A CONCEPTUAL FRAMEWORK FOR DELIVERING SUSTAINABLE BUILDING ENERGY EFFICENCY RETROFIT USING THE ENERGY PERFORMANCE CONTRACTING (EPC) IN CHINA

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ABSTRACT

Sustainable building has become a future development trend in the building sector. Building Energy Efficiency Retrofit (BEER) provides excellent opportunities to reduce energy consumption in existing buildings, and to promote environmental protection, the rational use of resources, occupants' health, all of which helps to improve the sustainability of existing buildings. Energy Performance Contracting (EPC) provided by Energy Service Companies (ESCOs) is a market mechanism to provide financial and technological support for energy efficiency projects. This paper aims to develop a sustainability promotion framework for BEER projects under the EPC mechanism to link the sustainable performance of BEER with the success factors of this EPC mechanism. Different types of building have different energy consumption characteristics. This research focuses on hotel buildings in China. The paper develops a framework for sustainable BEER through an EPC mechanism in hotel buildings based on the EFQM Excellence Model for business quality management. Interviews were conducted with experts from the hotel industry, from energy service companies and with academics. Based on the developed framework, the study has identified 11 performance indicators for sustainable BEER and 28 success factors of an EPC mechanism. This provides significant groundwork for future study in developing an assessment model to evaluate the sustainability of BEER projects.

KEYWORDS

building energy efficiency, hotel retrofit, energy performance contracting (EPC), ESCO, China

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1 INTRODUCTION

In China there are currently nearly 40 billion m^2 of buildings, and the urban building area covers up to 14 billion m^2. Ninety-five percent of existing buildings in China are "highly-energy consuming." According to the Key World Energy Statistics Report (IEA, 2006), existing buildings require over 40% of the world's total energy consumption, and account for 24% of world CO_2 emissions (IEA, 2006). Much of this consumption could be avoided by improving the efficiency of building energy systems, using current commercially viable technology. Building Energy Efficiency Retrofit (BEER) provides excellent opportunities for reducing energy consumption in buildings as well as for promoting environmental protection, rational resource use, and better health for the occupants. Although there are many benefits and large potential energy savings in existing buildings, not many have undergone energy efficiency retrofits.

Energy Performance Contracting (EPC) is a market mechanism to deliver energy efficiency projects. The EPC mechanism emerged in the U.S. during the 1970s and was introduced into China in 1998 (Shen, 2007). Energy Performance Contracting (EPC) is a financing package provided by Energy Service Companies (ESCOs) that includes energy savings guarantees and the associated design and installation services for energy efficiency projects. The EPC mechanism has great advantages for building owners wishing to implement energy efficiency retrofit projects and improve the sustainability of existing buildings.

Currently there are many sustainable building systems for newly constructed buildings and existing buildings, but few involve retrofitting at the project level. In order to implement the sustainable development principle in Building Energy Efficiency Retrofit (BEER) projects and improve the sustainability of these projects, this paper aims to develop a framework for sustainable BEER projects with an EPC mechanism, linking the sustainable performance of BEER with the success factors of the EPC mechanism. However, sustainability in different building types, e.g. residential buildings, commercial buildings, and public buildings reflects different characteristics. This research focuses on hotel buildings in China, because hotel energy takes up a large part of the total running cost, and consequently retrofitting in hotel buildings represents potentially big energy savings. The EFQM Excellence Model, is a performance management tool that provides business quality management based on mapping a company's critical success factors. This paper draws on this theory to develop a framework for sustainable BEER using an EPC mechanism. Potential key performance indicators for sustainable BEER and success factors of an EPC mechanism were consequently selected. This was then explored in a set of interviews conducted with experts from the hotel industry and energy service companies.

2 LITERATURE REVIEW

2.1 Energy consumption in hotel buildings

This research focuses on hotel buildings, which is one type of large-scale public/commercial building. According to the Tsinghua University Building Energy Research Center (THUBERC, 2007), energy consumption in large-scale public buildings and commercial buildings up to 70–300kWh/m^2 is 5–15 times that of urban residential buildings. Energy consumption in a starred hotel comprises the different operating schedules for the different functional facilities in the building. It includes the number of such facilities: the restaurants, the in-house laundry, the business centre, etc.; it takes account of the variability in occupancy levels throughout the year; it considers the varied preferences in indoor environment expected by the guests, etc. All these

aspects contribute to different operating schedules of building services systems and hence to different energy consumption situations in hotel buildings (Deng and Burnett, 2000).

In hotels the main energy consuming systems are heating, ventilation and air-conditioning (HVAC), lighting, hot water provision; electricity (lifts, etc.), and cooking. There is a lack of statistical data on detailed energy consumption in China. Energy costs in hotels constitute up to 6% of the total running costs. Take the U.S. for example: on average America's 47,000 hotels spend US$2,196 per available room each year on energy (EPA, 2009). Hotel energy consumption varies in individual countries. A survey in Beijing showed that the electricity consumption was 100–200 kWh/(m^2.a) (Xue, 2007). This range was 55–144.3 kWh/(m^2.a) in Chongqing in 2006 (Zhou et al., 2008). Another survey of nine starred hotels in Shanghai showed that the average energy consumption was 2.698 GJ/(m^2.a) (Xue, 2007). Typically, nearly 75 percent of a hotel's or motel's total energy use can be attributed to space heating, water heating, lighting, and cooling combined. Cooling and lighting alone make up half of the building's electricity consumption (EPA, 2007). There are potentially very big energy savings to be made in order to encourage hotel buildings to implement the Building Energy Efficiency Retrofit (BEER).

