



Montréal, Québec
May 29 to June 1, 2013 / 29 mai au 1 juin 2013

Barriers to the Design, Construction, Operation and Maintenance of Green Building: A State-of-the-Art Review

Hamid Afshari, Mohamed H. Issa, Qingjin Peng

Abstract: Despite the significant surge in green building in Canada and internationally, the green movement faces a number of barriers that not only limit the design and construction of new buildings but also the operation and maintenance of existing ones. This paper presents a comprehensive review of the literature investigating barriers to the effective design, construction, operation and maintenance of green buildings and the building industry's ability to overcome them. This is in an effort to identify the literature strengths and limitations, the ultimate aim being to provide researchers with a research roadmap and industry professionals with a comprehensive view of the challenges involved in sustaining the green building market. The review involves analyzing the literature based on a number of different parameters and making general recommendations based on the ones in the literature to overcome these barriers. This analysis shows an increasing interest in green building research and practice as evidenced by the increasing number of related research publications in recent years. Technical barriers tend to dominate the scientific discourse. Most research also focus on investigating barriers to the design and construction of green building with very little focus on the operation and maintenance phases. These barriers stress the need to involve governments at all levels in increasing public awareness, establishing new regulations and standards and defining sustainability as a key national strategic priority across all government departments, in the private sector and at the community level.

1 Introduction

The last decade has witnessed a significant surge in the green building market. Despite this surge, the green building industry faces a number of barriers that limit the construction of new green buildings and the effective operation of existing ones. Even though some research has been conducted to investigate those barriers, there is no agreement on their nature and on solutions needed to overcome them.

The goal of this study is to review the literature investigating barriers to the design, construction, operation and maintenance of green buildings. Specific objectives include: 1) identifying those barriers; and 2) recommending general solutions to overcome them. This is in order to provide researchers with a roadmap that would enable them to identify and address knowledge gaps and provide practitioners with an understanding of the challenges that lie ahead for which solutions would be needed.

This paper describes the specific methods used to review and analyze the literature followed by a presentation of the results of this analysis. The paper concludes with a summary of the limitations of the research as well as recommendations for future research in the field.

2 Research Methods

SCOPUS was used to identify papers, reports and books addressing barriers to the design, construction, operation and maintenance of green building. The key words “green building” and “sustainability in construction” were first used to locate them. The keywords “barrier”, “challenge”, “risk”, and “factor” were then used to limit the results found using the first set of keywords. Table 1 shows the specific research questions answered through this study as well as the location of their answers in the paper.

Table 1: Research Questions and Answers' Location in Paper

No.	Research Questions Answered in Paper	Answers' Location	
		Table or Figure	Section
1	How did the volume of research published change over the last few years?	Figure 1	3.1
2	Which countries publish the most research papers?	Figure 2	3.1
3	What are the primary research methods used by the literature in the field?	Figure 3	3.1
4	What types of buildings did the literature focus on?	Figure 4	3.2
5	What types of barriers and levels of analysis did the literature focus on?	Table 2	3.2
6	Which stakeholders face the most barriers?	Table 3	3.2
7	What are the main barriers making up every barrier type?	Table 4	3.2.1

The research also involved reviewing solutions suggested in the literature to overcome those barriers and categorizing them into larger, more general recommendations. Those recommendations are presented in section 4.

The research also involved reviewing solutions suggested in the literature to overcome those barriers and categorizing them into larger, more general recommendations. Those recommendations are presented in section 4.

3 Results and Discussion

This section summarizes the results of the analysis and includes a discussion of them in light of the state of the literature.

3.1 General Results

Figure 1 depicts the number of papers published over the last few years. The increasing number of papers as shown in Figure 1 reflects an increasing interest in green building research.

