Assessment of China's Evaluation Standard for Green Building:

A Sustainability Perspective

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ABSTRACT

China is facing multiple challenges of environmental degradation, resource scarcity, and rapid urbanization. The challenges along with people's needs to improve living condition force China to value the importance of developing green buildings. In 2006 the first national green building assessment tool - Evaluation Standard for Green Building (GBS) was released and widely implemented soon after. At the same time, the notion of sustainability is increasingly discussed by green building researchers and practitioners globally. There is a trend of transformation from environmentally friendly or energy efficient building to sustainable building. However, studies on the sustainability performance of GBS are still absent. This paper strives to make a comprehensive methodological assessment of GBS from sustainability perspective, to provide a picture of GBS's distance to the principles of sustainability, its advantages and limitations. The methodological framework of PICABUE developed by Mitchell et al. (1995) is applied as the guidance of analysis. Some suggestions are offered for the standard makers at the moment GBS is being revised for the second version.

Keywords: green building, Evaluation Standard for Green Building (GBS), PICABUE, sustainability indicators, assessment

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Yan Yu
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ABBREVIATIONS

AIJ	Architectural Institute of Japan
BAF	Biotope Area Factor
BEQUEST	Building Environmental Quality Evaluation for Sustainability through Time
BRE	Building Research Establishment of the UK
BREEAM	BRE Environment Assessment Method
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
DPSIR	A causal framework for describing the interactions between society and the environment
EEA	European Environment Agency
EU	European Union
GAQSIQ	General Administration of Quality Supervision, Inspection and Quarantine of PR China
GBCAS	Assessment System for Green Building of Beijing Olympic
GBS	Evaluation Standard for Green Building
GBTool	Green Building Challenge
GIS	Geographic Information System
HDI	Human Development Index
HI	Happiness Index
IPHA	International Passive House Association
LCA	Life-Cycle Assessment
LEED	Leadership in Energy and Environmental Design
MBP SYD	Miljöbyggprogram SYD (Environmental Construction Program: Southern Sweden)
MOF	Ministry of Finance of PR China
MOHURD	Ministry of Housing and Urban-Rural Development of PR China
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
PICABUE	A methodological framework for generating sustainability indicators developed by Mitchell et al.
SUD	Sustainable Urban Development
UN	United Nations
UNCED	United Nations Conference on Environment an Development
UNEP	United Nations Environment Programme
UNEP SBCI	UNEP Sustainable Buildings and Climate Initiative
WCED	World Commission on Environment and Development

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1. INTRODUCTION

1.1 Background

1.1.1 The Emergence of Green buildings and Building Assessment Tools

Environmental Issues such as climate change, pollution and resource depletion have become a more and more significant focal point of the public and academic research in the last few decades. Under this context, building has drawn much attention around the world in terms of environmental impacts during the entire life cycle including construction, operation and demolition phases (Kajikawa et al., 2011; Ding, 2008), as building takes up a considerable proportion of total anthropogenic energy and resource consumption (Pérez-Lombard et al., 2008; Kats, 2003). According to the report of UNEP (UNEP SBCI, 2009), buildings are responsible for approximately 30% of global greenhouse gas emission. And in developed countries, e.g. OECD countries, the energy consumption of buildings can reach 40% of the total amount (UNEP SBCI, 2009). Soil degradation, deforestation, noise pollution, and other environmental impacts relevant to buildings and the invariable process of urbanization, coupled with increasing risks of natural disasters originated from buildings, are all questioning the environmental performance of buildings.

The concern of building environmental performance can be traced back to the 1970s, when the oil crisis forced developed countries to search alternative primary energy sources and reduce consumption (Sun et al., 2008). Hereafter environmental consideration is continuously reforming the mindset of architecture design, construction and operation management. A number of attempts and practice of new technologies and ideas for better building performance sprang up in the market (Sun et al., 2008; Fenner & Ryce, 2008). The concepts such as energy efficient building, green building, and sustainable building were frequently used among practitioners of building industry. There is a trend that, in the 1990s and early 2000s, a batch of building environmental assessment tools were emerging with the task of evaluating the "greenness" of buildings (Cole, 1998; Crawley & Aho, 1999). This trend didn't only result from the needs of building sector to track their progress in building performance, but was also driven by the growing market and the demand that more information should be exposed to the public (Crawley & Aho, 1999). Some well-known and broadly implemented building environmental assessment tools are BREEAM, LEED, CASBEE, and GBTool. They will not be specifically discussed in this paper.

1.1.2 Green Building Development in China

The environmental problems in China are more and more severe along with the rapid economic growth, which has captured the attention of the whole world. China shows its increasing prominence in climate change (Matteis, 2012). Depletion of natural resources, water, soil and air pollutions are dominating the headlines of media. It is not only a problem of environment but also endangering the stability of society. The government and academia of China have also realized the challenges and started trying to change the situation in different ways. The development of green buildings is one of the strategies, as buildings contribute to 25% to 30% of energy consumption in China, even though the ratio is not as much as the ones in developed countries (Chinese Society for Urban Studies, 2008).

The voice of developing green buildings in China is derived from three main conditions regarding the constructions. First of all, the speed of urbanization of China is impressive over the last 30 years since China has applied market economy in the early 1980s. The population living in urban area has expanded from 17.9% in 1979 to 51.27% by the end of 2011, which is approximately 691 million (National Bureau of Statistics of China, 2013; Pan & Wei, 2012). For the first time in history urban population has exceeded rural area. And this tendency of urban immigration is considered to continue in the near future, since after the election in 2013 the new government will keep promoting the process of urbanization (Wen, 2013), in order to sustain the slowing-down economy. Thus, urban area keeps sprawling and arable lands shift into residential buildings and factories. Secondly, people are pursuing improvement in terms of living condition (Shen, 2012). Residential floor area per capita of urban area is continuously rising. During ten years between 1998 and 2007 this number is growing at the rate of $1m^2$ per year (Jin, 2009). More buildings would be constructed to meet the large demand. At the same time, energy demand of cooling and heating is dramatically increasing for the purpose of better indoor comfort (Shen, 2012), since the insulation of buildings is not advanced and district heating systems are not well established especially in the areas south of Huaihe River, where district heating is not mandatory according to regulations (Liu, 2012). And air conditioning and electric radiators are becoming affordable for more and more families. The third reason of developing green buildings is its obvious effect on resource saving. It is estimated that, if certain green building technologies are implemented, 20% of energy, 63% of water, 87% of timber could be saved from the current level (T. Wang, 2010). All of above call for well establishment of a green building development mechanism and set of institutions.

