VE exercise. While reflecting on this an interview participant (AE-M-2) said,

> "In an ideal situation, an integrated design process needs to consider the cost element and a value engineering process should not be required. The integrated design process if executed properly can be so beneficial that it can produce a Green Building project with low capital cost as compared to a traditional project."

The increased design synergies because of the integrated design approach result in mutually positive associations among performance criteria.

4.2.4.2. Constructability considerations. In case of GB projects, as some of the survey participants argued, there is an increased focus on different constructability considerations while the project is being developed and this has a positive influence on all performance criteria. Constructability considerations include the 'suitability of project design for execution', a condition presented in Table 5. According to interviewee *UK-F-2*, for realizing constructability of project design, good communication among design team is necessary. According interviewee *UK-M-7*, a contractor can also play an important role in ensuring the constructability of design and specifications. However, to realize this a contractor needs to be involved early in the project and sufficient time needs to be allocated to contractor for design review. Constructability considerations or in other terms 'suitability of project design for execution', is affected by the communication among design team, early involvement of contractor in project, and adequate time allocation for design review (shown in Table 5).

4.2.4.3. Commissioning and tuning process. Commissioning and tuning are the delivery-related aspects of well-executed projects. The main objective of commissioning is to result in a safe and orderly handover of the project from the builder to the owner, guaranteeing its operability in terms of performance, reliability, safety and information traceability. Commissioning conducted in a planned and effective way can affect the fulfilment of schedule, cost, safety and quality-related requirements of a project. Commissioning is a critical aspect of quality control and is critical to the delivery of a successful project. Buildings that are commissioned properly, have a better quality performance. For instance, the process ensures better performing lighting, HVAC systems, etc. Commissioning ensures that when operational, building systems will perform up to the mark, which means that the building will perform sustainably in its operational life as well. However, in case commissioning is not already a part of the cost and schedule planning of a project, then executing it may negatively associate with schedule and cost performance.

4.2.5. Compliance requirements

Often GB projects also receive third-party GB certifications. To comply with those certification requirements, projects need to follow a process, which not only helps to achieve sustainability performance but also quality performance. Although a project meeting the compliance requirements may take longer time and more budget to be delivered, a consideration of these in the project planning can help avoid cost and time overruns. According to survey participants, using a formal sustainable building rating scheme is an effective way of quality assurance as it helps to verify that the sustainable design attributes have been incorporated into a building and are correctly operating. This effectively contributes to sustainability performance. However, for the building to be green certified, extra time is associated with documentation and this also impacts the initial capital cost. Overall, because of the typical requirement in GBs to comply with third-party certifications, a mutually positive association exists between sustainability and quality performance criteria.

4.2.6. Project delivery method

The PDM used in a project determines the level of integration, which subsequently results in an association among different performance criteria. According to survey participants, most projects are delivered these days through a Design and Construct (D&C) approach. The D&C approach has largely been adopted in commercial projects. While the D&C approach is aimed to reduce project delivery cost and time, it works against the greater integration of sustainability outcomes whilst also impacting other performance criteria. In contrast to D&C, the Integrated Project Delivery (IPD) is a PDM, which is more suitable for GB projects as it results in increased integration. The association of a PDM with project integration is discussed in detail by a British interview participant (UK-M-7) involved in GB projects for 12 years as a design consultant as well as a contractor. He states that,

> "The extreme end delivery approaches are good while the midway approaches are not so good. For instance, a fully integrated design team with earlier contractor's involvement and making an Integrated Project Delivery is good in terms of delivering sustainable performance. Everyone is onboard, share same targets and goals in design and construction. The lines of communication are very clear, and the team players know the answer of "WHY" question very well. The traditional method in which contractor is brought on-board upon the design completion, also works well. The fun part of the traditional delivery is that it has the integrated design element. The design deliverables are very clear, and the design team does not rely on the contractor's input for design development. Design and Build as a delivery system in terms of delivering sustainability goals can get very muddy very quickly. This is because design development knowledge can get lost. Contractor is brought onboard at the end of the design development. In this delivery approach there is less cost overrun but more schedule overrun involved …. . The details relating the project are not passed properly from the client's team to the contractor's team and because of this the sustainability related details can get missed. In these two teams there is a limited knowledge transfer because of which the project suffers."

The interview findings highlight that a PDM affects performance criteria associations by affecting project team interests, team communication, team's understanding of project objectives, clarity of design deliverables, and transition of information from design team to contractor's team. A PDM being used in a project also affects project planning, constructability considerations, as well as value engineering.

4.2.7. Innovation in building industry

The associations among sustainability performance criteria are to some extent subject to the innovation in building materials, systems, designs and technology. Many sustainable approaches in building designs and building systems have still not become a trend, and a reason for this may be that there is further innovation required in this area to adopt the solutions to commercial use. With advancements in the building-related innovations, the three sustainability performance criteria can start to have increasingly positive associations among each other. According to an interviewee (AU-M-4), "in terms of sustainability, the technology and the products are changing so fast that what was relevant 3 years ago is not relevant anymore. So today, you can get much better outcomes without having to compromise on human comfort in any way." With further innovations in building-related solutions, interventions where the user's comfort and well-being (i.e. social sustainability) will not be achieved at the expense of higher LCC (i.e. economic sustainability) or higher emissions (i.e. environmental sustainability), may become commonplace.

