Deciphering the link between procurement systems and sustainable building success in Hong Kong

Tang, Ziwei; Skitmore, Martin; Ng, S. Thomas

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Ziwei Tang, PhD
Postdoctoral Fellow, Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, email: ziwei.tang@gmail.com

S. Thomas Ng, PhD, FICE
Associate Dean and Professor, Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, email: tstng@hku.hk

Martin Skitmore, PhD
Professor, School of Urban Development, Queensland University of Technology, GPO Box 2434, Brisbane, Q4001, Australia, email: rm.skitmore@qut.edu.au

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Deciphering the Link between Procurement Systems and Sustainable Building Success: A Delphi Study

Abstract: Sustainable building is regarded as one of the most effective approaches for saving resources, reducing greenhouse gas emissions, and supporting sustainable development. In the absence of prior research, Delphi as a group model-building approach for building a system dynamics model is appropriate for capturing the knowledge of construction professionals to identify the relationship between procurement systems and sustainable building success by facilitating efficient group communication. The concepts of the Delphi method are reviewed. Two rounds of Delphi questionnaires were carried out to identify the causal relationships between procurement system variables, critical success factors and success criteria. The causal loop diagram is built based on the results of two rounds of Delphi study which will serves as a basis for building a system dynamics model of sustainable building success in the future study. The results show that some critical success factors related to sustainable building including "market planning / business case for sustainability as sustainable objectives"; "top management commitment and support"; "sustainable strategic planning"; "green timing: early evaluation and adoption of sustainability considerations"; "training and education".

Keywords: Sustainable buildings; procurement systems; project success; critical success factors; project success criteria

1. Introduction

Sustainable building is regarded as one of the most effective approaches for realizing sustainable development. It aims to reduce the built environment's overall impact on human health and the natural environment during a building's whole life cycle including planning, design, construction, operation, maintenance, and removal. It is crucial to sustainable building success in reducing natural resource consumption, greenhouse gas emissions, and meeting the requirements of both clients and end users during building's life cycle. The importance of the procurement system for achieving project success has been well recognized over recent years (Horman *et al*., 2006). Good procurement practices for sustainable building are critical to reduce the overall cost of sustainable building projects and ensure they are on time, of good quality, and meet project sustainability goals (Mollaoglu-Korkmaz *et al*., 2011; Swarup *et al*., 2011).

Sustainable building procurement systems can be any of the procurement systems used in the construction industry (Vellalos & Gordon, 2013). However, unlike usual project procurement systems, which in most cases relate solely to the delivery stage, sustainable building procurement systems should involve the whole life cycle of the building to ensure all sustainability goals are met (Mithraratne & Vale, 2004; Scheuer *et al*., 2003). Compared to a traditional building project, the main differences identified in the literature in procuring a sustainable building include: (i) the need to identify sustainability-related project success criteria and goals (Pulaski & Horman, 2005; Varnäs *et al*., 2009); (ii) the need to 'green' the whole project procurement process and change the behaviour of the entire project team (Pitt *et al*., 2009); (iii) innovation, new knowledge, and learning within organizations (Pitt *et al*., 2009); (iv) intense interdisciplinary collaboration and team integration during a project's whole life cycle (Pulaski & Horman, 2005); (v) the demand for more communication between stakeholders (Klotz *et al*., 2009); (vi) more design iterations and higher construction standards (Pulaski & Horman, 2005); (vii) life cycle costing (Pitt *et al*., 2009); and (viii) operations and maintenance phase sustainability performance evaluation (Pitt *et al*., 2009).

There is little academic research into specific procurement systems for sustainable building. For example, in a case study of the City Tunnel Project in Malmö, Sweden, Vanegas (2003) suggested linking environmental impact assessment, environmental management systems, and green procurement; Sarkis *et al*. (2012) introduced a generic decision model for incorporating sustainability into subcontractor procurement based on both the analytic hierarchy process and the analytic network process. Dahl (2008) proposed integrating end-user feedback in a sustainable project procurement process. However, the majority of researchers used an experiential approach to examine current practices and case studies, or only focused on part of the procurement process, thereby losing synthesis.

Sherwood (2011) mentions in his book that if you want to understand a system and predict its performance, it is necessary to study the system as a whole. Although research has pointed out that the project procurement system affects the project outcome of sustainable buildings (Horman *et al*., 2006), it is unclear how the procurement system is related to sustainable building success criteria and sustainable building success factors. To understand a sustainable building procurement system and predict its performance, it is necessary to have a holistic and systematic view of the entire system; this can be achieved by systems science, which explores a system as a whole from a holistic, interacting, perspective (Skyttner, 2005).

Systems science views man and his environment as interacting systems and tries to analyse the interaction holistically from multiple perspectives (Skyttner, 2005). As applications of system science, systems approaches combine theory, empiricism, and pragmatics, and examine systems from a top down rather than bottom up standpoint (Skyttner, 2005). The various systems approaches can be categorized into four types of goal seeking and viability, exploring purposes, ensuring fairness, and promoting diversity (Jackson, 2003). Of these, system dynamics modelling is best suited for complex dynamic systems involving nonlinear relationships and both 'hard' and 'soft' data, and is considered a suitable approach to analyse the influence of different procurement systems on sustainable building success (Jackson, 2003).