To fill in the blank, China started to consider the development of green buildings as a national strategy in 1996, when researches on green building system was written on the 9th National Five-Year Plan as a primary project (Liu, 2012). In the following years several attempts on the assessment system of green buildings were generated. For example, Ministry of Housing and Urban-Rural Development of China (MOHURD) with three architect institutes compiled *China Eco-Housing Technology Assessment Handbook* (Nie et al., 2002), which was based on studies of other existing assessment tools in the world. During the preparation of 2008 Beijing Olympic Games, *Assessment System for Green Building of Beijing Olympic* (GBCAS) was released to guide the construction of Olympic facilities to meet the idea of "Green Olympics" (Green Olympic Building Research Group, 2003). This system borrowed the general framework of CASBEE (*Comprehensive Assessment System for Built Environment Efficiency,* Japan) and its advanced weighting system. The development and application of GBCAS provided plenty of experiences for generalization of green building assessment systems for entire country.

Figure 1 Three-Step Plan of Green Building Development Launched by MOHURD (Adapted from Shen, 2012)

2004. A three-step plan, including the initiation phase, national evaluation phase, and financial incentive & enforcement phase, was launched by MOHURD (Figure 1). In 2006, the first official assessment tool, *Evaluation Standard for Green Building* (GB/T 40378-2006, GBS), was proclaimed by MOHURD and General Administration of Quality Supervision, Inspection and Quarantine (GAQSIQ). GBS is the main object that is going to be discussed in this paper.

Although GBS was released 15 years later than BREEAM (*BRE Environmental Assessment Method*, UK), first green building assessment tool globally (Yuan & Wang, 2007), its implementation process was extremely rapid. Since the first building project was labelled as green building in April 2008, there have been 742 residential and public building projects certified by GBS by the end of 2012, with the total construction area of 75.8 million m^2 (Wang, Gao, Song, Li, et al., 2013). We can see from Figure 2&3 that the number of evaluated projects is growing at an exponential rate. As planned by MOHURD and the Ministry of Finance (MOF & MOHURD, 2012), certified green buildings should comprise more than 30% of total newly built buildings by 2020. And the ambition is to have a one-billion-m^2 increment of green building construction area in urban region by 2015. This ambition could be achieved through enforcement of green building certification of all government invested affordable housing projects in big cities (ibid.). Therefore, GBS will continue to be of enormous significance in terms of promoting green building development in the following decade.

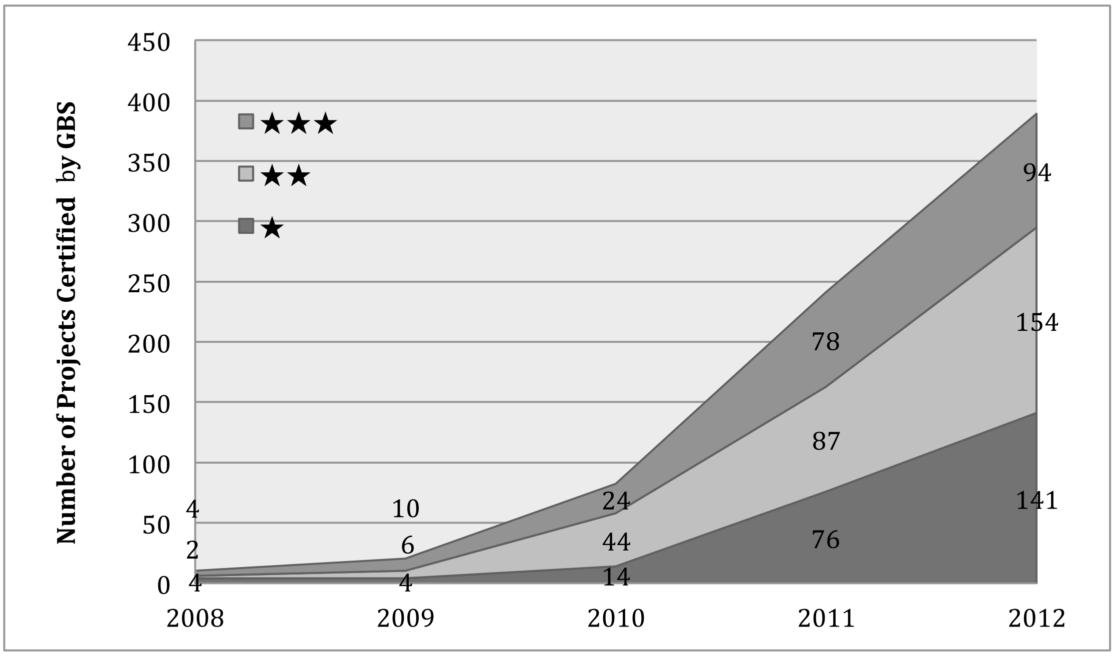

Figure 2 Number of Projects Certified by GBS in China from 2008 to 2012 (Data source: Wang et al., 2012)

