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Analysing Risk Factors and Risk Interdependencies in Green Building Projects: Insights from a Literature Review

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Content

Definitions

Green building (GB) definitions:

- a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on the climate and natural environment (World Green Building Council, 2016).
- the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life cycle, from siting to design, construction, operation, maintenance, renovation and deconstruction (U.S. Environmental Protection Agency, 2010).
- an eco-friendly economic facility that uses less natural resource to build and operate, and positively impacts productivity, health and welfare of human being throughout its entire life cycle (Dwaikat & Ali, 2016, Ding et al, 2018).

1. Motivation: Sustainability in Construction Industry

- Globally, the construction industry consumes 40% of total energy production, 12–16% of all water available, 32% of nonrenewable and renewable resources, 25% of all timber, 40% of all raw materials, produces 30–40% of all solid wastes, and emits 35–40% of CO_2 (Darko et al., 2017b).
- 39% of total U.S. energy consumption in 2017 was related to residential and commercial buildings (US EIA, 2018).
- Implementing **Green building (GB),** aka sustainable or high-performance building, projects offers several environmental, economic, and social benefits to the construction industry, including
  - reduced resources and material use, and
  - the reduction of global warming and climate change impact,
  - improved occupant health and comfort (Ahn et al., 2013; Zhao et al., 2016).

=> GB provides an opportunity for the construction industry to contribute to the sustainable development of the world (Butera, 2010, Hwang et al., 2015a).

Motivation (Cont.)

- most developed countries have started to implement sustainability policy and enacted new regulations to change the conventionally practiced patterns in the construction sector (Mohammadi & Birgonul, 2016).

- LEED (Leadership in Energy and Environmental Design), the world's most widely used GB rating system, has executed the certification process of numerous GB projects across 167 countries; and
- BREEAM (Building Research Establishment Environmental Assessment Method), the world's second mostly accepted rating system, has given certificates for many GBs in 77 countries (Ulubeyli & Kazanci, 2018).

- Overall, the global GB industry seems to be expanding rapidly as a developing market, and green practice has become a necessity for environmentally conscious project stakeholders (Zhao et al., 2016).

Motivation (Cont. 2)

- GB projects are more challenging and face more risk factors than traditional construction because of the extra goal of **sustainability** in addition to the normal goals, e.g. quality, time, cost, safety (Zhao et al., 2016; Hwang et al., 2017a).

- Some Uncertainties associated with Sustainability & GB
  - adopt some newly developed and complicated design approaches and construction technologies,
  - use innovative materials (such materials may lack of sufficient tests or have durability issues),
  - achieve third-party green certification, which may generate considerable uncertainties and unpredictable risks.
  - Furthermore, the number of regulatory requirements from governments and other public authorities (e.g., regarding site selection, energy, and recycling) accelerates each year and is expected to continue to increase in the future

  (Hwang et al., 2015a & 2017a; Yang & Zou, 2014)

- However, research efforts on risk management in GB projects are still very limited (especially risk interdependencies from a life cycle perspective)

Research Objective

To fill this research gap, the objectives of this study are to:

(1) Identify the risk factors associated with GB projects;

(2) Differentiate green-specific and common risk factors for construction projects; and

(3) Investigate the risk interdependencies among the identified risk factors.

In order to provide a better understanding of the risk factors influential throughout the life cycle of GB projects for both GB industry practitioners and researchers,
=> help project stakeholders to manage project risks more effectively

2. Literature Review

Some ***specific benefits of GB projects***

- Energy use in non-GBs was 50% greater than GBs, outdoor water use was 100% greater and indoor water use was 30% greater (Wedding & Crawford, 2008).
- The cost savings using green practices are greater than $1000 per annum (may directly be linked to reduced water use and energy savings) (Bond, 2010).
- In the US, compared with traditional buildings, GBs can reduce operating cost by 8–9%, increase building value and occupancy ratio by 7.5% and 3.5% respectively, and improve return on investment by 6.6% (Durmus-Pedini & Ashuri, 2010).
- A clear difference of 4% higher tenant satisfaction for GBs in general (Devine & Kok, 2015).
- Worker productivity in green offices is 2 - 3% higher (Edwards, 2006).

Literature Review: GB Risk Management

Despite rapid development of GBs over the past two decades, yet the research efforts on risk management in GB projects are very limited (Hwang et al., 2017a).

