Chapter 23
Analysis on the Effectiveness of Implementing Green Construction Guidelines

Zhiyu Huang, Yanyan Ke and Mingxue Ma

Abstract Green construction is an important strategy for energy saving in construction, thus contributing to the mission of sustainable construction. By appreciating the importance of green construction, this paper presents the key principles of Green Construction Guidelines (GCG) introduced by the Chinese government, including energy saving, land saving, water saving, materials saving, and environment protection (4S1E). Four case studies are chosen to examine the effectiveness of the principles defined in GCG. Green construction technology and management methods adopted in these cases for implementing green construction are particularly investigated through comprehensive survey. The impacts and benefits from implementing GCG have been presented.

Keywords Green construction · Effectiveness · Guideline · Technology · Management

23.1 Introduction

China has been developing rapidly over last several decades, driving by the massive scale of urbanization process. In line with this, the energy consumption on buildings and construction activities has been rising year by year, which has become one of the main contributor to the China's energy consumption. The research report by the Chinese Research Institute for Built Environment (CRIBE 2005) suggests that the construction activities adds the environmental load with 15–45 % of total

Z. Huang (✉)
Chongqing University of Science and Technology, Chongqing, China

Y. Ke
JiMei University, Xiamen, China

M. Ma
Northwest University, Xian, China

L. Shen et al. (eds.), *Proceedings of the 19th International Symposium on Advancement of Construction Management and Real Estate*,
DOI 10.1007/978-3-662-46994-1_23

burden on environment; construction caused waste is 40 % of the total waste; the energy consumed for building materials, transportation accounted for 10 % of total construction energy consumption; energy for operating building accounts for 20–40 % of total energy consumption. According to the study by Zhang and Huang (2006), the energy for implementing construction activities in China amounted to 32 % of the whole energy consumption in the country. It is estimated that by year 2020, the energy consumption for construction will be the largest part of total energy consumption in China. Therefore, energy saving by implementing sustainable construction practice will make significant contribution to the achievement of sustainable development in China.

The Ministry of Construction in China issued a Green Construction Guidelines (2007), hereinafter referred to as the "Guidelines", which is designed to provide guidance for the implementation of green construction. The guidelines project promote the green construction technology for the aim of achieving the saving of energy, land, water and material, and the environmental protection, so called "Four Savings and One Protection". The Guidelines are the premise of assurance for the maximum resource conservation and minimum construction activities' negative influence on environment. In 2006, the Ministry of Construction issued the Criteria for the Green Building Evaluation (GB/T50378—2006), requiring that in the construction and management, principles of green building construction should be actively implemented by adopting proper measures (RT-GCAC 2006). In 2008, the Ministry of Construction established an office responsible for evaluation of management, marking the first step of green building assessment activities. In conducting the evaluation, green buildings are divided into three categories: one-star, two-star and three-star. To gain the three-star level of green building, the practice of green construction is a must. As the end of 2013, a total of 1260 green building projects have been awarded green building throughout the country, including 480 one-star buildings, 530 two-star projects and 312 three-star projects (Sina Estate Nets 2014). And each year, the country provides a total of 20 billion cubic meters construction projects. Considering the size of the construction industry in China, the number of the buildings awarded as a green building is extremely limited. The green practice in construction has just started in many areas. Management in many construction enterprises is still lack of green construction knowledge. Therefore, studies on the green construction technologies, and promoting the green construction guidelines, either for conservation of natural resources or protect environment, all bringing about the positive significance.

Existing studies have examined extensively the present progress in practicing green construction, but mostly they studies have focused on technical measures, management methods. Among them, Zhong (2011) examined a commercial plaza project as an example which has adopted various green construction technologies. In this project, advanced management and technical measures were applied, aiming at reducing as much as possible the negative effects of construction activities on the consumption of resources and environment. Wen (2009) discussed the ways of energy-saving and water-saving in construction sites. Guo et al. (2011) opined that the construction firms are largely lack of the green construction technology in China

and suggested developing a green construction technology innovation system to mitigate the problem of insufficient innovation. Xiong (2010) conducted an analysis on the status quo of the implementation of current green standards and regulations, and pointed out that green construction has been effectively applied in many good cases. He identified a number of feasible measures for the implementation of green construction though examining a number of cases. And there are still other studies of green construction, for example, Sun (2011a) and Liu (2011).