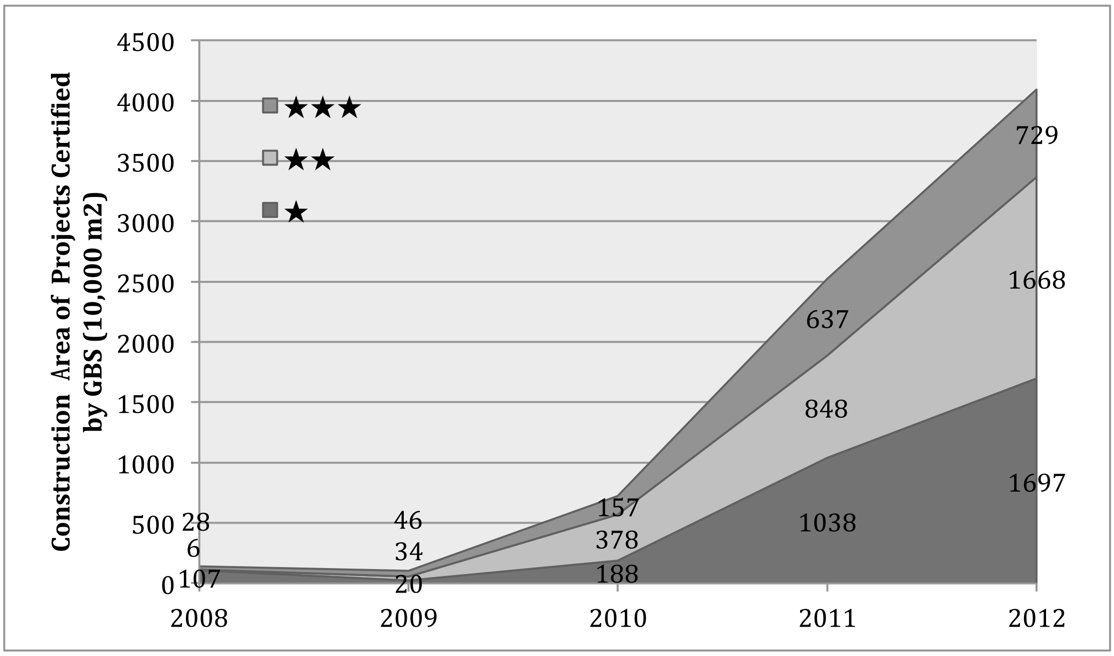

Figure 3 Construction Area of Projects Certified by GBS in China from 2008 to 2012 (Data source: Wang et al., 2012)

1.1.3 Introduction to GBS

GBS is designed based on popularly implemented green building assessment tools in the world in coalition with China's specific geographical, climatic, and socioeconomic characteristics (Zhi et al., 2010). The 2006 version of GBS (MOHURD & GAQSIQ, 2006) is able to evaluate newly built residential buildings and public buildings, whereof industrial constructions and buildings with special functions, e.g. hospital buildings are excluded. The standards for residential buildings and public buildings with detailed requirements are listed separately in two sections. The index system of GBS is a two-level system and consists of six major categories, including Land Saving & Outdoor Environment, Energy Saving & Energy Utilization, Water Saving & Water Resource Utilization, Material Saving & Material Resource Utilization, Indoor Environment Quality, and Operating Management. A total of 76 items for residential buildings and 83 items for public buildings are allocated under these categories (Figure 4). Within each category items are subdivided into mandatory items, general items and preference items (Table 1). Mandatory items are bottom-line criteria for each project that wants to be certified as green buildings. Once all of mandatory items are met, the project is rated as One-Star, Two-Star, or Three-Star Green Building dependent on how many general and preference items are achieved (Table 2). Figure 5 shows the flowchart of the certification process. The six categories of items are quite similar to the structure of LEED (*Leadership in Energy and*

Environmental Design, USA). However, unlike LEED, of which the final score of an evaluated project is simply an addition of all categories, GBS requires a minimum green performance for each category. This strategy keeps a certain degree of balance between different aspects of green buildings, so that a "green building" performs extremely badly in one aspect is avoided (Zhi et al., 2010; Wang et al., 2010).

