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Exploring the management of sustainable construction at the programme level: a Chinese case study

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Sustainable construction is achieved by the implementation of sustainable development principles in the construction industry. The complexity and higher level of inter-project conflicts that occur in large-scale projects mean that the implementation of sustainable construction in those projects is substantially different from that in smaller scale projects. A case study approach has been adopted to analyse the planning and implementation of sustainable construction in the Shanghai World Expo 2010 across the entire programme lifecycle. As one of the largest programmes in China, the Shanghai World Expo 2010 has the potential to serve as a showcase for the application of sustainable development principles in construction. The key factors that need to be considered in order to promote sustainable construction at the programme level are identified. These include the establishment of a dedicated department to coordinate various stakeholders' efforts and the release of conceptual guidelines and management regulations. In addition, a framework is proposed to implement sustainable construction at the programme management level.

Keywords: Green building, programme management, sustainable construction, sustainable development.

Introduction

The concept of sustainability presents significant challenges (e.g. energy efficiency and waste management) to the practitioners of the construction industry (Manoliadis *et al.*, 2006). On the one hand, the construction industry makes a significant contribution to society by providing a large number of employment opportunities and producing a variety of different buildings and infrastructure in order to fulfil the needs of both the individual and society as a whole. For example, the construction industry contributed 22.6% of GDP to China's economy and provided 36.7 million employment opportunities in 2009 alone (National Bureau of Statistics of China, 2010). Sustainability issues such as energy efficiency and waste management present significant challenges to construction industry practitioners. The existing building stock accounts for 30% of the total energy consumption (Chinese Construction Industry Association, 2010) and contributes some 25% of the greenhouse gas emissions of the whole nation (Center for Housing Industrialization, 2010). Similarly, some 300 million tonnes of waste are generated from construction activities each year (Chen *et al.*, 2010), and this accounts for 40% of the total waste generated in mainland China (Wang *et al.*, 2010).

Consequently, sustainability issues in the construction industry have attracted an increasing level of public attention. The last few decades have seen strong growth in sustainable construction practice worldwide with the primary objective being to mitigate the negative impacts of construction activities on the environment. This has led to an increase in research in this new field. However, research at the programme level has been minimal and of little consequence, according to our extensive literature review.

Ferns (1991, p. 149) defined a programme as 'a group of projects that are managed in a coordinated way to gain benefits that would not be possible were the projects to be managed independently'. This

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suggests that projects within a programme are, by nature, closely related and share a common goal. There are a number of benefits that can arise by managing projects within a programme framework, for example: cost savings that arise by selecting a common set of tools and procedures that are suitable for the majority of the combined projects within the programme, a better understanding of the dependencies between projects and clarification of the reporting hierarchies (Ferns, 1991; Pellegrinelli, 1997). In essence, a programme aims to align project delivery with the organization's strategy (Lycett *et al.*, 2004). Currently there is an increasing number of mega-projects that either have been completed or are under construction, e.g. the Shanghai World Expo pavilions and the London 2012 Olympic venues. These high profile projects share common characteristics (such as consisting of a number of inter-related sub-projects) and thus can collectively be classified as a programme, with sustainability acting as one of foci of these mega-projects. The aims of this research are to explore: (1) the benefits of, and barriers to, implementing sustainable construction at the programme management level; (2) the procedure to facilitate this implementation. A case study of a large-scale programme, the Shanghai World Expo pavilions in China was conducted to fulfil this purpose.

Development of sustainable construction

Sustainable construction is the approach that the construction industry uses to respond to sustainable development requirements (Bourdeau, 1999). According to Kibert (2008), 'sustainable construction' has been used interchangeably with other sustainability related terms such as green and high performance.

There are some common principles that sustainable construction practice should follow. For instance, it is recognized that construction activities generate a number of economic benefits on the one hand, while having serious environmental and social impacts on the community on the other hand. As a result, the triple bottom line approach (i.e. social, environmental and economic sustainability) has increasingly been adopted in a construction context so as to promote sustainable practice with the overall aim being to balance the economic, social and environmental impacts of construction activities (Bordass *et al.*, 2001; Chong *et al.*, 2009). In 1997 Hill and Bowen highlighted the four pillars of sustainable construction, i.e. social, economic, biophysical and technical, and subsequently developed a set of process oriented principles. According to Hill and Bowen (1997), the following of these overarching principles provides a guideline for the implementation of sustainable construction in practice. This was reinforced further by Bourdeau (1999) who argued that a sustainable construction framework should cover various processes including urban planning, production development and design, manufacturing and construction, operation and deconstruction.

Sustainable construction aims to create a sustainable and healthy built environment (Kibert, 1994). This includes ensuring that buildings and infrastructure have a positive impact on natural systems in an environmental, social and economic sense. Accordingly, a lifecycle approach should be considered when assessing the effects of construction activities and the performance of buildings on the environment. For instance, both embodied energy and operating energy should be reduced wherever possible (Sartori and Hestnes, 2007). The reduction, recycling and reuse of construction materials helps to achieve a closed loop of material flow, with the consequential reduction of construction and demolition waste (Schultmann and Sunke, 2007).

Some scholars look at sustainable construction from the managerial perspective, e.g. the selection of project procurement systems (Rwelamila *et al.*, 2000), the collaboration between government and private sectors to promote innovation (Bossink, 2002), the establishment of a solid body of knowledge about sustainable construction for all stakeholders (du Plessis, 2007), and the adoption of 'green' specifications (Lam *et al.*, 2009). Wu and Low (2010) asserted that project management in sustainable construction should focus on processes such as stakeholder management, organizational structure/s and commissioning quite distinct from practice (e.g. technologies). All participating parties must play a role in the process in order to achieve sustainable construction; for instance, Bilec *et al.* (2007) highlighted the role that civil engineers played in a 'green' initiative in order to enhance the awareness of the public and policymakers of both the costs and the benefits associated with green design. Drawing on data collected from 17 Fortune 100 owner corporations, Beheiry *et al.* (2006) found that having senior management's commitment to sustainability facilitated sustainable project planning which in turn helped to achieve better project outcomes. Shen *et al.* (2010) highlighted the knowledge of contractors and suppliers about the environmental consequences of construction activities, building materials and plants that should be incorporated in the process via a feasibility study. This approach provides useful insights to decision making at the planning stage when selecting appropriate building materials and construction technologies to achieve the sustainable construction goal.