These studies have made important impacts on promoting green construction development. Nevertheless, little studies have investigated the influence or the effectiveness of the Guidelines since its introduction. Therefore this paper aims for analyzing the effectiveness and benefits of the Guidelines on the development of green construction practice.

23.2 Research Methods

Several methods are incorporated in conducting this research. Literature review was conducted to confirm the understanding on the definition of green construction, the principles of the Guidelines. Sample building projects are used to examine the application of green construction technology and management measures. These samples are also used for comparative analysis on the effects of Guidelines to gaining the benefits of green construction. Furthermore, interviews are conducted to generate further research data to support analysis, in which four experts are involved in the interview survey.

23.3 Evaluation Indices in the Guidelines

The Guidelines are divided into six parts, namely, preface, general principles of green construction, overall framework of green construction, key aspects of green construction, the development of green technology, equipment, materials, and the demonstration project in the application of green construction. In general principles, the objective of "Four Savings and One Protection" is defined. The overall framework of green construction can be shown in Fig. 23.1.

Green construction is defined as including six criteria: the green construction management, environmental protection, saving material and material resource use, water saving and water resources utilization, energy saving and utilization, land saving and construction land protection. Specifications on these six elements are described from the perspective of technology and management. The further analysis in this paper focuses on the principles of these six elements.

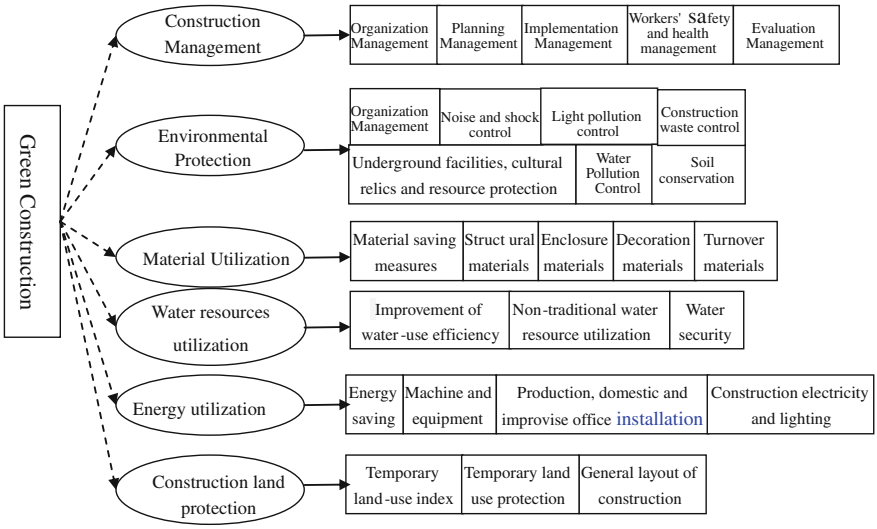

Fig. 23.1 Framework of green construction assessment

23.4 Case Studies on the Application of the Guidelines

23.4.1 Background of Case Studies

Four sample green building projects are selected for study, including two public buildings, one commercial project and one residential project. The details specifications of these sample cases are shown in Table 23.1.

Table 23.1 The sample green construction projects

Code of project	Location	Starting time	Structure type	Scale (km^2)	Project type	Remarks
A	Shanghai	10/2007	Frame-tube	l98	Commercial	Conservation-oriented project
B	Hangzhou	07/2008	Reinforced concrete frame	34	Public	Three-star green buildings
C	Beijing	04/2010	Frame shear wall	25	Residential	Non-specified project
D	Chongqing	08/2011	Reinforced concrete	74	Public	Green project

Sun 2011b, Wu et al. 2011, Wu 2008

23.4.2 Green Construction Management

As shown in Fig. 23.1, the green construction management is defined in several aspects, including organization, planning, implementation, evaluation and staff safety and health. It is required that the green construction project manager, as the primary person of responsibility in the preparation of construction plan, should take into account of the measures for "Four Savings and One Projection", strengthening management and supervision of the construction links, and performing the evaluation on the green construction and using innovation technology and equipment. Safety and health of construction personnel are particularly emphasized in examining green construction. There are five categories defined in the Guidelines from the perspective of construction management:

1. Organization Management (OM)
   OM1—establishing organization for implementing green construction
   OM2—allocating staff responsible for green construction
2. Planning Management (PM)
   PM1—produce green construction plan
   PM2—define methods for implementing plan
3. Action Management (AM)
   AM1—supervise all implementation procedures
   AM2—training for staff
   AM3—promotion and building up green construction culture
4. Evaluation Management (EM)
   EM1—self evaluation
   EM2—comprehensive evaluation
5. Safety and health management (SHM)
   SHM1—identify safety protection measures
   SHM2—proper arrangement on site
   SHM3—healthy living and working environment

As indicated in Table 23.2, the project A and B were conducted for construction in an earlier time, these two projects made good influence on implementing green practice in local construction market. In particular, the Project B is a three-star green building, demonstrating the active participation in practicing green construction although the Guidelines was just issued that time.

It is noted that the project management team in these projects contributed good efforts in promoting green practice through close supervision and providing proper training to staff. Nevertheless, it appears that safety and health are not given sufficient attention except the management for Project C having taken measures for safety and health.

Table 23.2 Comparison of the construction management measures

Measures	Case projects			
	A	B	C	D
OM				
OM1	Unspecified	Unspecified	O	O
OM2			O	O
PM				
PM1	Unspecified	O	O	O
PM2	Unspecified	Unspecified	O	O
AM				
AM1	O	O	O	O
AM2	O	O	O	O
AM3	O	O	O	O
EM				
EM1	O	Unspecified	O	O
EM2	X		X	X
SHM				
SHM1	Unspecified	Unspecified	O	Unspecified
SHM2			O	
SHM3			O	

23.4.3 Environmental Protection Measures

Environmental protection measures weigh heavily in the Guidelines, which requests for the implementation of seven aspects, including dust, noise, light pollution and so on. In line with these seven aspects, this study selected 20 specific technical measures for comparison, which are described as follows:

1. Dust control (DC)
   DC1—To avoid polluting the external environment during the process of materials delivery
   DC2—To limit the level of dust emission
   DC3—To plan the measures for controlling the dust from mechanical or explosive activities
2. Noise and Vibration Control (NVC)
   NVC1—To control on-site noise
   NVC2—To use low-noise and low-vibration tools
3. Light pollution control (LPC)
   LPC1—To adopt lampshade for night lamp during construction
   LPC2—To provide shielding measures for welding activities
4. Water pollution control (WPC)
   WPC1—To meet the national wastewater discharge standard (GB8978-1996)
   WPC2—To provide measures for sewage treatment
   WPC3—To monitor the standard of wastewater

Table 23.3 Comparison of the environmental protection measures

Measures	Case projects			
	A	B	C	D
OM				
OM1	Unspecified	Unspecified	O	O
OM2			O	O
PM				
PM1	Unspecified	O	O	O
PM2	Unspecified	Unspecified	O	O
AM				
AM1	O	O	O	O
AM2	O	O	O	O
AM3	O	O	O	O
EM				
EM1	O	Unspecified	O	O
EM2	X		X	X
SHM				
SHM1	Unspecified	Unspecified	O	Unspecified
SHM2			O	
SHM3			O	

WPC4—To protect the groundwater environment

5. Soil protection (SP)
   SP1—To protect the surface environment of the land and preventing from soil erosion
   SP2—To recycle the toxic waste
   SP3—To restore the destructed vegetation land
6. Construction Waste Management (WM)
   WM1—To produce waste reduction plan
   WM2—To achieve the rate of 30 % for waste reuse and recycle
   WM3—To provide enclosed garbage containers
7. Protection for underground facility and resources (UFR)
   UFR1—To plan the measures for protecting the underground facilities
   UFR2—To plan the measures for protecting the historical trees
   UFR3—To analyze the CO_2 emission

The application of these measures in the four case studies are shown in Table 23.3.

It can be seen that the specifications of dust control, noise control, vibration control, light pollution control and water pollution control are well practiced in practice. There is a need for efforts to improve waste management and monitor the quality of water. In particular, the management in the organization needs to give due attention on these areas.