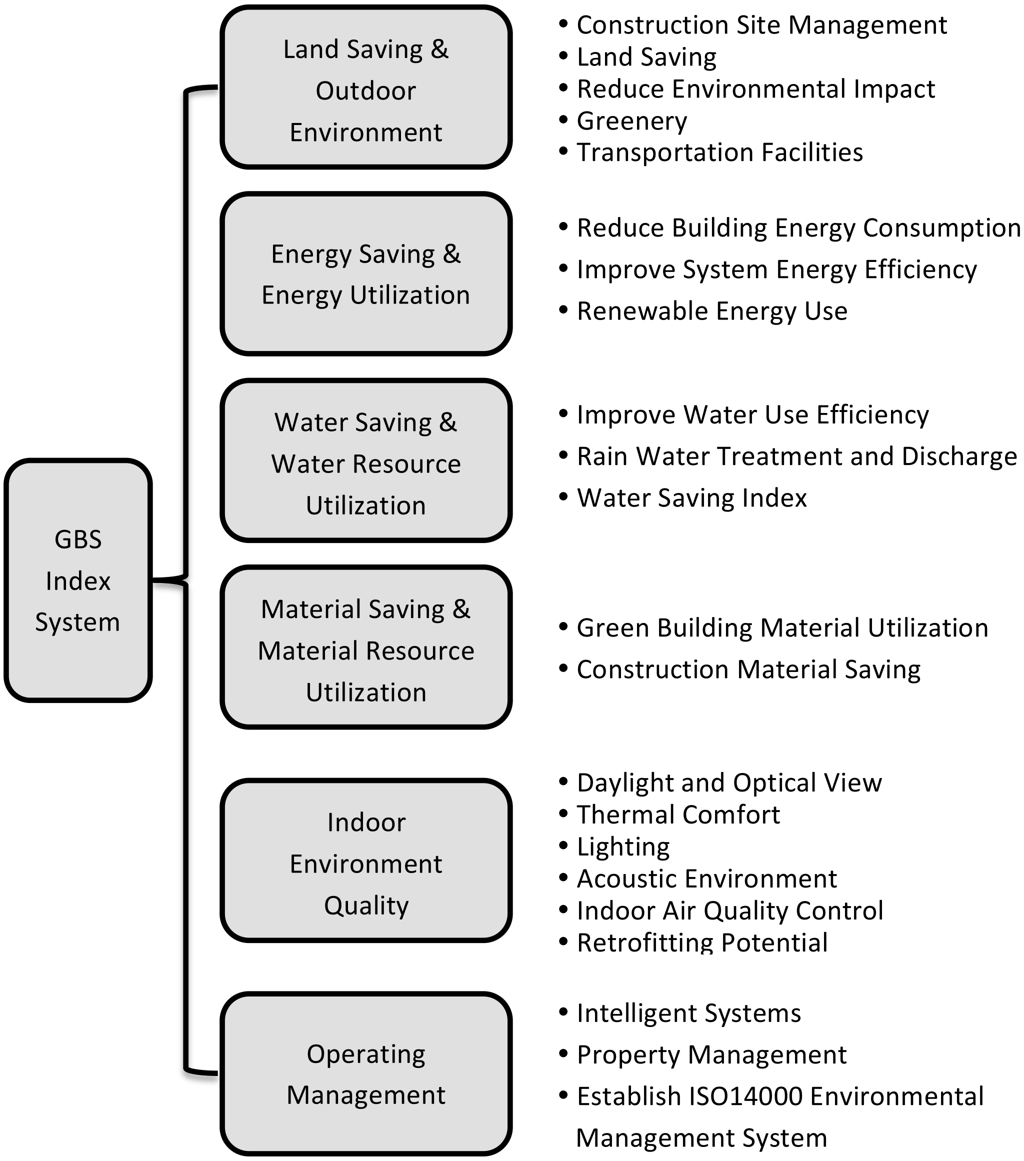

Figure 4 Structure and Categories of GBS Index System (Adapted from Shen, 2012)

Categories	Land Saving & Outdoor Environment		Energy Saving & Energy Utilization		Water Saving & Water Resource Utilization		Material Saving & Material Resource Utilization		Indoor Environment Quality		Operating Management	
	R*	P**	R	P	R	P	R	P	R	P	R	P
Mandatory	8	5	3	5	5	5	2	2	5	6	4	3
General	8	6	6	10	6	6	7	8	6	6	7	7
Preference	2	3	2	4	1	1	2	2	1	3	1	1
Total	18	14	11	19	12	12	11	12	12	15	12	11

*R=Residential Buildings; **P=Public Buildings

Table 1 Numbers of Items Allocated in Each Category of GBS (Data source: MOHURD & GAQSIQ, 2006)

Grades	General Items												Preference Items	
	Land Saving & Outdoor Environment		Energy Saving & Energy Utilization		Water Saving & Water Resource Utilization		Material Saving & Material Resource Utilization		Indoor Environ-ment Quality		Operating Manage-ment			
	R	P	R	P	R	P	R	P	R	P	R	P	R	P
★	4	3	2	4	3	3	3	5	2	3	4	4	-	-
★★	5	4	3	6	4	4	4	6	3	4	5	5	3	6
★★★	6	5	4	8	5	5	5	7	4	5	6	6	5	10

*R=Residential Buildings; **P=Public Buildings

Table 2 Numbers of Items to Be Reached by Categories for an One/Two/Three-Star Certification (Adapted from MOHURD & GAQSIQ, 2006)

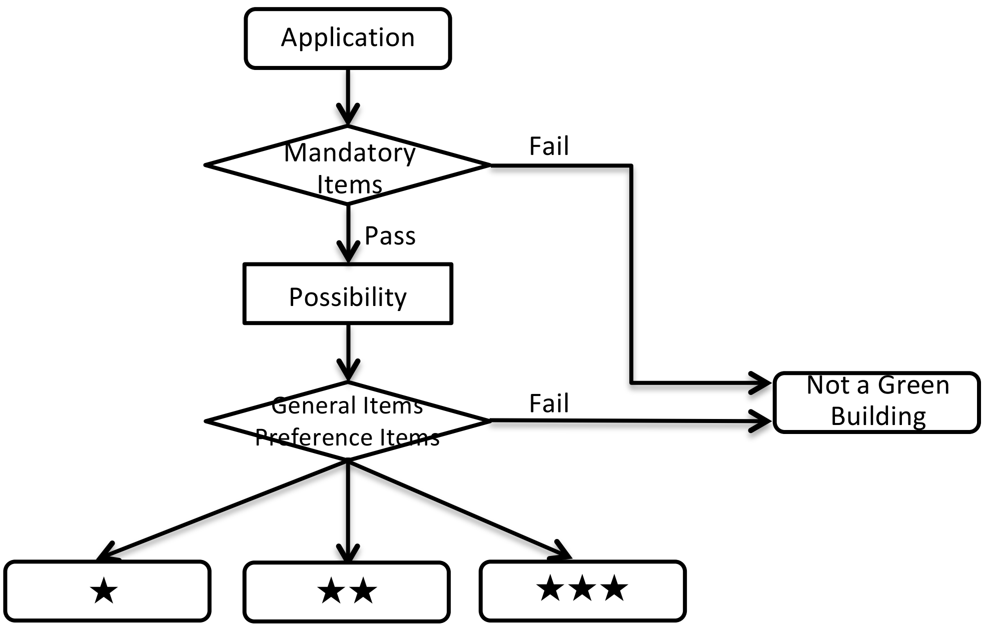

Figure 5 Flowchart of GBS Certification Process (Adapted from Shen, 2012)

1.2 Problem Formulation

Although GBS is a result of synthesizing merits and abandoning weak points of different building assessment tools, it still emphasizes on energy efficiency and reducing natural resource consumption. However, the emerging idea of sustainability has significantly broadened the current context of environmental protection. There is an extensive discussion amongst academia and building technologists whether the existing methods of building assessment could fulfill the new sustainability agenda and how we can improve them (Cole, 2005). Social and economic issues of human society together with ecological systems and services should all be recognized and integrated when designing building assessment tools (ibid.). Ding (2008) also argued that an ideal assessment method calls for a "multi-dimensional approach" to deal with the multifaceted sustainability needs. Nevertheless, architecture and sustainability science are both multidisciplinary fields, which doubled the difficulty of solving the puzzles (Kajikawa et al., 2011).

