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Modelling stakeholder-associated risk networks in green building projects

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Abstract

This research aims to model the interactive networks of the risks associated with different stakeholders in green building projects and to gain an understanding of the key risk networks. Case studies of green star accredited office building projects were undertaken in China and Australia. Case data were collected through focused group workshops, face-to-face interviews and desktop studies, and analysed by using social network analysis methods. The results show that while reputation risk is important in both countries, the ethical risk of 'assessment experience and fairness' has been highlighted as crucial in the Chinese context. The results further show that government plays an important role in improving the societies' knowledge and awareness on green technology uptake in China. The social network analysis method in this research improves the effectiveness and accuracy of stakeholder and risk analysis by demystifying the social complexity which is usually overlooked in traditional linear risk impact analysis.

Keywords: Green building project; Risk; Stakeholder; Social network analysis

1. Introduction

Building construction accounts for 40% of global raw materials consumption (U.S. Green Building Council, 2014), and in operation they consume 32% of the world's renewable and non-renewable resources, 12% of available water, 40% of energy, and produce 40% of CO_2 emissions (GBCA — Green Building Council of Australia, 2013). The urgent imperative these figures present to policy makers has led to a myriad of regulatory attempts to drive green building project over recent decades. While sustainability awareness has grown at a steady rate, the uptake of green buildings has been slower than expected (Mukherjee and Muga, 2010). The implementation of green building project development encounters lots of risks due to the traditional conservative and reactive behaviour of parties/stakeholders in the built environment (Kibert et al., 2000; Bullen and Love, 2010), and the transient relationship of project teams and stakeholders (Larsson and Cole, 2001). According to the 5th Edition of the PMBOK Guide (2013), project risk is "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, or quality". Various risks, which range from technical challenges, affordability, lack of legal regulations and incentives, to knowledge gaps and unpredictable behavioural patterns, would possibly arise from the complex social reality in the shift towards green buildings (Lu et al., 2013). As stated by Prum and Del Percio (2009), risk sources should be analysed and each stakeholder in a green building project should assess their risks and take measures to mitigate the possible risk impacts. Stakeholder and risk analyses are important not only for developing a comprehensive risk list and recognising the causes of risks, but also contributing to effective decision-making and efficient communication in green building project management.

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With the rapid economic and urbanization development, the construction industry has become a pillar of the Chinese national economy. The Chinese government proposed to develop 10 million new affordable green buildings every year in the next 10 years (Guo and Su, 2011). All buildings in China, including new development and existing buildings, are required to achieve a minimum of 50% energy consumption reduction compared to 1980s (MOHURD, 2011). This is a massive undertaking, which also presents great opportunities for overseas companies, since China is still in its infancy in green building development and management (Wang, 2010). Australia in the Asian Century White Paper clearly emphasised the vital importance to identify the actions that Australian business sector should take to seize the opportunities and meet the challenges arising from China which is already unfolding.

Meanwhile, the KPMG survey in 2014 has shown that the Chinese State Owned Enterprise investment in the Australian Real Estate market has increased steadily in recent years: For example, in Sydney, China Greenland Group has invested over AUD 1.5 billion, followed by China Wanda Group with AUD 425 million, Shimao Property with AUD 390 million and Beijing Capital Development Holdings with over AUD 330 million. More Chinese firms are looking for investment and brand promotion opportunities in the green building sector as green has become an industry imperative both in Australia and China.

However working in different business environments where the institutional and economic developments, as well as the political and sociocultural settings are quite different from the host countries is not an easy task (Kytle and Ruggie, 2005). A multinational firm operating in an environment fraught should fully understand the risk exposures to maintain profit, market share as well as long-term stability (Ashley and Bonner, 1987). Most of the risks are associated with project stakeholders including the government and supply chain members, because of different claims, interests, and culture backgrounds (Zhang, 2011). This requires an in-depth understanding of local construction project management mechanism, relevant policies, and project risks.

The central issue is “what the differences and similarities of risks are in green building project development in China and Australia”. Even so, how to identify the critical risks and mitigate them by engaging appropriate stakeholders is more important for the green developers to understand. This study aims to answer abovementioned two questions by analysing case projects. While the study is not intended to be statistically generalizable across the industry, it unveils a deeper understanding of the complexity of the green building project environment. A social network analysis (SNA) method, which is dedicated to demystify complex social environment, was used to assist the case study analysis process. This paper starts with discussions of four research paradigms on risk and stakeholder analysis; then the social network analysis (SNA) method is explained. The results of the two case projects are compared and explained to assist researchers' and industry practitioners' understanding of project stakeholder associated risk networks.

2. Literature review and theoretical underpinning

A literature review was conducted to identify and analyse the research paradigms regarding risk and stakeholder analyses in green buildings. To start, a database search was carried out by using Science Direct, Scopus, Google scholar and Ebsco Host searching engines, which are the popular databases in the construction field. The complete search codes are listed as follows:

> TITLE-ABS-KEY (sustainable building) OR TITLE-ABS-KEY (green building) AND TITLE-ABS-KEY (risk) OR TITLE-ABS-KEY (stakeholder).

An initial review of the search results was carried out by reading the abstracts and skimming the contents of the articles in order to filter the papers relevant to the research aim. In total, 40 research papers were reviewed in detail to identify the ways of analysing the impact of risks and stakeholders on green building development in these studies. Four research paradigms are inducted as indicated in Table 1. The paradigms and the interactions in and between project stakeholders as well as risks are illustrated in Fig. 1 (a, b, c and d).

2.1. Paradigm (a): linear impact analysis

The first research paradigm is named as linear impact analysis because the publications in this group analysed the impact of project risks or stakeholders separately on green building projects. Three sub-groups are identified:

Sub-(a1) project risks: The five papers mainly focused on a type of risks to analyse organizational performance in green buildings. Rajendran et al. (2009) and Dewlaney et al. (2011) interviewed contractors and designers regarding the safety performance of green and non-green buildings to test the presence of difference in recordable incident rates and lost time case rates between the two project types. Bartlett and Howard (2000), Robichaud and Anantatmula (2011) and Lu et al. (2013) emphasised on cost risks, analysed the cost/benefit of green building development, and proposed strategies to deliver a green building project within acceptable cost constraints and enhanced economic value. These studies provided valuable information/evidence for the industry to integrate green concept into business operation. However, limitations are inevitably related to onefold perspective investigation, which presented facts, but neither analysed the cause-effect relationships existed in system complexity, nor integrated the project stakeholders for performance improvement.

Sub-(a2) project stakeholders: It is not surprising that quite a few papers investigated project stakeholders' roles in green building project development with the boom of project stakeholder analysis and engagement research in the last decade. Researchers separated project stakeholders into two groups: the first group are those who are leading the green initiative, such as government (Circo, 2008; Henry and Paris, 2009; Theaker and Cole, 2001), contractor/builder (Gunhan,

Table 1
Summary of stakeholder-risk research paradigms in green building projects.