4.2.8. Project management

Effective project management can play a very important role in

balancing the attention of a team towards multiple performance criteria. As an interviewee (SN-M-9) stated, "the project management is quite important to make a project successful as you have to consider the time, cost and quality aspects." According to *UK-M-7,* while the project team is focussing on building construction, the sustainability, cost, and quality performance can drop off. A project manager with good oversight of different GB aspects can play an important role by keeping things in balance. Hence, project management can play an important role in determining the performance criteria associations.

4.2.9. Value engineering

A VE exercise is often conducted in case the project scope exceeds its budget. In case the VE exercise is conducted in a GB with a disregard of sustainability considerations, then in an attempt to reduce cost, sustainability performance and quality performance may get negatively affected. While eliminating green features to reduce capital costs, VE exercise may not consider lifecycle costs, resulting in increased operational costs (Chalifoux, 2006). While reflecting on the UAE-based projects, an interview participant (AE-M-2) mentioned, "[often] during the project design development, a stage comes when the estimated cost of the project becomes significantly higher than the budgeted amount. This is a problematic situation where Value Engineering is performed. During this process, the tendency is to cut the costliest project aspects, which is an erroneous practice as the costly aspects of a project are often also the key aspects to benefit the project." For instance, efficient building glazing can have a significantly higher cost as compared with inefficient glazing. In case the VE exercise substitutes such glazing with low efficiency counterparts, it can significantly affect energy use and subsequently greenhouse gas emissions. In such a situation an improvement in cost performance is realized at the expense of sustainability performance. Hence, in a case where VE is unavoidable, it is important to regard all the potential issue while a certain design feature is being eliminated.

4.2.10. Project planning

The early and appropriate decision-making, preparation and planning in a GB project has a strong influence over the associations of GB performance criteria. Appropriate planning in a GB project can mean a well-defined scope and early consideration of sustainability in project. Appropriate planning implies a well-defined schedule and an appropriate budget corresponding to the project scope. As a result of aptly conducted planning, the negative associations among performance criteria may be avoided.

4.2.10.1. Early incorporation of sustainability vision. Along with survey participants, some interview participants (UK-M-4; UK-M-3) have also argued that the late incorporation of sustainability in a project can lead to negative associations of environmental sustainability with economic sustainability performance as well as schedule and cost performance. Sustainability is a highly integrated aspect of project design. In case the sustainability outcomes are outlined earlier in a project design development, they can be integrated into design elements at the minimum potential cost. The late incorporation of environmental sustainability measures can lead to a redesign activity adding to project cost. Furthermore, the late incorporation of sustainability in a project may not be able to significantly reduce LCC. Considering 'green goals' in the later project stages may also result in a negative impact of schedule performance on sustainability performance.

4.2.10.2. Appropriate time and cost allocation. Cost and time allocation in a project can significantly determine the performance criteria association. According to survey participants, the early considerations of sustainability within the project scope can render the sustainability performance independent of the cost and schedule performance, as appropriate time and budget are allocated to different aspects related to GB project development. The importance of time and budget allocation in GBs is primarily due to the additional project development-related activities in GBs resulting from their inclusion of sustainability considerations. Rigorous project implementation approaches, e.g. soft landings processes mean that performance targets will not affect schedule or cost because these have already been planned and allowed for early in the process. Cost performance for sustainable projects depends on the cost planning performed for the sustainability initiatives included in the project, and it does not depend on the nature of the sustainability initiatives.

According to a Singapore-based interview participant (SN-M-9),

> "When cost is being planned for the project, it is important to give due consideration to the green systems being installed in the building. Otherwise, a contractor may have to work within the already set low cost and the quality of construction may be affected because of it."

4.2.10.3. Use of buffers and contingencies in project planning. An important aspect of project planning is to leave contingencies in resources, as well as in time and project budget. These buffers can play an important role in determining the performance criteria associations, as according to an interviewee (UK–F-3): "achieving sustainability within a set capital cost is a difficult thing to do, particularly when the capital cost is fixed." Another interviewee (AU-M-8) states, "if the project funding allows for additional project measures, then it is easy to make a case for sustainable aspects. However, if the cost is under pressure, then sustainability is often found a low-hanging fruit, and it is often one of the first elements to be sacrificed." Contingency for sustainability performance can also occur within project design as discussed by some interview participants (AU-M-2; AU-F-4). According to an interview participant (AU-M-2), "as architectural consultants, we design projects with 10% margin in terms of Green credit points and we also ask our contractors to keep this margin in consideration. Because of this margin, the projects get the overall aspired certification rating even in case it cannot meet some individual credit points."