23.4.4 Material Savings and Resource Utilization Measures

The Guidelines specifies five areas on materials saving, and each areas include various specific specifications. This study refers to the four sample projects and examines 26 specifications under the five areas, which are addressed in the follows:

1. Materials saving measures (MS)
   MS1—material loss is 30 % lower than the norms
   MS2—proper arrangements for the purchase of materials and the time for delivery to site
   MS3—material stacked orderly
   MS4—transport of materials properly to avoid double handling
   MS5—the procurement of materials within 500 km more than 70 %
2. Structural Materials (SM)
   SM1—use of ready-mixed mortar
   SM2—use of high-strength reinforced and high-performance concrete
   SM3—reinforcement steel processing and distribution
   SM4—optimal method for materials cutting and installation
   SM5—optimal method for special construction activities
3. Maintenance materials (MM)
   MM1—applying the materials with weather-bearing and good durability
   MM2—insulation and soundproofing of doors and windows
   MM3—insulation of accessory materials
   MM4—structural solution for the insulation system
4. Decoration Materials (DM)
   DM1—overall layout of veneer materials
   DM2—use of new materials
   DM3—meeting the requirements for adopting sewage coating grassroots
   DM4—synchronization of the embedded components with construction
   DM5—procurement for wood products and glass lamp from manufactures
   DM6—reduction in using liquid adhesive on site
5. Replaceable Materials (RM)
   RM1—Durable and easy for maintenance and demolition
   RM2—Production of formwork by professional firm
   RM3—Using steel formworks or steel-framed bamboo formworks
   RM4—Optimal the methods of using formwork
   RM5—Replacement of concrete formwork with the external wall insulation board
   RM6—Applying multiple-uses and moveable site office

The application of these measures in the four case studies are summarized in Table 23.4.

It can be seen from Table 23.4 that the project B adopted fewer measures for materials saving and resource utilization, while the projects A, C, and D are found adopted more measures for materials saving, structural materials and recyclable

Table 23.4 Comparison of the material savings and resource utilization

Measures	Case projects			
	A	B	C	D
MS				
MS1	O	Unspecified	O	O
MS2	O		O	O
MS3	X		X	O
MS4	O		X	O
MS5	X		O	X
SM				
SM1	O	X	X	O
SM2	O	X	X	X
SM3	X	X	X	X
SM4	X	O	O	O
SM5	O	X	X	X
MM				
MM1	Unspecified	Unspecified	O	O
MM2			O	O
MM3			O	X
MM4			X	X
DM				
DM1	Unspecified	Unspecified	Unspecified	O
DM2				O
DM3				O
DM4				O
DM5				O
DM6				O
RM				
RM1	O	Unspecified	O	O
RM2	X		X	X
RM3	X		X	O
RM4	O		X	O
RM5	O		X	X
RM6	O		X	O

materials. Among them, the projects A and D put more emphasis on the optimization and use of recyclable materials, with particular focus on the optimization of using formwork. Regarding maintenance materials and decoration materials, the project C adopted due measures. There are three reasons behind this: Firstly, according to the existing building energy efficiency design specification, it is required to apply insulation and sound insulation in order to meet these standards. Maintenance materials and insulation materials should both comply with the relevant norms and standards, so there is no need to add additional measures; Secondly,

these two technologies are not difficult for application, and they have gained the popularity in practice; Thirdly, China Construction Industry Association developed a Checklist of the National Construction on the Implementation of Green Construction Demonstration Projects, upon which the two items assumes lower score, thus they do not attract attention from construction firms.

23.4.5 Water Saving and the Utilization of Water Resources

The Guidelines specifies three areas on water saving and water resourcing, including improvement of water utilization efficiency, use of non-traditional water resources, and water use safety. Each areas include various specific specifications. This study refers to the four sample projects and examines 9 specifications under the three areas, which are addressed in the follows:

1. Water utilization efficiency (WUE)
   WUE1—use of advanced water-saving construction techniques
   WUE2—reducing the use of municipal tap water
   WUE3—proper arrangement for water supply network
   WUE4—water recycling device and its use
   WUE5—water quota and measurement
2. Non-traditional water resources (NTW)
   NTW1—use of foul-water and collection of rainwater harvesting
   NTW2—use of underground water
   NTW3—use of non-traditional water and recyclable water for more than 30 %
3. Water use safety (WUS)
   WUS1—test of water quality and water safety measures

The application of these measures in the four case studies are summarized in Table 23.5.

It can be noted from the above table that the importance to efficiency of water use, especially to the reduced use of municipal tap water has been considered across all the four sample projects. Project D, in particular, planned properly the water use arrangement on site. The advantage of the height difference of the terrain was fully taken to collect rainwater, along with the establishment of a collecting pool for hydrocephalus in pits and the rinse water for pumps. In this project, water metering system was established, water saving statistics was properly recorded, and the project was considered well meeting the requirements of the Guidelines for improving water use efficiency.