Paradigms	Descriptions	Publications	Numbers
Paradigm (a): linear impact analysis	Sub-(a1): risk and green building performance	Bartlett and Howard (2000); Rajendran et al. (2009); Robichaud and Anantatmula (2011); Dewlaney et al. (2011); Lu et al. (2013)	5
	Sub-(a2): stakeholder and green initiative	Theaker and Cole (2001); Riley et al. (2003); Bilec and Ries (2007); Rivera-Camino (2007); Circo (2008); Henry and Paris (2009); Cronin et al. (2011); Gunhan (2012); Valdes-Vasquez and Klotz (2012); Liu et al. (2013)	10
	Sub-(a3): stakeholder-identified risk and green building	Ahn and Pearce (2007); Cooke et al. (2007); Qi et al. (2010); Lam et al. (2010); Wong et al. (2010); Li et al. (2011); Zhang et al. (2012a); Love et al. (2012); Zuo et al. (2012); Shi et al. (2013)	10
Paradigm (b): semi-linear impact analysis	Stakeholder-associated risk and green building	Kearins and Pavlovich (2002); Williams and Dair (2007); Hoffman and Henn (2009); Prum and Percio (2009)	4
Paradigm (c): network impact analysis	Sub-(c1): Stakeholder interrelations in green building	Van Bueren and Priemus (2002); Dammann and Elle (2006); Lorenz et al. (2008);	3
	Sub-(c2): Risk interactions in construction projects	Ren (1994); Zhi (1995); Chapman (2001); Glickman and Khamooshi (2005); Allan and Yin (2011); Fang et al. (2012); Yildiz et al. (2012)	7
Paradigm (d): SNA-based risk-stakeholder interaction and management model		Yang and Zou (2014)	1

2012; Riley et al., 2003), and consultant (Bilec and Ries, 2007); while the second group is external project stakeholders (Cronin et al., 2011; Rivera-Camino, 2007). Two recent studies (Liu et al., 2013; Valdes-Vasquez and Klotz, 2012) particularly emphasised on the significance of collaborative working and project stakeholder engagement for green practices. These studies clarified the undeniable responsibility of project stakeholders to foster and create a more sustainable local and global construction industry/community. However, the interactions of project stakeholders were not clearly analysed. This was criticized by researchers who have 'network' perception. Pryke (2012) believed a building construction project takes place in a non-linear, complex, iterative and interactive environment, in which the impact of project stakeholders cannot be easily identified with a dyadic-discussion. He pointed out that analysis of the impact of project stakeholders acting through 'the network of relationships' is important, especially as it can differentiate the stakeholders' importance.

Sub-(a3) stakeholder-identified project risks: This group of studies covered green practices in several regions (including Australia, China, Hong Kong, Singapore, UK, and US), and analysed risks from project stakeholders' perspective (as indicated in Fig. 1(a) with dotted arrow). These studies mainly conducted questionnaire surveys (Ahn and Pearce, 2007; Lam et al., 2010; Li et al., 2011; Qi et al., 2010; Shi et al., 2013; Wong et al., 2010; Zhang et al., 2012a), interview (Cooke et al., 2007) or case studies (Love et al., 2012; Yang and Zou, 2013) to collect industry practitioners' opinions regarding green-related project risks. The project stakeholders involved were mainly project team members including contractors, consultants, and developer/owner. Although these studies provided useful references for future green building project risk management, limitations do exist: (1) most risks were not clearly designated to the associated stakeholders, particularly the external ones. This increased the difficulties in practice to develop corresponding risk responses and communication strategies to mitigate project risks. (2) The impact of each of the identified risks was basically calculated independently with number of counts (e.g. the times interviewees mentioned the risks). Neglecting the sequences of risks' cause-effect relationship is not a realistic approach (Eybpoosh et al., 2011) as the occurrence of one risk may "trigger one or more other risks with potential propagation phenomena like reaction chains, amplification chains or loops" (Fang et al., 2012).

To sum up the above points, the studies in Paradigm (a) view risks and stakeholders separately. They did not consider the associations between project risks and project stakeholders, the interrelation between risks and the subsequent influence of risks.

2.2. Paradigm (b): semi-linear impact analysis

This research paradigm acknowledged the associated relationship between project stakeholders and risks. A desktop analysis was conducted by Kearins and Pavlovich (2002) to describe the risks related with broad range of stakeholders in Sydney's Olympics projects. Williams and Dair (2007) identified four stakeholder groups in a project lifecycle and used case studies to analyse the risks related to each group. Hoffman and Henn (2009) investigated the social and psychological barriers on individual, organizational and institutional levels in green building projects. Prum and Percio (2009) proposed risk mitigation strategies to project stakeholders along green building supply chain. Comparing to Paradigm (a), this group of studies codified specific knowledge regarding 'who has what risks', which can facilitate the practitioners to develop detailed and actionable plans to engage project stakeholders and mitigate project risks. Similarities between Paradigms (a) and (b) are that the interrelationships between risks were not considered. This is the major difference from the network perspective and why this paradigm is named as semi-linear impact analysis.

2.3. Paradigm (c): network impact analysis

The network analysis paradigm emphasises on the concepts of interdependence and complexity in a project environment. Rather than prioritising project risks/stakeholders independently essentially with respect to their attributes (impact and probability for risks; power, legitimacy, and urgency for project stakeholders), this group of studies rethinks project complexity from a conceptual level by analysing the interfaces between individual risks and stakeholders, and reflecting the roles of each actors (i.e. risks and stakeholder) in the whole project systems. The interactions among project risks and stakeholders are modelled and represented in terms of a project risk-stakeholder network. Two subgroups studying on stakeholders and risks respectively are summarised as follows:

Sub-(c1) stakeholder interrelations in green building project: Three studies have mapped the interrelations of green-related project stakeholders in the construction industry. Van Bueren and Priemus (2002) presented the dependency relationships between the players in decision making processes of built environment (re)development. Lorenz et al. (2008) included more external project stakeholders, such as researchers and educators, in a supportive network for sustainable construction implementation. Damman and Elle (2006) symbolized the conflicts and areas of consensus between the different technological frames (groups of stakeholders) in green building project. Although these studies presented the project stakeholder network perspective, the interrelation analyses are qualitative oriented, which cannot indicate the impact levels of each stakeholder and relationship in the network as proposed by Rowley in 1997, who considered one approach for understanding project stakeholder interdependent interactions is by using concepts from social network analysis to examine characteristics of entire stakeholder network structures and their impact on project's performance, rather than individual stakeholder influences. Rowley (1997) examined how a stakeholder network structure, namely network density and the project stakeholders' centrality, can impact the focal project's degree of resistance to stakeholder pressures. With the increasing popularity of application of network theories in construction research (Pryke, 2012; Yang and Shen, 2015), the stakeholder network in green building project should be further explored by using simulative and quantitative network analysis methods.

Sub-(c2) risk interactions in building projects: The identified seven papers recognised the interdependency of risks in building projects; however, none applied this perspective in green buildings despite there are a number of risks in this type of projects. This is presented with a dotted arrow in Fig. 1(c2) to indicate the lack of studies on risk interactions in green building projects. Furthermore, the studies are either conducted qualitative analysis only (e.g. Yildiz et al., 2012), or have relatively small number (around ten) of risks in the network (e.g. Ren, 1994) which underrated the project

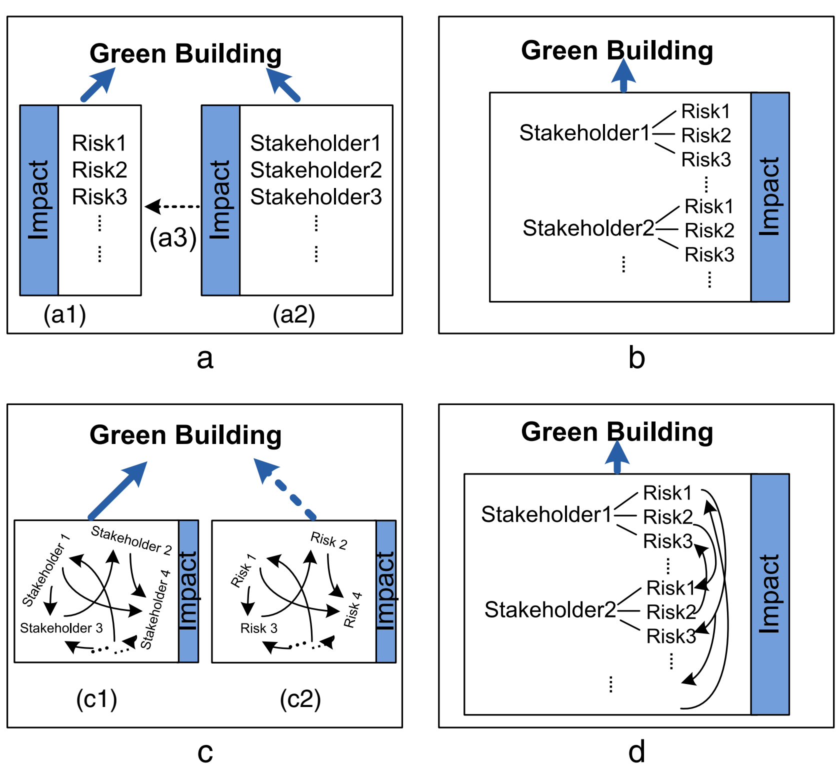


Fig. 1. The four stakeholder-risk research paradigms in green building projects.