5. Discussion

The detailed analysis shows that the associations among sustainability performance and quality performance of GB projects are mutually positive. This can be due to the facts that sustainability considerations are a part of the project design in case of GB projects, and project quality is about realizing the originally conceived design and specifications. The underlying conditions identified confirm that the performance criteria are related in different ways (i.e. positively and negatively) under different circumstances (i.e. under the influence of different variable states of the identified conditions). This means that the associations among performance criteria can be modified by controlling the underlying conditions. This also implies that sustainability performance does not essentially need to be realized at the expense of project management-related performance criteria.

For GB project development the identified conditions have different values. The project clients and project team have little or

no control over external environment-related conditions (i.e. 'Regional constraints', 'Regional climate', 'Compliance requirements', and 'Innovation in building industry'). The changes in these conditions are subject to time and region. With the developments in the construction industry in a region, these conditions can undergo changes. Apart from these external environment-related conditions, other conditions are project-specific and are controllable by the project team and decision-makers. This highlights that with effective project planning and management strategies, good performance on individual performance criteria can be achieved. 'Client's vision and motivation' is a critically important condition as it can determine the preferences for performance criteria. This condition also affects the performance criteria indirectly by affecting multiple underlying conditions responsible for performance criteria associations. While most of the discussed conditions can occur in non-GB projects as well, some of the identified conditions are intrinsically related to GBs including 'Life-Cycle perspective', 'Regional Constraints', and 'Compliance requirements' e.g. energy efficiency requirements. Most of the identified conditions occur within the earlier project stages. This highlights that the decisions made, and the actions taken in the earlier project stages significantly determine how the performance criteria interrelate.

The identified conditions have been covered to some extent in the existing literature. This coverage gives confidence in the results and is outlined below.

- For 'regional constraints', previous studies have considered the geography and climatic conditions as success factors (Ihuah et al., 2014). The limited supply of sustainable materials and products have been considered as barriers of GB development (Ahn et al., 2013; Dalibi et al., 2017).
- For 'life-cycle perspective', previous studies have emphasized the use of a life-cycle perspective for GB development (Qin et al., 2016; Sourani, 2011).
- For 'client's vision and motivation', some studies have emphasized the commitment and involvement of clients in GB projects (Bakar et al., 2009; Enache-Pommer and Horman, 2009; Olanipekun et al., 2018; Ruparathna and Hewage, 2015). Other studies have also highlighted the importance of the owner's ability in defining project scope and making decisions (Gultekin et al., 2013; Sinem Korkmaz et al., 2011; Molenaar et al., 2009).
- For 'quality of project development process', some studies have emphasized the use of good design practices in GB projects (Attia et al., 2017; Qin et al., 2016; Worzala and Bond, 2011). Integrated design approaches and integrated work environment in GB development have also been emphasized (Ahn et al., 2013; B. Z. Li and Yao, 2012; Nash et al., 2011; Swarup et al., 2011). The importance of constructability of designs has also been highlighted (Qin et al., 2016). Furthermore, the important role of the commissioning process in GBs has also been discussed (Enache-Pommer and Horman, 2009; Kantola and Saari, 2016).
- For 'Project Delivery Method', the effect of different PDMs on different performance criteria including sustainability criteria have been extensively studied for GBs (Bilec, 2008; Carpenter, 2005; El Asmar et al., 2013; Gultekin et al., 2013; Hanks, 2015; Korkmaz et al., 2010a,b; Sinem Korkmaz et al., 2011; Molenaar et al., 2009; Mollaoglu-Korkmaz et al., 2011; Swarup et al., 2011).
- For 'innovation in building industry', the use of innovative technological approaches has been emphasized for GBs (Y. Y. Li, Chen, Chew, Teo and Ding, 2011).
- For 'project management', the importance of the competence and skilfulness of the project manager for GB development has been highlighted (Y. Y. Li et al., 2011; Shen et al., 2017).
- For 'project planning', the importance of adequate planning in GBs has been highlighted (Bakar et al., 2009; Ihuah et al., 2014). The significance of adequate time allocation in case of GBs has been amply addressed in the literature (Ahn et al., 2013; Bakar et al., 2009; Hwang and Tan, 2012; Ihuah et al., 2014; Lam et al., 2009; Qin et al., 2016; Shi et al., 2013; Sourani, 2011; Wai et al., 2012). The significance of adequate budget allocation has also been covered (Bakar et al., 2009; Ihuah et al., 2014) and the role of good resource allocation has been highlighted (Wai et al., 2012). Furthermore, the importance of the early introduction of sustainability in GB development has been extensively discussed (Enache-Pommer and Horman, 2009; Gultekin et al., 2013; Korkmaz et al., 2010a; Swarup et al., 2011).

The underlying conditions resulting in associations among different performance criteria have much importance. Since the identified conditions are reported to affect project performance on multiple criteria, these conditions may also qualify as success factors. The more strongly they relate to the performance criteria and the higher the number of performance criteria they affect can be the two functions determining their criticality for project success. The scope of this study is limited to the identification of these conditions and not about determining their criticality for project success. This research gap can potentially be filled by future studies.