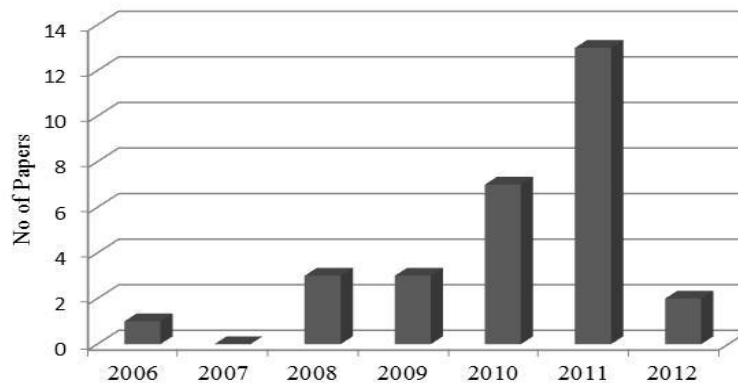


Figure 1: Reviewed Research Papers per Year of Publication

Figure 2 depicts the number of papers published by country of origin. This country of origin refers to the country where the research in question was conducted. As depicted, researchers from the USA, China, Canada, and Malaysia seem to be leading research in the field.

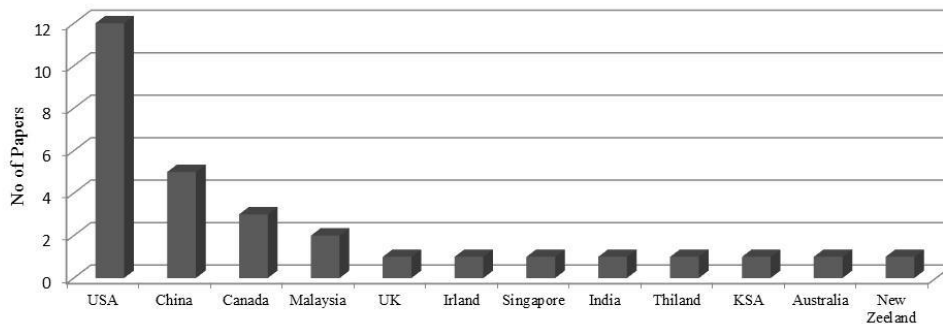


Figure 2: Reviewed Research Papers per Country of Origin

The literature review also involved analyzing barriers per building lifecycle phase. Twenty-two papers focused on barriers encountered during the design and construction phase while only one paper focused on the operation and maintenance phase. Six papers in total identified barriers faced throughout the entire building lifecycle.

The review also involved analyzing the primary research methods used in the papers reviewed. As shown in Figure 3, most research studies used surveys (questionnaires), interviews, workshops, and case studies as their primary research method.

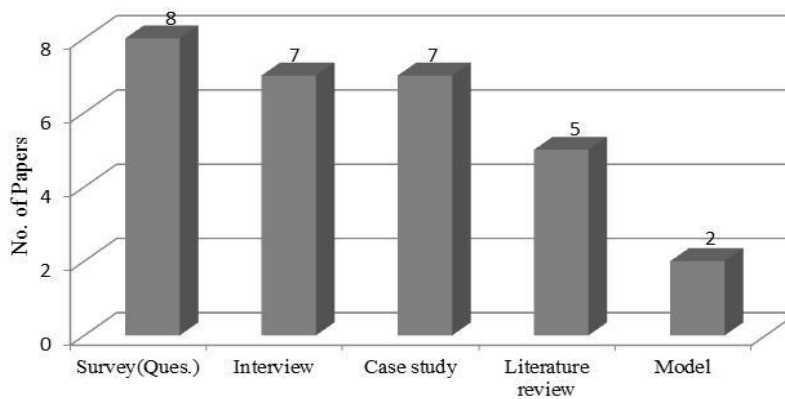


Figure 3: Primary Research Methods used in Reviewed Research Papers

3.2 Detailed Results

This section presents the detailed results of the analysis.

3.2.1 Barrier Type, Level of Analysis and Stakeholder Group

The analysis also involved categorizing papers according to the type of buildings for which barriers were investigated. As shown in Figure 4, most research seems to focus on barriers to green buildings in general. Similar number of papers focused on academic buildings, residential buildings and commercial or administrative buildings.