complexity. Only one study (by Fang et al., 2012) proposed a systematic methodology for network theory-based analysis of risk interactions. Three steps were introduced for the process of developing the project risk network structure; several topological indicators were presented as well with mathematical equations. The application of the proposed approach was illustrated by using a case study of a tramway infrastructure project. This study demonstrated the importance of project risk network analysis, complements the classical project risk analysis, and considered stakeholders in the risk network. However, the research was limited to the binary structure of risk relationship with 1 representing existence of impact and 0 means no impact, but did not address the concerns about the probability and consequence of the impact between risks.

2.4. Paradigm (d): stakeholder-associated risk network analysis model

Yang and Zou (2014) developed a stakeholder-associated risk network analysis model by combining the classical risk management process and Social Network method. Rather than focusing on risks'/stakeholders' attributes, this model views characteristics and interdependencies of risks as arising out of the social structural environment in order to better understand the decision-making process. While Paradigms (a), (b) and (c) have recognised the importance of analysing risks and stakeholders in green building project development, there is lack of investigations on the interdependence between risks and mitigation strategies with proper stakeholder engagement. The previous studies did not provide a holistic view for green building developers to understand the complex project environment, nor analysed the social complexity with a scientific methodology. Paradigm (d) differentiates itself from the other three paradigms from four standpoints. First, the risk sources in green building project are analysed with the identification of associated project stakeholders. Second, the stakeholder-associated risks in the project are viewed as interdependent rather than independent, autonomous units. Third, the impact of the risks is quantitatively calculated. Fourth, the interfaces of different project stakeholder groups are analysed. By identifying the directions of influence in the entire risk network, project managers can conduct systemic analysis, communicate with internal and external project stakeholders about the influential risks, and develop risk response or mitigation strategies accordingly. In essence, the application of the social network perspective to investigate the patterns of stakeholder-associated risk networks as well as the forces which shape these patterns, and unlocks risk interactions inside the project's whole relationship network. All of these are intended to provide a rationale for stakeholder communication and risk response strategies and facilitate the decision-making process in green building project management. The next section will introduce the social network method and how it can be used to analyse stakeholder-associated risks.

3. Social network analysis method

The social network theory views a project as a systems environment, which is joined by various relationships. The purpose of network analysis is to examine how relationship structures impact behaviours, and this theory is concerned with the "structure and patterning" of these relationships over time and seeks to identify both their causes and effects (Wasserman and Galaskiewicz, 1994; John, 2000). Social network theory has been used in many areas. For example, Hagedoorn (2002) used it on strategic alliances, Loosemore (1998) used social network analysis to investigate interpersonal relationships under crisis conditions, Ho et al. (2004) applied social network theory gauging the effect of different communication means towards the ethical attitudes of construction project personnel, and Pryke (2004) applied it to analyse coalitions.

The network perspective differs in fundamental ways from standard social and behavioural science research and methods (Wasserman and Faust, 1994). In social network analysis, the risks can be analysed by the patterns or structures of ties among them and the stakeholders associated with them. Project managers can study the influence of this structure on individual risks and stakeholders within this network system (Loosemore, 1998). There are five major steps to analyse stakeholder-associated risks (Yang and Zou, 2014):

1. Identification of project stakeholders and their risks
2. Yang and Zou (2014) identified eight risk categories and fifteen stakeholder groups in green project development based on extensive literature review. Risk categories include: time (risks related to time management), cost (risks related to cost increase and return), quality and technical issues (risks related to the product quality, including technical barriers, material availability and work quality), organization and management (risks related to organizational structure, knowledge, and relationship management), policy and standards (risks related to regulations and standards), safety (risks related to occupational health and safety), ethics and reputation (risks related to social and ethical issues), and environment (risks related to environment protection). The project stakeholder groups include: client, consultant, contractor, subcontractor/supplier, end user, financial organization, government, environmental organization, professional association, media, public, labour union, assessor/certifier, researcher/educator, and others. The outcomes from this step are a complete list of stakeholders, and the risks associated with them. All of the stakeholder-associated risks will be numerically coded with S#R*, in which # indicates the number of associated stakeholder and * is the risk number related to this stakeholder. Determination of stakeholder-associated risk interrelations

The Design Structure Matrix Method proposed by Steward (1981) is adopted in this study to facilitate the link identification process. This approach has been widely recognised by researchers as an efficient tool to depict and assess interrelations among units using a matrix format (Danilovic and Browning, 2007). This step defines the links in the project risk network, which represent the impact between two nodes. The link is defined by the impact from one risk to the other, and the likelihood of the interaction between risks. The interactions are assessed by measuring the impact and likelihood with a five-point scale, where "5" represents the highest degree and "1" indicates the lowest. Focus groups, semi-structured interviews and questionnaire survey with project team and stakeholders can be conducted to determine the interaction between risks.

3. Visualisation of project risk network

In the network, different shapes of the nodes represent risks associated with different stakeholders, while different colours of the nodes represent different risk categories. The arrows with values in the network are the interrelations among the risks, of which the thicknesses indicate the degrees of influence degrees (i.e. impact * likelihoods) of the interrelations.

Table 2
Explanation of measures in social network method.

Types	Measures	Explanation
Network measures	Density	It refers to the proportion of actual links presenting within a network to the maximum number of potential links if all network actors are interconnected with each other (Chinowsky et al., 2008). Network density ranges between 0 and 1. The higher the density, the more connections are in the network.
	Cohesion	It indicates network complexity by considering the reachability of nodes, where *reachability* is defined as the number of ties to approach nodes in a network according to the geodesic distance (Parise, 2007). The higher the cohesion, the closer the risks are connected in the network.
Node/link measures	Degree of nodes	It provides an indication of the immediate connectivity characteristic of a risk. 'In-degree' refers to incoming relations (impacted by) and 'out-degree' to outcoming relations (impact to) (Loosemore, 1998). The degree of each node is the weight sum of links which are incident from the node.
	Betweenness centrality	It calculates the occurrence in which a specific node/link is situated between other pairs of nodes/links on the basis of the shortest path (Newman, 2001).
	Status centrality	It computes the relative influence of a node within a network by measuring the number of the immediate neighbours (first degree nodes) and also all other nodes in the network that connect to the node under consideration through these immediate neighbours (Katz, 1953).
	Brokerage	It describes the role and capability of a particular node in bridging different subgroups within a network under a selected partition vector. In this study, the subgroups/partitions in the stakeholder-associated risk network are the various stakeholder groups and risk categories.
Partition measures	Immediate interface	It measures the interactions between various stakeholder/issue categories from a local perspective, by counting the number of direct connections between every pair of stakeholder/issue groups (Fang et al., 2012).
	Global interface	It investigates the interactions between different stakeholder/issue categories from a global point of view, by calculating the number of both direct and indirect connections between every pairs of stakeholder/issue groups (Fang et al., 2012).

4. Decipherment of project risk network

Three types of measures are useful for network analysis: Network measures, Node/link measures, and Partition measures. Table 2 explains the meanings of each measure.