The purpose of building a system dynamics model is to understand the causes of a dynamic problem, which in this case, involves causes of varying levels of sustainable building success during the building life cycle. In system dynamics studies, the structure of a system – defined as 'the totality of the relationships that exist between system variables' (Barlas, 2007) – can usually be demonstrated diagrammatically by the causal links and loops between the variables. Causal-loop diagrams used prior to simulation analysis can depict the basic hypothesized causal relationships between variables and bring the internal structure of the system into focus (Homer & Oliva, 2001). To link procurement systems to sustainable building success, the causal-effect relationships need to be determined between procurement system variables, critical success factors (CSFs), and success criteria (SC) for sustainable building. Therefore, the main objective of this study is to capture the relationships between the variables in a system dynamics manner to propose a hypothesis of the model structure that causes the behaviour and dynamic patterns of the system and, based on this, to construct an appropriate causal loop diagram.

2. Procurement System for Sustainable Building

A typical procurement system consists of activities for selecting appropriate procurement and contracting strategies, selecting project participants, purchasing materials and equipment, and managing contracts. The most frequently used procurement systems for traditional projects are: (i) traditional design-bid-build (DBB); (ii) design and build (DB) including five variants namely package deal; design and manage; design, manage and construct; novation design and build; and develop and construct; (iii) management orientated such as construction management and management contracting; and (iv) partnering (Hibberd, 1991; Morledge & Smith, 2013; Walker & Hampson, 2008).

In addition to these four procurement systems, integrated project delivery (IPD) is an innovative procurement system included in this study. IPD was developed recently and has received much attention in the construction industry (Jayasena & Senevirathna, 2012). It is treated as a significant new development in procurement innovation as it integrates the expertise of project teams during the early project stages, while incorporating design decision making, collaborative contracting, and BIM technologies (Ghassemi & Becerik-Gerber, 2011; Raisbeck *et al*., 2010).

Although different procurement systems have their own advantages and disadvantages, these have similar categories. For example, they all involve team cooperation, with only the levels of cooperation being different – DBB and IPD have a low and high level respectively. Team cooperation can also be viewed as a procurement system variable (PSV). The PSVs are recognized based on the above intensive literature review of the definition of different procurement systems and their advantages and disadvantages. Table 1 summarizes 24 of these.

Table 1: Procurement system variables (PSV)

Reference	*Procurement System Variables*
PSV-1	Level of team cooperation
PSV-2	Level of coordination
PSV-3	Flow of communications / information
PSV-4	Level of flexibility
PSV-5	Level of team integration
PSV-6	Level of control and monitoring
PSV-7	Clients' allocated responsibility
PSV-8	Early commitment of cost and time
PSV-9	Certainty of cost and time
PSV-10	Cost of extra training and management of alternative delivery methods
PSV-11	Life cycle considerations
PSV-12	Process familiarity
PSV-13	Process complexity
PSV-14	Process length
PSV-15	Level of competition
PSV-16	Team members' competence
PSV-17	Supply chain effectiveness
PSV-18	Management requirement for clients
PSV-19	Innovation
PSV-20	Risks
PSV-21	Conflicts / adversary relationship
PSV-22	Claims
PSV-23	Incentives for performance
PSV-24	Punishment for performance

Many previous research studies have identified the critical success factors (CSFs) and success criteria (SC) for sustainable building (Tables 2-3) and therefore, to build a system model linking procurement systems with sustainable building success, the research questions firstly addressed in this study are: (i) what are the relationships between CSFs; (ii) how do CSFs influence SC; and (iii) how do PSVs relate to CSFs?

Table 2: Critical success factors for sustainable building success

Reference	*Critical Success Factors*
CSF-1	Clear understanding of sustainable objectives
CSF-2	Alignment of team members' goals and project goals
CSF-3	Budget control
CSF-4	Life-cycle costing
CSF-5	Market planning / business case for sustainability as sustainable objectives
CSF-6	Risk management / long-term consideration of precaution and risk
CSF-7	Competent project manager / good leadership
CSF-8	Competent team members
CSF-9	Top management commitment and support
CSF-10	Sufficient knowledge / expertise for sustainable building
CSF-11	Strategic sustainability planning

CSF-12	Project life cycle process planning and control
CSF-13	Life cycle team integration
CSF-14	Green timing: early evaluation and adoption of sustainability considerations
CSF-15	Sustainable building technical feasibility
CSF-16	Reliable and available sustainable materials, products or systems
CSF-17	Sustainability in integrated design
CSF-18	Early involvement and cooperation of participants
CSF-19	Engaging the final and temporary users / involving the community
CSF-20	Monitoring / evaluating performance and feedback during project life cycle
CSF-21	Contract conditions such as the project 'green' goals, payment provisions, penalties, incentives, risks, and liabilities
CSF-22	Sustainability in supply chain management
CSF-23	Communicating and coordinating sustainable opportunities and objectives across the stakeholder groups
CSF-24	Innovation
CSF-25	Training and education
CSF-26	Effective stakeholder benefits management and realization process
CSF-27	Continuous value enhancement process
CSF-28	Organizational learning / continuing research & development
CSF-29	Project environment (nature, economic, social, political, business, technological)

Table 3: Success criteria for sustainable building success

Reference	***Success Criteria***
SC-1	Success level of traditional project performance (cost, quality, schedule, safety)
SC-2	Success level of sustainable performance (environmental)
SC-3	Success level of sustainable performance (social)
SC-4	Success level of sustainable performance (economic)
SC-5	Success level of participants' satisfaction

3. Research Method

In the absence of prior research, qualitative approaches are needed to explore the issues involved (Islam *et al*., 2006). As there is very little research into the relationships between CSFs and SC for sustainable building, group model building provides a suitable approach for capturing the knowledge of construction professionals.