It is worth noting that there is a gap in the existing body of knowledge with respect to the implementation of sustainable management specifically from the perspective of programme management, according to our extensive literature review. Construction programmes form part of an organizational framework that comprises a number of existing projects and new defined projects, wherein all the components of the framework must satisfy an overall strategic target. The Project Management Institute (PMI, 2006) defines programme management as 'the centralized coordinated management of a programme to achieve the programme's strategic benefits and objectives' (p. 4). In addition, 'An essential programme management responsibility is the identification, rationalization, monitoring, and control of the interdependencies between projects; dealing with the escalated issues among the projects that comprise the programme; and tracking the contribution of each project and the non-project work to the consolidated programme benefits' (p. 7). Artto *et al.* (2009) highlighted that lack of inter-project coordination and inter-organizational theory should be one of the key concerns in programme management research. The conceptual model for this study is drawn from the literature review and is shown in Figure 1. As the figure indicates, a large programme aims to achieve a common strategic goal among a number of inter-related projects. It is not unusual for conflicts to exist between projects and stakeholders. In the sustainable construction context, multi-stakeholder coordination and multi-project integration, which play critical roles in programme management, should also be taken into consideration. Accordingly, the aim of this research is to fill this gap in the knowledge by examining the key factors that need to be considered for sustainable construction at the programme level.

Research methodology

A case study approach was adopted to explore the benefits, barriers and procedures involved in the implementation of sustainable construction at the programme level. As Yin (1994) pointed out, the case study approach is most appropriate for 'how' and 'why' types of research questions. The research aims are to investigate 'why use sustainable construction at the programme level' and 'how to manage sustainable construction at the programme level'. Thus the case study approach is appropriate to satisfy these research needs. The use of a quantitative approach, such as a questionnaire/survey was not considered appropriate

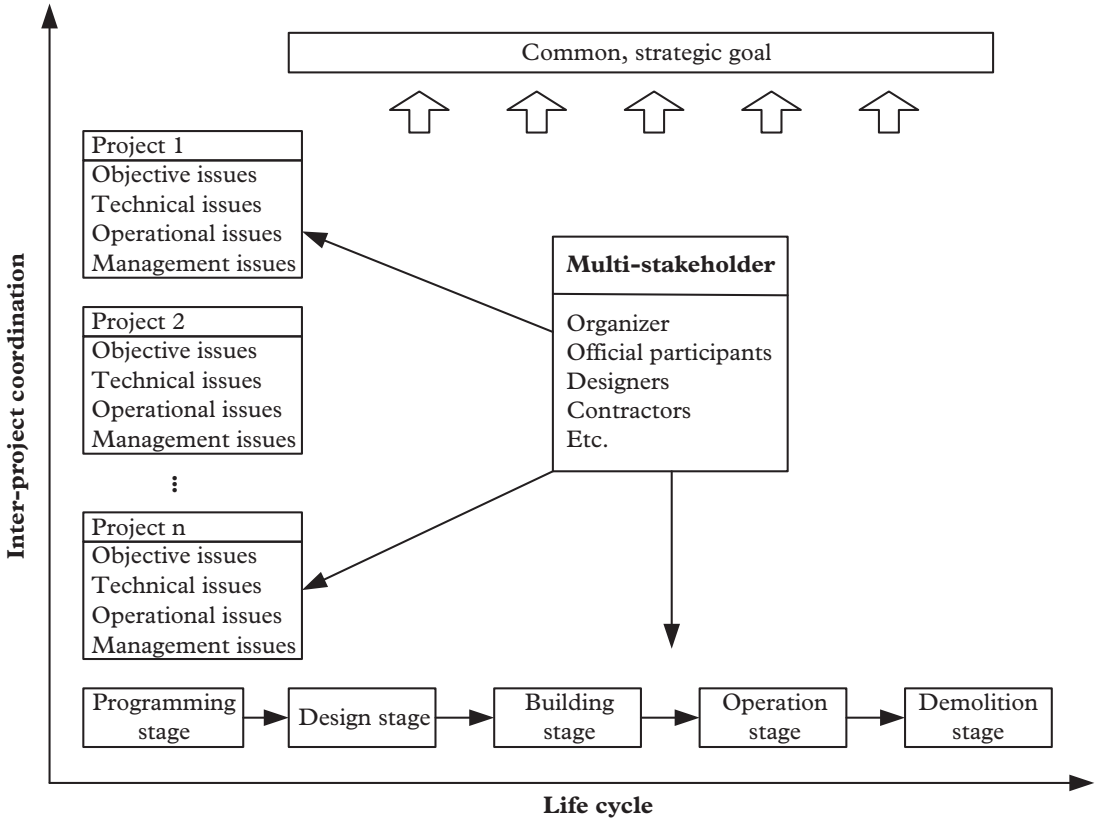

Figure 1 Conceptual framework of sustainable construction programme management

because of the exploratory nature of this research. The advantage of the qualitative approach is that it allows the analysis of complex behaviour within its natural setting (Abowitz and Toole, 2010). The Shanghai World Expo 2010 was selected as the case studied in this research because of its large scale and the number of sub-projects involved. The data collection was commenced in 2007 just before the commencement of mass construction work for the Shanghai World Expo.

The authors used a mixed research methodology to assist with verification of the data collection process, i.e. observation of the project processes, attending site meetings and workshops, conducting informal interviews and the review of relevant project documents. A unique component of this case study involves the researcher working as a core member of the project management office of the Shanghai World Expo 2010 since the primary construction work began in 2007. The project management office was established by the organizer (the Bureau of the Shanghai World Expo Coordination) to manage the implementation of numerous sub-projects within the programme. The researcher was in an excellent position to observe at first hand the organizer at work and also was able to have a direct input into the implementation of the guidelines and management regulations for sustainable construction from the initial design stage through to the eventual demolition stage. According to Mitropoulos and Nichita (2010, p. 154), observation is a good approach to gain 'a first-hand understanding of the project situation and the problems that occurred'. The observations were made by the researcher in various ways, including: (1) attending all the site meetings related to the construction management planning of the Expo sites; and (2) directly participating in the development of the managerial documents such as the 'Programme Master Plan' and the 'Construction Management Manuals' for the Shanghai World Expo 2010.

The researcher also discussed and conducted informal interviews about sustainable construction with 12 management staff from the programme management office: three from the technical office, seven from the pavilion owner organizations, five from the design consultant companies and five from the contractors involved in the development of the Shanghai World Expo 2010. The discussion and informal interviews with these personnel occurred on more than one occasion. In particular, the researcher had regular meetings with the personnel from the programme management office and the technical officers. These personnel were chosen because of their extensive involvement in sustainable construction of the Shanghai World Expo 2010 programme. The purpose of the discussions and informal interviews was to understand the perceptions and attitudes about sustainable construction at the programme level from different stakeholders' perspectives.