The literature review identified a total of 231 barriers. These barriers were classified by barrier type and level of analysis as shown in Table 2. Four types of barriers were identified: financial, managerial, social and technical. The three levels of analysis used include:

- Individual level: Barriers at this level are those encountered at the individual observer level. They can be subjective given how difficult it is for individuals to achieve pure rationality (March and Simon 1958, Simon 1957). They are based on cognitive heuristics which can lead to a wide variety of decision-making biases (Bazerman 1998, Kahneman and Tversky 1973, Kahneman and Tversky 1979).
- Organizational level: These barriers occur at the company level and tend therefore to be Managerial in nature. Unlike barriers at the individual level, they are usually encountered by a group of people.
- Strategic level: These are barriers at the industry level that are prevalent among construction companies with at least one common characteristic such as region, size, or project type. External factors such as government policies or economic and social conditions can affect them. Solutions to overcome these barriers usually need intervention at a higher level such as the government to be implemented.

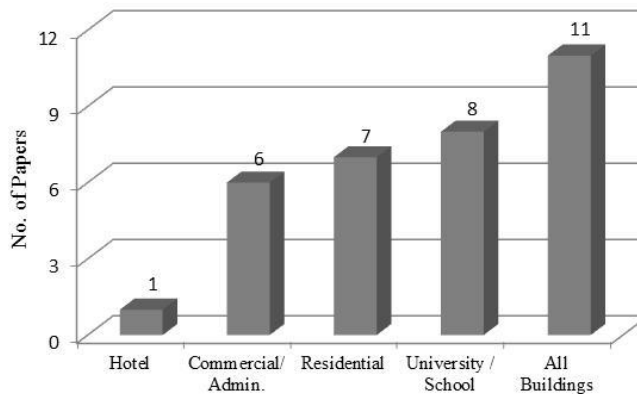


Figure 4: Reviewed Research Papers per Building Type

Table 2: Reviewed Research Papers per Barrier Type and Level of Analysis

Barrier Type	Barrier Level of Analysis			Total
	Individual	Organizational	Strategic	
Financial	2	41	N/A	43
Managerial	3	41	6	50
Social	9	24	13	46
Technical	6	80	6	92
Total	20	186	25	231

These barriers were also classified according to the group of stakeholders that usually encounter these barriers. The analysis defined five main groups of stakeholders: Contractor, designer, government, occupant, and owner and building manager. Table 3 shows the results of this analysis.

As shown in Table 2 and 3, barriers at the organizational level seem to be the most prevalent. Table 3 shows how barriers encountered by building occupants are mostly barriers encountered at the individual level and are not therefore the result of bad managerial decisions. Owners and building managers also face many of the barriers identified which, understandably, tend to be at the organizational level. Many of

their barriers are also of the financial and managerial type whereas barriers faced by designers tend to be technical and social in nature.

Table 3: Reviewed Research Papers per Stakeholder Group, Barrier Type and Level of Analysis

Stakeholder Group	Barrier Level of Analysis				Barrier Type			Total
	Individual	Organizational	Strategic	Financial	Managerial	Social	Technical	
All	4	10	14	2	4	14	8	28
Contractor	N/A	22	N/A	3	1	1	17	22
Designer	N/A	23	N/A	2	1	8	12	23
Government	N/A	8	10	2	6	7	3	18
Occupants	9	2	N/A	1	1	3	6	11
Owners/Building Managers	7	117	1	32	37	13	43	125

3.2.2 Main Barriers per Type

As a total of 231 specific financial, managerial, social and technical barriers were identified, the following subsections will only focus on listing and describing the major 15 barriers under which all of these specific barriers fall.