As a scientific endeavour, this study is limited in certain aspects. The associations among performance criteria are determined using a survey-based methodology. This, therefore, involves cognitive bias from the survey participants. The underlying conditions resulting in performance criteria associations also have some limitations. It is possible that some other conditions in addition to the identified conditions are responsible for performance criteria associations, and these additional conditions are left unidentified because of the limited survey sample (i.e. $n = 104$) and interview sample ($n = 30$). Furthermore, another limitation is that the effects of the key identified conditions on performance criteria associations have only been discussed qualitatively. Future research may focus on developing multi-objective optimization models based on the conditions identified in this study. This may require establishing the quantitative effect of the underlying conditions on performance criteria associations. Furthermore, to consider the identified conditions as success factors for GB development, future studies may need to establish quantitative relationships to determine the criticality of these conditions for project success using large sample of GB projects which is beyond the scope of this study.

6. Conclusion

This study aimed to identify the associations among sustainability and project management-related performance criteria in GB projects, and the underlying conditions determining those associations. A mixed methods approach was used to address this aim. A multiregional online questionnaire survey and semi-structured interviews were used as data collection methods. Primarily, the questionnaire survey data was quantitatively analysed, and the interview data were qualitatively analysed.

Based on the questionnaire survey data, the associations among performance criteria were identified. While the positive associations were prevalent among performance criteria, some cases of negative, and no associations were also identified. This study has identified different conditions which drive associations among performance criteria. The analysis showed that variations in these conditions lead to different associations among performance criteria. Hence, desirable performance criteria associations could be achieved upon optimizing these underlying conditions. Some key conditions identified and discussed in detail include, 'project

planning', 'quality of project development process', 'life-cycle perspective', 'project management', 'project delivery method', 'client's vision and motivation', 'regional constraints', 'regional climate', 'compliance requirements', and 'innovation in building industry'. Some of the identified conditions have been emphasized by previous research supporting findings. Based on the influence of these conditions on performance criteria, they can also be considered as success factors for GB development.

One of the key findings of this study is that sustainability performance in a Green Building may not influence schedule and cost performance in case the identified conditions can be appropriately controlled while developing a project. Findings also establish aspects which are necessary to ensure that achieving higher performance on sustainability criterion would not affect performance on other criteria.

This study has both practical and theoretical implications. For the practice of GB development, this study identified a number of underlying conditions determining performance criteria associations. Practically, by understanding the pivotal role of conditions, decision-makers would be able to consider these conditions in their project development plans. The control of these conditions by project clients or a project team can help achieve optimal results for a project across different performance criteria. In theoretical terms, holistic decision-making and project management-related frameworks can be developed from the findings. The identified conditions can lead to more comprehensive multi-objective optimization models specifically designed for GB projects.

Acknowledgement

The authors acknowledge the support provided for this study by the Department of Building and Real Estate at the Hong Kong Polytechnic University.

Appendix

Table A
Meaning of good performance on different criteria as explained in survey questionnaire

Good performance in criterion …	implies
Environmental sustainability	lower emissions, less resource use, and use of recyclable materials
Social sustainability	better indoor air quality, healthy and productive spaces
Economic sustainability	lower life-cycle cost, and lower operation and maintenance costs
Cost performance	delivering projects on budget or under budget
Schedule performance	delivering projects within the specified time or before the specified time
Quality performance	delivering projects within specifications

Table B
Overall characteristics of interview participants

Participant ID	Region where experience based	Role in GB projects	Years of involvement in GBs
AE-M-1	UAE	Sustainability Consultant	3
AE-M-2	UAE	Sustainability Consultant	10
AU-F-2	Australia	Design Consultant	18
AU-F-4	Australia	Sustainability Consultant	6
AU-F-6	Australia	Sustainability Consultant	8
AU-F-7*	Australia	Design Consultant	10
AU-F-8*	Australia	Design Consultant	9
AU-M-2	Australia	Design Consultant	9
AU-M-4	Australia	Design Consultant	10
AU-M-5*	Australia	Design/BIM manager with contractor	10
AU-M-7	Australia	Sustainability Consultant	7.5
AU-M-8	Australia	Project Manager	15
AU-M-17*	Australia	Design Consultant	20
AU-M-20*	Australia	Sustainability and Design manager with Contractor	14
PK-M-1*	Pakistan	Design Consultant; Project Manager; Sustainability Consultant	3.5
PK-M-2*	Pakistan	Lead Engineer with contractor	1
SN-M-3	Singapore	Facilities Management Professional	13
SN-M-5	Singapore	Design Consultant	22
SN-M-9	Singapore	Engineering Consultant; Green Mark Manager	10
UK-F-1	UK	Sustainability Advisor; Design Consultant	10
UK-F-3	UK	Sustainability Consultant	5
UK-F-4	UK	Sustainability Consultant; Environmental Designer	5
UK-F-5	UK	Design Consultant	15
UK-F-6	UK	Sustainability Consultant	10
UK-M-1	UK	Sustainability Consultant; Design Consultant	10
UK-M-3	UK	Sustainability Consultant	7
UK-M-4	UK	Energy Auditor; Engineering Consultant	10
UK-M-5	UK	Sustainability Consultant; Design Consultant	6
UK-M-7	UK	Design Consultant; Contractor	12
HK-M-4	Hong Kong	Design Consultant	10

Note: "*" represents the interviews conducted over telephone.