The importance of involving the stakeholders in the process of system dynamics model building has already been emphasized by Forrester (1961), as the power of system dynamics lies in the way in which information gained from the clients is used. Therefore, involving different sustainable building project stakeholders in the process of designing a causal-loop diagram can not only elicit their knowledge of the causal relationships between the variables but also allow the problem to be interpreted from different perspectives. Zavacki (1997), for example, has explored how to apply the group model building approach to building a system dynamics model claiming that, as an organizational intervention process, it can increase insights into the problem, and is intended to enhance team learning, share perceptions of the problem, create alignment, and develop potential solutions to improve system performance.

3.1 Delphi Study

The Delphi technique is a popular group technique for forecasting and helping decision making by facilitating an efficient group communication process (Landeta, 2006). It is well suited as a research instrument when there is incomplete knowledge of a problem or phenomenon (Skulmoski *et al*., 2007). Linstone and Turoff (1975) propose the following classic definition of the Delphi approach in that ‘Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem’.

To achieve ‘structured communication’, it is important to obtain some feedback of the individual contributions to information and knowledge, assess the group judgment or view, provide opportunities for individuals to revise their views, and provide some degree of anonymity for the individual responses (Linstone & Turoff, 1975). According to Linstone & Turoff (1975), the Delphi technique is most suitable when the research problem does not lend itself to precise analytical techniques, but can benefit from subjective judgments on a collective basis, time, and cost - making frequent group meetings infeasible while the heterogeneity of the participants must be preserved to assure the validity of the results.

Delphi researchers apply the method in many fields, such as economics, management, social sciences and natural sciences. For construction engineering and management research field, Delphi has been employed to study construction risks, identify differences in perceptions of construction process quality and define pairwise comparisons for input into the analytic hierarchy process (Hallowell & Gambatese, 2009).

Benefits of Delphi method include: (a) adequate time for thinking and reflection due to the sequential nature of the questionnaires, (b) participants remaining problem-centred and focused because of structured communication (c) use of questionnaires instead of focus group interviews to avoid the possibility of face-to-face debates, (d) undue influence of dominant personalities, and (e) avoidance of group think (Heiko, 2012).

As a group model-building approach for building system dynamics models, the Delphi method was identified in Zavacki (1997) book as a promising alternative to deal with a situation in which it may be inconvenient for group panels working in dispersed places to meet and may have limited time to participate in focus group meetings, which suits for the current study.

In summary, the Delphi method is well suited for idea generation by engaging a group of construction professionals to share their knowledge and mental models of the causal relationships between the CSFs, PSVs and SC from different locations while maintaining anonymity.

3.2 Selection of panel members

Careful selection of the panel is critical for carrying out the Delphi method successfully (Chan *et al*., 2001). Since in-depth knowledge and a sound experience of sustainable building procurement were required, a purposive approach was adopted for selecting the focus group of experts, with the following criteria:

- construction industry professionals with extensive working experience in the construction industry in Hong Kong; and
- construction industry professionals currently or previously involved in the process of sustainable building procurement and management in Hong Kong.

The panel for a Delphi study should be able to represent a wide range of opinions, and involve 10 to 30 participants (Dunn, 2015; Rayens & Hahn, 2000). Thirty-five construction professionals with experience in procuring sustainable buildings were invited to participate via email and telephone, and a total of 21 respondents agreed to participate in the Delphi study.

The 21 panel members, each on behalf of a single company, represent a wide distribution of construction professions (Table 4) and offer diverse views for the Delphi survey.

Table 4: The Delphi study panel

Organization	***Job position***	***Number of panelists***
Main contractor	Executive director	2
	Chief engineer	1
	Senior project manager	1
Public developer	Managing director	1
	Procurement manager	1
Private developer	Senior project manager	2
Consultant	Senior sustainability consultant	1
	Designer	1
Subcontractor	Procurement manager	1
	Senior project manager	3
Supplier	Managing director	1
Facility manager	Senior assets manager	1
Academics	Assistant professor	1
	Honorary professor	1
	Adjunct associate professor	1
Non-governmental organization	Research fellow	2

3.3 First round Delphi study

Based on the literature review and discussions with construction professionals, the first questionnaire contained 33 propositions (Table 5) from hypotheses concerning the potential relationships between CSFs, PSVs, and SC. The underlying hypotheses of these propositions were as follows: First, the CSFs will influence the success level of SC in a way that the better the CSFs, the higher the success level of SC; conversely, the worse the CSFs, the lower the success level of SC. Second, some of the PSVs may relate to CSFs while some may not; in addition, some CSFs may not relate to any PSVs. Figure 1 shows the preliminary causal-loop diagram which includes the 33 propositions.

Table 5: Propositions of potential relationships between CSFs, PSVs and SC

Proposition	***Content***
Proposition 1a	CSF-9 “top management commitment and support” and CSF-29 “project environment” lead to CSF-11 “sustainable strategic planning”, which leads to CSF-5 “market planning / business case for sustainability” which, together with CSF-7 “competent project manager” and CSF-8 “competent team members” lead to CSF-1 “clear understanding of sustainable objectives”
Proposition 1b	CSF-1 “clear understanding of sustainable objectives” leads to CSF-2 “alignment of team members’ goals and project goals”, which leads to