2.2 Building energy efficiency retrofits (BEER)

A definition of Building Energy Efficiency Retrofit (BEER) is the reduction of building energy use through certain approaches to improve the building envelope and the equipment systems, while maintaining the comfort of the building's indoor environment (Shanghai Construction and Transportation Commission, 2008). Besides retrofitting of building envelopes and equipment systems, improvement of operating and management practices should also be considered. Building energy efficiency improvements typically include the envelope structure, the equipment systems, as well as more precise control systems, and conversion to renewable energy where appropriate. Staff training and new management and monitoring strategies ensure continued optimal operation and savings.

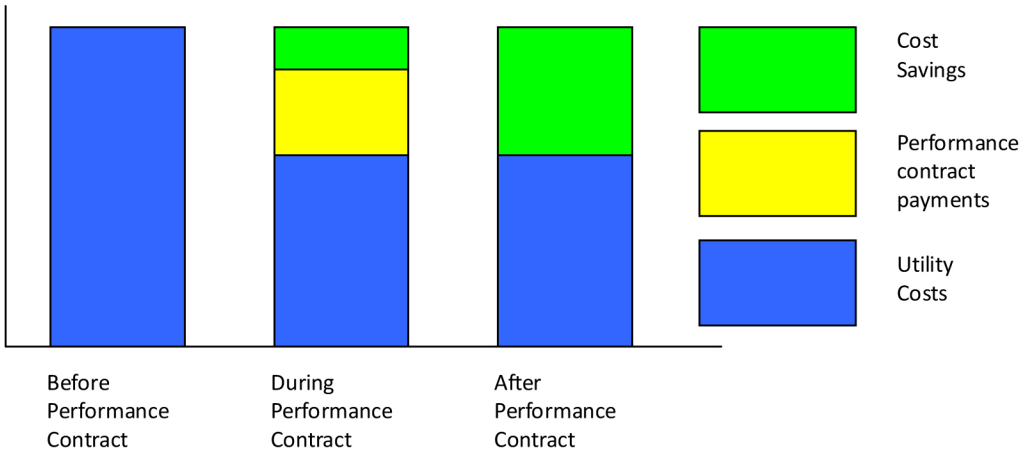
Building energy efficiency retrofits should follow an AIM (Audit-Implement-Monitor) process, which includes the following steps (CMHC, 2002):

- Audit—a study of the building and the way it uses energy, which leads to a definition of appropriate measures;
- Implement—the implementation of the measures, including engineering, project management, subcontracting, and commissioning;
- Monitor—the monitoring and tracking of energy savings to be sure they are achieved as expected, and that they are sustained.

2.3 Energy performance contracting (EPC) mechanism

Energy Performance Contracting is a mechanism for procuring and implementing capital improvements today that are self-funding over time through guaranteed operational savings. Performance contracting uses operational savings and avoided capital expenditure to fund repayment of capital for building/infrastructure improvements. However, the EPC principle is not limited to being a financing tool. An Energy Performance Contract in the EPC business may be broadly defined as a contract between an ESCO and the owner of the building consuming the energy, involving an energy efficiency investment in the owner's facilities, the performance of which is somehow guaranteed by the ESCO, with financial consequences for

FIGURE 1. Basic Concept of Energy Performance Contract.



the ESCO (Taylor et al., 2007). Under an energy performance contract, the ESCO will provide financing for a specified set of energy efficiency retrofit measures, along with the associated design, engineering, and installation services. The owner or user can obtain facilities that are highly energy efficient and make potential savings with little or even no initial investment. The basic concept of energy performance contracting is shown in Fig. 1. The first bar represents the total utility costs of one facility before the introduction of the performance contract. In the second bar, after retrofitting, the cost savings are shared between the owner and the ESCO during the performance contract period. After the performance contract period, all the cost savings belong to the owner, which is shown in the third bar.

3 UNDERSTANDING SUSTAINABLE BEER UNDER EPC

Sustainable BEER is the integration of sustainable development into existing buildings and retrofit projects (Xu & Chan, 2010). In recent decades more attention has been paid to the issue of sustainable retrofit. Keeping and Shiers (1996) proposed "green" refurbishment and analyzed its potential benefits. Sobotka and Wyatt (1998) applied the principles of "sustainable development" to the renovation of apartment buildings. Sitar et al. (2006) developed a model of sustainable renovation for a multi-apartment building. The sustainable renovation of a building was presented in two scenarios that examined the connection between the possibilities of using architectural design, renovation technology, and energy efficiency for the heating of the building. Mickaityte et al. (2008) arrived at a conceptual model of sustainable building refurbishment. Xu and Chan (2010) proposed an assessment framework for sustainable BEER from the result of the project, the technical process, and the organizational process perspectives, based on a balance scorecard.