Table C
Correlations among performance criteria of GB office projects[2]

Correlations	Overall (104)			Experience						Region											
				0-10 Green Office experience			10 + Green Office experience			Australia (43)			India and Pakistan (19)			Singapore (18)			UAE (16)		
	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)
Environmental Sustainability Performance affecting Social Sustainability Performance	85	7	9	80	7	13	91	7	2	88	7	5	84	5	11	78	11	11	81	6	13
Economic Sustainability Performance affecting Environmental Sustainability Performance	78	16	6	79	16	5	77	16	7	81	14	5	84	16	0	67	28	6	88	6	6
Social Sustainability Performance affecting Environmental Sustainability Performance	77	14	9	77	15	8	77	14	9	74	14	12	84	11	5	67	17	17	88	13	0
Quality Performance affecting Environmental Sustainability Performance	76	18	6	77	20	3	74	16	9	70	26	5	89	11	0	61	28	11	94	6	0
Social Sustainability Performance affecting Economic Sustainability Performance	72	15	13	67	18	15	79	12	9	67	19	14	79	11	11	61	28	11	81	0	19
Social Sustainability Performance affecting Quality Performance	71	27	2	74	23	3	67	33	0	63	37	0	79	16	5	67	33	0	88	13	0
Quality Performance affecting Social Sustainability Performance	64	29	7	62	31	7	67	26	7	74	23	2	68	21	11	33	61	6	63	25	13
Environmental Sustainability Performance affecting Quality Performance	63	19	17	61	20	20	67	19	14	70	16	14	32	53	16	72	11	17	81	0	19
Quality Performance affecting Economic Sustainability Performance	63	25	12	66	25	10	60	26	14	63	28	9	63	16	21	50	44	6	81	13	6
Environmental Sustainability Performance affecting Economic Sustainability Performance	63	14	23	64	8	28	60	23	16	56	14	30	63	16	21	67	22	11	88	0	13
Economic Sustainability Performance affecting Cost Performance	63	19	18	64	16	20	60	23	16	51	33	16	74	0	26	61	22	17	88	6	6
Economic Sustainability Performance affecting Social Sustainability Performance	62	29	10	61	28	11	63	30	7	63	30	7	74	21	5	50	39	11	63	25	13
Economic Sustainability Performance affecting Quality Performance	62	27	12	62	25	13	60	30	9	53	35	12	79	11	11	50	44	6	69	13	19

(*continued on next page*)

Table C (*continued*)

Correlations	Overall (104)			Experience						Region											
				0-10 Green Office experience			10 + Green Office experience			Australia (43)			India and Pakistan (19)			Singapore (18)			UAE (16)		
	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)	Positive (%)	No Effect (%)	Negative (%)
Schedule Performance affecting Cost Performance	62	17	21	62	18	20	60	16	23	53	21	26	68	11	21	67	17	17	63	19	19
Social Sustainability Performance affecting Schedule Performance	22	58	20	21	54	25	23	63	14	16	65	19	21	63	16	22	56	22	38	50	13
Schedule Performance affecting Social Sustainability Performance	26	56	18	31	54	15	19	58	23	14	63	23	47	47	5	17	67	17	38	44	19
Cost Performance affecting Economic Sustainability Performance	54	18	28	62	11	26	42	28	30	30	28	42	74	0	26	50	28	22	94	0	6
Economic Sustainability Performance affecting Schedule Performance	30	50	20	30	48	23	30	53	16	23	58	19	47	42	11	17	61	22	44	31	25
Environmental Sustainability Performance affecting Cost Performance	48	19	33	56	18	26	37	21	42	35	23	42	74	11	16	44	17	39	63	25	13
Cost Performance affecting Quality Performance	46	17	37	49	18	33	42	16	42	26	23	51	63	16	21	56	11	33	69	13	19
Schedule Performance affecting Environmental Sustainability Performance	29	46	25	36	43	21	19	51	30	16	51	33	58	42	0	17	50	33	38	38	25
Environmental Sustainability Performance affecting Schedule Performance	45	35	20	49	34	16	40	35	26	35	40	26	89	11	0	33	33	33	38	50	13
Cost Performance affecting Schedule Performance	44	32	24	48	28	25	40	37	23	42	35	23	42	37	21	44	28	28	50	25	25
Social Sustainability Performance affecting Cost Performance	43	25	32	44	23	33	42	28	30	28	37	35	63	5	32	44	28	28	56	13	31
Quality Performance affecting Cost Performance	36	21	43	44	16	39	23	28	49	19	33	49	63	16	21	33	22	44	50	0	50
Schedule Performance affecting Economic Sustainability Performance	41	41	17	44	36	20	37	49	14	23	53	23	68	26	5	33	50	17	63	19	19
Cost Performance affecting Environmental Sustainability Performance	39	29	32	49	28	23	26	30	44	21	28	51	68	26	5	33	50	17	63	13	25
Quality Performance affecting Schedule Performance	30	32	38	31	31	38	28	33	40	21	37	42	47	26	26	22	28	50	38	31	31
Cost Performance affecting Social Sustainability Performance	31	34	36	38	33	30	21	35	44	16	35	49	68	21	11	11	56	33	44	19	38
Schedule Performance affecting Quality Performance	35	35	31	39	30	31	28	42	30	12	47	42	63	26	11	33	28	39	56	19	25