	CSF-26 “effective stakeholder benefits management and realization process”. CSF-26 “effective stakeholder benefits management and realization process” contributes to SV-5 “success level of participants’ satisfaction”
Proposition 2	CSF-10 “sufficient knowledge / expertise for sustainable building” increases CSF-7 “competent project manager” and CSF-8 “competent team members”, which in turns increases CSF-10 “sufficient knowledge / expertise for sustainable building”
Proposition 3	PSV-4 “level of flexibility”, PSV-14 “process length”, PSV-12 “process familiarity”, PSV-13 “process complexity”, and PSV-7 “allocated responsibility for clients” relate to CSF-29 “project environment” and PSV-18 “management requirement for clients”
Proposition 4	PSV-18 “management requirement for clients” relates to CSF-7 “competent project manager”
Proposition 5	PSV-15 “level of competition” relates to PSV-16 “team members competence”, which relates to CSF-8 “competent team members”
Proposition 6	CSF-21 “contract special conditions for incentive & penalties”, CSF-7 “competent project manager” and CSF-8 “competent team members” influence CSF-20 “monitoring / evaluating performance and feedback during project life cycle”, which contributes to SV-1 “success level of traditional project performance (cost, quality, schedule, safety)”, SV-2 “success level of sustainable performance (environmental)”, SV-3 “success level of sustainable performance (social)”, and SV-4 “success level of sustainable performance (economic)”
Proposition 7	PSV-6 “level of control and monitor” relates to CSF-20 “monitoring / evaluating performance and feedback during the project life cycle”
Proposition 8	CSF-21 “contract special conditions for incentive & penalties” influences CSF-24 “innovation”, CSF-12 “project life cycle process planning and control”, CSF-20 “monitoring / evaluating performance and feedback during project life cycle” and CSF-6 “risk management / long-term consideration of precaution and risk”
Proposition 9	PSV-23 “incentives for performance” and PSV- 24 “punishment for performance” relate to CSF-21 “contract special conditions for incentive & penalties”
Proposition 10	CSF-25 “training and education” increases ‘sufficient knowledge / expertise for sustainable building’, which together with CSF-21 “contract special conditions for incentive & penalties” influencing CSF-24 “innovation”
Proposition 11	PSV-19 “innovation” relates to CSF-24 “innovation”
Proposition 12	CSF-25 “training and education” influences CSF-28 “organizational learning / continuing research & development” that, together with CSF-24 “innovation” lead to CSF-27 “continuous value enhancement process”. CSF-27“continuous value enhancement process” contributes to SV-1“success level of traditional project performance (cost, quality, schedule, safety)”, SV-2 “success level of sustainable performance (environmental)”, SV-3 “success level of sustainable performance (social)”, SV-4 ”success level of sustainable performance (economic)” and SV-5 “success level of participants’ satisfaction”
Proposition 13	CSF-2 “alignment of team members’ goals and project goals”, CSF-23 “communicating and coordinating sustainable opportunities and

	objectives across the stakeholder groups" and CSF-22 "sustainable supply chain management" influence CSF-26 "effective stakeholder benefits management and realization process", which contributes to SV-5 "success level of participants' satisfaction"
Proposition 14	PSV-2 "level of coordination" relates to CSF-2 "alignment of team members' goals and project goals"
Proposition 15	CSF-22 "sustainable supply chain management" influences CSF-26 "effective stakeholder benefits management and realization process", CSF-4 "life-cycle costing", and CSF-16 "reliable and available sustainable materials, products or systems"
Proposition 16	PSV-17 "supply chain effectiveness" relates to CSF-22 "sustainable supply chain management"
Proposition 17	CSF-22 "sustainable supply chain management" influences CSF-4 "life-cycle costing", which contributes to SV-4 "success level of sustainable performance (economic)"
Proposition 18	PSV-11 "life cycle consideration" relates to CSF-4 "life-cycle costing"
Proposition 19	CSF-13 "life cycle team integration" influences CSF-23 "communicating and coordinating sustainable opportunities and objectives across the stakeholder groups", CSF-18 "early involvement and cooperation of participants", and CSF-19 "engaging the final and temporary users / involving the community"
Proposition 20	CSF-13 "life cycle team integration", CSF-7 "competent project manager / good leadership", CSF-8 "competent team members", and CSF-21 "contract conditions" influence CSF-12 "project life cycle process planning and control". CSF-12 "project life cycle process planning and control" leads to SV-1 "success level of traditional project performance (cost, quality, schedule, safety)", SV-2 "success level of sustainable performance (environmental)", SV-3 "success level of sustainable performance (social)", and SV-4 "success level of sustainable performance (economic)"
Proposition 21	PSV-1 "level of team cooperation" relates to CSF-23 "communicating and coordinating sustainable opportunities and objectives across the stakeholder groups" and CSF-13 "life cycle team integration"
Proposition 22	PSV-2 "level of coordination", PSV-5 "level of team integration", and PSV-11 "life cycle consideration" relate to CSF-13 "life cycle team integration"
Proposition 23	PSV-3 "flow of communication / information" relates to CSF-23 "communicating and coordinating sustainable opportunities and objectives across the stakeholder groups"
Proposition 24	PSV-6 "level of control and monitoring" relates to CSF-12 "project life cycle process planning and control"
Proposition 25	CSF-18 "early involvement and cooperation of participants", CSF-19 "engaging the final and temporary users / involving the community", and CSF-14 "green timing: early evaluation and adoption of sustainable considerations" influence CSF-17 "integrated sustainable design"
Proposition 26	CSF-17 "integrated sustainable design" contributes to SV-2 "success level of sustainable performance (environmental)", SV-3 "success level of sustainable performance (social)", and SV-4" success level of sustainable performance (economic)"