Quite a number of studies on systematically analysing the current building performance evaluation methods and combining them with sustainability were carried out in the past few years (Cooper, 1999; Ding, 2008; Kajikawa et al., 2011; Cole, 2005; Cole, 1998; Kaatz et al., 2005; Sanya, 2011; Lutzkendorf & Lorenz, 2006). Cooper (1999) questioned that a single assessment method, for example, merely doing iterative assessments at each stage of building's lifetime, might not be sufficient for a broad notion of sustainability. Cole (2005) pointed out the distinction between the aims of assessment tools and their roles on market transformation. He suggested that there should a more effective mechanism to involve all stakeholders in order to consider the business community's attitude on sustainability (Cole, 2005). Ding (2008) discussed the limitations of current assessment tools applied in different countries and brought about a sustainable model of building assessment, which highlighted the importance of considering sustainability at the appraisal stage of a project. Lutzkendorf & Lorenz offered a "job-sharing approach" and a "integrated building performance" proposal for the next generation of building assessment tools (Lutzkendorf & Lorenz, 2006). Many of the aforementioned studies spoke at the circumstance of developed countries, since building assessment methods were originated in developed countries. However, as Cole (2005) argued, although the import of these methods to developing countries has profoundly promoted green building development in those regions, there are always intrinsic cultural biases within these methods and local context is often neglected.

The studies and analyses on GBS and other international building assessment tools are abundant but mainly from Chinese scholars (Sun et al., 2008; Yuan & Wang, 2007; Zhi et al., 2010; Wang et al., 2010; Wang, Gao, Song, Li, et al., 2013; Li, 2010; Zhu & Lin, 2012; Wu et al., 2008; Wan et al., 2009; Li et al., 2011; Li & Zhou, 2012). However, these articles solely made some introductions of the tools or simply compared the differences of structures, techniques, and specific setting of items between GBS and the rest. The critiques to GBS are very scattered and unorganized. No one has really analyzed GBS from the systemic point of view. There isn't a methodological study or a comprehensive framework to guide the generation and upgrading of the current version of GBS. Moreover, recent Chinese studies on GBS didn't touched the core debates of sustainability (Cooper, 1999) especially on social and economic facets. Unless we jump out of the systems of existing assessment tools and overview the issue from a holistic perspective, we won't understand the fundamental contradictions and will stay struggling in the marsh of technical problems.

It has been seven years since the first version of GBS was proclaimed and widely utilized. A lot of problems about configuration and operation of GBS were discovered and collected during implementation. MOHURD and GAQSIQ are planning to revise GBS and a draft of 2nd generation GBS (MOHURD & GAQSIQ, 2012) is circulating among policy-makers and participants in the green building industry. In this way the government wants to gather some opinions and suggestions for the revision. As discussed above, a well-structured green building assessment tool is crucial to green building development. And the revised GBS could influence the whole building industry with a sustainability concern in the next decade, and even the sustainability awareness of the entire society.

Thus, the aim of this paper is to systematically evaluate the current GBS from a sustainability perspective, in order to find its internal problems which block its way to adapt sustainability. The research questions are as follows:

1. To what extent does GBS follows the criteria of sustainability?

2. What are the beneficial characteristics and limitations of GBS from sustainability perspective?

3. And how can we fix the limitations?

2. CONCEPTS CLARIFICATION

Before any analysis and arguments are carried out, a few important concepts and terminologies will be discussed and clarified below, so as to avoid misunderstanding and frame a consistent language system of the paper. For some terminologies, e.g. sustainability, accurate definitions won't be provided because the meanings are still vague and the academia hasn't come to a consensus to these terms.

2.1 Sustainability and Sustainable Development

The GBS explicitly propose, in its Article 1.01, the role of promoting sustainable development:

> *"The standard have been formulated in order to implement national technological and economic policies for resource saving and environmental protection, promote sustainable development and standardize the evaluation of a green building."* (MOHURD & GAQSIQ, 2006)

When it comes to the concepts of sustainability and sustainable development, most researches would mention the definition made by the World Commission of Environment and Development (WCED). In WCED's report *Our Common Future* sustainable development was explained as follows:

> *"...development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations."* (WCED, 1987)

Although this definition was rather vague and ambiguous, it addressed that human should respect the future of our planet and the discussions about sustainability was raised from different perspectives and scales (Mebratu, 1998). Since then, the terms sustainability and sustainable development are so widely used and to different people and atmosphere they mean different things (Clark, 2011). The debates on what sustainability is and what to be sustained and developed are enormous (ibid.). Gibbon et al. (1995) suggested *"the exercise of definitions is one useful way to examine several perspectives and to understand competing views",* but the absence of an exact and overarching definition doesn't necessarily hinder the sustainable actions and practice (Gibbon et al., 1995). The meaning of sustainability is always changing as time goes, and the intrinsic uncertainty and flexibility of sustainability is something we should respect (Bell & Morse, 2008). This paper will not step into the jungle of arguments regarding the fundamental goals, the main problems and study hotspots of sustainability. Nevertheless, we will focus on the understanding from building sector and its related fields.

The terms "sustainability" and "sustainable development" are sometimes indiscriminately used. Yet government and private sector are inclined to use "sustainable development", while the word "sustainability" is favoured by the academia and non-governmental organizations (NGOs) (Robinson, 2004). Robinson explained this distinction from the philosophical start point of the relationship between human society and the nature, which is to say that "sustainable development" is from an anthropogenic perspective while "sustainability" is more biocentric (ibid.). Here come the debates of strong sustainability and weak sustainability. Weak sustainability means that increment in manufactured capital can sacrifice some of environmental deterioration, as long as the summation of all economic, social and ecological factors is positive (Rennings & Wiggering, 1997); while strong sustainability foci on ecological sustainability, which doesn't care much about financial or cost-benefit balance (Common & Perrings, 1992; Rennings & Wiggering, 1997). As an industrial sector greatly driven by market, it is unrealistic for building industry to apply to perfectly strong sustainability and give up the profitability. The green building agenda is sometimes deemed to be week sustainability. This paper assumes that the green building development goes an anthropogenic and weak sustainable way, but that doesn't mean exploiting the nature is encouraged. It means that while making the greatest effort to save the ecosystem, living condition of human should not decrease especially in developing countries, and optimizing profit is unavoidable in the building sector.