Table D
Factors identified from survey and interviews

Representative conditions	Conditions identified from survey and interviews
Access to sustainable building materials	Limited tenders on sustainable materials; Local sourcing of materials
Adequate allocation of project budget	Appropriate budget allocation for project sustainability aspects
Adequate time allocation for project development	Appropriate delivery time allocation for project
Attention towards details	Attention towards detailing, finishing and workmanship
Complexity in design	Increased innovation and complexity
Early incorporation of sustainability in project	Early design decisions involving green building concepts
Execution of commissioning and fine-tuning	Commissioning and tuning process
Execution of sustainable design during construction	Incorporation of predefined specifications
Focus on capital cost of project	Competitive cost driven procurement; Inappropriately high cuts in capital cost
Focus on reducing operational costs	Inappropriately high operating and maintenance cost reductions
Involvement of project team in defining project requirements	Articulation of the deliverables by team members
Life-cycle based project development approach	Long term project considerations in project development
Material delivery time	Longer green material delivery time
Monitoring and controlling operational performance of building	Building maintenance and tuning upon handover
Monitoring of project development	Contract administration; Quality checks and audits
Motivation of Users towards sustainable outcomes	Occupants' learning and motivation for sustainability
Preferences in contractor's engagement	Appropriate contractor selection
Project team's understanding of project goals and aspirations	Detailed understanding of project's vision; Understanding of quality targets by project team; Misconceptions of project design team
Rework because of poor workmanship	Re-working because of poor workmanship
Rigor of project design development	Better design and installation; Design specifications
Setting of a detailed sustainability charter or brief	Clear definition of project scope in documentation
Suitability of project design for execution	Constructability considerations
Sustainability brief aligned with project budget	Congruence among cost planning and scope of work
System and material selection	Decisions relating equipment selections; Focus on choice of materials and products; Use of materials with low VOCs; Use of non-standard materials, practices and requirements; Use of pragmatic solutions; Use of recycled materials; Restrained use of resources; Considerations towards product quality during selection; Use of systems with low emissions (because of low energy consumption)
Team working on project with value management mind-set	Cost-benefit optimization; Exercise to find suitable economic solutions
Use of clearly defined and standardized approaches for GB development	Using formal process of a Green Building rating scheme; Compliance requirements
Use of energy-oriented design methodology	Use of energy-efficient building features and systems
Use of integrated design approach	Using integrated and holistic design approach
Using appropriate project delivery method	Using Fast-Track delivery approach; Using appropriate Procurement Methodology; Using appropriate project delivery process
Value Engineering exercise	Appropriately conducted Value Engineering exercises

References

Ahmad, T., Aibinu, A.A., 2017. Project delivery attributes influencing green building project outcomes: a review and future research directions. Built. Environ. Proj. Asset. Manag. 7 (5), 471–489.

Ahmad, T., Aibinu, A.A., Stephan, A., 2019. Managing green building development – a review of current state of research and future directions. Build. Environ. 155, 83–104. https://doi.org/10.1016/j.buildenv.2019.03.034.

Ahn, Y.H., Pearce, A.R., Wang, Y., Wang, G., 2013. Drivers and barriers of sustainable design and construction: the perception of green building experience. Int. J. Sustain. Build. Technol. Urban Develop. 4 (1), 35–45.

AKBAYRAK, B., 2000. A comparıson of two data collectıng methods: ınterviews and questıonnaires. Hacettepe Üniversitesi Eğitim Fakültesi Dergisi 18 (18).

Analytics, D.D., 2016. World Green Building Trends 2016: Developing Markets Accelerate Global Green Growth. Smart Market Report.

Attia, S., Eleftheriou, P., Xeni, F., Morlot, R., Ménézo, C., Kostopoulos, V., et al., 2017. Overview and future challenges of nearly zero energy buildings (nZEB) design in Southern Europe. Energy Build. 155, 439–458.

Baccarini, D., 1999. The logical framework method for defining project success. Proj. Manag. J. 30 (4), 25–32.

Bakar, A., Hassan, A., Abd Razak, A., Abdullah, S., Awang, A., 2009. Project management success factors for sustainable housing: a framework. Asian J. Manag. Res. 66–80.

Bilec, M.M., 2008. Investigation of the Relationship between Green Design and Project Delivery Methods. Lawrence Berkeley National Laboratory.

Bourdeau, L., 1999. Agenda 21 on Sustainable Construction. CIB report publication, p. 237.

Brady, S.R., 2015. Utilizing and adapting the Delphi method for use in qualitative research. Int. J. Qual. Methods 14 (5). https://doi.org/10.1177/1609406915621381, 1609406915621381.

Carpenter, D.S., 2005. Effects of Contract Delivery Method on the LEED (Trademark) Score of US Navy Military Construction Projects (Fiscal Years 2004-2006). Naval Postgraduate School, Monterey, California.