5. Identification and simulation of project risk mitigation actions

The critical risks and interrelations are identified based on the results in the last step. The critical risks will be removed from the network, and the network measures can be recalculated.

The SNA-based model presented by Yang and Zou (2014) filled in the research gaps left in the other three research paradigms, and has been demonstrated as a useful tool for assessing risk interactions and risk mitigation actions in green building projects. The case study analysis of green risks of two office buildings presented in this research will follow the steps in this SNA model.

4. Research methodology

4.1. Why case study approach

This research has adopted a case study approach. The research aims to obtain an in-depth understanding of stakeholder-associated risks and their interactions in green building project under different political and cultural settings, namely China and Australia. The emphasis here is more on 'how' and 'why' rather than 'what'. Green building project is relatively new and still in its infancy stage. Such new generation of building projects involves application of new technology and requires new sets of skills, which are not applied to ordinary building project management. Furthermore the collection of the data that is required to develop the project risk network requires several interactions with project team rather than a single round of 'tick and flip' survey exercise. As such it would not be suitable to use population-wide or sample-sized questionnaire surveys or selective interviews. Instead case study methods are the preferred choice. Case based data collection and case study analysis is a preferred technique when 'how' and 'why' questions are considered (Yin, 2009). This research addresses a 'how' type of question in order to understand how risks are connected in complex green building projects. Given the above mentioned reasons, the case selection was not random but based on theoretical/selective sampling. The case projects were chosen because they have high level project complexities, which make its stakeholder and risk analysis more meaningful, due to the complex relationships in the projects, and the project managers had challenges managing them. The data was collected by workshops and interviews, with more details in the following sections.

4.2. Case selection and data collection

4.2.1. The Chinese case

The Chinese case selected for this research was a multi-storey green office building project located in Shenzhen city, the southern China. The building occupies 3000 m^2 of land, and has 14 storeys including 2 underground basement levels. The total indoor area is 18,114 m^2. The total cost is \$80+ millions Chinese Renminbi (RMB). It implements a design principle of 'localisation, low cost, low energy consumption, and scalability'. The building uses many green technologies for energy saving, water saving, material saving, indoor air quality control and renewable standardisation. The external façades uses energy saving glasses and the shading panels integrated solar panel plus green roofing and green walling. Rain water and grey water were collected for reuse after filtering. The finance and occupancy of the building all belong to the same organization, which is a research and design institute whose core business is undertaking research to improve building performance in terms of energy, water, indoor air, etc. To this end, it is a 'leading by example'. The building has been granted the LEED (Leadership in Energy and Environmental Design) golden prize and a number of the Chinese national green ratings and awards.

A workshop was organized to identify the internal and external stakeholders and their associated risks in the project. Eight project team members attended the workshop including project managers, consultant engineer, main contractor and end users, The workshop participants contributed to the development of risk interrelationship matrix in which the possibility and consequence of the impact between risks were determined with five-point values (5 meaning extremely high, 1 meaning extremely low). In addition, a number of interviews with the team members were conducted at a later stage to obtain further information and clarify ambiguities. The researchers also had a site visit to the built facility, to gain first hand understanding of the technologies applied to the building.

4.3. The Australian case

The case project is a three-storey university mixed use building, which had a contract sum of over \$10 million Australian dollars. It was constructed using World Leading practices as required by the Green Building Council of Australia to target a 6 Stars rating for As Design and As Built. The case project presented considerable difficulties to the project management team, requiring the adoption of a relationship based a collaborative approach to management and project delivery. A number of new technologies have been designed and applied to this building project, such as the hot and chilled water from the mechanical system to be fed from a newly constructed Central Plant more than 400 m from the building. The Central Plant also houses a Black Water Treatment Plant which treats all sewerage from the building for use in flushing all toilets and urinals. The fan coil mechanical system was redesigned to adapt active chilled beams. The initial electrical design for the building included a 44 kW Photovoltaic Array system to enable the building to be carbon neutral. A wetland was included as part of the building and outdoor learning spaces were added to the wetland towards the end of the construction works. The data was collected through surveys and interviews with key project participants together with desktop-studies on the project information provided by the design-and-construct head contractor. The key information obtained included: project scope, cost, time; the project stakeholders; the risks related to each stakeholder; and the interdependencies among the risks.

5. Results and explanation

Three groups of SNA indicators, namely network measures, node/link measures, and partition measures, are used to decipher the structural configurations of the risk relations of these two building projects.

5.1. Risk interaction networks: network measure results

In SNA, density and cohesion are two network measures: The higher the density, the more risk interrelations are there in the network; and the higher the cohesion, the more complexity of the risk network is. Fig. 2 shows the risk networks in both projects. The network density and cohesion value are (0.338, 0.624) in the Chinese case project and (0.37, 0.703) in the Australian case project. In both cases, cohesion values are higher than network density values. This indicates that the risk interrelations are more complex when considering the propagating effects in the whole networks. Most risks are associated with internal stakeholders (client, contractor, and subcontractor/suppliers) in both case projects.

In the Chinese case project, in total, 9 stakeholders were identified with 26 'green related' risks and 220 risk interactions (Table 3). Comparing with the Australian case project which has 127 'green-related' risks associated with 20 stakeholders, and 867 risk interactions, the numbers of project stakeholders, risks and their interactions are much less.

Table 4 shows the risk groups in the two projects. Comparing with the Australian case, relatively higher attention was paid on the quality/technical issues in the Chinese case which mainly refer to the green building design, construction and assessment experiences in China. Although the Chinese government launched a series of green programme since 2004, there still is a shortage of green building skills in the Chinese construction industry (Andrews-speed, 2009). Lack of knowledge and awareness to the green technologies of building professionals became one of the critical barriers in green building project development and construction in China (Zhang et al., 2011).