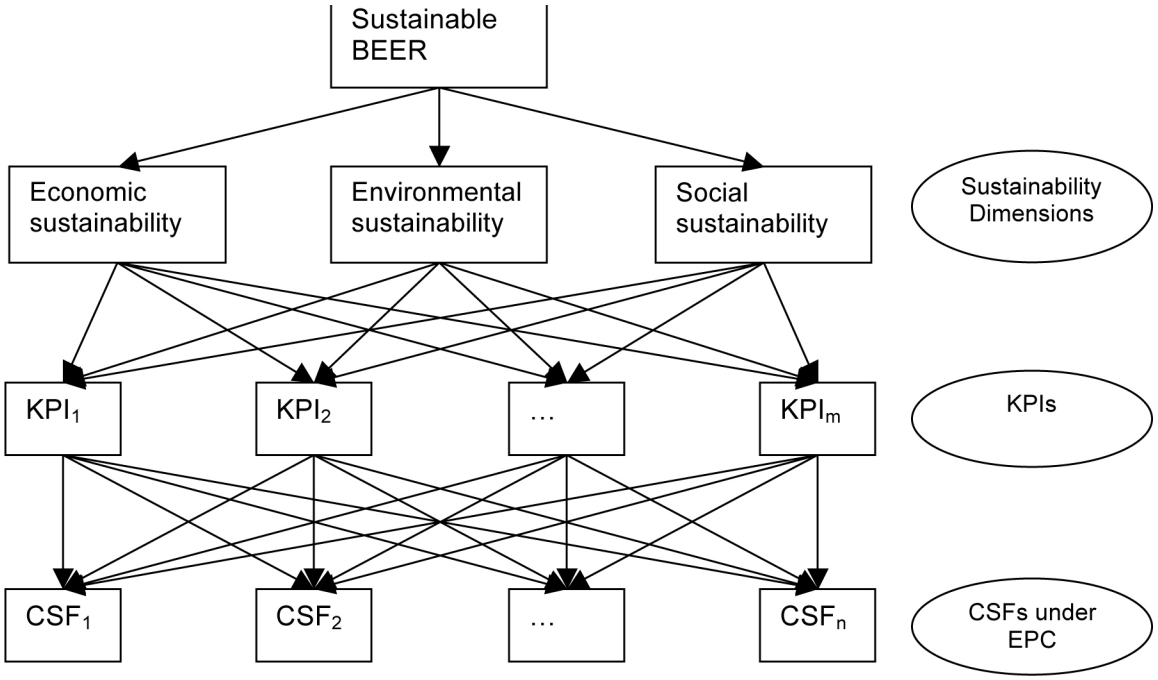
According to the concept of sustainable development, a truly sustainable BEER should consider economic viability, environmental quality, and social equity at the project level. The economic sustainability of BEER includes the cost efficiency of the retrofit project. Economic sustainability is achieved by reducing the retrofitting capital costs and the running costs of the retrofitted building. As this research is about hotel buildings, it also aims to increase the operating profit of the hotel by improving its competitiveness and attractiveness after the retrofit.

However, BEER environmental sustainability is the main objective of these projects. Saving energy and therefore money is inherent in a successful project result. Besides, envi-

ronmentally friendly activities should be embraced in the project process. The social sustainability of BEER at the project level includes improving public awareness and energy efficiency education, improving health and safety, and taking account of the local cultural heritage, etc. Sustainable development is not only an end goal, but also a continuous process. The Anne Arundel County Public Schools (AACPS) Development Office (2005) also indicated that project sustainability involves two processes: (1) maintaining the outcomes, goals and products; (2) institutionalizing the process. As part of the sustainable development strategy, analysis and understanding of sustainable projects should address both the project result and the project process. Previous research paid more attention to the result of the retrofit, the design, the choice of materials, and the technical process, rather than the organizational project process. The Energy Performance Contracting (EPC) mechanism as a delivery method has great advantages for building owners implementing sustainable building energy efficiency retrofits. An EPC offers a streamlined approach to improving facilities. ESCOs can provide a full range of services and work continuously with owners to ensure that they get optimal long-term energy performance. According to the analysis above, in order to achieve sustainable BEER, it is necessary to integrate sustainable development strategy into both the sustainability performance of the BEER and the EPC mechanism.

The BEER process can be simplified into four phases: energy audit, design, execution, and operation. This study takes EPC mechanism as the retrofit business model and focuses on hotel buildings in China. Understanding the relationship can clearly help to define the sustainable performance of BEER and achieve success through the EPC mechanism. Fig. 2 shows the theoretical framework of sustainable BEER under the EPC mechanism. Sustainable BEER contains the three dimensions. The sustainability of each dimension can be measured by BEER projects' Key Performance Indicators. Identified at the bottom level are the EPC critical success factors affecting the Key Performance Indicators.

FIGURE 2. A theoretical hierarchy of sustainable BEER.



4 A CONCEPTUAL ANALYSIS FRAMEWORK

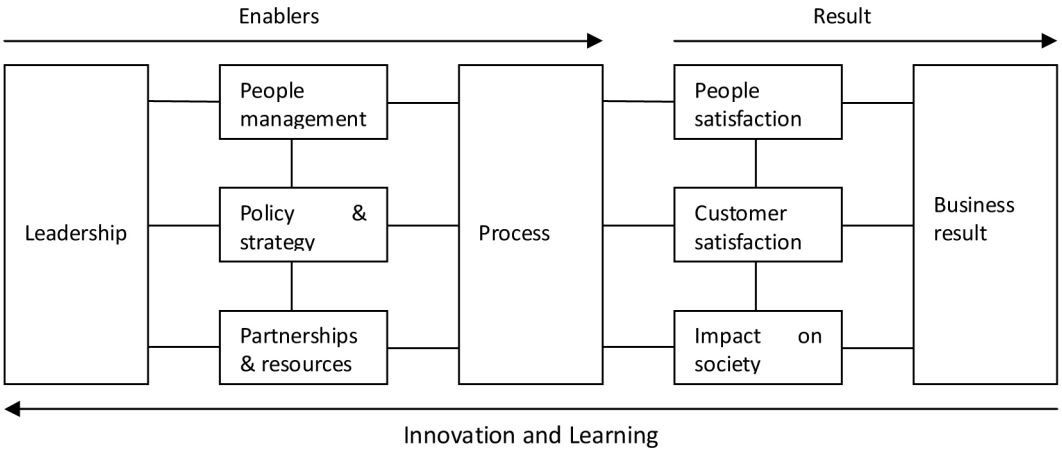
4.1 Theoretical formulation of the framework: The EFQM Excellence Model