- Zhao et al. (2016) categorized a list of 28 risk factors of ***GB projects in Singapore*** into 11 groups through a questionnaire survey and developed a risk assessment model using fuzzy synthetic evaluation approach.
  - the *top 10 risk factors:* "inaccurate cost estimation", "delay in issuance of documents", "unclear detailed design or specifications", "unclear requirements of clients", "default supply of materials / equipment / plants", "strict safety and health regulations", "intervention of clients", "labor and materials price fluctuations", "variations in design, and delayed payments from clients";
  - the *top 3 risk groups:* "cost overrun risk", "client-related risk", and "procedure complexity".

- Qin et al. (2016b) identified 56 risk factors throughout the life cycle of ***GBs in China*** based on an empirical questionnaire survey among the owners, contractors, resident engineers, and designers.
  - there were obvious differences between owners and contractors, owners and engineers, and designers and contractors.
  - So suggested that project stakeholders need to implement appropriate risk management strategies according to their perceptions of risk importance.

LR: GB Risk Management (2)

- Hwang et al. (2017a) identified and evaluated risk factors of the ***commercial GB projects in Singapore*** based on a comprehensive literature review, structured interviews and a questionnaire.
  - the top 5 critical risk factors are: "inflation", "currency and interest rate volatility worsened by the import of green materials", "durability of green materials", "damages caused by human error", and "shortage of green materials".
  - risks of *design change* and *poor construction quality* of commercial GB projects are less critical than traditional commercial projects; but the adoptions of green ideas, materials, and technologies had posed additional risks to these projects.
- El-Sayegh et al. (2018) identified 30 risks of the ***GB projects in the UAE*** based on literature review, and grouped them into five categories (management, technical, green team, green materials, and regulatory/economic).
  - the 5 five risks are: "shortage of clients' funding", "insufficient or incorrect sustainable design information", "design changes", "unreasonably tight schedule for sustainable construction" and "poor scope definition in sustainable construction".

LR: GB Risk Management (3)

Most risk factors in GB projects are interrelated having cause-effect relationships.

- To analyze the risks' inter-relationship in complex GB projects, Yang & Zou (2014) developed a social network analysis (SNA) based stakeholder-associated risk analysis method. Several important findings from the case study include:

  (1) internal stakeholders (contractor, consultants and subcontractors), media and assessor/certifier play more important roles in GB as compared to the external stakeholders;

  (2) the ethical/reputation risks are considered more significant for different stakeholders in GB development;

  (3) risk within one category would have more direct connections; and

  (4) technological barriers and risks are not as important as perceived.

LR: GB Risk Management (4)

- Further, Yang et al. (2016) modeled the interactive networks of the risks associated with stakeholders in GB projects based on the SNA method and case studies of green star accredited ***office building projects*** undertaken in ***China and Australia***. The results showed that
  - reputation and ethical risks were important in both countries.
  - government played an important role in improving society's knowledge and awareness on green technology uptake in China.

- Li et al. (2017) adopted system dynamics approach and established a risk identification feedback chart and a risk flow chart to identify investment risks of *prefabricated construction projects* (a new form of GB project) in ***China*** and to estimate quantitatively the investment risk factors. Critical risk factors were therefore analyzed and corresponding measures were proposed.

3. Methodology: a systematic review process

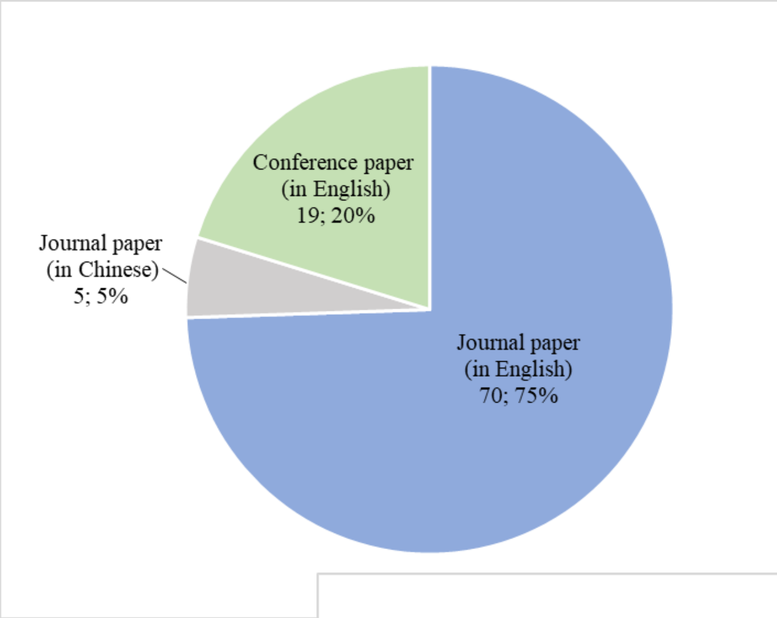
A six-step review approach to search documents related to studying risk factors in GB projects.