Chalifoux, A., 2006. Using life cycle costing and sensitivity analysis to “sell” green building features. J. Green Build. 1 (2), 39–48.

Dalibi, S., Feng, J., Shuangqin, L., Sadiq, A., Bello, B., Danja, I., 2017. Hindrances to green building developments in Nigeria's built Environment:“The project professionals' perspectives”. In: Paper Presented at the IOP Conference Series: Earth and Environmental Science.

Darko, A., Chan, A.P., Owusu-Manu, D.-G., Ameyaw, E.E., 2017. Drivers for implementing green building technologies: an international survey of experts. J. Clean. Prod. 145, 386–394.

David Botterill, V.P., 2012. Key Concepts in Tourism Research. in. London. SAGE Publications Ltd. Retrieved from. http://sk.sagepub.com/books/key-concepts-in-tourism-research. doi:10.4135/9781473914674.

El-Rayes, K., Kandil, A., 2005. Time-cost-quality trade-off analysis for highway construction. J. Constr. Eng. Manag. 131 (4), 477–486.

El Asmar, M., Hanna, A.S., Loh, W.-Y., 2013. Quantifying performance for the integrated project delivery system as compared to established delivery systems. J. Constr. Eng. Manag. 139 (11), 04013012.

Enache-Pommer, E., Horman, M., 2009. Key processes in the building delivery of green hospitals. In: Paper Presented at the Proceeding from the Construction Research Congress.

Encyclopedia of Research Design, 2010. In: Salkind, N.J. (Ed.), Thousand Oaks, California.

Gultekin, P., Mollaoglu-Korkmaz, S., Riley, D.R., Leicht, R.M., 2013. Process indicators to track effectiveness of high-performance green building projects. J. Constr. Eng. Manag. 139 (12), A4013005.

Hagens, V., Dobrow, M.J., Chafe, R., 2009. Interviewee transcript review: assessing the impact on qualitative research. BMC Med. Res. Methodol. 9 (1), 47.

Hanks, N.M., 2015. Investigation into the Effects of Project Delivery Methods on LEED Targets. MSc Thesis. University of San, Francisco, San Francisco, California.

Hwang, B.G., Tan, J.S., 2012. Green building project management: obstacles and solutions for sustainable development. Sustain. Dev. 20 (5), 335–349.

Ihuah, P.W., Kakulu, I.I., Eaton, D., 2014. A review of critical project management success factors (CPMSF) for sustainable social housing in Nigeria. Int. Sustain