Proposition 27	CSF-17 “integrated sustainable design” influences CSF-15 “sustainable technical tasks feasibility” that, together with CSF-16 “reliable and available sustainable materials, products or systems” influence CSF-6 “risk management / long-term consideration of precaution and risk”
Proposition 28	PSV-15 “level of competition” relates to CSF-16 “reliable and available sustainable materials, products or systems”
Proposition 29	CSF-6 “risk management / long-term consideration of precaution and risk” influences CSF-3 “budget control”, which contributes to SV-1 “success level of traditional project performance (cost, quality, schedule, safety)”
Proposition 30	CSF-6 “risk management / long-term consideration of precaution and risk” contributes to SV-1 “success level of traditional project performance (cost, quality, schedule, safety)”, SV-2 “success level of sustainable performance (environmental)”, SV-3 “success level of sustainable performance (social)”, and SV-4 “success level of sustainable performance (economic)
Proposition 31	PSV-8 “early commitment of cost and time”, PSV-9 “certainty of cost and time”, and PSV-10 “cost for extra training and management of alternative delivery methods” relate to CSF-3 “budget control”
Proposition 32	PSV-7 “allocated responsibility for clients”, PSV-9 “certainty of cost and time”, PSV-20 “risks”, PSV-21 “conflicts / adversary relationship”, and PSV-22 “claims” relate to CSF-6 “risk management / long-term consideration of precaution and risk”

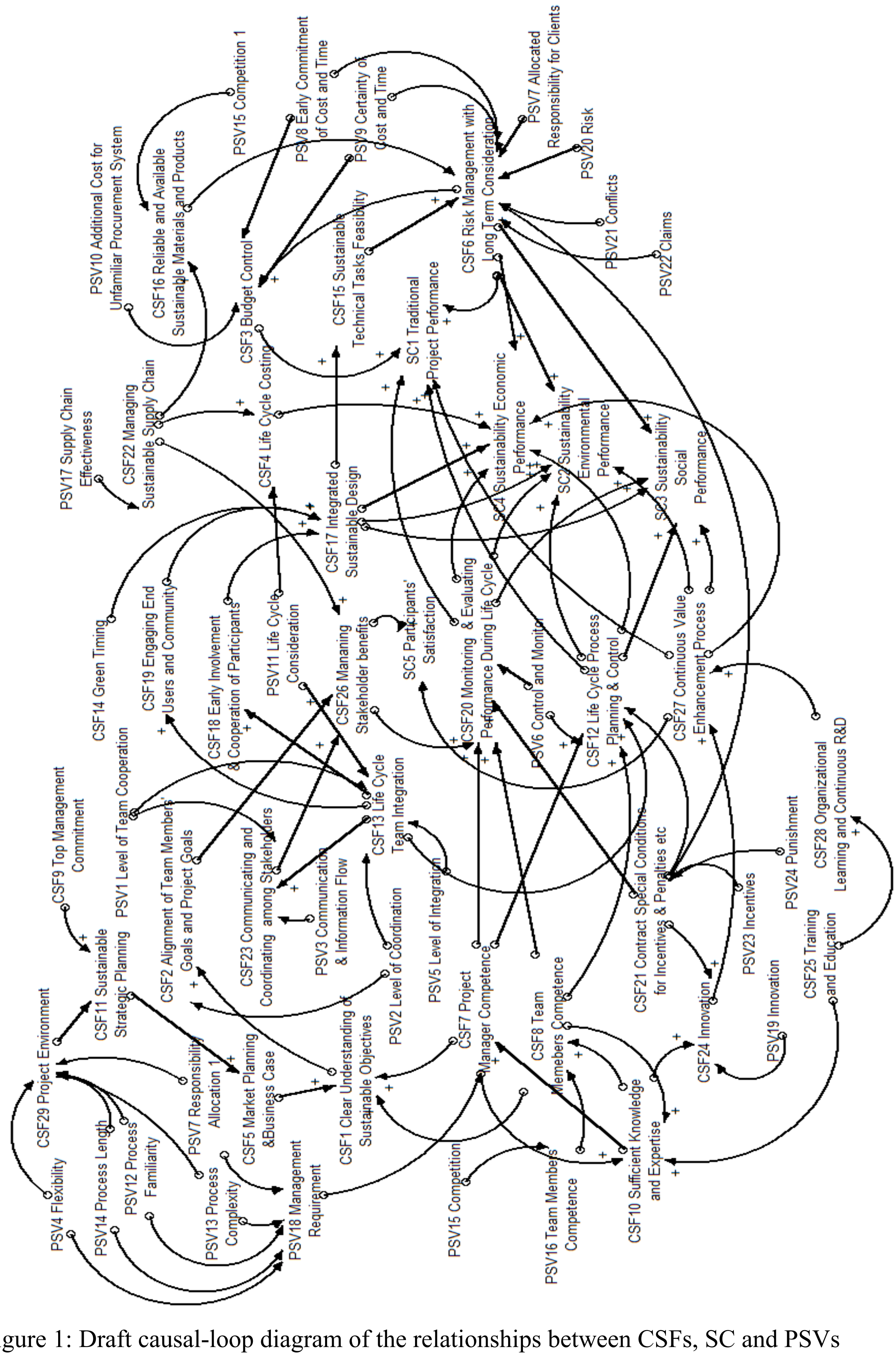

Figure 1: Draft causal-loop diagram of the relationships between CSFs, SC and PSVs

The panel members were asked to consider each proposition and indicate whether they agreed or disagreed with the statement and, if they disagreed, to specify the reason, or add comments to indicate their view. The purpose of the first-round questionnaire is to generate ideas and seek different opinions regarding the proposed relationships. A total of 21 Delphi questionnaires were sent to the panel members. 23 semi-structured interviews were carried out, and 21 interviewees agreed to participate further in the Delphi research. The data from the 21 first-round questionnaires were analysed, and are summarized and presented in Table 6. The percentage of agreement decides the level of consensus, as discussed in the next section.