Furthermore, the practice of using non-traditional water sources was implemented across all the four surveyed projects, especially the collection of rainwater and proper use of underground water. For ensuring the quality of water sources particularly the non-traditional water and recycling water, effective water quality testing and health protection measures should be provided in order to avoid adverse effects

Table 23.5 Comparison of water saving practice

Measures	Case projects			
	A	B	C	D
WUE				
WUE1	O	O	X	O
WUE2	O	O	O	O
WUE3	X	X	X	O
WUE4	O	X	O	O
WUE5	X	X	X	O
NTW				
NTW1	O	O	X	O
NTW2	O	O	O	O
NTW3	X	X	X	X
WUS	O	Unspecified	Unspecified	Unspecified

on human health. In this regards, the project A provided adequate facilities for this, and projects B, C and D did not specify how the water quality can be assured.

23.4.6 Energy-Saving and Energy Use

Energy-saving and energy use is addressed in the Guidelines in four areas, including the energy-saving measures, Management for equipment and tools, temporary facilities for living and production, and electricity for construction and lighting. The detailed specifications for investing the four case studies are as follows:

1. Energy-saving measures (ESM)
   ESM1—To define the norms of energy consumption for construction
   ESM2—To provide Energy-saving construction equipment
   ESM3—Set standards for electricity control and measurement in different allocations
   ESM4—Optimization of equipment resources
   ESM5—The use of renewable energy
2. Management for Equipment and Tools (MET)
   MEM 1—Establish equipment management system
   MEM 2—Selection of adequate mechanical equipment
   MEM 3—To improve the utilization and load rate for equipment
3. Temporary facilities for production and living (TFPL)
   TFPL1—proper design for temporary facilities, attention to sunlight, ventilation and lighting
   TFPL2—use of energy-saving materials
   TFPL3—regulating the number of air conditioning facilities and their use time
4. Electricity for construction and lighting (ECL)

Table 23.6 Comparison of energy-saving and energy utilization measures

Measures	Case projects			
	A	B	C	D
ESM				
ESM1	O	X	X	X
ESM2	O	O	X	O
ESM3	X	X	O	O
ESM4	O	X	X	O
ESM5	X	X	X	O
MET				
MET 1	O	O	O	O
MET 2	O	X	X	O
MET 3	O	O	X	O
TFPL				
TFPL1	Unspecified	Unspecified	Unspecified	X
TFPL2				X
TFPL3				O
ECL				
ECL1	O	O	O	O
ECL2	X	X	X	X

ECL1—use of energy-saving lighting appliances
ECL2—illumination ≤20 %

The applications of these specifications in the four sample projects are summarized in Table 23.6.

As seen from Table 23.6, the construction enterprises have given proper attention to energy conservation measures. Various measures for ensuring the availability of construction equipment and their management are adopted across all the four sample projects. Nevertheless, the temporary facilities for production, living and site office vary between different projects because of the restrictions by the topography and site size. The projects A, B and C are absent of the relevant instructions, and even D that can only provide the air conditioning configuration requirements and the restrictions on the use of time.

23.4.7 Land Saving and Land Protection During Construction

The Guidelines specifies three areas for land saving and land protection during construction, including land quotation for temporary use, land protection for temporary use, and construction site plane. There are 11 specific measures specified under the three areas, which are described as follows:

Table 23.7 Comparison of land saving and protection during construction

Measures	Case projects			
	A	B	C	D
LQT				
LQT1	Unspecified	Unspecified	O	O
LQT2	Unspecified		X	X
LPT				
LPT1	Unspecified	Unspecified	O	O
LPT2			X	O
LPT3			X	O
CL				
CL1	Unspecified	Unspecified	O	O
CL2			O	O
CL3			O	O
CL4			X	O
CL5			O	O
CL6			O	O

1. Land quotation for temporary use (LQT)
   LQT1—proper provision of temporary facilities and design for them for minimum land area
   LQT2—utilization rate of temporary facilities >90 %
2. Land protection for temporary use (LPT)
   LPT1—reducing the amount of excavation and backfill
   LPT2—try best to use wasteland
   LPT3—protect the existing green vegetation
3. Construction layout (CL)
   CL1—make full use of the existing buildings, roads for temporary facilities
   CL2—shorten on-site transportation distance
   CL3—meet the need for the temporary office and living room
   CL4—use movable fences in construction site
   CL5—proper road system on site
   CL6—avoid dismantle and moving of temporary facilities

The applications of these specifications in the four sample projects are summarized in Table 23.7.