2.2 Green Building

Many similar terms associated to green building emerged during the development of different building assessment systems and programs (Yoshida & Sugiura, 2010). These terms include but not limited to "eco-housing", "eco-architecture", "energy-efficient building", "green building" and "sustainable building". Each of them has its own definition, which shows the understanding of their creators. Liu (2012) made a summary of these terms and compared the similarities and differences. Liu found that most of the definitions emphasized the environmental aspects while explicitly mentioned the social and economic pillars of sustainability, and they addressed the view of entire life cycle of the building (Liu, 2012). For example, GBS defines green building as follows:

> *"...a building which during its life cycle, to a maximum degree, can save resources such as energy, land, water and material, help protect the environment, help diminish pollution, provide healthy, suitable and high-performance spaces for people to use, and coexist harmoniously with nature."* (MOHURD & GAQSIQ, 2006)

From terms such as "energy-efficient building" and early definitions of "green building" till recent ones, there is a general trend that the meanings of these concepts is changing from a single-dimensional basis to a multi-dimensional one and more factors tend to be incorporated (Kajikawa et al., 2011). Cole (1999) argued that the notions of "sustainable" and "green" are completely distinct and should be carefully noted. He pointed out that "Green building" only "implicitly acknowledges sustainability as a goal", while "sustainable building" contains environmental, social and economic facets and address global equity between developed and developing countries (Cole, 1999). However, there is no need to choose one term and abolish the other. It is not "sustainable building" is replacing "green building", but the notion of "green building" or "sustainable building" is expanding and becomes more comprehensive. In this sense, this paper will keep using the term "green building" but the notion is profoundly sustainable.

The definition given by GBS weights too much on the environmental aspects. Indeed, GBS mentioned that green buildings should "provide healthy, suitable and high-performance spaces for people to use" (MOHURD & GAQSIQ, 2006), but living condition is just one factor of social considerations. Aspects such as culture, working, community solidarity, local economy, etc. are yet to be supplemented. The definition of sustainable building provide by CASBEE is preferred, although it is not the best either. Three features of a CASBEE sustainable building are as follows:

> *"1. To save energy and resources, recycle materials and minimize the emission of toxic substances throughout its life cycle;*
>
> *2. To harmonize with the local climate, traditions, culture and the surrounding environment; and*
>
> *3. To be able to sustain and improve the quality of human life while maintaining the capacity of the ecosystem at the local and global levels"* (AIJ, 2005)

2.3 GBS as Sustainability Indicators

From the system analysis point of view, the world is a complex system that consists of multi-level of infinitely many systems. The essences of systems are not usually obvious. In order to study the complex activities within a system and figure out the essential relationships between systems, we need indicators to simplify the complexity of systems (Bossel, 1999). As Bossel (1999) described, indicators are developed to condense huge quantity of information collected by observers, which could to some extent represent and explain the reality. Indicators are widely used in scientific researches related to systems. For example, ecologists take the population of key species as an indicator to describe and monitor the health of a certain ecosystem (Bell & Morse, 2008). There are basically two types of indicators based the system one is studying: 1) the indicators that provide a picture of the system itself; and 2) the indicators that provide information about the system's influences on other systems that are relevant to it (Bossel, 1999). Bell and Morse (2008) further distinguish indicators into state indicators (e.g. concentration of heavy metals in a lake) and process indicators (e.g. flow of heavy metals discharged into a lake), which offers a clear understanding of the term indicator.

It is not difficult to imagine Sustainability indicators are developed as important methods and tools in sustainability science and sustainability issues, as sustainability embraces many aspects and the elements within the systems are very complex and interconnected. Institutes, different levels of governments, private consultants and even financial organizations are all publishing their own indicators. The Agenda 21 document (UNCED, 1992) released after the UN Conference on Environment & Development held in Rio de Janerio in 1992 provided a list of 132 sustainable development indicators in four categories, which is a famous one among enormous such indicator frameworks. Sustainability indicators become increasingly popular is under the background that the terms are ambiguous, the data are puzzling and the methods are complicated while doing sustainability assessment (Kajikawa et al., 2011). As Bell and Morse said, sustainability indicator is "measuring the immeasurable" and is a vital path to implement the research findings of different disciplines in relation to sustainability in reality (Bell & Morse, 2008).

Sustainability indicators should meet certain features that are listed below, as Harger & Meyer (1996) suggested:

1. Simplicity: the indicators should pursue maximum simplicity;

2. Scope: the indicators should avoid overlapping each other and should embrace environmental, social and economical aspects of human activities;

3. Quantification: the indicators should be measurable;

4. Sensitivity: the indicators should sensitively reflect change;

5. Timeliness: the indicators should be able detect performance trend over time.

In this paper, we will regard GBS as one of sustainability indicator systems, because building assessment tools have similar characteristics to other sustainability indicators (Kajikawa et al., 2011). Firstly, GBS simplifies big amount of elements and data of building performances and establishes a common language between stakeholders. Secondly, GBS covers a broad range of sustainability factors from energy consumption, land use, and water quality to indoor comfort. Thirdly, GBS incorporate both qualitative and quantitative methods. Finally, GBS reflects the degree of sustainability acknowledgement and development of technology regarding green buildings. GBS as sustainability indicators is the basis of the application of the methodological framework, which will be explicitly introduced in the next section.

3. PICABUE

3.1 PICABUE as a Tool to Evaluate GBS

As we discussed in the beginning, there is lack of a methodological framework to underpin the construction of GBS as well as the evaluation and modification of the current GBS under implementation. Without a fundamental and relevant methodology to guide the selection of indicators, their justification and utilization remain an unavoidable problem (Mitchell et al., 1995). The necessity of possessing an overarching theoretical and methodological tool as foundation of an indicator system involves that 1) it provides a reliable and reasonable method for indicator selection; 2) it can organically integrate the knowledge of associative disciplines and stakeholders; 3) it effectively organizes and simplifies the process; and it ensures the robustness of the system over a long period (ibid.).