Table 6: First round Delphi questionnaire results

Proposition	***Agree***	***Disagree***	***Percentage of agreement***	***Percentage of disagreement***
Proposition 1a	18	3	86%	14%
Proposition 1b	20	1	95%	5%
Proposition 2	19	2	90%	10%
Proposition 3	19	2	90%	10%
Proposition 4	21	0	100%	0%
Proposition 5	18	3	86%	14%
Proposition 6	21	0	100%	0%
Proposition 7	19	2	90%	10%
Proposition 8	18	3	86%	14%
Proposition 9	21	0	100%	0%
Proposition 10	16	5	76%	24%
Proposition 11	20	1	95%	5%
Proposition 12	18	3	86%	14%
Proposition 13	21	0	100%	0%
Proposition 14	21	0	100%	0%
Proposition 15	21	0	100%	0%
Proposition 16	21	0	100%	0%
Proposition 17	20	1	95%	5%
Proposition 18	21	0	100%	0%
Proposition 19	18	3	86%	14%
Proposition 20	20	1	95%	5%
Proposition 21	21	0	100%	0%
Proposition 22	21	0	100%	0%
Proposition 23	21	0	100%	0%
Proposition 24	21	0	100%	0%
Proposition 25	21	0	100%	0%
Proposition 26	21	0	100%	0%
Proposition 27	20	1	95%	5%
Proposition 28	20	1	95%	5%
Proposition 29	20	1	95%	5%
Proposition 30	20	1	95%	5%
Proposition 31	21	0	100%	0%
Proposition 32	21	0	100%	0%

Note: Total respondents: 21

3.4 Consensus

Delphi studies usually vary from two to five rounds (Critcher & Gladstone, 1998). This iterated process allows participants to reconsider their opinions in light of the views of other panel members until a consensus is reached or saturation of opinion occurs (Rayens & Hahn, 2000). On the one hand, the goal of the Delphi approach is to seek the most reliable consensus of the panel group (Rowe *et al*., 1991). However, the criterion used to define consensus is subject to interpretation. In one case, it is defined as a percentage higher than the average percentage of the majority opinion, whether this represents agreement or disagreement with a statement (Heiko, 2012). In another case, consensus is defined as having 80% of the subjects' votes fall within two categories on a 7-point scale (Hsu & Sandford, 2007; Ulschak, 1983). On the other hand, some studies consider saturation of opinion to be more important than reaching a consensus.

Heiko (2012) proposes that one of the advantages of a policy Delphi is that the participants are allowed to react to and assess different viewpoints from other panel members who may not share a common vision or underlying set of values. In a study reviewing the measurement of consensus in Delphi studies, claims that 'consensus among the participants may be an outcome of the process, but it is not the primary intention. Rather, all the opposing viewpoints of a central policy issue are gathered'. Landeta and Barrutia (2011) support this view, proposing that Delphi is not concerned with seeking a consensus but rather exploring the reasons behind different opinions.

As Table 6 shows, propositions 4, 6, 9, 13, 14, 15, 16, 18, 21, 22, 23, 24, 25, 31 and 32 obtain 100% agreement, with the remaining propositions all having a minimum of 76% agreement.

3.5 Second round Delphi study

To explore the reasons for the different opinions, the importance of the objections raised by individual experts was analysed and summarized; the feedback from the first round was included in the second-round questionnaire to achieve saturation of opinion. The second-round questionnaire consisted of feedback from the first round, the original propositions, and alternative propositions, accompanied with a summary of reasons. Propositions with consensus in the first round Delphi study are not included in the second round study. Total twelve propositions with different opinions by panel members are analysed and summarized to generate alternative propositions. The panellists were then asked to reconsider both the original and alternative propositions in the light of other panellists' responses and to supply further opinions.

Twenty-one questionnaires were emailed to the panel members. After one week, a reminder letter sent to all the experts who had not returned the questionnaire and a final reminder letter was sent two weeks later. Finally, 19 responses were obtained.

4. Delphi Results and Analysis

Whether a proposition has reached a consensus is determined by the average percent of majority opinions (APMO) cut-off rate. To reach consensus, a statement must achieve a percentage of 'agree' or 'disagree' that is higher than the APMO cut-off rate (Cottam *et al.*, 2004). The APMO cut-off rate is considered as a 'certain level of agreement', which leaves broad freedom of analysis and interpretation for the Delphi facilitator (Heiko, 2012)[1]. The APMO consensus measure defined by (Kapoor, 1987) is adopted here, with:

$$APMO = \frac{Majority\ Agreements + Majority\ Disagreement}{Total\ number\ of\ opinions\ expressed} \times 100\%$$

where 'Majority' is defined as a percentage over 50% (Cottam *et al.*, 2004). To calculate APMO, the number of agreements and disagreements first need to be converted into percentages per proposition to decide whether it is over 50%. Then, the total number of majority agreements and majority disagreements are added together and divided by the total number of opinions expressed.

To calculate APMO, the values in Table 7 were broken down as follows:

- Number of majority opinions agreeing = 374
- Number of majority opinions disagreeing = 0

[1] More examples of using the APMO cut-off rate can be found in the Delphi studies of Makukha & Gray (2004) and Saldanha & Gray (2002).

- Total number of majority opinions = 374
- Total number of opinions expressed = 374 + 109 = 456
- Therefore, average percent of majority opinions = 374 ÷ 456 = 76%

Table 7 shows the results of second-round Delphi study based on the APMO cut-off rate of 76%.