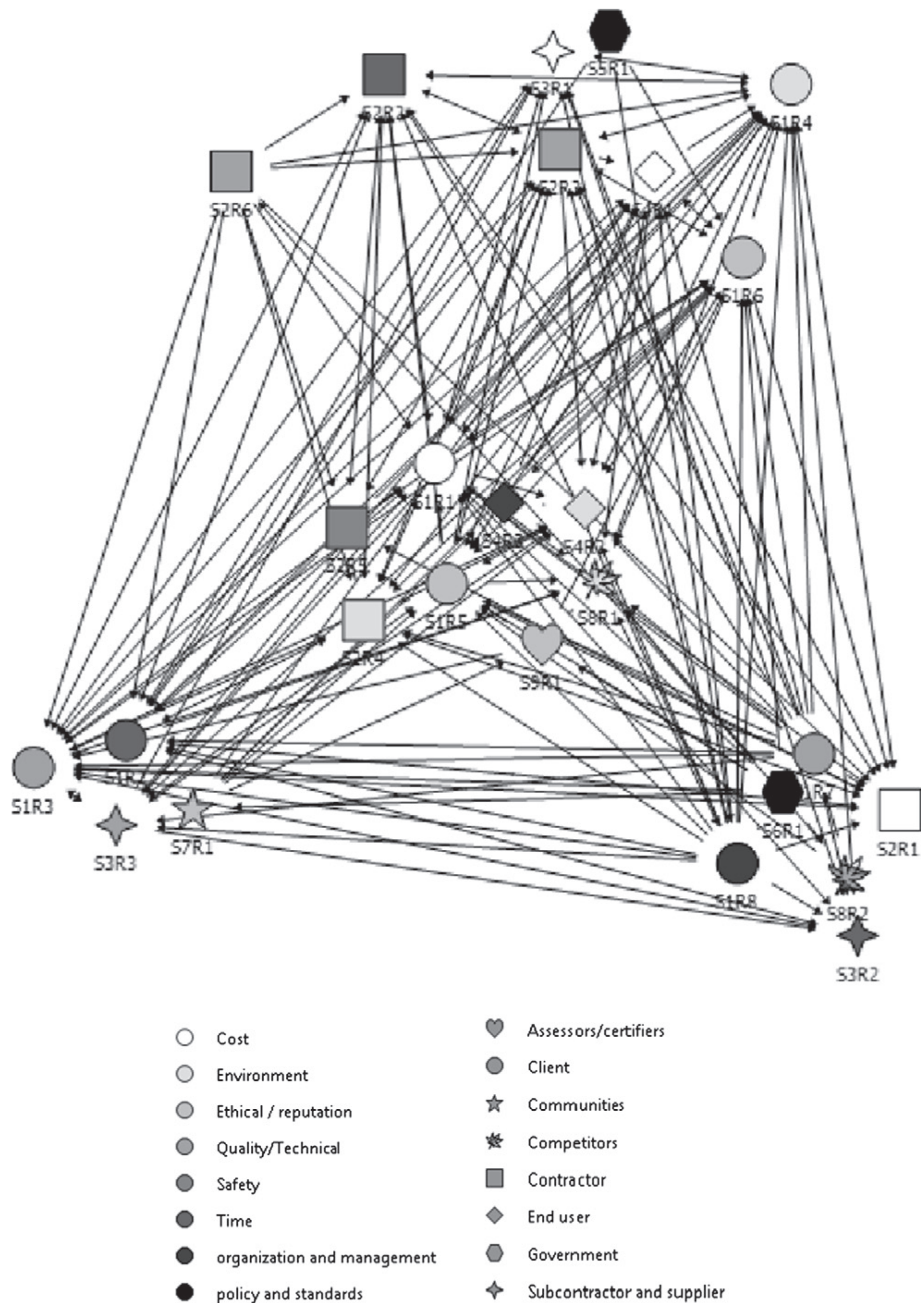
Two risks in the Chinese case project are related to policy and standards; while policy risks were not proposed in the Australian project. In advanced countries the provision and consistency of appropriate policies reduced industry practitioners' concern on policy changes and transparency (Hsu, 2001); however, in developing countries such as China, the impact of policy risk on building development is considered to be more significant (Zhang et al., 2012b). The policy risks in green building project are mainly related to the political commitment on the transparent and unified decision-making and implementation process (Andrews-speed, 2009; Wang et al., 2008). In China, most of the green building technologies still do not have a unified design codes and standardised application process (Zhang et al., 2011). This increased the difficulties on green building assessment, thereby impacts the fairness.

Apart from the above mentioned differences, as shown in Table 4, the Chinese industry also concerns more on the organization and management issues, but less on the ethical/reputation, cost, and time risks. However, since the striking difference of risk numbers in the two projects, it is more meaningful to compare the critical risks instead of quantities.

5.2. Risk impact rankings: node/link measure results

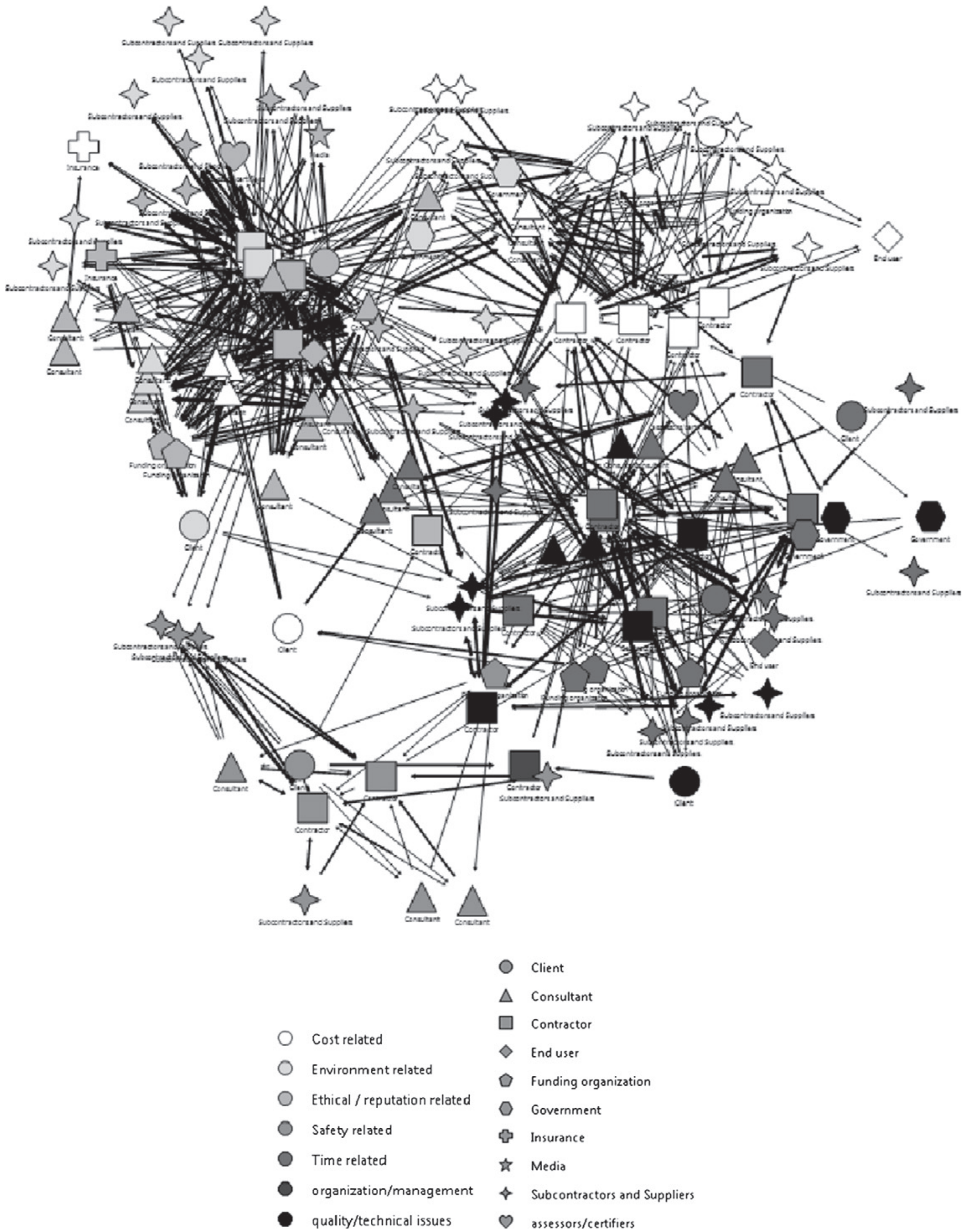
The comparison of critical nodes and links are based on the calculation of out-degree, degree difference, betweenness, out-status centrality, and brokerage values.

The out-degree shows the direct impact from a risk to the others, and the higher the degree difference, the stronger impact of the risk to the others comparing to the impact received by the risk. Fig. 3 shows the out-degree and degree difference in the Chinese case project. S1R8 (Tender selection mechanism to choose experienced green building contractor and suppliers) has the highest out-degree of 283; S6R1 (Transparent green building assessment standards) has the highest degree difference of 270 with no direct impact from the others, followed by S1R7 (Experience on green building project management). These three risks basically have high direct impact on the others. Comparing with the Australian case project in which the reputation risks



a) The Chinese project

Fig. 2. Stakeholder-associated green risk networks.



b) The Australian project

Fig. 2 (*continued*).

associated with contractors and consultants have higher direct impact, the Chinese practitioners viewed the management process (as S1R8), policy issue (as S6R1), and industry capacity (as S1R7) are critical in the current green building practice.