The EFQM Excellence Model is one of the most widely used organizational frameworks in Europe. It is the basis for the majority of national and regional Quality Awards. The EFQM Excellence Model is a non-prescriptive framework based on nine criteria. Five of these are "Enablers" and four are "Results." The "Enabler" criteria cover what an organization does and how it does. The "Results" criteria cover what an organization achieves. "Results" are caused by "Enablers," and "Enablers" are improved using feedback from "Results." The EFQM Model is presented in diagrammatic form as shown in Fig. 3. The arrows emphasize the dynamic nature of the model. They show innovation and learning helping to improve enablers that in turn lead to improved results. The EFQM Model is based on the premise that excellent results with respect to Performance, Customers, People and Society are achieved through Leadership driving Policy and Strategy, which is in turn delivered through People Partnerships and Resources, and Processes. The EFQM model is used to measure and improve the overall quality of the organization.

The EFQM Excellence Model can be used for improving sustainability performance. However, it is suitable for business organization in enterprises, rather than at project level. For this study, in order to introduce the EFQM as a framework for measuring the sustainability performance of a BEER project, it is necessary to modify and improve it. Some researchers have tried to use EFQM for construction projects. Bassioni et al. (2005) built a conceptual framework for measuring business performance in construction based on the EFQM Excellence Model and Balanced Scorecard. Westerveld (2003) modified it for projects and established the Project Excellence Model. One of the essential characteristics of the EFQM Model is that it distinguishes result areas (the results the organization has achieved (the "what")) and organization areas (Management of the organization (the "how")) (Westerveld, E., 2003). This research focuses on sustainable BEER projects and their organization under an EPC mechanism. In order to implement the EFQM Excellence Model at the project level, the performance criteria of sustainable BEER projects could be regarded as result areas, and the critical success factors (CSF) under EPC, as organizational areas:

- Result areas—Performance criteria of sustainable BEER projects
- Organizational areas—Critical success driving factors under an EPC mechanism.

FIGURE 3. EFQM Excellence Model.



4.2 Key result areas of sustainable BEER

"Key Result Areas" refer to general areas of outcomes or outputs for which a role is responsible. Before developing a set of Key Performance Indicators for sustainable BEER, it is necessary to analyze their Key Result Areas (KRAs). Previous performance measurement frameworks and systems in building retrofits and sustainable construction could be studied for finding KRAs.

There are a wide variety of sustainability performance measurement tools for existing buildings and retrofits. Most of them are decision-making tools for selecting retrofit scenarios and retrofit actions. Reddy et al. (1993) offered a frame-based decision support model for building refurbishment. Rosenfiels and Shohet (1999) developed a decision-support model for semi-automated selection of renovation alternatives. Alanne (2004) proposed a multi-criteria "knapsack" model to help designers select the most feasible refurbishment actions in the conceptual phase of a refurbishment project. Flourentzou et al. (2002) and Caccavelli and Gugerli (2002) presented a retrofit decision-making model for existing buildings. This model brings energy, indoor environment quality (IEQ) scenarios and cost analysis into the decision-making process. Dascalaki and Balaras (2004) introduced a new XENIOS methodology for assessing refurbishment scenarios and the potential of applying renewable energy sources and rational use of energy in the hotel sector. Matinaitis et al. (2004), Matinaitis et al. (2007), and Zavadskas et al. (2008) proposed methods for appraising building renovation and energy efficiency improvement projects in an economic perspective. Juan et al. (2010) developed a hybrid decision-support system for sustainable office building renovation and energy performance improvement. All the above models are decision-making tools for use before implementing a retrofit. Another tool named IPMVP (International Performance Measurement & Verification Protocol) is the most commonly used in retrofit projects for verification and measurement of the energy saving result of a retrofit project.

Many global organizations have developed comprehensive sustainability assessment systems to promote sustainability in building environments. Current well-known comprehensive assessment systems for green or sustainable building are the LEED, developed by the U.S. Green Building Council; the BREEAM, developed by BRE Global in the UK; the GBTool/SBTool, developed by the Green Building Challenge (a collaboration of more than 20 countries), and the HK-BEAM developed in Hong Kong. Several versions of these sustainable systems have been formulated, all of them having special versions for existing buildings. However, the existing building sustainable evaluation tools assess mainly the actual performance of a building and simply give guidance on its potential best performance. With specific reference to retrofit projects, BRE Global is developing a new standard to enable the sustainable refurbishment of existing housing, entitled BREEAM Domestic Refurbishment.