The research results were verified by reviewing the project documents or archive data relevant to sustainable construction; for example, the 'Official Guidelines for the Development of the Shanghai World Expo 2010', the 'Project Progress Reports', the 'Operational Manual' and the 'Field Meeting Notes', etc. As an unobtrusive approach, the review of the project documents allowed the case study to be non-reactive by acquiring an initial contextual understanding directly related to the research topic.

The following data were collected for this study:

- The overall objectives and targets for sustainable construction in the Shanghai World Expo project were collected from the relevant project documents.
- The guidelines provided by the organizer for each official participant to implement sustainable construction in its pavilion were collected from the review of the relevant project documents.
- The attitudes and behaviour of project participants towards sustainable construction and the relevant guidelines were noted through observation of the project process, by attending site meeting and workshops, and by informal interviews with various project participants such as the organizer, architects, contractors and official participants.

The forms of data collected in the case study were all text-based, ranging from diary, field notes, review notes through to interview notes. All these data were noted and transcribed. The identification of key themes through coding forms the cornerstone of qualitative data analysis (Coffey and Atkinson, 1996). The thematic coding procedure developed by Flick (2009) was used for this purpose (pp. 319–21) as paraphrased below:

- Step 1: produce a short description of each diary or note, providing information with regard to the research question.
- Step 2: conduct an in-depth analysis of the first diary or note with the aim of developing a system of categories.
- Step 3: apply open coding and selective coding (see Strauss and Corbin, 1990) in order to generate thematic domains and categories for the first diary or note.
- Step 4: cross-check the developed categories and thematic domains to establish a thematic structure.

- Step 5: assess the thematic structure established in step 4 in other diaries and notes and modify accordingly.

During the coding process, emerging themes across the following areas were highlighted across all data from various sources of information: (1) the Shanghai World Expo pavilion developments (as a programme) background; (2) major challenges for the management of sustainable construction in the Shanghai World Expo pavilion developments; (3) the sustainable construction practices adopted; (4) the reasons for, and benefits of, sustainable construction at the programme level in the Shanghai World Expo pavilion developments; (5) lessons learnt from the sustainable construction during the Shanghai World Expo pavilion developments. Interim findings were shown to project participants for validation. Project participants were given the opportunity to rectify misunderstandings or add more comments about sustainable construction at the Shanghai World Expo programme. As Mitropoulos and Nichita (2010) pointed out, the case study approach does not provide for generalizations of the case study findings; however it does demonstrate critical lessons learnt for similar types of projects or projects in a similar scenario. This study reports the sustainable construction practices adopted in the Shanghai World Expo pavilion developments and will provide useful insights about sustainable construction for similar mega-projects or programmes.

Case study: The Shanghai World Expo 2010

Background

The Shanghai World Expo 2010 has been recognized as one of the largest projects undertaken in China in recent years. As a showcase for sustainable construction, the main theme of the Shanghai World Expo 2010 was defined as 'Better City, Better Life', and included five streams, i.e. 'Blending of Diverse Cultures', 'Economic Prosperity', 'Innovation of Science and Technology', 'Remodelling of Communities' and 'Rural–urban Interaction'. This main theme ('Better City, Better Life') provided an overarching guideline for the pavilion developments in terms of sustainable construction.

The construction site is located in the areas between the NanPu Bridge and the LuPu Bridge along both sides of the HuangPu River. The total planned land is 5.28km^2. The primary construction work for this programme began in late 2007 and all the sub-projects were scheduled to be completed prior to 1 May 2010. The Shanghai World Expo 2010 programme consisted of a number of sub-projects, e.g. the major pavilions, the public utilities, the transportation infrastructure, the park, as well as the logistics of running all the facilities. Most of the buildings were temporary, except for the Expo Boulevard, the China Pavilion, the Expo Cultural centre, the Expo Centre and the Theme Pavilion. Those permanent buildings were retained after the exhibition.

The large programme of the Shanghai World Expo 2010 included three types of pavilions, that is: (1) the self-built pavilion: a pavilion that was designed and built by an official participant or an enterprise on the plot allocated by the organizer; (2) a rented pavilion: a stand-alone pavilion built by the organizer and subsequently rented to an official participant; (3) a joint pavilion: a pavilion constructed by the organizer to be shared by more than one participant; these were free of charge and were mainly allocated to developing countries. Most pavilions were self-built pavilions.

Major issues related to programme management of sustainable construction

There were a number of sustainable construction challenges at the programme level that the organizer had to face during the Shanghai World Expo 2010.

The first issue dealt with the multi-owner characteristics of the large programme. Each owner of a self-built pavilion had his/her own perspectives about value, objectives and methodology for the implementation of their project. Moreover, each owner faced different conditions in their project management process. For example, some owners secured large amounts of funding that allowed them to employ highly qualified project management consultants, designers and contractors to achieve sustainable construction. In contrast, some other owners only had limited funding available and this restricted their attempts to implement sustainable construction practices. For instance, some architects of a self-built pavilion intended to use solar or geothermal energy as the power supply system for their pavilion. However, the high upfront cost of equipment such as solar Photo Voltaic panels and geothermal pumps prevented their implementation. Similarly, some official participants were not convinced about making a large upfront investment for something (a pavilion) that was temporary and would be demolished after the completion of the Expo 2010.

Second, the vast majority of the owners of the self-built pavilions were not familiar with local conditions with respect to sustainable construction, e.g. the legal regulations in China, the approval procedures of the local government, the procurement of construction materials from the local market, the local construction

conditions in Shanghai such as weather, water supply, power supply, etc.

All these issues were related to the implementation of sustainable construction. For example, initially the owner of one self-built pavilion intended to adopt a special kind of heat-shielding material in the facade design. However, the architect was uncertain of a variety of issues, e.g. its availability in the local market, the price, the method of transportation to the site, the storage of the raw materials on site and the approvals required from the local government, etc. Moreover, during the sustainable design phase, some of the foreign architects did not have the essential knowledge of the wind and sunlight conditions in Shanghai that were very crucial for natural lighting and ventilation requirements.

Additionally, different owners of self-built pavilions had diverse views and understanding with respect to sustainable construction. An example was that countries with sufficient water resources did not regard water-saving design as critical for sustainable construction. Moreover, different ideas existed about the principles for sustainable construction. For instance, some architects argued that a high plot ratio in terms of an increase in density of development in residential districts was a good way to save and use land, while others perceived it would make the residents uncomfortable as they would feel crowded and congested. In addition, participants from different countries and regions were familiar with different tools for sustainable construction (e.g. LEED in the United States and BREEAM in the UK). Therefore, it was difficult for the organizer to choose one single standardized tool for every owner to use in the construction of sustainable buildings. Indeed, most of these rating tools 'were developed for local use and do not allow for national or regional variations (such as) differences in climatic conditions, income level, building materials and techniques, building stocks and appreciation of historic value' (Ding, 2008, p. 457). Therefore, modification for the local context is essential to ensure the effectiveness and usefulness of a green building rating scheme that has been developed in another context.