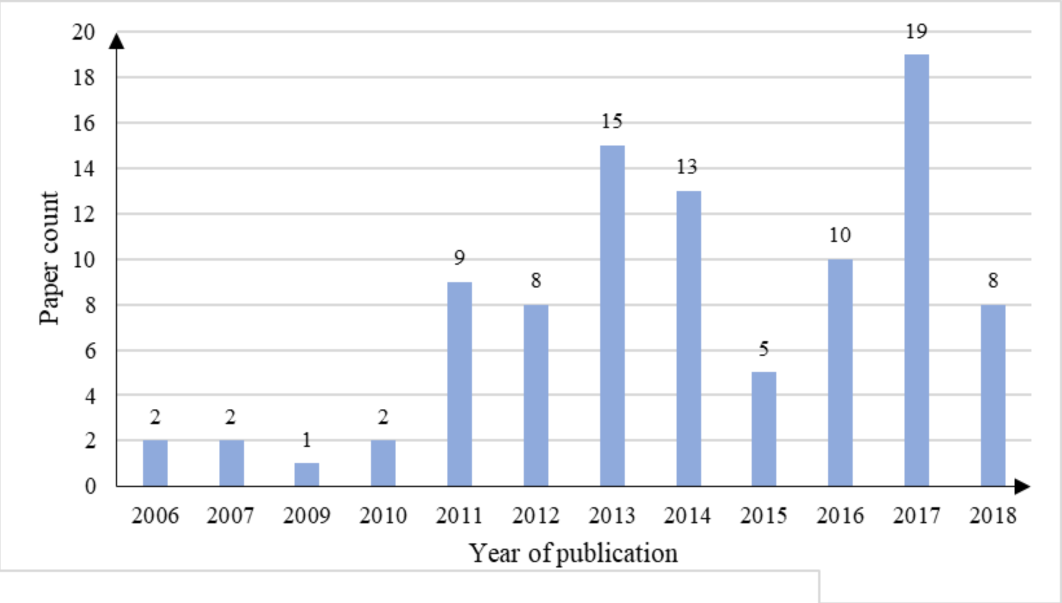
Query: “[(green | sustainable | high-performance) (building | project | construction | retrofit)]“AND “[(risk) (factor | management | assessment | analysis | evaluation)]”

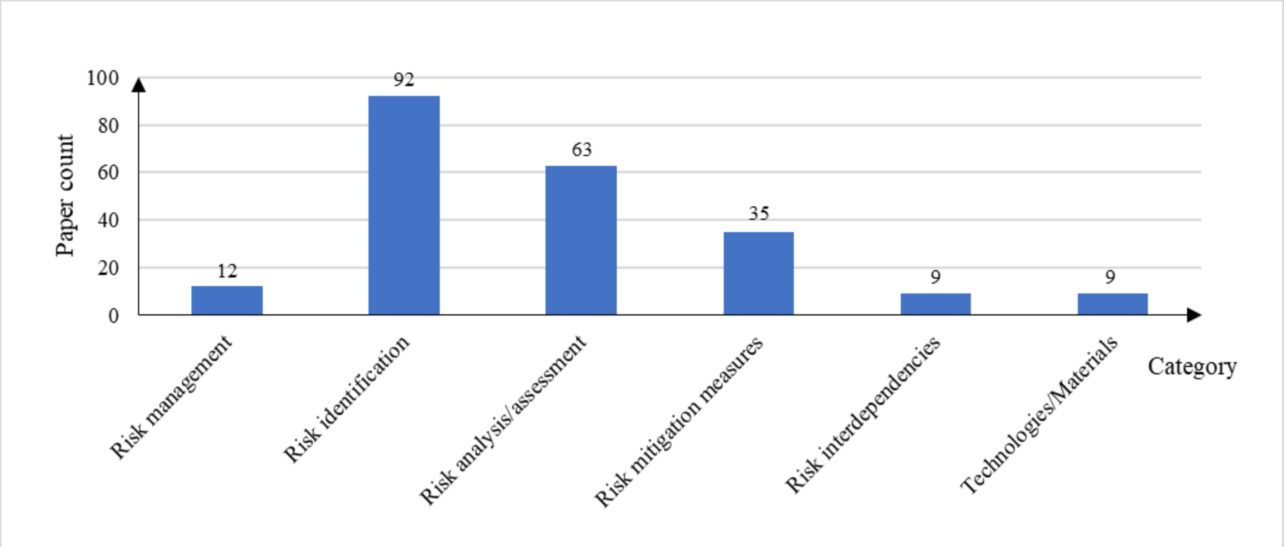
Literature review processes	Pub. count	
1: Retrieving relevant documents based on searching keywords	Scopus	183
	WOS	85
2: Removing redundancies		209
3: Removing invalid documents which do not have article information		187
4: Removing irrelevant ones by reading titles and abstracts of documents		141
5: Selecting and categorizing relevant ones by reading full-texts of documents		54
6: Adding relevant papers from the reference lists of reviewed documents		94