3.2.2.1 Financial Barriers

As shown in Table 4, three main financial barriers were identified in the literature:

- High costs: High initial capital costs are usually perceived as a major financial barrier (e.g., Chan et al. 2009, Zhang et al. 2011, Edwards and Kumphai 2012). These are usually due to the cost of applying new green technologies (Cupido et al. 2010) the cost of certifying these buildings to meet green building standards (Chansomsak and Vale, 2010), and the cost of maintaining these buildings (Briller and Hamilton, 2011). Limited construction budgets further exasperate the problem (Skabelund et al., 2010).
- Uncertainty about long-term benefits: The lack of empirical, documented data about the long-term cost benefits of green buildings fuels this uncertainty (Chen *et al.* 2011, Saleh et al. 2011). Discrepancies between expected versus achieved green building credits result in less benefits than anticipated (e.g. higher rebuilding costs or less tax credits), compounding the problem further (Tollin, 2011).
- Lack of incentives: This includes the lack of public and private incentives (Bin Esa *et al.* 2011, Van Schaack and BenDor 2011) such as loans and tax credits.

3.2.2.2 Managerial Barriers

As shown in Table 4, four main barriers could be identified:

- Ineffective organizational structure: An organization's internal structure can be the source of many problems (Alshuwaikhat and Abubakar 2008, Stafford 2011) and if ineffective, can have an impact on its culture (Hellmund *et al.* 2008, Hoffman and Henn 2008), the degree of internal support for green building initiatives (Brinkhurst, 2011), and the leadership responsible for fostering these initiatives (Robichaud and Anantatmula, 2011).
- Lack of communication and collaboration: The green building delivery process requires higher levels of team integration, collaborative working and decision-making than the conventional

building delivery process (e.g., Edwards and Kumphai 2012). Lack of experience with the process can result in too many (Zhang, Shen and Wu, 2011) or few communication channels (Li *et al.*, 2011), thus the need to ensure a sound internal structure as explained earlier (Edwards, 2006).

- Lack of guidance: This refers to the lack of policies, regulations, and guidelines to inform the design, construction, operation and maintenance of green buildings at the organizational level (e.g., Mason *et al.* 2011, Yang and Zhou 2010) and the absence of an organizational framework to guide the setting, implementation and adoption of this guidance (Cupido, 2010).
- Competing stakeholder interests: The green building delivery process brings together more stakeholders with different and sometimes competing interests than the conventional building delivery process (Winston, 2010). Aligning those with the larger goals of the project can be challenging (e.g., Zhang *et al.*, 2011).

Table 4: Main Barriers Identified per Barrier Type

Barrier Type	Main Barriers	No. of Barriers
Financial	High costs	20
	Uncertainties about long-term benefits	12
	Lack of incentives	11
Managerial	Ineffective organizational structure	25
	Lack of communication and collaboration	12
	Lack of guidance	9
	Competing stakeholder interests	4
Social	Lack of public awareness	32
	Lack of government and green building standard organizations support	10
	Low demand for green buildings	4
Technical	Lack of knowledge & training	44
	Problems with existing technologies	27
	Limited resources	13
	Lack of suitable technologies	8

3.2.2.3 Social Barriers

As per Table 4, social barriers include:

- Lack of public awareness: This barrier refers to the need to raise people's awareness of the importance of green building (Chan *et al.* 2009, Winston 2010, Bin Esa *et al.* 2011) and build more support at the community level to ensure a thriving green building market.
- Lack of government and green building standard organizations support: Government support and involvement is crucial in advancing the practice of green building (Mason *et al.*, 2011). Their involvement can help regulate green building by developing policies, procedures, regulations and guidelines that would support the industry. Non-governmental standard organizations such as the Canada Green Building Council also play a pivotal role in developing and promoting this guidance as well as encouraging its adoption (Chansomsak and Vale, 2010).
- Low demand for green buildings: While some regions are thriving green building markets, others might not attract as much investments. Analyzing why this is the case is crucial to addressing the low demand for green buildings in some areas and ensuring widespread adoption of green building principles (Yang and Zhou, 2010).