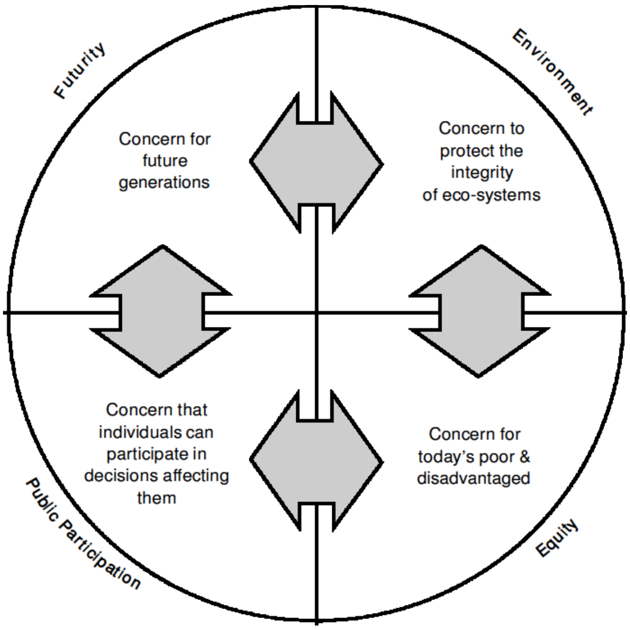

Figure 6 PICABUE's Four Principles of Sustainable Development (Source: Cooper, 1999)

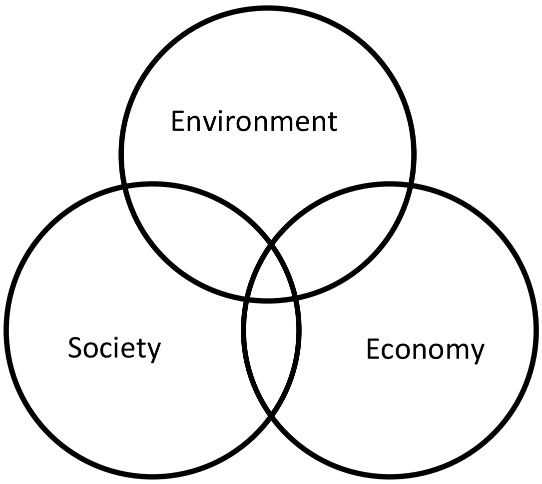

Figure 7 Three-Pillar Model of Sustainability

In order to systematically evaluate whether or not GBS correspond with the criteria of sustainability, which is the main task of this paper, the methodology framework PICABUE designed for developing sustainability indicators is introduced here. PICABUE is the acronym of seven steps to process the construction of sustainability indicator systems invented by Mitchell et al (1995), which stands for **P**rinciples, **I**ssues, **C**onstruction, **A**ugmentation, **B**oundary, **U**ncertainty, and **E**valuation.

PICABUE addresses the quality of human life while the principles of sustainability should be incorporated. Mitchell et al (1995) specified that sustainability is constituted of four principles: environment, futurity, equity and public participation (Figure 6). The environment principle deals explicitly with the ecosystem, realizing that human activities on one hand extract resources for natural environment, on the other hand discard matters that are harmful for the nature. The intrinsic value of the nature apart from things we treasure as resources should also be respected (Mitchell et al., 1995). Distinctive from the other model of sustainability, in which sustainability is composed of environmental, social and economic pillars (Figure 7), PICABUE incorporates social and economic aspects into futurity, equity and public participation. Futurity stands for inter-generational equity, which means the exploitation of the environment through human activities shouldn't exceed a certain threshold, so as to ensure the well being of future generations. The equity principle of PICABUE represents the intra-generational equity, which means people geographically and economically should have equal opportunities to access to environmental capital and should share responsibility to environmental degradation. (Palmer et al., 1997) The fourth principle public participation states that everyone should have an unblocked channel to take part in the process and influence decision-making. PICABUE stresses the importance of public participation which makes it very unique among many sustainability models (Ding, 2008). Palmer et al. (1997) further argues that traditional commitments of sustainability don't pay enough attention to public participation, while the awareness and requirements of public participation is rising (Joubert et al., 1997).

Cooper (1999) suggests that the four principles of sustainability derived from PICABUE should be applied to building or city sustainability assessment. And it is already been widely used for sustainable urban development (SUD) (Curwell, 2000). The Building Environmental Quality Evaluation for Sustainability through Time (BEQUEST), which is an EU funded research, training and practice network, used PICABUE as a common language of understanding SUD and as a tool to develop their indicator system for SUD (Hamilton & Cooper, 1998). In order to improve the latest version of BREEAM, the Centre for Sustainable Construction of the UK's Building Establishment got inspiration from BEQUEST (Cooper, 1999). A number of projects regarding SUD assessment are carried out using BEQUEST, e.g. Flores, 2009. PICABUE was first created to generate indicator systems, but in this paper we are going to use PICABUE as an assessment tool to measure GBS's distance from sustainability and find out what factors should be considered. Mwasha et al (2012) reviewed a few well-known conceptual frameworks for developing sustainable performance indicators, including PICABUE and DPSIR. DPSIR (Driving Force, Pressure, State, Impact, Response) is a causal framework adopted by European Environment Agency for interpreting the interactions between the environment and human society (EEA, 2012), which is one of the most popular indicator frameworks. Mwasha et al (2012) argue that selection of such frame works as PICABUE and DPSIR greatly depends on goals and intentions. The intentions of indicators should be at least one of the following: 1) Assessing current state; 2) Monitoring changes and trends; 3) Forecasting hazardous conditions before happening; 4) Identifying causative agents; and 5) Finding interdependence between indicators (Cairns et al., 1993). DPSIR is designed for figuring out pressure and conflicts in order to find methods to resolve them or mitigate change. However PICABUE is more comprehensive and multi-dimensional to define the current state and evolution trend. Therefore PICABUE is more suitable for GBS evaluating.