In summary these previous sustainable models for building retrofits can be classified mainly into two categories: decision tools for decision making at the primary stage of retrofit projects, and labeling tools for existing buildings. Previous research on performance measurements for construction projects is mostly concerned with the performance from project management objectives, such as the three iron triangles: time, cost, quality, and people satisfaction. Following the review above, this study intends to examine the KPIs from three areas:

- KRA 1: Project results—energy saving, project profitability, etc.
- KRA 2: Project life cycle sustainability—environmental quality, health & safety etc.
- KRA 3: Project management objectives—cost, quality, time, satisfaction, etc.

4.3 Categories of EPC project Critical Success Factors (CSF)

This section aims to develop the CSFs of the EPC mechanisms. The term "CSFs" in the context of project management was first used by Rockart in 1982 and is defined as those factors predicting success on projects (Chan, 2004). Sanvido et al. (1992) indicated that the CSFs are those few things that must go well to ensure success for a manager or an organization. Therefore, they represent those managerial or enterprise areas that must be given special and continual attention to bring about high performance.

There has been no systematic research to investigate the critical success factors (CSFs) of EPC in delivering sustainable BEER projects. However, there are many lists of critical success factors for construction projects introduced by various researchers in previous decades. Belassi and Tukel (1996) classified the factors into five distinct groups, according to which element they relate to: the project manager; the project team; the project itself; the organization; or the external environment. Chua et al. (1999) maintain that the success of a construction project is determined by four aspects: project characteristics; contractual arrangements; project participants; and interactive processes. Chan et al (2004) identified five groups of factors, namely: project-related factors; procurement-related factors; project management factors; project participants-related factors; and external factors. All the above classification methods have some similarity. The critical success factors can be divided into five categories: contracting factors, project management factors, leadership and team factors, project-related factors, and external factors. Contractual arrangement, which defines the contracting parties' obligations and rights in various ways, has been identified as one major factor for the success of construction projects (Chan & Yu, 2005; Chan & Suen, 2005). The contracting factors include: contract type; contract award method; as well as tasks and risk allocation. Equitable risk allocation dictates both the content and the type of the contract (Gordon, 1994; Diekmann and Girard, 1995; Chan & Yu, 2005). Project management factors related to communication, planning, monitoring and control, and project organization will help or hinder effective coordination throughout the project life (Chua et al, 1999). The capability of project manager and team members can influence project success. Project type and size underline some factors that are important to success. The external environment can include the political, economic, socio-cultural and technological (PEST) context in which the project is executed. Factors such as the weather, work accidents or the government's favorable or unfavorable legislation can affect the project in all its phases (Dimitrios, 2009).

Although, most categories of critical success factor for general construction projects may suit the EPC projects, some specific success factors and their importance under each category will need to be changed. For example, as more organizations become involved in BEER projects and new technologies are used, external environment and project characteristics will have a greater influence on the success and performance of energy efficiency projects. The most critical element for success in an EPC project is the development of a mutually beneficial contract for both the owner and the ESCO. Human-related factors and organizational factors indeed impact upon the project result. Apart from these factors, some special issues require more effort in consideration of the characteristics of EPC project. There is not much research studying the CSFs for EPC or retrofit projects. Sanvido and Riggs (1991) arrived at 10 success factors for retrofit project management: project team characteristics; team member characteristics; contracting; information management; planning; communications; time management; space management; management of the working environment; and resources/

support. Zhang et al (2008) identified four categories of CSF for EPC in China: external factors; internal technology factors; internal management factors; and internal financing factors. The financing package and arrangement is one of the key tasks in EPC projects, which alone can affect the success of a project. Besides, partnership between the owner and the ESCO will be a fundamental ingredient for project success, as good partnership helps create a situation conducive to the success of performance contracting (Yik & Lee, 2004). Davies and Chan (2001) also indicate partnership as one of the key ingredients for performance contracting success. Kellen (2003) and Flanagan (2005) argue that critical success factors need to be identified in order to provide focus for performance management and measurement. Haktanir and Harris (2005) supported their views and highlighted the discernible link between critical success factors, industry context, and performance measurement. Critical success factors (CSFs) should be discussed in the context of performance measurement. This research focuses on the sustainability of BEER projects. Sustainable development strategy should be considered when organizing the EPC mechanism. In China there is lack of statistical data about energy consumption; and energy consumption varies in different hotels. Thus reference standards for measuring energy performance could be problematic. Retrofit measurement and verification (M&V) is concerned with quantifying the result of the retrofit project. The purpose of M&V is to verify the predicted and contractually specified energy savings, and to account for any changes in any consumption levels resulting from the retrofit (Guide to EPC, 2000). In summary, this part of the review provides an outline for selecting nominated success factors of EPC for sustainable BEER projects. According to the analysis above, there are eight categories of CSFs for EPC in an energy efficiency project:

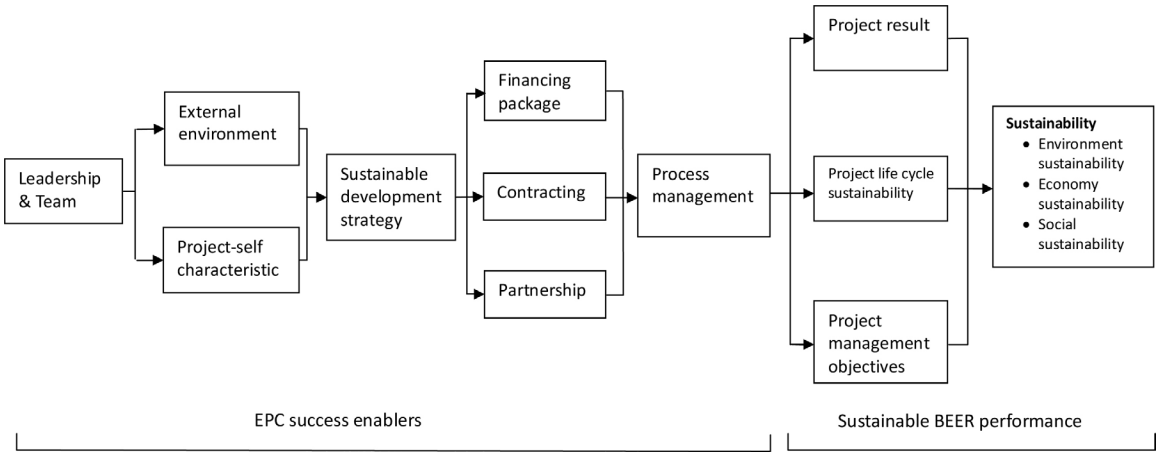
- the external environment;
- the project's internal characteristics;
- the leadership and team;
- the sustainable development strategy;
- the financing package;
- the contracting;
- the partnership;
- the process management.

4.4 The developed framework

Fig. 4 shows the conceptual analysis framework for sustainable BEER under an EPC mechanism. The logic of the framework starts with the leadership and team as the main driver in EPC organization. The leadership and team, the external environment and the project's internal characteristics together guide the financing, contracting, and partnership of a project, and they are transferred into the processes for implementation. Once they are implemented in projects throughout the organization, the project's results would be measured through measurement and verification (M&V). The sustainable building energy efficiency retrofit could be measured through project results, project life cycle sustainability process, and project management objectives. This proposed framework links the sustainable BEER performance with the critical success factors of an EPC.

Because of the lack of literature in this specific topic, this research conducted a set of interviews with experts from industries and academics to help select potential KPIs for sustainable BEER in hotel buildings and CSFs of EPC. The framework developed from this

FIGURE 4. A conceptual framework for analyzing sustainable BEER under an EPC mechanism.



contains two parts: KRAs in the result part and CSFs categories in the organizational part, which together provide a guideline for analyzing and selecting the potential success factors during future interviews.

5 POTENTIAL KPIS AND CSFS

In order to select performance indicators that would assess the sustainability of BEER in hotel buildings and affect factors of EPC project success, a series of semi-structured interviews with 17 professionals were conducted. Nine of the professionals were engineering managers of hotels; five were contractors' project managers; and three were academic researchers. All of them had more than five years' experience in the field of energy efficiency. BEER is a relatively new business venture in China, and there are not many professionals available who have a comprehensive view of BEER with regard to hotel buildings. The interviews were conducted between April and July 2010. Each of the interviews lasted between one and two hours, and the interviews were tape recorded and fully transcribed.

As the interviewees were senior personnel who could provide first-hand diverse and rich information, the interviews were intentionally unstructured to facilitate the free flow of ideas. The interviews covered about five issues: 1) the participants' understanding of sustainable development theory; 2) the features of good retrofit projects; 3) EPC project organization; 4) problems in the EPC process; 5) the participants' expectations and evaluation of the projects. During the interview three KRAs and eight categories for selecting potential KPIs and CSFs were also presented to the experts. Questions were open, and interviewees were encouraged to add any details that they considered relevant.

After that, a Qualitative Data Analysis (QDA) was conducted on the collected information through interview and through searching secondary information from the literature. The analysis process contained two steps: summarization and compilation. First, all the collected information and secondary material from literature was summarized into items. In this process, transcribed data was read carefully line by line, and the data was divided into meaningful analytical units, and then coded. Coding is defined as marking the segments of data with symbols and descriptive words. Second, the items with similar meaning were categorized together and compiled into one indicator or factor.

TABLE 1. Selected performance indicators for sustainable BEER in hotel buildings.

Code	Indicators	Descriptions
SPI-1	Cost benefit performance	This indicator is one of the economic indicators that reflect the project investment and project profitability.
SPI-2	Time performance	It contains two meanings in this type of project: the contract period and the duration from project planning to retrofitting finish.
SPI-3	Quality performance	It is the total features required by product or service of the project to satisfy a given purpose.
SPI-4	Hotel function improvement	Hotel function improvement through energy efficiency retrofit, which is one of project business result.
SPI-5	Health and safety	This indicator is to measure health and safety of all the participants during the retrofit process.
SPI-6	Energy consumption & resources saving	It is one of most important project objectives. It is the real energy conservation after the hotel retrofit.
SPI-7	Hotel energy management	This indicator is about operation of the energy management system. It reflects the efficiency improvement of the energy management system after the building retrofit.
SPI-8	Innovation and improvement	It is about constituting innovation during the project process, i.e. new technologies application, and project management innovation.
SPI-9	Environmental loading	It is the quality of the indoor and outdoor environment during the life cycle of the project.
SPI-10	Culture protection and transmission	Culture protection and transmission during the project, especially in retrofitting the building envelope.
SPI-11	Stakeholders' satisfaction	The degree of satisfaction of all the participants and stakeholders.