3.2.2.4 Technical Barriers

Technical barriers include:

- Lack of knowledge & training: Lack of knowledge about green building principles (Hellmund et al., 2008), technologies (Zhang et al., 2011) and requirements (Chen et al., 2011) can be debilitating and require extensive training and education to ensure practitioners in the field are able to address them. This can have a significant impact during design, construction or post-occupancy when the need to improve energy efficiency and reduce energy costs is at its highest (Bond, 2011). Poor design quality (Robichaud and Anantatmula, 2011), improper commissioning (Tollin, 2011) and maintenance (Zhang et al., 2012) can also affect the performance of green buildings.
- Problems with existing technologies: While the practice of green building has witnessed tremendous success, the relative novelty of the field is such that there are technical problems with existing green building technologies (Edwards, 2006). Some new technologies are difficult to implement (Hellmund et al., 2008). Others can carry tremendous risk and might need to be validated before they can be implemented safely (Griffin et al., 2010).
- Limited resources: This barrier refers to the lack of skilled and experienced personnel such as architects, designers, engineers and contractors (Potbhare et al., 2009) and green building materials (Griffin et al. 2010, Saleh et al. 2011). The time needed to achieve green building certification is another limitation that also needs to be addressed (Scammell and Waugh, 2009).
- Lack of suitable technologies: While there are problems with existing technologies, there is also a need for new technologies (Potbhare et al., 2009), new machinery and equipment (Li et al. 2011), and new standards and regulations to advance the practice (Winston, 2010).

4 Recommendations to Overcome Barriers

A number of context-specific solutions were made by researchers to address barriers to the design, construction, operation and maintenance of green buildings. This study involved categorizing those solutions into more general recommendations and adding to them when appropriate. These recommendations include:

- Increasing public awareness: This is essential as most problems seem to stem from a lack of public support as shown in Table 4. Increasing public awareness is a multi-faceted recommendation that needs to be implemented using a number of ways. Ways to do so involve using the media to promote green building and sustainability, planning community events that showcase green building success stories, and educating the public through public lectures, seminars and workshops.
- Improving education and training for construction professionals: Providing continuous professional development opportunities (i.e. training and educational opportunities) to practitioners in the field is essential to advancing the practice and ensuring they stay on top of the latest changes in the field.
- Establishing new guidance: New policies, procedures, regulations, and guidelines need to be established at the federal, provincial and municipal level to regulate and benchmark the practice of green building. Developing this guidance will help establish a national strategic vision and encourage and promote the practice of sustainability among new market players. New standards are also needed to address the constant changes in the field and lessen the gap between knowledge generation (i.e. research) and knowledge translation (i.e. practice). Guidance should also be developed at the organizational level to ensure compliance at this level with the new vision.

- Restructuring construction organizations: Motivating internal key players in construction organizations is the key to ensuring their success. Organizations need leaders to champion their new vision. They also need internal restructuring of their various departments, staff and business processes to address the new challenges that come with embracing sustainability.
- Fostering innovation: There is a constant need to improve existing technologies and introduce new ones to stay on top of the latest changes in the field. As practitioners themselves are not responsible for devising these technologies, it is essential that there is close collaboration with researchers to do so in order to improve the green building delivery process and ensure continued success.

5 Conclusion

This research involved investigating barriers to the design, construction, operation and maintenance of green building in the literature and developing general recommendations to overcome them. A detailed analysis of those barriers and recommended solutions was undertaken, the aim being to conduct a state of the art review to establish a new vision for researchers and practitioners. The literature review showed the following results:

- There is an increase in the number of scientific publications over the last few years about barriers to green building which is indicative of the increasing interest in green building and the growth of the green building market.
- Most researchers seem to have focused on barriers to the design and construction of buildings. With the industry's increasing focus on the maintenance of existing buildings and infrastructure, future research needs to shift its focus to addressing barriers encountered post-occupancy and associated with their maintenance and rehabilitation.
- Technical barriers in particular seem to dominate the scientific discourse, which is indicative of the importance of technical experience and expertise when building green, thus the need to address these barriers first and foremost.
- Other important barriers include social and technical barriers at the individual level, technical and financial barriers at the organizational level, and social and managerial barriers at the strategic level. These results highlight the need to improve technical training for practitioners by developing technical training programs at the institutional level, and the need to raise public awareness of the importance of green building at all levels. There is also a need to increase investments in green building at the organization level and a need to improve the management of the green building process and existing guidance on building green at the strategic level.
- Occupants encounter technical barriers when operating and maintaining green buildings as much as owners and building managers, thus the need to focus more on the role that building occupants play in effectively operating and buildings they live and work in.
- Governments should play a pivotal role in increasing public awareness, establishing new regulations and standards for green building professionals and defining sustainability as a key strategic priority to advance research and practice in the field.

Despite its contribution, this literature review showed how there was little research on barriers to the effective operation and maintenance of green buildings, making the need to analyze those phases of utmost importance. Future research should also focus on investigating the effectiveness of current management practices of green building organizations and undertaking more post-occupancy evaluations of green buildings to validate, if applicable, some of their potential long-term benefits.

References:

- Alshuwaikhat, H.M. and Abubakar, I., 2008, An Integrated Approach to Achieving Campus Sustainability: Assessment of the Current Campus Environmental Management Practices. *Journal of Cleaner Production*, 16:1777-1785.
- Bazerman, M., 1998, Judgment in Managerial Decision Making, New York, John Wiley
- Bin Esa, M.R., Marhani, M.A., Yaman, Noor, R.A.A.H., Noor Rashid, H., Adnan, H. 2011. Obstacles in Implementing Green Building Projects in Malaysia, *Australian Journal of Basic and Applied Sciences*, 5:1806-1812.
- Bond, S. 2011. Barriers and drivers to green buildings in Australia and New Zealand, *Journal of Property Investment & Finance*, 29 (4):494-509.
- Briller, D.L. and Hamilton, B. ,2011,Using LEED® to Facilitate The Eisa Goal of Zero Fossil Fuel Use in New Federal Buildings, *Strategic Planning for Energy and the Environment*. 30(4):7-70.
- Brinkhurst, M., Rose, P., Maurice, G., Ackerman, J.D. 2011, Achieving campus sustainability: top-down, bottom-up, or neither? , *International Journal of Sustainability in Higher Education*. 12(4):338-354.
- Chan, E.H.W., Qian, Q., Lam, P.T.I., 2009, The market for green building in developed Asian cities-the perspectives of building designers. *Energy Policy*, 37:3061–3070.
- Chansomsak, S. and Vale, B. ,2010, Processing Practices of Sustainable School Design. *Journal of Green Building*, 5 (2):147-157.
- Chen, Q., Kinzel, G., Zimmerman, A., Potter, S., Lichtensteiger, M. 2011. Barriers and Impediments to A Holistic Approach to Promoting Super-Energy-Efficient (SEE) Homes, *Journal of Green Building*, 6(1):93-103.
- Cupido, A.F., Baetz, B.W., Pujari, A., Chidiac, S. 2010. Evaluating Institutional Green Building Policies: A Mixed-Methods Approach, *Journal of Green Building*, 5(1):115-131.
- Edwards, B. 2006. Benefits of Green Offices in the UK: Analysis from Examples Built in the 1990s. *Sustainable Development*, 14:190–204.
- Edwards, T.J. and Kumphai, W. 2012. Sustainability in Multi-tenant Office Buildings: Anatomy of a LEED EBOM Program, *Energy Engineering*, 109: 7-23.
- Griffin, C.T., Knowles, C., Theodoropoulos, C., Allen, J.H. 2010. Barriers to the implementation of sustainable structural materials, Structures and Architecture - *Proceedings of the 1st International Conference on Structures and Architecture*, ICESA, 1349-1357.
- Hellmund AIA, A.J., Van Den Wymelenberg K.G., Baker, K. 2008. Facing the Challenges of Integrated Design and Project Delivery, *Energy Engineering*, 105:36-47.
- Hoffman, A. J. and Henn, R. 2008. Overcoming the Social and Psychological Barriers to Green Building, *Organization Environment*, 21(4): 390-419.
- Kahneman, D. and Tversky A. 1979. Prospect theory: An analysis of decision under risk. *Econometrica*, 47:263-291.
- Kahneman, D. and Tversky, A. 1973. On the psychology of prediction. *Psychological Review*, 80: 237-251.