Built Environ. 3 (1), 62–71.
Ika, L.A., 2009. Project success as a topic in project management journals. Proj. Manag. J. 40 (4), 6–19.
Jiang, A., Zhu, Y., 2010. A multi-stage approach to time-cost trade-off analysis using mathematical programming. Inter. J. Sustain. Built Environ. 10 (3), 13–27.
Johnson, R.B., Onwuegbuzie, A.J., 2004. Mixed methods research: a research paradigm whose time has come. Educ. Res. 33 (7), 14–26. https://doi.org/10.3102/0013189x033007014.
Kantola, M., Saari, A., 2016. Project delivery systems for nZEB projects. Facilities 34 (1–2), 85–100.
Khang, D.B., Myint, Y.M., 1999. Time, cost and quality trade-off in project management: a case study. Int. J. Proj. Manag. 17 (4), 249–256.
Kibert, C.J., 1994. Establishing principles and a model for sustainable construction. In: Paper Presented at the Proceedings of the First International Conference on Sustainable Construction.
Korkmaz, S., Horman, M., Molenaar, K., Gransberg, D., 2010a. Influence of Project Delivery Methods on Achieving Sustainable High Performance Buildings Report on Case Studies. Research Sponsored by the Charles Pankow Foundation, DBIA.
Korkmaz, S., Riley, D., Horman, M., 2010b. Piloting evaluation metrics for sustainable high-performance building project delivery. J. Constr. Eng. Manag. 136 (8), 877–885. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000195.
Korkmaz, S., Riley, D., Horman, M., 2011. Assessing project delivery for sustainable, high-performance buildings through mixed methods. Architect. Eng. Des. Manag. 7 (4), 266–274.
Lam, P.T., Chan, E.H., Chau, C., Poon, C., Chun, K., 2009. Integrating green specifications in construction and overcoming barriers in their use. J. Prof. Issues Eng. Educ. Pract. 135 (4), 142–152.
Li, B.Z., Yao, R.M., 2012. Building energy efficiency for sustainable development in China: challenges and opportunities. Build. Res. Inf. 40 (4), 417–431. https://doi.org/10.1080/09613218.2012.682419.
Li, Y.Y., Chen, P.-H., Chew, D.A.S., Teo, C.C., Ding, R.G., 2011. Critical project management factors of AEC firms for delivering green building projects in Singapore. J. Constr. Eng. Manag. 137 (12), 1153–1163.
Marzouk, M., Madany, M., Abou-Zied, A., El-said, M., 2008. Handling construction pollution using multi-objective optimization. Constr. Manag. Econ. 26 (10), 1113–1125.
Molenaar, K., Sobin, N., Gransberg, D., McCuen, T., Korkmaz, S., Horman, M., 2009. Sustainable, High Performance Projects and Project Delivery Methods: A State-Of-Practice Report. Charles Pankow Foundation.
Mollaoglu-Korkmaz, S., Swarup, L., Riley, D., 2011. Delivering sustainable, high-performance buildings: influence of project delivery methods on integration and project outcomes. J. Manag. Eng. 29 (1), 71–78.
Moselhi, O., 1993. Schedule compression using the direct stiffness method. Can. J. Civ. Eng. 20 (1), 65–72.
Nash, D.J., Comm High-Performance Green, F., Natl Res, C., 2011. Objectives and Challenges Associated with Federal High-Performance Green Buildings. Achieving High-Performance Federal Facilities: Strategies and Approaches for Transformational Change, pp. 17–26.
Nations, U., 1992. Report of the United Nations conference on environment and development. In: Paper presented at the Rio de Janeiro (3–14 June 1992) A/CONF.
Olanipekun, A.O., Xia, B., Hon, C., Darko, A., 2018. Effect of motivation and owner commitment on the delivery performance of green building projects. J. Manag. Eng. 34 (1) https://doi.org/10.1061/(ASCE)ME.1943-5479.0000559.
Ozcan-Deniz, G., Zhu, Y., Ceron, V., 2011. Time, cost, and environmental impact analysis on construction operation optimization using genetic algorithms. J. Manag. Eng. 28 (3), 265–272.
Pan, W., Dainty, A.R., Gibb, A.G., 2012. Establishing and weighting decision criteria for building system selection in housing construction. J. Constr. Eng. Manag. 138 (11), 1239–1250.
Qin, X., Mo, Y., Jing, L., 2016. Risk perceptions of the life-cycle of green buildings in China. J. Clean. Prod. 126, 148–158.
Rahimi, M., Iranmanesh, H., 2008. Multi objective particle swarm optimization for a discrete time, cost and quality trade-off problem. World Appl. Sci. J. 4 (2), 270–276.
Roulet, C.-A., Flourentzou, F., Foradini, F., Bluyssen, P., Cox, C., Aizlewood, C., 2006. Multicriteria analysis of health, comfort and energy efficiency in buildings. Build. Res. Inf. 34 (5), 475–482.
Ruparathna, R., Hewage, K., 2015. Sustainable procurement in the Canadian construction industry: current practices, drivers and opportunities. J. Clean. Prod. 109, 305–314. https://doi.org/10.1016/j.jclepro.2015.07.007.
Saunders, M.N., 2011. Research Methods for Business Students. 5/e: Pearson Education India.
Shen, W., Tang, W., Siripanan, A., Lei, Z., Duffield, C.F., Wilson, D., Wei, Y., 2017. Critical success factors in Thailand' s green building industry. J. Asian Architect. Build Eng. 16 (2), 317–324.
Shi, Q., Zuo, J., Huang, R., Huang, J., Pullen, S., 2013. Identifying the critical factors for green construction – an empirical study in China. Habitat Int. 40, 1–8. https://doi.org/10.1016/j.habitatint.2013.01.003.
Siegel, S., Castellan, N., 1988. Nonparametric Statistics for the Behavioural Sciences 2. Ed. Statistics. McGraw-Hill, New York.
Soetanto, R., Zhang, S., Pan, W., Kumaraswamy, M., 2014. A multi-criteria decision framework for the selection of low carbon building measures for office buildings in Hong Kong. Int. J. Energy Sect. Manag. 8 (4), 456–476.
Sourani, A., 2011. Barriers to addressing sustainable construction in public procurement strategies. Eng. Sustain 164 (ES4).
Stephan, A., Stephan, L., 2016. Life cycle energy and cost analysis of embodied, operational and user-transport energy reduction measures for residential buildings. Appl. Energy 161, 445–464.
Swarup, L., Korkmaz, S., Riley, D., 2011. Project delivery metrics for sustainable, high-performance buildings. J. Constr. Eng. Manag. 137 (12), 1043–1051.
Tayyab, A., 2019. A Survey of Performance Criteria Interrelationships in Green Building Projects.
Vanegas, J.A., DuBose, J.R., Pearce, A.R., 1995. Sustainable technologies for the building construction industry. In: Paper Presented at the Symposium on Design for the Global Environment, Atlanta, GA. November.
Wai, S., Yusof, A.M., Ismail, S., Tey, K., 2012. Critical Success Factors for Sustainable Building in Malaysia.
Wang, W., Feng, Q., 2008. Multi-objective optimization in construction project based on a hierarchical subpopulation particle swarm optimization algorithm. In: Paper Presented at the Second International Symposium on Intelligent Information Technology Application.
Worzala, E., Bond, S., 2011. Barriers and drivers to green buildings in Australia and New Zealand. J. Prop. Invest. Financ. 29 (4/5), 494–509.
Zhu, Y., Inyim, P., Rivera, J., 2012. SimulElCon: a multi-objective decision-support tool for sustainable construction. In: Paper Presented at the International Conference on Construction & Real Estate Management.