Betweenness centrality indicates the level of control over the impact passing through a node/link. Table 5 displays the top ten ranked risks and the interrelations with the highest betweenness centrality in the Chinese project. Different from the Australian case in which most high betweenness centrality risks are associated with contractor, in the Chinese project client plays more connection 'hub' roles in a project environment. A risk related to end users within the 'organization and management' risk category (S4R3 - Appropriate user behaviour) also has high betweenness centrality. This finding shows the important impact of user behaviour on energy consumption in occupation stage in China. Previous studies have shown that about half of the energy consumption depends on

Table 3
Summary of risks and stakeholder groups identified in the Chinese project.

Stakeholder category	Stakeholder	Number of risks	Risk ID	Risk	Risk category
Client	IBR	8	S1R1	Cost risk if budget found to be inadequate	Cost
			S1R2	On time design, construction and occupation of building	Time
			S1R3	Failure of achieving green building standard targets	Quality/technical
			S1R4	Higher than expected energy use	Environment
			S1R5	Demonstration of social responsibilities	Ethical/reputation
			S1R6	Enterprise awards	Ethical/reputation
			S1R7	Experience on green building project management	Quality/technical
			S1R8	Tender selection mechanism to choose experienced green building contractor and suppliers	Organization and management
Contractor	FTJA	6	S2R1	Responsible to ensure project is delivered within budget	Cost
			S2R2	On time deliver the building	Time
			S2R3	Responsible to ensure project is delivered to green building quality standard	Quality/technical
			S2R4	Waste minimisation	Environment
			S2R5	Ensuring construction safety when working on some green features	Safety
			S2R6	Experience on green building construction	Quality/technical
Subcontractor and supplier	Subcontractor and supplier	3	S3R1	Responsible to ensure the building component is delivered within budget	Cost
			S3R2	On time deliver the building	Time
			S3R3	Green products and the final work satisfy green building quality standards	Quality/technical
End user	IBR and its staff	3	S4R1	The maintenance cost should be within budget	Cost
			S4R2	Comfort and health in the built environment	Safety
			S4R3	Appropriate user behaviour	Organization and management
Government	Local government for building approval	1	S5R1	Standardised approval process and policy on green building design and implementation	Policy and standards
	Local government for green certificate approval	1	S6R1	Transparent green building assessment standards	Policy and standards
Communities	Green building committee	1	S7R1	Green building promotion and social responsibility	Ethical/reputation
Competitors	Other consultants	2	S8R1	Experience on green design and project management	Quality/technical
			S8R2	Energy saving from green design	Environment
Assessors/certifiers	Assessors/certifiers	1	S9R1	Assessment experience and fairness	Ethical/reputation

the design characteristics of the dwelling and devices, while the rest half depends on user behaviour (Janda, 2009). Gill et al. (2010) also investigated the contribution of user behaviour to actual building energy consumption and their results showed that energy-efficiency behaviours account for 51%, 37% and 11% of the variance in heat, electricity, and gas consumption respectively. The end users' behaviour was not identified as a critical risk in the Australian project, which may be because of the increasing user knowledge and positive attitude over the last decade in Australia as the Yang and Zou' study (2013) has shown. However, in China, the knowledge and awareness of clients and end users on building energy efficiency are still a critical issue needing to be improved (Xu et al., 2011). As Andrews-Speed (2009) emphasised that, though policies and regulations are critical to energy saving, the 'underlying requirement for success' is a change in attitudes and behaviour throughout society in China.

Table 4
Summary of risk groups in the two case projects.

Risk categories	Percentage of risks	
	Chinese case	Australian case
Quality/technical	23.09%	11.80%
Ethical/reputation	15.38%	21.26%
Cost	15.38%	22.05%
Environment	11.54%	12.60%
Time	11.54%	22.05%
Policy and standards	7.69%	0.00%
Organization and management	7.69%	0.79%
Safety	7.69%	9.45%
Total	100%	100%

All of the important links are related to the key risks in Table 5. As Yang and Zou (2014) stated, the source risks of the links in betweenness centrality results should be treated with caution because by controlling these risks, the links can be cut off. Comparing with the Australian project in which the contractor, consultants and subcontractors are the main sources of critical risk links, in the Chinese case project, the client, assessor, end user and government are owners of key risk connections. This shows an interesting difference between the two countries. In a mature green building market such as Australia, the risk network is connected by the green 'constructors' who are responsible for the design and construction works; whereas in a developing market such as China, the risk network is mainly shaped up because of client and external project stakeholders although most risks are caused by internal project stakeholders. This means that project risk network segmentation mainly relies on builders and consultants in

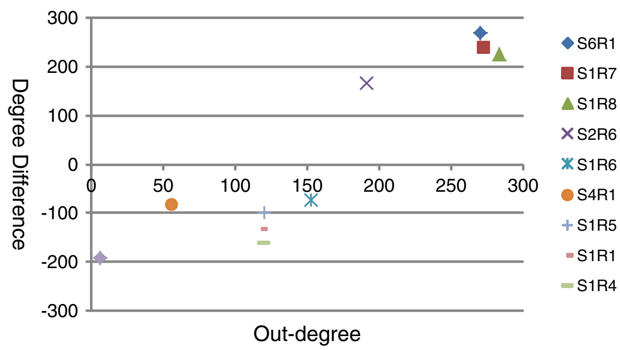


Fig. 3. Distribution of risks with high degree values in the Chinese case project.

Australia, while in China clients, government and end users take more responsibilities on the reduction of risk network complexity. According to industry evolution theories (Audretsch, 1995), industry change at the early stage is usually driven by exogenous factors, such as the political requirements, and expectations from the upstream supply chain. The Chinese green building project is just beginning the "Marketplace Building" stage (Jackson and Harji, 2013), in which government policies, client's experience and reputation, and end user attitudes are the critical issues causing other risks in the whole industry. In Australia, after more than ten years of development, the growth of green building market occurs as the mainstream players (e.g. internal stakeholders) to "provide the capital, talent and creativity needed to address pressing social and environmental challenges" (SocentVC, 2009).

In Table 5, another risk worth mentioning is S9R1 (assessment experience and fairness) related to the assessors' ethics, which is the sources of two important links. Although in Table 4, it seems that there is less concern on ethical/reputation issues in China. However, when looking into the details, a significant difference between the two countries exits. The Australian industry considers reputation as a priority: For example, funding organization identified "reputation affected if Green star not achieved" as a main risk; contractors, consultants and subcontractors concern the impact of non-performance on repeat business opportunity. However, in China, the bidders view assessors' experiences and fairness as a critical risk, due to the immature policy systems and corruption issues in China. According to a report produced by the National Bureau of Corruption Prevention, there are 15,010 cases of corruption recorded in the public construction sector between 2009 and 2011 (Xinhua Net, 2011). Le et al. (2014) considered that the 'flawed regulation systems' and 'lack of a positive industrial climate' are the main causes of corruption in the Chinese construction industry. Severe measures against bribery have been implemented nationally by the new Chinese government leading by President Xi Jinping since 2013. Nevertheless, international firms should understand the potential ethical risks in the construction industry.

Status centrality computes the relative influence of a node within a network by measuring the number of the immediate neighbours (first degree nodes) and also all other nodes in the network that connect to the node under consideration through these immediate neighbours (Katz, 1953). Fig. 4 shows the status centrality map in the Chinese project. The risk impacts decrease along with the distance between the risk (node) and the central of the circle. The status centralities results in the two countries also show the similar findings with those from the degree and betweenness analyses. In the Chinese case project, the three risks (S1R7, S6R1 and S1R8) have higher impact within the network. They are associated with client and government, and are within 'quality/technical', 'policy and standards', and 'organization and management' risk categories respectively. But in the Australian case project, internal stakeholders including contractor and consultants associated reputation risks are more important as highlighted by Yang and Zou (2014). Fig. 4 also shows that S9R1 (assessment experience and fairness) is a critical risk with the consideration of the propagating effects in the network. This supported the finding in the link betweenness analysis.