Eleven performance indicators were selected. These were: the traditional iron triple-cost, time, and quality; environmentally related indicators—energy consumption and resources saving, hotel energy management, and environmental loading; social related indicators—health and safety, culture protection and transmission, and stakeholders' satisfaction; and other indicators—hotel function improvement, and innovation and improvement. The detailed descriptions of selected performance indicators are listed in Table 1. On the other side, 28 success factors of the EPC mechanism for sustainable BEER were selected under the previously identified eight factor categories, which are shown in Table 2

6. CONCLUSIONS

This research aims to implement the sustainable principle in Building Energy Efficiency Retrofits (BEER) and improve sustainability of these projects through formulating a framework for sustainable BEER projects under an energy performance contracting (EPC) mechanism. This research reviewed BEER in hotel buildings and EPC mechanisms, and defined the relationships between sustainable development, BEER, and EPC mechanisms. A conceptual framework was formulated based on the EFQM Excellence Model. After that a set of interviews were conducted to identify the potential key performance indicators for sustainable BEER and success factors of the EPC mechanism.

TABLE 2. Selected success factors of EPC for sustainable BEER in hotel buildings.

Groups	Factors
External factors	Economic environment
	Social environment
	Policy support
	Nature environment
	Available technology
Project-self factors	Hotel operation status
	Project complexity
	Building age
	Site and location limitation
	Tourism season and operating time limitation
Leadership & Team factors	Owners' awareness of to EPC
	Organizing skill of leader
	Team members' technical background
	Communication skills
Sustainable development factors	Owners' and ESCOs' awareness of to SD theory
	Sustainable development strategy planning
	Control mechanism of sustainable development strategy
Financing factors	Available financing market
	Awareness of financing institute to EPC
	Credit of ESCOs and owners
	Project financial status
Contracting factors	Savings share
	Task and Risk allocation
Partnership factors	Trust
	Effective coordination
Project process factors	Develop appropriate organizational structure
	Project objectives control mechanism
	Accurate M&V

The framework is divided into the critical success factor categories of EPC for driving sustainability and sustainable performance result factors of a BEER project. The sustainable performance result factors include: project results; sustainable process; project management objectives. The CSF categories include: the leadership and team; the external environment; the project's internal characteristics; sustainable strategy management, contracting, partnership, the financing package, and the project process management. Most interviewees believed this conceptual framework could be a guidance tool to incorporate the sustainability principle into BEER projects. Finally, 11 potential KPIs for sustainable BEER and 28 CSFs of EPC were selected, based on the developed framework, through analysis of the collected qualitative data from the interviews.

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REFERENCES

AACPS Development Office (2005). Introduction to project sustainability, AACPS Development Office.

Alanne, K. (2004) Selection of renovation actions using multi-criteria "knapsack" model. *Automation and Construction*, *13*(3), 377–391.

Bassioni, H. A., Price, A. D. F., Hassan, T. M. (2005). Building a conceptual framework for measuring business performance in construction: An empirical evaluation. *Construction Management and Economics, 23*, 495–507.

Belassi, W. & Tukel, O. I. (1996). A new framework for determining critical success-failure factors in projects. *International Journal of Project Management, 14* (3) 141–151.

Caccavelli, D., & Gugerli, H. (2002). TOBUS—A European diagnosis and decision-making tool for office building upgrading. *Energy and Buildings, 34*(2), 113–119.

Chan, A. P. C., Scott, D., and Chan, A. P. L. (2004). Factors affecting the success of a construction project. *Journal of Construction Engineering and Management, 130* (1) 153–155.

Chua, D. K. H., Kog, Y. C., and Loh, P. K. (1999). Critical success factor for different project objectives. *J. Constr Eng Manage, 125*(3), 142–150.

Chan E. H. W., & Yu, A. (2005). Contract strategy for design management in design and build projects. *Intl Journal of Project Management, 23* (8).630–639.

Chan E. H.W., & Suen, H. (2005). Legal issues of dispute management in international construction projects contracting. *Construction Law Journal, 21* (4), 291–305.

CMHC (2002). Retrofitting a city: A guide for municipalities to implement a building retrofit program. Produced by Canada Mortgage and Housing Corporation.

Dascalaki, E., & Balaras, C. A. (2004) XENIOS—A methodology for assessing refurbishment scenarios and the potential of applications of RES and RUE in hotels. *Energy and Buildings, 36* (11) 1091–1105.

Davies, H. A., & Chan, E. K. S. (2001). Experience of energy performance contracting in Hong Kong. *Facilities 19*, 261–268.

Deng, S. M., & Burnett, J. (2000). A study of energy performance of hotel buildings in Hong Kong. *Energy and Buildings, 31,* 7–12.

Diekmann, J. E., & Girard, M. J. (1995). Are contract disputes predictable? *Journal of Construction and Engineering Management, 121*(4), 355–363.

Dimitrios, L. (2009). Analysis of Project Success Criteria and Success Factors: How to maximise success in your projects using meaningful criteria and factors Version 4. *Knol*. (2009 Jul 8). Retrieved from: http://knol.google.com/k/dimitrios-litsikakis/analysis-of-project-success-criteria/3ib8exvrc87n4/4.

EPA (2007). Energy Star Building Upgrade Manual Facility Type: Hotels and Motels. Retrieved from: http://www.energystar.gov/ia/business/EPA_BUM_CH12_HotelsMotels.pdf.

EPA (2009). Hotels: An Overview of Energy Use and Energy Efficiency Opportunities. Retrieved from: http://www.energystar.gov/ia/business/challenge/learn_more/Hotel.pdf.

Flanagan, C. (2005) *An Investigation into the Performance Measurement Practices of Irish Hotel Groups.* Unpublished MSc thesis. Dublin Institute of Technology, Dublin.