Table 7: Results of second-round Delphi questionnaire

Propositions	*Agreed*	*Disagreed*	*Percentage of agreement*	*Percentage of disagreement*	*Consensus*
Proposition1a					
Original	14	5	74%	26%	
Alternative	15	4	79%	21%	Reach
Proposition1b					
Original	13	6	68%	32%	
Alternative	18	1	95%	5%	Reach
Proposition2					
Original	16	3	84%	16%	Reach
Alternative	10	9	53%	47%	
Proposition3					
Original	13	6	68%	32%	
Alternative	16	3	84%	16%	Reach
Proposition5					
Original	12	7	63%	37%	
Alternative	14	5	74%	26%	
Proposition8					
Original	13	6	68%	32%	
Alternative	17	2	89%	11%	Reach
Proposition10					
Original	15	4	79%	21%	Reach
Alternative	11	8	58%	42%	
Proposition12					
Original	13	6	68%	32%	
Alternative	15	4	79%	21%	Reach
Proposition17					
Original	14	5	74%	26%	
Alternative	18	1	95%	5%	Reach
Proposition19					
Original	13	6	68%	32%	
Alternative	17	2	89%	11%	Reach

Proposition27					
Original	13	6	68%	32%	
Alternative	17	2	89%	11%	Reach
Proposition28					
Original	14	5	74%	26%	
Alternative	16	3	84%	16%	Reach

Table 7 shows neither result of Proposition 5 surpasses the APMO rate, which means that consensus was not achieved in the second round. Based on the first-round Delphi result, the original proposition had 86% agreement, so the original proposition was adopted. Proposition 2 and 10 have reached consensus of their original versions, while the other nine propositions reach consensus of the alternative versions. The final propositions of these nine alternative propositions are summarized in Table 8.

Table 8: Nine alternative propositions reach consensus

Proposition	***Content***
Proposition 1a	Alternative: CSF 29 influences CSF9, CSF9 leads to CSF11, which leads to CSF5, then together with CSF7 and CSF8 lead to CSF1
Proposition 1b	Alternative: CSF1 leads to CSF12, CSF20, and CSF2. CSF2 leads to CSF26. CSF26 contributes to SC5
Proposition 3	Alternative: PSV4, PSV14, PSV12, PSV13, and PSV7 relate to PSV18
Proposition 8	Alternative: CSF21 influences CSF2, CSF24, CSF12, CSF20 and CSF6
Proposition 12	Alternative: CSF25 influences CSF28 and CSF24, which both lead to CSF27.CSF27 contributes to SC1, SC2, SC3, SC4 and SC5
Proposition 17	Alternative: CSF4 influences CSF22, which contributes to SC4
Proposition 19	Alternative: CSF13 influences CSF23, CSF18 and CSF19 which should be both way
Proposition 27	Alternative: CSF17 influences CSF15, which together with CSF16 influence CSF6. CSF6 in turn influences CSF 15 and CSF6
Proposition 28	Alternative: PSV15 relates to CSF16 and CSF3.Suggestion: Competition should also relate to Budget Control

After two rounds of Delphi study, not only was a consensus reached, but also the reasons for different opinions were explored and thus the goal of seeking experts' opinions regarding the causal relationships between variables was reached – making just two Delphi rounds sufficient. Figure 2 shows the final causal-loop diagram of the relationships between the CSFs, SC, and PSVs based on the outcome of the two Delphi rounds.