Brokerage values indicate the roles of risks to connect different stakeholder groups. Table 6 shows the top 10 risks which are considered as critical because they play significant roles to connect different stakeholder groups in the Chinese project. Obviously, the client has an important position in communicating with other stakeholders in order to mitigate the risks. In the Australian project, the head contractor took more communication responsibilities. This finding is consistent with the results from node betweenness analysis. Although this fact may be due to the different project contract types as explained when comparing the network measure results, it also inspires thinking on the industry environment difference. From the degree and centrality analyses results, we can conclude that in China, in comparison with Australia, the external project stakeholders including government, end users, and assessors can cause more significant risks. Thereby, it requires large coordination work from client, who usually engages and communicates with external stakeholders more comparing to contractors (Yang, 2014). This finding shows to international firms, especially developers, the importance of establishing communication networks with local government, assessors as well as end users to mitigate the 'green' risks in China.

5.3. Stakeholder and risk interfaces: partition measure results

Partition measures compute the interfaces between each pair of stakeholder/risk groups. Tables 6 and 7 show the interfaces of stakeholders and risk categories from immediate as well as global points of view in the Chinese project.

Table 5
The key risks and links according to the betweenness centrality.

Rank	Risk ID	Node betweenness centrality	Link ID	Link betweenness centrality
1	S1R5	0.067	S1R7 → S1R8	40.00
2	S1R3	0.067	S1R6 → S4R3	12.55
3	S1R6	0.056	S1R5 → S4R3	11.29
4	S1R4	0.046	S9R1 → S1R3	8.177
5	S1R8	0.042	S4R3 → S1R4	7.78
6	S4R3	0.037	S1R3 → S1R5	7.61
7	S1R1	0.034	S1R3 → S4R2	7.38
8	S1R2	0.028	S4R1 → S1R4	7.38
9	S2R3	0.022	S5R1 → S1R8	7.20
10	S2R4	0.019	S9R1 → S1R6	6.39

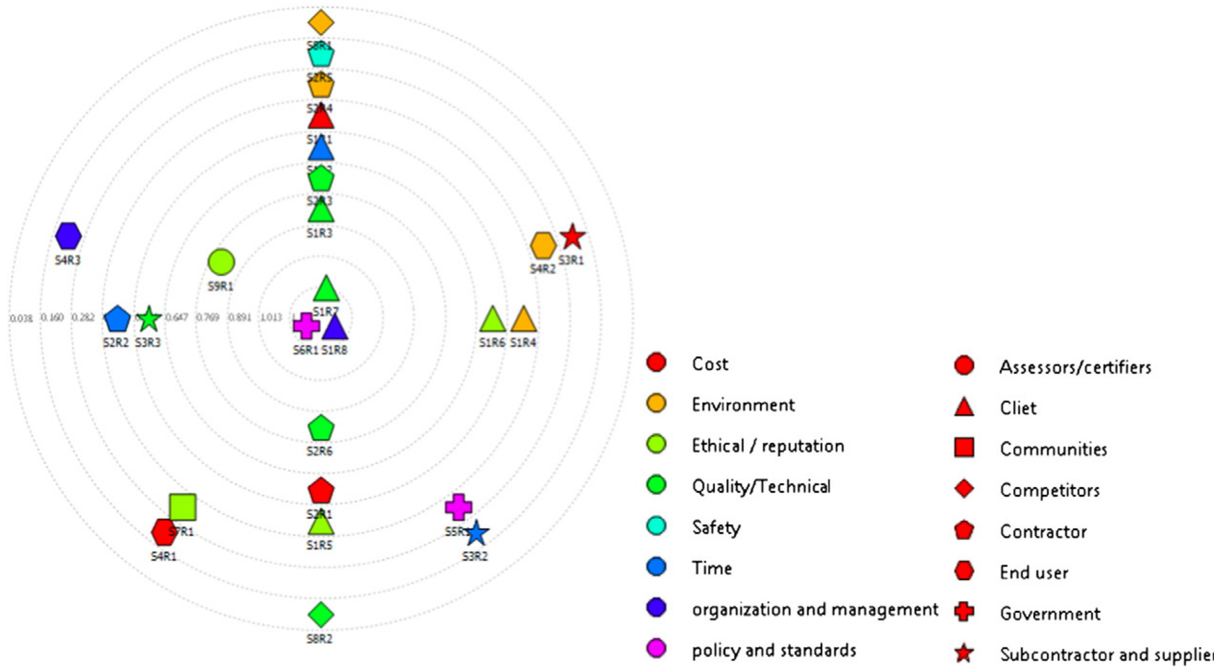


Fig. 4. Risk locations in the status centrality map in the Chinese case project.

As shown in Table 7(a), S1 (Client) receives high impacts from the internal stakeholders (contractor and subcontractors). This is similar with the Australian project which suggested that communication between internal project stakeholders is important. Apart from this, Chinese client is also impacted significantly by the green building assessment government body (S6). The structure and practice of commercial green building assessment organizations are also different in the two projects: The Green Building Council of Australia (GBCA) is a not-for-profit industry association that promotes sustainability in the built environment; while in China, the green assessment body is a government department developing state standards based on the national guidelines. The Green Building Committee of China has similar organization natures as GBCA, but mainly plays roles as green concept promoter. As explained in the above sections, government's role, especially the green assessment division, in China should not be neglected.

Considering the propagated consequences in Table 7(b), the communication with end users should also be enhanced in the Chinese project. This mainly because that energy using behaviour can affect the building operation and maintenance cost significantly; however, in China end users are still lack of knowledge and awareness on energy saving (Xu et al., 2011). This was not considered as a priority in the Australian project as also concluded based on the betweenness centrality analysis.

According to the interface results between risk categories (Table 8), both cases show that ethical/reputation related risks have noticeable impact on other risk categories. However, in the Chinese project, 'quality/technical', 'organization and management' and 'policy and standards' related risks show more significant impact on other categories comparing to the Australia project, especially when considering the propagated effects in the global view. Again, these findings have been evidenced in the previous sections.

6. Discussions of the differences between Chinese and Australian cases

Although this study does not aim to be generalizable across the industry, the research findings provide a deeper understanding of

Table 6
The brokerage values of key risks based on the partition vector as stakeholder groups.

Risk ID	Partition value	Coordinator	Gatekeeper	Representative	Itinerant	Liaison	Total
S1R4	Client	7	16	5	2	67	97
S1R5	Client	0	10	6	2	68	86
S1R3	Client	3	10	3	2	64	82
S1R1	Client	4	3	7	2	61	77
S1R6	Client	1	12	3	2	57	75
S1R2	Client	0	4	0	2	47	53
S1R8	Client	0	12	0	0	28	40
S2R3	Contractor	0	9	17	11	3	40
S2R4	Contractor	0	9	12	11	1	33
S1R7	Client	0	7	0	0	18	25

Table 7
Interfaces between stakeholders in the Chinese case project.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
(a) Immediate interface									
S1	507	353	239	193	0	0	0	110	0
S2	369	317	0	37	0	0	0	0	0
S3	156	0	37	32	0	0	0	0	0
S4	126	0	0	54	0	0	0	14	0
S5	41	0	0	0	0	0	0	0	0
S6	97	0	0	0	0	0	0	24	16
S7	36	0	0	32	0	0	0	0	9
S8	18	0	0	0	0	0	0	25	0
S9	4	0	0	0	0	0	0	20	0
(b) Global interface									
S1	0.57	0.41	0.15	0.12	0.04	0.00	0.03	0.02	0.00
S2	0.39	0.32	0.04	0.03	0.01	0.02	0.01	0.00	0.00
S3	0.22	0.06	0.04	0.02	0.01	0.01	0.01	0.00	0.00
S4	0.19	0.08	0.04	0.05	0.00	0.01	0.02	0.00	0.00
S5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S6	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S8	0.01	0.03	0.01	0.02	0.00	0.02	0.00	0.02	0.01
S9	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00

the complexity of the green building project environment. In particular the differences in the numbers of green risks in the two countries can be explained from two perspectives:

- *Project contract types*: The Australian building is a Design-Build project, in which the head contractor subcontracts the design work to several consultants, and most construction activities to specialised subcontractors or trades; while the Chinese building is a combination of force account and traditional procurement type, in which the client has its own team for design, and only contracts the construction work to a major firm who may have its own workforce (including trades and labourers). Since the design work was completed by themselves' staff, the Chinese client does not have a consultant stakeholder group, which reduced the project environment complexity significantly. This could be explained by the cultural differences as the Chinese tend to adopt a centralised management system while the western culture prefers the decentralized authority.
- *Project construction practices*: There is a major difference between Australian and Chinese construction firms: Usually in Australia, the head contractors do not have their own labours, so they have to subcontract most construction works to subcontractors. In contrast, most of the Chinese construction firms have permanent employees working on different trades on sites, and only subcontract sporadic works to external firms. This not only reduces the labour cost, but also minimises the coordination works, thereby mitigates risks. However, for international contractors in China, they have to be aware of the dispute risk with local construction labours (Zhang, 2011), as well as labour restrictions and cost to use sources of labour from inside/outside the host country (Ashley and Bonner, 1987).

Tables 9 and 10 summarise the critical risks in the two projects. These critical risks were identified by combining the results from degree, node betweenness centrality, status centrality, and breakage values. These risks should be mitigated with high priority because they either have significant direct impact on other risks, or severely increase the complexity of the risk interactions. Based on the discussions in the previous sections, the key similarity and differences between the two case projects are summarised as follows:

- The ethical/reputational risks are important in both countries, but difference also exists: In Australia, all project stakeholders on the supply chain including client, contractor, consultant, subcontractor/suppliers and end users care about the reputation impact if Green Star is not achieved. However, in the Chinese project, two of the three critical ethical/reputation risks are associated to client regarding its social responsibilities and

Table 8
Interfaces between risk categories in the Chinese case project.

	Cost	Time	Quality/technical	Environment	Ethical/reputation	Organization and management	Policy and standards	Safety
(a) Immediate interface								
Cost	68	73	97	71	28	0	0	12
Time	59	68	73	78	0	0	0	9
Quality/technical	265	171	188	241	82	0	0	34
Environment	50	21	27	48	74	6	0	8
Ethical/reputation	83	2	132	39	74	44	0	0
Organization and management	84	46	56	90	73	0	0	0
Policy and standards	20	10	85	12	63	41	0	0
Safety	20	7	3	28	4	0	0	0
(b) Global interface								
Cost	0.10	0.10	0.43	0.09	0.14	0.14	0.05	0.03
Time	0.08	0.10	0.06	0.04	0.03	0.08	0.03	0.01
Quality/technical	0.15	0.14	0.33	0.16	0.18	0.10	0.06	0.01
Environment	0.08	0.04	0.08	0.06	0.07	0.07	0.05	0.04
Ethical/reputation	0.06	0.03	0.17	0.10	0.14	0.14	0.08	0.01
Organization and management	0.11	0.00	0.01	0.11	0.05	0.01	0.05	0.00
Policy and standards	0.00	0.00	0.45	0.00	0.21	0.00	0.00	0.00
Safety	0.02	0.02	0.06	0.01	0.01	0.01	0.00	0.00

Table 9
Numbers of critical risks in each category.

Risk categories	Chinese case	Australian case
Ethical/reputation	3	10
Cost	2	4
Time	1	4
Quality/technical	3	0
Environment	2	2
Organization and management	2	0
Safety	1	2
Policy and standards	2	0
Total numbers	16	22

enterprise awards, while the other one related to assessors' ethical behaviour. Particularly, the ethical risk 'assessment experience and fairness' has been highlighted as crucial for the success of Chinese green practice.

- In the Chinese project, relatively higher attention was paid on the quality/technical risks which mainly refer to green building design, construction and assessment experiences, due to shortage of green building skills in the Chinese construction industry. As Li and Colombier (2009) stated that inadequate technical capacities as well as a lack of information and a trained workforce pool hinder the spread of green technologies in China.
- There are two 'policy and standards' key risks in the Chinese case project, which relate to the political commitment on the transparent and standardised approval and assessment processes. But in the Australian case project, the policy risks are not a concern of the industry. The Chinese governments play an important role, including develop rigorous policy systems, and improve the societies' knowledge and awareness on green technology and energy saving.
- Two 'organization and management' risks including client's tender selection mechanism and building end user behaviour are also highlighted as important in the Chinese project. During the interviews, the project client stated that they mitigate these risks by referring to the advanced international practices and training of their staff (building end users). Being aware that the client in this particular Chinese project is a research and design institute with core business on green building design. In other green building projects, these organization and management risks may be more problematic due to the lack of client knowledge on green building development.
- From project stakeholder management perspective, enhancing communications between internal stakeholders can contribute to a smooth green building design and construction in both countries. However, international developers to China may need more coordination work and spend more on subcontracting and labouring. Furthermore, clients in Chinese projects should engage Chinese government, assessors and end users with more caution.

Since there are significant green related risk differences between China and Australia building projects, international AEC (Architectural/Engineering/Construction) firms need to decide on the appropriate market entry mode and business strategies (Ling et al., 2005) to undertake green building project overseas, and adopt cross-cultural communication and dispute resolutions (Pheng and Leong, 2000).

7. Conclusion

This paper leverages the collective knowledge of risks and stakeholders in a network to generate better risk management solutions in green building development process. This research

Table 10
The group information of critical risks in the two projects.

Chinese case		Australian case	
Stakeholder group	Risk categories	Stakeholder group	Risk categories
Client	Ethical/reputation	Client	Ethical/reputation
Client	Cost	Funding organization	Time related
Client	Time	Funding organization	Ethical/reputation
Client	Quality/technical	Funding organization	Ethical/reputation
Client	Environment	Contractor	Cost
Client	Ethical/reputation	Contractor	Cost
Client	Quality/technical	Contractor	Cost
Client	Organization and management	Contractor	Time
Contractor	Quality/technical	Contractor	Time
Contractor	Environment	Contractor	Environment
Contractor	Safety	Contractor	Environment
End user	Cost	Contractor	Safety
End user	Organization and management	Contractor	Ethical/reputation
Government	Policy and standards	Contractor	Ethical/reputation
Government	Policy and standards	Consultant	Time
Assessors/certifiers	Ethical/reputation	Consultant	Ethical/reputation
		Consultant	Ethical/reputation
		Consultant	Ethical/reputation
		Subcontractors and Suppliers	Safety
		End user	Ethical/reputation
		Consultant	Cost
		Consultant	Ethical/reputation

adopts an innovative social network analysis method to identify the critical stakeholders and risks in green building development projects. The social network method, perceives green building development as a sophisticated system in which numbers of risks and problems created by various stakeholders are intertwisted with the consequent impacts among them. This perspective improves the effectiveness and accuracy of stakeholder and risk analyses by demystifying the social complexity which is usually overlooked in traditional linear impact analysis.

This research also contributes to cross-national comparisons. China and Australia were selected due to the fact that trades in the sustainable building development projects across the two countries are increasing dramatically, while disparate operational systems bring up difficulties to overseas building professionals to implement their inherent industry practices. The research outcomes show that in China the government is the key driver of green technology uptake and quality assurance; while in Australia sustainable building development has to be self-motivated to build up organizational reputation. This research highlights the differences of critical risks and stakeholders in the two nations, and explains the reasons underlining the distinction, which could guide practitioners on successful green building development in overseas markets.

Conflict of interest

The authors declare that there are no conflict of interest.

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