Methodology (Cont.)

Stats 94 selected papers from literature review







4. Results

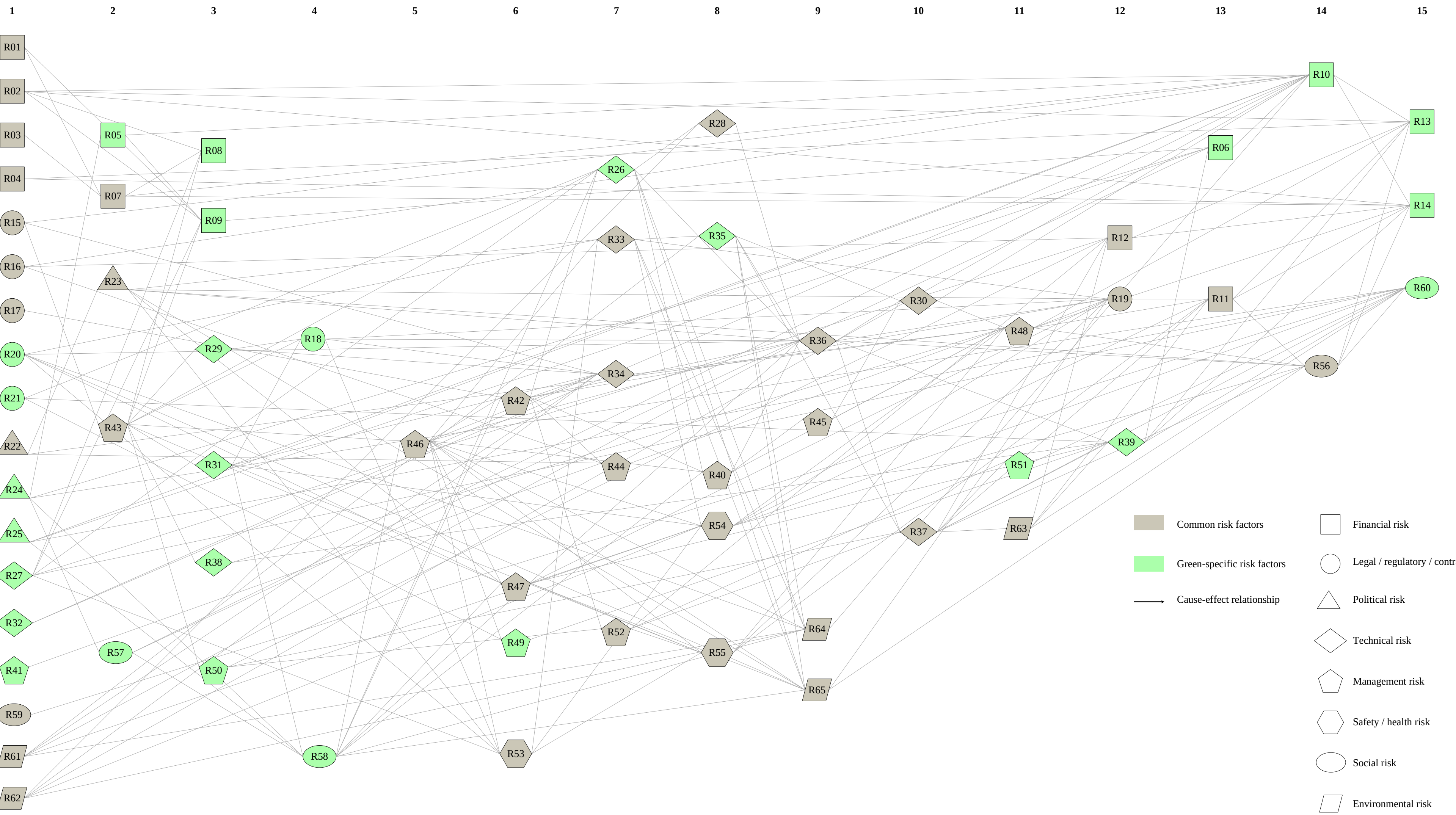
Risk factors for GB projects

- After the content analysis of the selected literature, 65 risk factors and 8 corresponding risk groups were summarized:
  - financial risk,
  - legal / regulatory / contractual risk,
  - political risk,
  - technical risk,
  - management risk,
  - safety / health risk,
  - social risk, ad
  - environmental risk.

Results (Cont.): Risk Factors and their interrelationship

Risk source		Risk event	Risk consequence
R01 Increasing inflation rate	R32 More complex design / construction techniques in GB projects	R06 Difficulty in financing GB projects	R13 Low payback rate for GB projects
R02 Increasing tax rate	R33 The use of unauthorized technologies / materials in construction	R08 Inaccurate estimate of GB project budgeting	R14 Long payback period because of sustainable practices
R03 Fluctuations in currency exchange rate	R34 Poor productivity of labour / equipment	R09 Inaccurate estimate of GBs' long-term return on investment	R56 Reputation damage
R04 Increasing interest rate for loan	R38 Lack of standard method and experience for GB certification evaluation	R10 Higher investment cost to go green	R60 Poor public acceptance or dissatisfaction to GB projects
R05 Inaccurate prediction of / lack of market demand for GB projects	R41 Limited number of green consultants / contractors / sub-contractors / suppliers to choose from	R11 Cost claims arising from failure to achieve standard requirements	R65 Environmental / ecological damage
R07 Fluctuations in labour / material price	R42 Poor communication and cooperation among project stakeholders	R12 Higher operating cost than anticipated	
R15 Employment constraints	R43 Lack of skilled and experienced professionals and labours	R19 Breach of contract or failure to achieve contract conditions	
R16 Import / export restrictions	R44 Poor availability of materials / products / equipment / technologies	R30 Variations in design during construction	
R17 Unclear / inadequate contract conditions	R45 Special request/inappropriate interventions from clients	R35 Poor performance and viability of green materials / products / technologies	