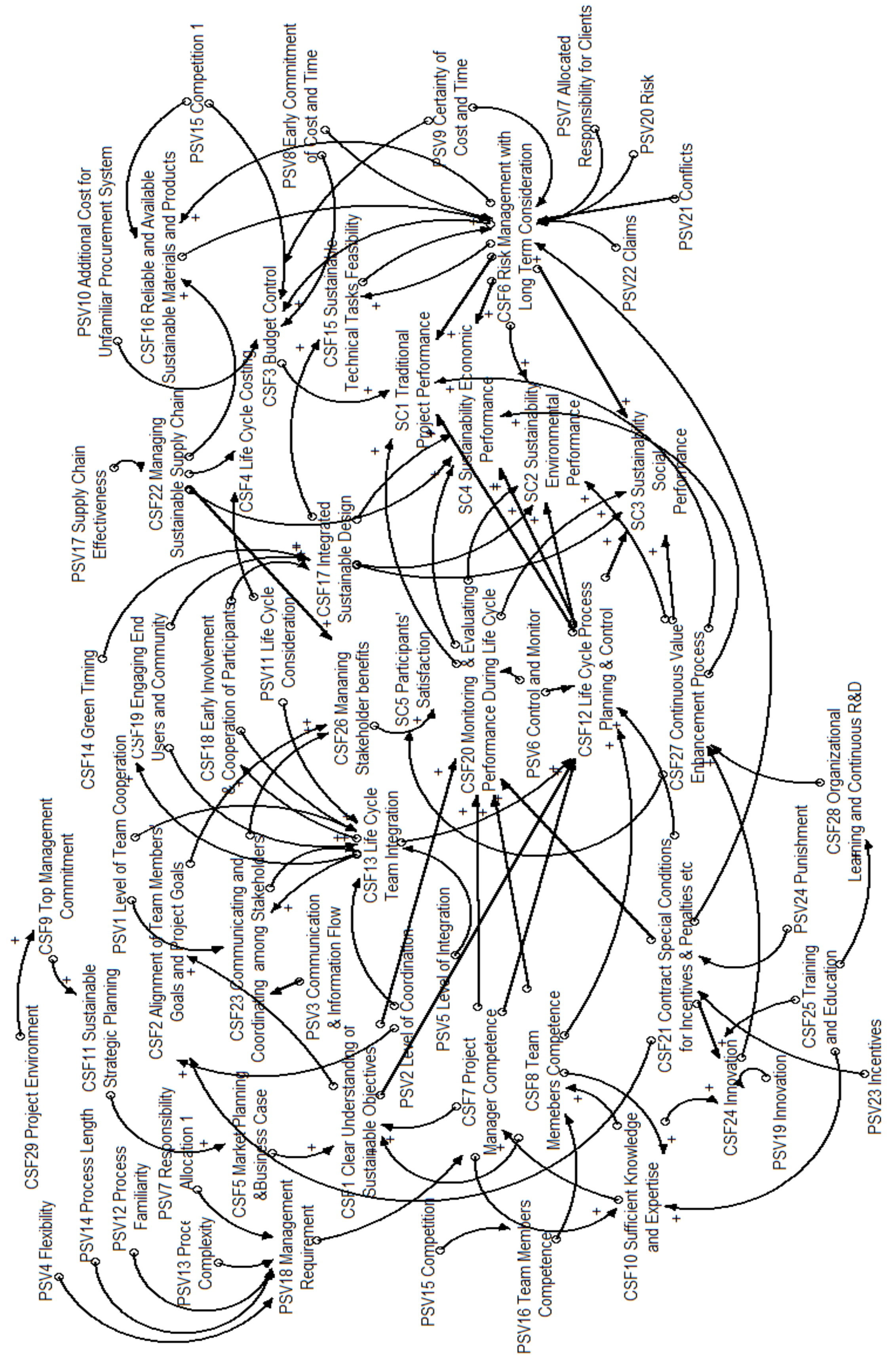

Figure 2: Causal-loop diagram of the relationships between CSFs, SC and PSVs

4 Discussion

While the CSF and SC approach is widely accepted by project managers as a useful tool to better control and measure project success, researchers have also pointed out several shortcomings of this approach (Belassi & Tukel, 1996; Fortune & White, 2006; Larsen & Myers, 1999; Nandhakumar, 1996). The first shortcoming is the lack of identification of the interrelationships between CSFs. CSFs are usually treated as independent factors, and the most common technique is to identify a single list of CSFs without considering the interrelationships between them. Indeed, Fortune & White (2006) indicated that the CSF approach does not provide a mechanism to examine the interrelationships between the factors, which are as important for the project success as the individual factors. The second shortcoming relates to the timespan. The CSF approach tends to view implementation as a static process instead of a dynamic one and ignores the potential for a factor to have varying levels of importance at different stages of the implementation process (Fortune & White, 2006; Larsen & Myers, 1999). The third shortcoming has to do with the relationships between CSFs and SC. There have been few studies linking project SC and CSFs to clarify how CSFs will determine different aspects of success (Westerveld, 2003).

Therefore, in this research, the causal-effect relationships between CSFs and SC were identified, as well as the relationships between PSVs and CSFs, to generate a systematic view of these relationships by two Delphi rounds. In the absence of prior research, Delphi as a group model-building approach is considered as appropriate for capturing the knowledge of construction professionals to build a causal loop diagram of sustainable building success by facilitating efficient group communication. The final causal-loop diagrams were built based on these causal-effect relationships. This contributes further to the understanding of how changes to procurement systems can influence sustainable building success".

Moreover, the results showed that some CSFs were not related to the PSVs including CSF5 “market planning / business case for sustainability as sustainable objectives”, CSF9 “top management commitment and support”, CSF11 “sustainable strategic planning”, CSF14 “green timing: early evaluation and adoption of sustainability considerations”, CSF25 “training and education” and CSF 28 “organizational learning / continuing research and development”.

Although these CSFs do not relate to procurement systems, they are critical for project success too; thus, when procuring sustainable buildings, these CSFs should also be considered.

5 Conclusion

To link procurement system with sustainable building success, the Delphi method, as one of the group model-building approaches, was chosen in this study to capture the knowledge of construction professionals to identify the causal-effect relationships between PSVs, CSFs, and SC of sustainable building success. A panel of experts with relevant experience in procuring sustainable building projects was invited to participate in the Delphi study. Two rounds of questionnaires were carried out. Semi-structured interviews were conducted during the first round of Delphi study to solicit experts' opinions regarding the main differences between sustainable building and conventional building procurement, thereby suggesting suitable procurement method and improvement strategies for an optimal sustainable building procurement system. The main suggestions included having more incentive or competition for innovation, more training and education for subcontractors, involving facility managers earlier and improving green supply chain management.

The average percent of majority opinions (APMO) cut-off rate is adopted as a consensus measure. As the consensus was reached after two rounds, it can be taken that two Delphi rounds were sufficient. The reasons for differences in opinions were also explored; therefore, the goal of seeking experts' opinions regarding the causal relationships between variables can be considered fulfilled. A final causal-loop diagram of the relationships between CSFs, SC, and PSVs was established, which serves as a system dynamics model structure and lays the foundation for future system dynamics model building for sustainable building success. In the future study, a generic system dynamics model for sustainable building success will be designed to simulate the influence of different procurement systems on sustainable building success. Extensive simulations can be carried out for five typical procurement systems—separated procurement system using Design Bid Build (DBB), integrated procurement system using Design Build (DB), management orientated procurement system using Construction Management (CM), discretionary procurement system using Partnering and discretionary procurement system using Integrated Project Delivery (IPD) to determine their weaknesses in procuring sustainable buildings. Policies based on the weakness of the different procurement systems then can be proposed and tested in the SD model to improve the success level of sustainable building

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