There were also several conflicts that arose during the implementation of the programme and the organizer had to work hard to ensure both control and a coordinated endeavour. To explain, each official participant developed their own project plan (e.g. design, construction programming, procurement, transportation and storage of equipment and materials) according to his/her own requirements. However, conflicts soon arose between different project plans from different participants. For example, one official participant intended to increase the height of his pavilion and would negatively affect the daylight available to other pavilions to the northern side of this pavilion. Similarly, conflicts also arose in terms of the access routes and location of machinery for the pavilions; the construction schedule and the transportation of materials/equipment access routes. Poor coordination of these activities was detrimental to construction efficiency, e.g. wasting resources and time which were unsustainable. Therefore, from a programme perspective, a critical component of sustainable construction was the coordination of the construction works of each individual pavilion with the aim of minimizing the occurrence of conflicts.

All the above issues needed to be addressed by the organizer's programme management team during the process of promoting sustainable construction. In an attempt to address these issues, a dedicated department, the Technical Office, was established under the direction of the programme management team with one of its main tasks being to promote and manage sustainable construction at the programme level by:

- developing a series of conceptual guidelines to assist the organizer to promote sustainable construction;
- providing information (support) about sustainable construction related to design, construction and procurement; and
- assisting participants to facilitate the implementation of sustainable construction by ensuring better coordination and conflict resolution among the various parties.

Although it was called the Technical Office, the functions of this new department encompassed managerial as well as technical issues. Soon after its inauguration the Technical Office held a series of meetings to discuss how to direct official participants to better promote sustainable construction. These meetings were held at a critical time between November and December 2007, i.e. just before the primary construction work commenced.

To address the challenges highlighted above, the Technical Office developed a framework for implementing sustainable construction in the Shanghai World Expo programme. As shown in Figure 2, the organizer initially developed qualitative conceptual guidelines to clarify the fundamental principles and policies for implementing sustainable construction within the large programme. Subsequently, the participants were encouraged to refer to the established green building rating tools such as LEED, BREEAM, GBCA Green Star or SBTool as an appropriate methodology for developing a detailed sustainable construction plan. These detailed plans were allowed to be as diverse as the participants wished, provided that they satisfied the basic requirements that were set in

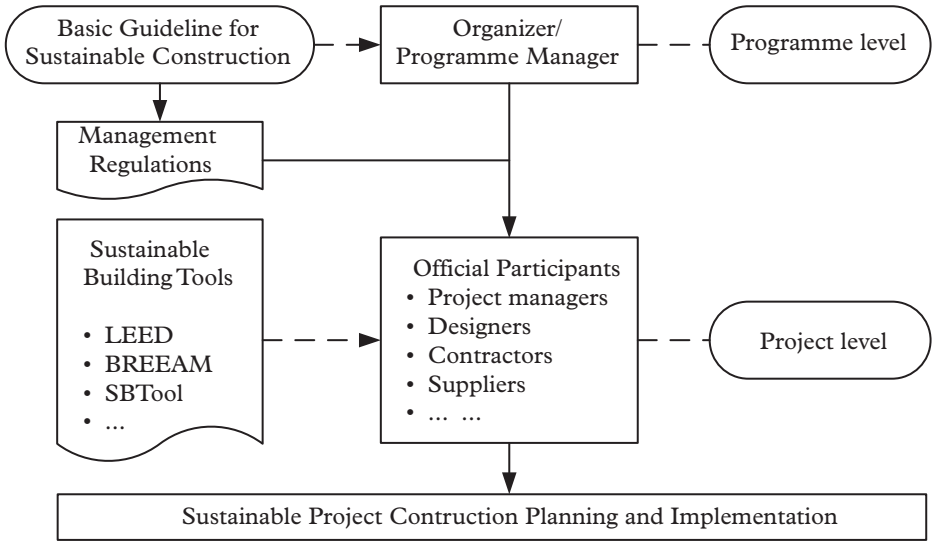

Figure 2 Roles of the different parties in promoting sustainable construction for the Shanghai World Expo 2010 at the programme level

the management regulations established by the organizer.

Conceptual guidelines for sustainable construction at the programme level

The overall objective of the Shanghai World Expo 2010 in terms of sustainable construction was, in a qualitative sense, to save natural resources and energy as much as possible, to minimize the amount of environmental loadings and to provide the most comfortable place for living and working, i.e. in keeping with the main theme of the Shanghai World Expo 2010, of a 'Better City, Better Life'. Conceptual guidelines for sustainable construction in the Shanghai World Expo programme were developed to fulfil this objective. It is generally accepted that sustainable construction planning should be based on the project lifecycle wherever possible, i.e. the implementation of sustainable construction should concentrate not only on the inception, design and construction phases but also on the operation and demolition phases of a project. Accordingly, the lifecycle approach was adopted for the development of the basic guidelines for sustainable construction for the Shanghai World Expo 2010 (see Figure 3).

Inception phase

In an attempt to facilitate the adoption of sustainable construction for the Expo, three tasks were defined very early on in the programme. First, a programme management team that included a sustainable construction division was established. Second, the fundamental principles for sustainable construction were defined to include energy conservation, environment protection as well as good human health. Third, as a precursor to the actual design, a pre-design meeting was organized to address the sustainability issues of the design phase, which proved to be critical in influencing the subsequent stages towards a more sustainable construction disposition.

Design phase

As the most crucial phase to facilitate the implementation of sustainable construction, the design phase had to address a number of sustainability issues such as land use planning, energy conservation, resource efficiency, reduction of environmental loading, high quality of service design and performance tuning design.

During the land use planning phase, two critical issues were highlighted for sustainable construction in the Shanghai World Expo programme. First, an integrated land use plan was required in order to minimize, as much as possible, the environmental impacts on the land. Second, a large area of public green lands and parks was planned to improve the environmental quality of the construction location.

Energy conservation was another critical issue during the design stage. Designers were requested to take into consideration energy efficiency, as well as the application of renewable energy principles, as part of the overall design. In terms of water efficiency designers were encouraged to employ water efficient appliances and to reduce the generation of wastewater. Meanwhile, grey water and rainwater was to be used as much as possible to reduce the usage of potable water.