- Li, Y.Y., Chen, P.H., Seng Chew, D.A., Teo, C.C., Ding, R.G. 2011. Critical Project Management Factors of AEC Firms for Delivering Green Building Projects in Singapore. *Journal of Construction Engineering and Management* © ASCE. 1153-1163.
- March, J. and Simon, H. 1958. Organizations, New York, John Wiley.
- Mason, S.G., Marker, T., Mirsky, R. 2011. Primary Factors Influencing Green Building in Cities in the Pacific Northwest. *Public Works Management & Policy*, 16:157–185.
- Potbhare, V., Syal, M., Korkmaz, S. 2009. Adoption of Green Building Guidelines in Developing Countries based on U.S. and India Experiences. *Journal of Green Building*, 4 (2):158-174.
- Robichaud, L.B. and Anantatmula, V.S. 2011. Greening Project Management Practices for Sustainable Construction. *Journal of Management in Engineering* © ASCE, 47-57.
- Saleh, A.A., Kamarulzaman, N., Hashim, H., Hashim, S.Z., 2011. An Approach to Facilities Management (FM) Practices in Higher Learning Institutions to Attain a Sustainable Campus. *The 2nd Int'l Building Control Conference, Procedia Engineering*, 20:269–278.
- Scammell, L. and Waugh, L.M. 2009. A Survey of Building Industry Members to Determine Factors Affecting LEED Implementation. *2nd international 8th Construction Specialty Conference of CSCE*, St. John's, Newfoundland and Labrador, Canada: 1189-1198.
- Simon, H. 1957. Models of man, New York, John Wiley.
- Skabelund, L.R., Gabbard, R.T., Anderson, B.G., Champion, B.L. 2010. Turning A Corner: Kansas State University Seeks to Meaningfully Address Green Building and the Sustainable Use of Energy and Resources on Campus and in the Broader Community, *Journal of Green Building*, 5(4):34-66.
- Stafford, S.L. 2011. How Green Is Your Campus? An Analysis of the Factors That Drive Universities to Embrace Sustainability, *Contemporary Economic Policy*, 29(3):337–356.
- Tollin, H.M. 2011. Green Building Risks: It's Not Easy Being Green, *Environmental Claims Journal*, 23:199-213
- Van Schaack, C. and BenDor, T. 2011. A comparative study of green building in urban and transitioning rural North Carolina, *Journal of Environmental Planning and Management*, 54:1125-1147.
- Winston, N. 2010. Regeneration for Sustainable Communities? Barriers to Implementing Sustainable Housing in Urban Areas. *Sustainable Development*, 18:319–330.
- Yang, G.S. and Zhou, Y.P. 2010. Research on the Government Incentive of Green Buildings in China. *International Conference on Management and Service Science (MASS)*, 978-1-4244-5326-9/10© IEEE
- Zhang, X., Platten, A., Shen, L. 2011. The market for green building in developed Asian cities the perspectives of building designers, *Building and Environment*, 46: 2153-2160.
- Zhang, X., Shen, L., Wu, Y. 2011. Green strategy for gaining competitive advantage in housing development: a China study, *Journal of Cleaner Production*, 19:157-167.
- Zhang, X., Shen, L., Tamb, V.W.Y., Lee, W.W.Y. 2012. Barriers to implement extensive green roof systems: A Hong Kong study, *Renewable and Sustainable Energy Reviews*, 16:314– 319.