Flourentzou, F., Genre, J. L. & Roulet, C. A. (2002). TOBUS software—An interactive decision aid tool for building retrofit studies, *Energy and Buildings 34*, 193–202.

Gordon, C. M. (1994). Choosing appropriate construction contracting method. *Journal of Construction and Engineering Management, 120*(1), 196–210.

Guide to EPC (2000). Guide to energy performance contracting: Measurement and verification of energy saving in energy performance contracting. State of Hawaii, Department of Business.

Haktanir, M. & Harris, P. (2005) Performance Measurement Practice in an Independent Hotel Context: A Case Study Approach. *International Journal of Contemporary Hospitality Management*, *17*(1) 39–50.

International Energy Agency. (2006). *Key World Energy Statistics*. Retrieved from: http://www.iea.org/textbase/nppdf/free/2006/key2006.pdf

Juan, Y. K., Gao, P., & Wang, J. (2010). A hybrid decision support system for sustainable office building renovation and energy performance improvement, *Energy and Buildings, 42* (3) 290–297.

Keeping, M., & Shiers, D. (1996). The "green" refurbishment of commercial property. *Facilities, 14*(3/4), 15–19.

Kellen, V. (2003) *Business performance measurement: At the crossroads of strategy, decision-making, learning and information visualisation*. Chicago, IL: Faculty of E-Commerce, DePaul University

Martinaitis, V., Kazakevicius, E., & Vikauskas, A. (2007). A two-factor method for appraising building renovation and energy efficiency improvement projects, *Energy Policy, 35*(1) 192–201.

Martinaitis, V., Rogoza, A., & Bikmaniene, I. (2004). Criterion to evaluate the "twofold benefit" of the renovation of buildings and their elements, *Energy and Buildings, 36*(2004) 3–8.

Mickaityte, A., Zavadskas, E. K., Kaklauskas, A., & Tupenaite, L. (2008). The concept model of sustainable buildings refurbishment. *International Journal of Strategic Property Management, 12*, 53–68.

Reddy, P.V., Socur, M. & Ariaratnam, S.T. (1993). Building renovation decision support model. In Proceedings of the ASCE *5th International Conference on Computing in Civil and Building Engineering*, *June 7–9*. Anaheim, CA, USA. (1547–1554).

Rosenfiels, Y. & Shohet, I. M. (1999). Decision support model for semi-automated selection of renovation alternatives. *Automation in Construction, 8*(4), 503–510.

Sanvido, V. E., & Riggs, L. S. (1991). Managing retrofit projects, A final report submitted to the Construction Industry Institute, Technical Report No. 25. Department of Civil Engineering University of Texas at Austin.

Shanghai Construction and Transportation Commission. (2008). Evaluation Standard of Energy Efficiency for Existing Building., DG/TJ 08-2036-2008, China.

Shen, L. H. (2007). Promoting EPC mechanism and strengthening energy conservation cooperation in Northeast Asia. National Development and Reform Commission Energy Research Institute, China.

Sitar, M., Dean, K., & Kristja, K. (2006). The existing housing stock—New renovation possibilities: A Case of apartment building renewal in Maribor. Research report presented at the Conference, *Housing in an expanding Europe: theory, policy, participation and implementation* (ENHR). Urban Planning Institute of the Republic of Slovenia, July 2006, Slovenia.

Sobotka, A., & Wyatt, D. P. (1998) Sustainable development in the practice of building resources renovation, *Facilities, 16*(11), 319–325.

Taylor, R. P., Govindarajalu, C., Levin, J., Meyer, A. S. & Ward, W. A. (2007). *Financing Energy Efficiency: Lessons from Brazil, China, India, and Beyond*. The World Bank.

THUBERC (2007). 2007 *Annual Report on China Building Energy Efficiency*. China Building Press, Beijing, China.

Westerveld, E. (2003). The Project Excellence Model: Linking success criteria and critical success factors. International Journal of Project Management, 21, 411–418.

Xu, P. P., Chan, H. W. E., & Xu, Y. (2010). An assessment framework for sustainable building energy efficiency retrofit (BEER) project under energy performance contracting (EPC) mechanism based on Balanced Scorecard, Proceedings of the *CRIOCM 2010 International Symposium on Advancement of Construction Management and Real Estate*, 7–8 August 2010, Malaysia. (24–33).

Xue, Z. F. (2007). *Energy Saving in Public Buildings*. China Construction Industry Publishing Company, Beijing (in Chinese).

Yik, F. W. H., & Lee, W. L. (2004) Partnership in building energy performance contracting. *Building Research and Information, 32*(3), 235–243.

Zavadskas, E., Raslanas, S., & Kaklauskas, A. (2008). The selection of effective retrofit scenarios for panel houses in urban neighborhoods based on expected energy savings and increase in market value: The Vilnius case. *Energy and Buildings, 40*(2008) 573–587.

Zhang, Y., Han, Q. M., Liu, C. B., Sun, J. Y. (2008). Analysis for critical success factors of energy performance contracting (EPC) projects in China. Proceedings in *Industrial Engineering and Engineering Management, 2008. IEEE International Conference,* 8–11 Dec 2008, Singapore. (675–679).

Zhou, Y. C., Wu, X. S., Xin, H., & Xiang, S. P. (2008). Hotel buildings energy consumption survey and analysis in Chongqing. The proceedings of *16th National HVAC&F Conference*, Nov 2008, Chongqing.