From Table 23.7, it can be seen that some projects such as A and B do not have proper measures for protecting land during construction, whilst projects C and D have established various measures for ensuring that land is proper used and protected for temporary facilities during construction. In fact, temporary facilities during construction process can have major impacts on land pollution, thus good efforts must be contributed by senior management in construction organization to this important aspect.

Table 23.8 Measures of Green Construction Techniques

Measures	The scores on various aspects for green building					
	The score in the guideline	The score by A	The score by B	The score by C	The score by D	Average compliance (%)
Construction management (M1)	12	6	3	11	8	58
Environmental protection (M2)	20	10	4	13	16	53.7
Material utilization (M3)	26	10	1	9	17	35.6
Water utilization (M4)	9	6	4	3	6	52.8
Energy saving (M5)	13	7	4	3	9	44.2
Land protection (M6)	11	0	0	7	10	38.6
Total techniques (T)	91	39	16	46	66	45.9
Rate of adopted techniques (Pi) (%)	100	42.8	18	50.5	72.5	

23.5 Discussion

The above sections have demonstrated the application of various measures in the four sample projects under the six categories, namely, green construction management, environmental protection, materials utilization, water utilization, energy saving, land protection. The Guideline has specified various number of techniques for each categories for awarding green building. However, in reality, the measures in each categories are not fully implemented in practice. For example, the Guideline has specified 12 technical points (12 scores) for the category Construction Management, as shown in Table 23.8. However, the sample project A only receives 6 score in this category, and B with 3, C with 11 and D with 8. Table 23.8 provides the summary of the application status in applying the Guidelines between the four sample projects.

23.6 Conclusion

Implementation of green construction requests for the full cooperation between construction stakeholders including contractor, client, government department and various professional bodies. The Guidelines for implementing green building is available, but this study suggests that the measures and specifications in the Guidelines are not well applied by construction industry. The four sample projects examined in this study show that green performance can be achieved if good efforts are contributed throughout the organization, particularly, the efforts from senior management are essential to ensure the application of green practice.

This study also demonstrates that the grading system defined in the Guidelines provides effective mechanism for promoting green performance. The analysis in the

paper suggests that those projects with good compliance with the Guidelines would receive higher grade of green building. The effectiveness of the Guidelines will be further studied with collecting more sample projects in the further stage of this study.

References

(2005) Technical guidelines for green building. China Academy of Building Research, Beijing

"Green construction guide" working group (2007) Green construction guide. Ministry of Construction of the People's Republic of China 9

Green Building Evaluation Standard Compilation Group (2006) Evaluation standard for green building (GB/T50378—2006). Ministry of Construction of the People's Republic of China

Guo Han, Shao J, Dong K (2011) Establish of green construction technology innovation system. Green Build 1:49–53

Liu R (2011) Evaluation methods and measures of green construction. Dev Guide Build Mater 10:141–142

Sina Estate Nets (2014) Quantitative analysis of green building assessment identification program in 2013. Building energy efficiency (1)

Sun H (2011a) Research on evaluation system of green construction. Sci Technol Inf 329(17):365

Sun J (2011b) Elte green construction technology in Xinzhuang dragon's dream shopping plaza project. Constr Qual 1(29):45–60

Wen L (2009) Saving energy and reducing consumption of green construction management. Sci Technol Innov Herald 17:168

Wu P-C (2008) Elte green construction comprehensive technology of Fuzhou Wangxing Town. Fujian Constr Sci Technol 3:50–52

Wu F, Miao F-X, Zuo H-G, Guo D (2011) Green construction plan of Hangzhou science and technology museum. Zhejiang Constr 28(2):40–45

Xiong L (2010) Feasibility study on enterprise green construction. Sichuan Archit 4(30):225–227

Zhang L, Huang L (2006) The empirical analysis of life cycle cost evaluation of energy-saving architecture. Constr Econ 8

Zhong Jianmin (2011) Research on green construction technology in shopping plaza combined with examples. Constr Technol 7:149–248