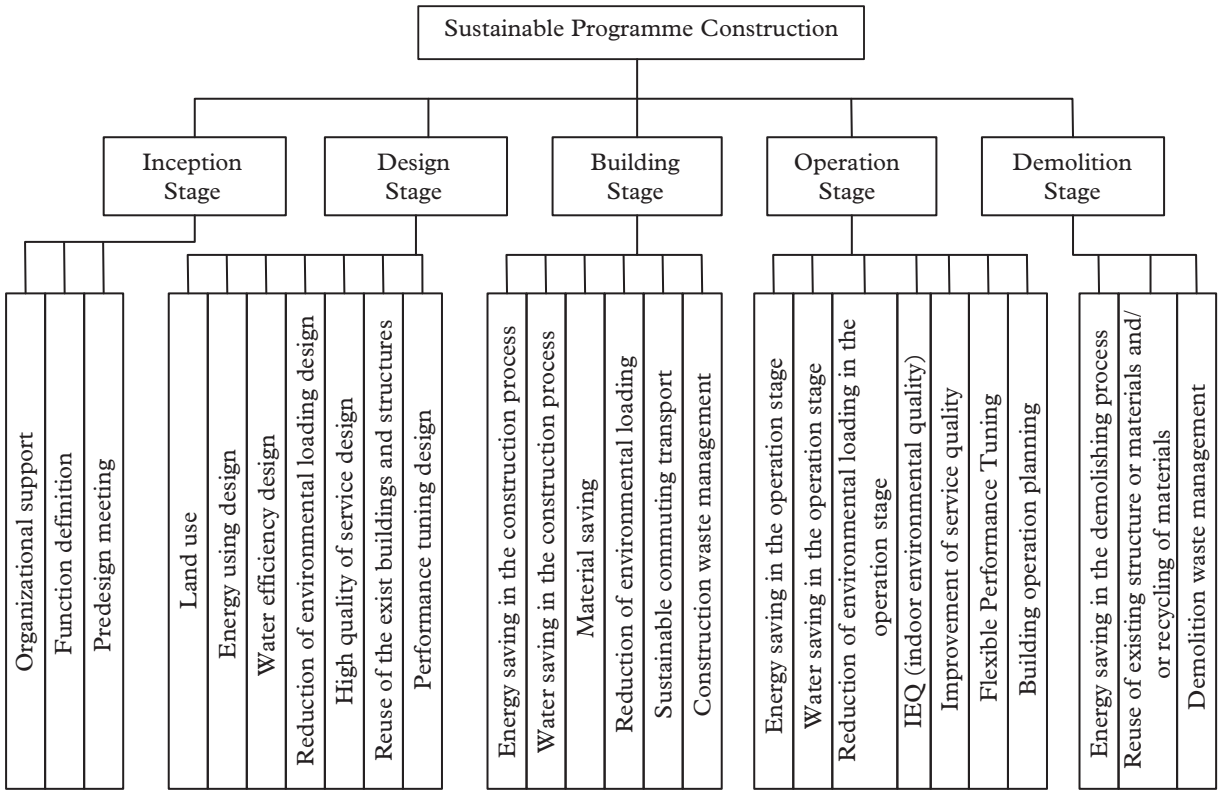

Figure 3 Basic guideline for sustainable construction for the Shanghai World Expo 2010

The reduction of environmental loading included the reduction of waste water, gas and solid waste. A high quality of service design was intended to improve the level of comfort and satisfaction for the end users. Designers were also encouraged to use or to renovate existing buildings wherever possible as part of the World Expo. Similarly, designers were asked to consider flexibility and adaptability for their buildings as part of the design process. After consulting with official participants, the organizer specified both the location and boundary of the land for building, and the maximum height for each pavilion. In this way it was hoped that conflicts between pavilion owners would be minimized.

Construction phase

With an area of 5.28km^2, the Shanghai World Expo was a very large construction site and this presented significant challenges on how to build the project in a sustainable way keeping in mind the need for energy, water and material efficiency during the construction process, reduction of environmental loading, the transportation of construction materials and equipment in a sustainable manner and ensuring the proper management of waste on the various project sites. In addition, the conceptual guidelines also required occupational health and safety to be taken into consideration during the construction phase. Against this background the organizer developed management regulations for the construction sites, which were designed to regulate the construction programming, the transportation route for materials/equipment, the standby location of machinery and the transportation of the construction and demolition waste through and off the site. These regulations were instrumental in minimizing the conflicts between the individual pavilion developments.

Building operation

The operation phase was closely related to the design phase. During the operation phase, energy conservation and water saving needed to be taken into consideration; similarly, the environmental loading needed to be reduced and the indoor environmental quality needed to be maintained so that users felt comfortable. Furthermore, the high service quality and performance tuning function had to be made available to the user. In order to ensure that the operation phase was managed in a sustainable manner, the conceptual guidelines required the development of an operational plan that concentrated on sustainable operations for each individual sub-project before the Expo could commence.

Demolition phase

As most pavilions were temporary buildings, the management of the demolition of the pavilions became an important factor. To some degree, the demolition of all the temporary buildings, although occurring in a short period of time, could be regarded as a weakness in the construction process. For instance, solid waste and environmental pollution (e.g. noise, dust, etc.) are critical issues at the demolition stage of a building's lifecycle. Similarly, demolition requires a large amount of equipment that would then consume a certain amount of energy for transport and disposal of waste (Cole and Kernan, 1996) even though it accounts for a very small percentage of lifecycle primary energy consumption (Scheuer *et al.*, 2003). Therefore, it was essential to reuse and recycle waste, to reduce environmental pollution and to save energy during the demolition phase to achieve the sustainable construction goal. It is worth noting that waste was not a serious issue in the Shanghai World Expo 2010 programme. Most of the pavilions were made of prefabricated materials such as steel, and were assembled on the sites. The demolition work was simply to disassemble the components, most of which could then be reused and recycled thereby reducing the amount of construction waste. As a result, energy savings from demolition/transportation equipment were more a concern of the sustainable construction programme management team at that stage. However, waste remains a critical issue in mega-projects that predominately use concrete or brick structures rather than prefabricated materials.