R18 Difficulty in conforming to strict regulations for GB projects	R46 Poor project management ability during construction	R36 Defective work and improper quality control	
R20 Inadequate laws / regulations for implementing GB projects	R47 Inappropriate waste management behaviour during construction / demolition	R37 Unstable operation performance of GB projects	
R21 Change / lack of GB certification system	R49 Lack of documents and related information for GB certification	R39 Failure to achieve expected green certification standard	
R22 Government bureaucracy and complicated approval procedures	R50 Lack of property management experience in GB projects	R40 Unclear allocation of roles and responsibilities	
R23 Corruption and bribery	R52 Inappropriate using behaviour of occupants	R48 Delay in project completion	
R24 Lack of / change in GB-related policies	R53 Incomplete safety management plan	R51 Increasing maintenance burden for GB projects	
R25 Lack of GB-related incentives from government	R57 Inadequate insurance for GB projects	R54 Injuries and accidents during construction	
R26 Poor scope definition of green/sustainable construction	R58 Tendency to maintain conventional attitudes and practices in project team	R55 Damages to building structure / property caused by human error	
R27 Lack of benchmark / shared information	R59 Different occupant perceptions on living	R62 Indoor environmental quality	

Results (Cont.): Risk Factors inter-relationships



5. Conclusion

- the cause-effect relationships among the 65 risk factors were analysed by pairwise comparison and a network (comprising 65 nodes and 216 links) was established to illustrate the risk interdependencies.
- Such a network could provide project stakeholders with better knowledge and understanding of potential risk factors for GB projects.
- Future research will further examine the risk interdependencies based on expert interviews and questionnaire surveys, to develop an evaluation model assessing critical risk factors and risk interdependencies qualitatively, and to propose a set of appropriate risk mitigation measures.

Thank you

Comments and suggestion are appreciated