The main function of the conceptual guidelines was to act as a sustainable construction reference guide to the owners of each self-built pavilion. This document provided the framework and overarching principles for sustainable construction to all sub-projects within the Shanghai World Expo programme. The objectives set out in the guidelines were all qualitative and no specific quantitative targets were defined. The informal interviews and the review of project documents revealed that the organizer had considered defining specific targets. However, this proved difficult to implement because of the differences in preferences and economic situation of the various official participants. Therefore, the adherence to the basic guidelines was voluntary. Consequently, some pavilions used more sustainable construction features and achieved more of the quantitative objectives than others. For instance, the Shanghai Case Pavilion worked to the following requirements: (1) the amount of reused materials would not account for more than 10% of the total building materials in terms of weight; (2) the pavilion steel structure was to comprise at least 30% of recycled steel emanating from the demolition of old buildings in Shanghai; and (3) 100% of the concrete component was to comprise cast-in-situ concrete utilizing ready-mix high performance recycled aggregate from recycled concrete waste. Another example was the Hamburg Case Pavilion which was designed to be both energy and carbon neutral with all energy supply coming from clean energy systems. The energy consumption of the Hamburg Case Pavilion was 50kw per square metre per year, which was the equivalent of a quarter of the typical office building in Shanghai. The sustainable construction features of the Broad Pavilion included: (1) all building components were prefabricated; (2) the work was to use a zero waste approach; (3) 170mm polymeric foam materials were used as wall and roof insulation; (4) all windows were triple glazed; (5) the construction cost was to be less than RMB3000 per square metre; (6) air conditioning use in summer was to be 20% less than that for traditional buildings; and (7) the adoption of high level air filtering equipment to ensure a 99.9% dust and bacteria free air for the pavilion.

Because of the diverse background of each of the Expo participants they were encouraged to develop further detailed plans of sustainable construction for their own sub-project. For example, official participants were allowed to choose their own green building system (e.g. LEED, BREEAM, GBCA Green Star or SBTool) as the most suitable alternative for sustainable construction according to their own economic situation and personal preference. Ding (2008) suggested that the usage of these rating tools should be expanded from design guidelines to an enabler of the collaboration between the design and construction teams. This is supported by Kaatz *et al.* (2005) who argued that building assessment tools could be better used as a project management and briefing tool to foster effective participation of all stakeholders.

Although the official participants had the authority to manage their own construction process, they were required to satisfy the basic requirements for sustainable construction set out by the organizer. This requirement was set out in the programme management document as the management regulations (Bureau of Shanghai World Expo Coordination, 2008).

Management regulations

The organizer also took steps to develop rigorous management regulations to ensure the execution of sustainable construction in the projects. As mentioned previously, the Shanghai World Expo 2010 was a large multi-stakeholder programme that involved organizations and countries from all over the world.

Accordingly, the promotion of sustainable construction was the responsibility of all official participants as well as the host organization. With this in mind the organizer introduced several new regulations to promote and regulate the implementation of sustainable construction by addressing the key issues of sustainable management of the construction and operation.

Those management regulations required the official participants to be aware of the laws and regulations in China that related to environmental protection, human health, radiation protection and security requirements. Moreover, the official participants were required to take necessary measures to avoid water and air pollution, production of hazardous waste and disturbance of adjoining residents. Similarly, it was also necessary to ensure that adequate natural lighting was made available while other issues such as moisture, noise, earthquake and deodorization should be dealt with within the individual exhibitor's areas.

Another critical issue that was specified in the management regulations was sanitation. Sanitation management was considered to be a critical aspect of risk management as, if done properly, it could prevent the outbreak of infectious diseases in such a large-scale site as the Expo 2010. Accordingly, the management regulations required the official participants to ensure the normal and safe functioning of the facilities for water supply, drainage and sanitation as well as the provision of sufficient equipment for ventilation within their exhibition zones.

In addition, the 'Oversight of the organizer' section of the management regulations specified that the organizer had the authority to suspend any activities of the official participants that were considered likely to damage the environment or disturb the local residents. These regulations had been set as mandatory requirements for the official participants throughout the project lifecycle, i.e. design procurement, construction, operation and demolition of their pavilions. The official participants could pursue other sustainable construction features for their pavilions but that was their own responsibility.

Programme implementation

During the implementation of this programme, the organizer was responsible for site planning, design and construction works for the road system, the skywalk, public facilities, permanent pavilions, the joint pavilions and the rented pavilions, while the official participants had a nominated representative who was responsible for the design and construction works of the self-built pavilions.

With regard to the self-built pavilions the official participants were allowed to select a plot of land on the Expo Site on a 'first come, first served' basis. The largest land area for a self-built pavilion was 6000m^2. Inside the plot of land, the architect generally had a free rein with respect to the design works and how they were to exhibit their creative ideas. The construction of infrastructure (roads and power and water supply systems) commenced in late October 2007. This was followed by the construction of the permanent pavilions which got underway in February 2008. The organizer opted to use the permanent buildings as a showcase for the application of sustainable technologies.

The permanent buildings included: the Expo Boulevard, the China Pavilion, the Expo Cultural centre, the Expo Centre and the Theme Pavilion. The Expo Boulevard acted as the main axis for traffic flow during the Expo period and remained as the main axis for the landscapes of Shanghai city after the Expo had finished. It featured six Sun Valleys that collected rainwater and dispersed sunlight into the two underground levels of the boulevard. Similarly, natural water resources in Huangpu River and the massive underground soil resources were considered during the design and construction of the Expo Boulevard. For instance, the ground heat pump air conditioning system and the river source heat pump air conditioning systems were used to control the interior temperature. These two heat pump systems were energy efficient and led to an annual reduction of some 2000 tonnes of carbon dioxide emissions. Similarly, the systems were designed to collect and recycle rainwater for the purposes of toilet flushing, irrigation and thermal comfort control within the Expo Boulevard.

With an area of 160 126m^2, the China Pavilion was designed with natural shading features where an inverted pyramid structure acted as shading for the entire building. In this way sunlight could enter the building during the cooler seasons whereas it would be automatically shaded during the warmer seasons from May to October. A number of sustainable construction features including river sourced heat pump conditioning systems, rainwater harvesting and automatic irrigation were considered during the design and construction of the Expo Cultural centre and the Expo Centre. In addition, wired glass filled with argon gas provided better thermal transmittance values and 30 000m^2 of solar PV panels were installed on the roof of the Theme Pavilion. These panels were able to generate 2.8MW of electricity each year. Similarly, vertical greening systems were used to increase the capacity of the buildings to weather extreme climate conditions.

In mid-2008, the primary construction work for the self-built pavilions got underway. Because not all

these got underway at the same time, the organizer was obliged to complete all the infrastructure facilities and roads before the commencement of construction for the first batch of self-built pavilions. With sufficient time to arrange the construction schedule, the official participants' representatives were afforded the time to re-think how they could make the construction process more sustainable. In order to facilitate the implementation of sustainable construction within the programme, the organizer held several meetings with the representative of each official participant before the construction works started. In this way they were able to discuss the main themes, the design alternatives, the coordination issues of the construction work and thereby were able to provide a significant amount of onsite information to them. This information covered a broad area and included the weather/climatic conditions of the region, the ability to access the appropriate construction materials as well as the laws, regulations and building codes for both the design and construction of the buildings.

Similarly, the organizer established a streamlined approval system for the self-built pavilions. Throughout the entire programme, the organizer followed the principle of providing the official participants, wherever possible, assistance in achieving sustainable activities and all sub-projects were finished on time. Despite the fact that each pavilion was different in terms of design and construction, all the representatives of the self-built pavilions took sustainable construction into account and were able to comply with the management regulations. Similarly, some exhibitors used their building as a stage to demonstrate their creative ideas and techniques for sustainable construction. For instance, for the construction of the dome of the India Pavilion, bamboo (the ancient 'green' material) was used because of its low cost and inherent strength. To reflect a Spanish tradition, 8524 wicker panels were used in the construction of the Spanish Pavilion to reflect an exterior basket structure supported by steel framework. The Japanese Pavilion on the other hand featured a double-layer pillow membrane with integrated solar cells.

Generally, the World Expo 2010 can be considered as being successful in promoting sustainable construction at the programme level. However because of the number of stakeholders in this large programme it was inevitable that variations would occur. As an example, the original plan required the skywalk to be designed to connect with the second floor of each self-built pavilion to facilitate pedestrian access. Unfortunately because each self-built pavilion had different requirements and conditions for the connections the design parameters could not be established in time to facilitate this occurrence. Consequently the original plan had to be changed and this caused a lot of unnecessary work and increased expenditure in terms of both money and time which was in direct contradiction to the principles of sustainable construction.

Discussion

Why sustainable construction programme management?

Traditionally the focus of sustainable construction at the project level was aimed at minimizing resource consumption and maximizing benefits from individual projects (Hill and Bowen, 1997; Ding, 2008). A large construction programme consists of a set of interrelated projects, often with conflicting objectives such as expectation and attitudes towards sustainable construction. According to Bourdeau (1999), approaches, interpretations and priorities for sustainable construction vary from country to country. This presents a significant challenge in mega-projects particularly those involving participants from different countries as was the case for the Shanghai World Expo 2010, the Asian Games and the Olympic Games.

The case study of the Shanghai World Expo indicates four significant benefits for sustainable construction at the programme level. First, it builds common sense and basic sustainable construction principles for all the sub-project owners. Sustainable construction at the programme level provides an overarching principle and guidelines for sustainability issues to be addressed in the entire programme. It helps to coordinate all the sustainable construction efforts in all sub-projects within the programme. In the Shanghai World Expo, despite the fact that the programme organizer had little authority over the sub-project owners, the management regulations established basic requirements for all official participants to satisfy when implementing sustainable construction. A typical example was the special regulation about 'sanitation', 'waste disposal' and 'management of hazardous issues' which was specified by the organizer of the Shanghai World Expo 2010 to control the behaviour of participants. This regulation provided a starting point for official participants to address sustainability issues in their pavilion development with a degree of flexibility. Secondly, various plans for the implementation of sustainable construction in individual projects could be integrated into a uniform plan at the programme level. For instance, the procurement plan for sustainable construction materials and the sustainable management plan for construction sites (e.g. waste management) of each individual project could be established in an integrated and collaborative manner. Thirdly, it provided a platform for knowledge/information sharing of sustainable con-

struction for each project within the programme, e.g. environmental factors that should be commonly addressed for each project; common risks or difficulties encountered when implementing sustainable construction; more effective and efficient programming for each project and the activities necessary to improve each project's sustainability performance and knowledge about improving the effectiveness for the customization of existing green building tools. The fourth and final benefit related to the breaking down of the inter-project conflicts that may occur when implementing sustainable construction. The organizational plan for the management of sustainable construction at the programme level, and the subsequent workshops and meetings helped the organizer to identify a variety of conflicts experienced by official participants when endeavouring to achieve the sustainable construction goal. Consequently, an integrated and coordinated assistance approach was utilized by the organizer when dealing with the official participants. These benefits could not have been achieved if sustainable construction was managed at the project level because of the enormity of the coordination task required by the numerous sub-projects within the Shanghai World Expo programme.

The key differences between sustainable management of large programmes and projects are summarized in Table 1.

There have also been numerous studies that have examined technical aspects such as construction technologies and building materials when striving for sustainable construction (Sartori and Hestnes, 2007; Schultmann and Sunke, 2007; Chong *et al.*, 2009). The case study of the Shanghai World Expo 2010 showed that sustainable management of a large construction programme usually focused on the organizational and managerial issues (e.g. coordination between projects) rather than the technical issues (see Table 1). This is broadly consistent with Wu and Low's (2010) findings that inter-organization coordination presents a crucial project management task for sustainable construction. Robichaud and Anantatmula (2011) emphasized that the adoption of green building certification tools such as LEED should be considered as a key project management practice when striving for a sustainable construction goal. In our case study, the use of established green building rating tools was recognized as the appropriate methodology for developing a detailed sustainable construction plan by each individual official participant at the project level. Considering the number of participants with various levels of knowledge and acceptance of various tools, it was necessary for the organizer to introduce management regulations to ensure that at least the basic requirements would be met. This is compounded by the limitations associated with most green building rating schemes (i.e. developed in another context without consideration of the local context) that have reduced their effectiveness and usefulness (Ding, 2008).

Lessons learnt

There were some critical lessons learnt from this case study. For instance, preparation works should be clarified and established from the very beginning of the management programme. In order to facilitate sustainable construction at the programme level, the following measures need to be taken into consideration: (1) clarification of the organizational responsibility of both the programme manager and the sub-projects' owners; (2) a clear definition of the main common, strategic goal for the programme; (3) a dedicated department (or office) with clear roles and responsibilities to regulate, direct and facilitate the behaviour of sustainable construction at the programme management level; and (4) holding pre-meetings to coordinate the efforts of the various participants striving to achieve sustainable construction. Clearly, stakeholder engagement plays a critical role in sustainable construction (Wu and Low, 2010; Robichaud and Anantatmula, 2011).

Table 1 Differences between sustainable management of programmes and projects

Comparative items	Programme	Project
Objective issue	Focus on strategic sustainable construction objective for the whole programme. Benefits of different projects that owners should be concerned with	Focus on the sustainable construction objective of a single project. Benefits that different project partners should be concerned with
Organizational issue	Focus on organizational relationship issues between different sub-project owners	Focus on organizational relationships between different parties to a project
Technical issue	Focus on conceptual technical guidelines for all the projects within the programme	Focus on the detailed technical design for a single project
Managerial issue	Focus on administration and regulation rules for all the projects within the programme	Focus on a systematic process and procedure for the sustainable management of a project

Based on our research of the Shanghai World Expo 2010, especially the in-depth discussion with members of the programme management team during site meetings the authors have developed a checklist for promoting sustainable construction at the programme level (see Table 2). This checklist can be used as a guide to verify the implementation of sustainable construction of other mega-projects at the programme level.

Another critical finding of this study is that a specific quantitative target should be defined and supported to achieve sustainable construction at the programme level, e.g. in the construction stage of each pavilion, the rate of utilization of non-conventional or recycling water must be more than 30%; the rate of utilization of energy saving lamps on site must be more than 90%. This target was not defined in detail in the Shanghai World Expo project owing to the fact that the pavilions were funded separately by different participants. The basic guidelines about sustainable construction developed in this project were qualitative and conceptual hence they could be regarded as the fundamental principles for green building design. The provisions in the management regulations (e.g. oversight by the organizer) about sustainable construction were mandatory and required all owners of pavilions to comply with the stipulated regulations. Those requirements were in the form of general statements, with no specific quantitative targets. Accordingly the practice of sustainable construction varied across the board. Some pavilions had clearly made more effort to achieve a higher level of sustainable construction. In the course of the site meetings, workshops and informal interviews, the message from participants was unanimous that quantitative targets for sustainable construction should be specified as early as possible in large programmes with a single source of funding or a small number of owners, e.g. the sports venue developments for the Asian and Olympic Games.

Interestingly, some interviewees had also been involved in the management of other mega-projects in China, e.g. the Pudong International Airport in Shanghai and the Asian Olympic Games 2010 in Guangzhou. Those interviewees indicated that the approach with respect to sustainable construction at the programme level varied from one programme to another mainly because of the unique background of

Table 2 A checklist for promoting sustainable construction at the programme level

Items	Yes/No
(1) Has the organizational responsibility used to achieve sustainable construction been clarified?	
(2) Have the sustainable construction goals been defined?	
(3) Has a special office or department been established to manage sustainable construction at the programme level and have its functions been clearly defined?	
(4) Does the programme have a land use plan?	
(5) Are there any energy saving design guidelines?	
(6) Are there any water efficiency design guidelines?	
(7) Are there any guidelines for the reduction of environmental loadings?	
(8) Are there any guidelines for high quality service design?	
(9) Are there any design guidelines for reusing existing buildings and structures?	
(10) Are there any guidelines about performance tuning design?	
(11) Does the construction process have an energy saving plan?	
(12) Does the construction process have a water saving plan?	
(13) Does the project have a plan for materials saving and reuse?	
(14) Does the project have a plan for the reduction of environment loading in the construction process?	
(15) Does the project have a plan for sustainable transportation?	
(16) Does the project have a plan for waste management during the construction process?	
(17) Does the project have a guideline for energy saving during the operation phase?	
(18) Does the project have a guideline for water saving during the operation phase?	
(19) Does the project have a guideline for the reduction of environmental loading during the operation phase?	
(20) Does the project have a guideline about IEQ (indoor environmental quality) improvement?	
(21) Does the project have a plan for improving service quality?	
(22) Does the project have a plan for flexible performance tuning?	
(23) Does the project have an energy saving plan for the demolition process?	
(24) Does the project have a plan for the reuse of structures and materials resulting from the demolition phase?	
(25) Does the project have a plan for waste management during the demolition phase?	

each programme, in particular, in terms of the authority of the programme manager over the sub-project owners. If the programme manager has full authority over the sub-project owners, rigorous quantitative targets can be established, whereas if the programme manager does not have full authority over the sub-project owners, it is generally better to establish qualitative guidelines or basic principles to help direct, rather than force the sub-project owners to meet quantitative targets of sustainable construction. With regard to those items with mandatory target requirements, such as avoiding the production of hazardous waste, the programme manager could use management regulations to require the sub-project owners to comply with those requirements.

Conclusion

Sustainable construction has attracted much public attention as a result of an increasing level of public awareness about the impacts of construction activities on the environment; however, most of those studies have focused on the project level. There is still a lack of research about the implementation of sustainable construction at the programme level. Construction programmes generally consist of a number of projects, thereby requiring an approach that considers the diverse requirements of each project with the view of achieving the overall strategic target. Sustainable construction at the programme level endeavours to define the strategic sustainability related objectives of the whole programme so that the benefits of the numerous project stakeholders can be taken into account. These results provide a useful reference for the promotion of sustainable construction within the context of multi-stakeholder management, especially in the very early stages of a large programme. Considering the increasing number of large-scale and complicated engineering projects planned by the government to counteract the financial crisis, it is imperative that a systematic process of sustainable construction is implemented for mega-projects.

As a mega-project in China, the Shanghai World Expo 2010 has the potential to serve as a showcase for sustainable construction. In an attempt to achieve this goal, the organizer has gone to great lengths to promote sustainable construction throughout the planning, design, construction operation and demolition stages of the project lifecycle. Using a case study approach, a number of measures were identified for the implementation of sustainable construction in this large-scale programme. Two levels of sustainable construction management used by the organizer were highlighted, i.e. basic guidelines and management regulations. The basic guidelines are voluntary. The management regulations are mandatory; however, they do not define specific quantitative targets for sustainable construction. Because stakeholders from all over the world were involved in this large programme, the implementation of sustainable construction became both a technical and managerial issue. The organizer played a critical role in guiding all the stakeholders to conduct their projects in a sustainable way within the context of their own preference of project management.

The contributions of this study to the body of knowledge are twofold. From a theoretical perspective, the research findings have extended the existing body of knowledge with regard to sustainable construction, particularly from the perspective of programme management. The differences between sustainable construction at the programme level and that at the project level are indicated in Table 1. The results clearly showed that the implementation of sustainable construction at the project level in a large programme was not of itself sufficient to achieve the overall strategic target of a programme. From a practical application perspective, this study highlights sustainable construction practice at the programme level in the Shanghai World Expo 2010, thereby providing a series of lessons learnt for other large programmes in the future. The managerial checklist included in this study can complement the traditional technical guidelines such as LEED, BREEAM or SBTool for facilitating the implementation of sustainable construction in large programmes in the future.

The limitation of this research is due to its exploratory nature. The approaches adopted in this research (e.g. observations, site meetings, informal interviews, workshops and project document reviews) have led to the successful collection of a large amount of data to fulfil the research objectives of this study. However, this approach is limited, especially in terms of the generalizability of the results or control over the conditions of causality. Therefore, it would be interesting to integrate this approach with some empirical methods, e.g. survey research, or mixed methods in the contextualist research approach proposed by Green *et al.* (2010) to further validate and improve the framework developed in this study.

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