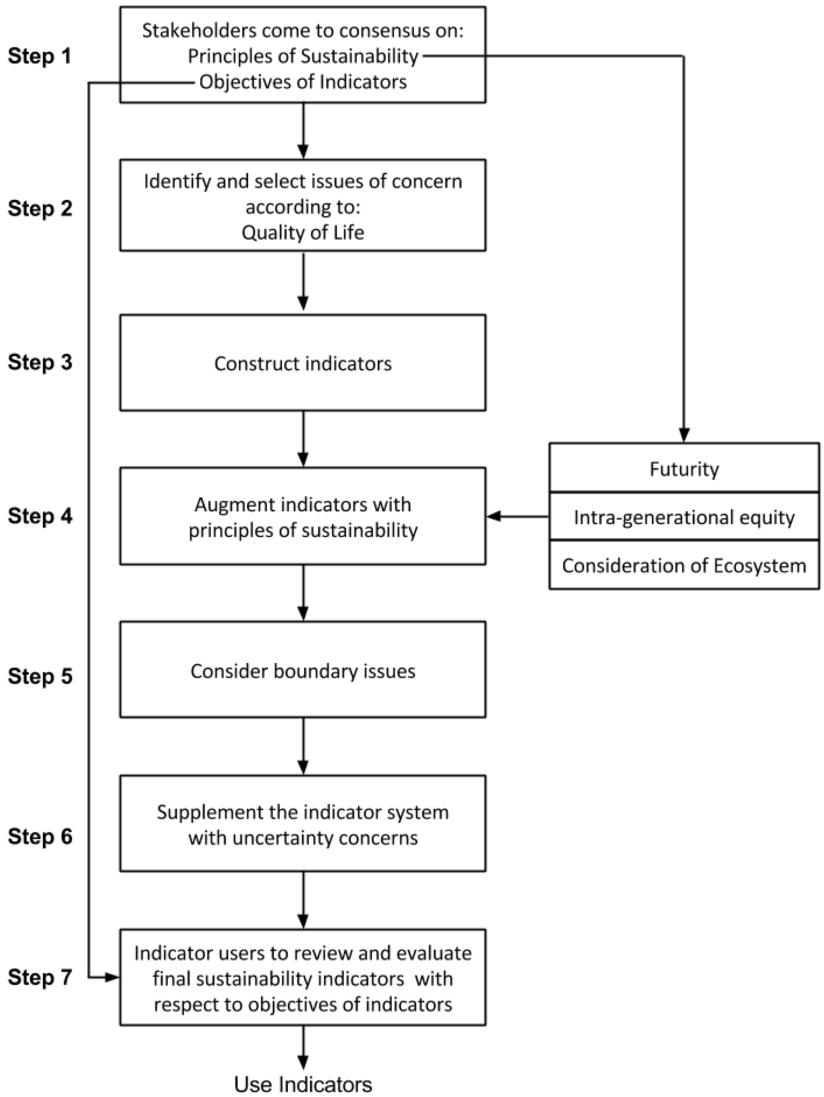

Figure 8 PICABUE Methodological Framework for Construction of Sustainability Indicators (Adapted from Mitchell et al., 1995)

3.2 Structure of PICABUE

The structure and the process of implementing of PICABUE are briefly introduced in this section. The methodological framework is illustrated in Figure 8. The seven steps described below will guide the analysis process and will be extensively demonstrated in the Analysis and Findings part.

(1) **P**rinciples: At the first step, the objectives and intentions of the sustainability indicator system should be determined before any action is taken. An indicator system could undertake one or several of the five types of objectives mentioned in Section 3.1. It's crucial to identify objectives because each objective demands specific features of indicators. The other task for this step is that stakeholders related to the system should come to a consensus what is sustainability and what aspects of sustainability should be considered, not only addressing the comprehensiveness of sustainability but also offering an agreement to ensure that everyone is in the same discourse.

(2) **I**ssues: In this step issues of concern are identified and selected. From an anthropocentric perspective, quality of human life is considered to be central to sustainable development. Issues related to quality of life are deconstructed and subdivided (through several levels) into a set of concrete but interrelated components. Then as it is neither necessary nor practical to collect data on all of issues, the components we need should be selected dependent on the objectives determined in the first step.

(3) **C**onstruction: After relevant issues are identified and selected, indicators are used to measure the issues. Sometimes already existing indicators could be borrowed but for other cases new indicators should be constructed. The indicators should comprehensively cover all of the issues and avoid overlapping. At the same time they should be succinct and easy to be understood. As a result, which type of indicator to use, individual indicator, composite indicator or key indicator, is a tricky task.

(4) **A**ugmentation: The constructed indicators are based on quality of life and environmental concerns, which is considered "weak" sustainability indicators. Hence the three of the four principles of sustainability: futurity, equity and environment are incorporated in the system and indicators are thus modified.

(5) **B**oundary: Defining boundary of a system is always crucial to clarify and simplify

problems. For some indicators the flows go across the boundary and such transboundary indicators should be carefully dealt with and well constructed.

(6) **U**ncertainty: Uncertainty within a system is inevitable. Uncertainty could comes from: 1) limited knowledge on the system itself, 2) incomplete datasets of the system, and 3) unpredictable behaviour in the system. A mechanism needs to be established in advance to deal with the uncertainty.

(7) **E**valuation: At last the designed indicators should be reviewed based on the following criteria: relevance and scientific validity, sensitivity to change over time and space, consistent and measurable data, understandability, appropriate data transformation, and possible target or threshold values.

It should be added that the principle of public participation should be considered through all seven steps of PICABUE. Stakeholders should be motivated and effective to involve in the process. Moreover, specialists and professionals should be actively consulted. (Mitchell et al., 1995)

4. RESEARCH METHODS

4.1 Research Strategy

Conducting research methods should respect the epistemological and ontological considerations (Bryman, 2008). Before using a research strategy the ontology and epistemology of this paper is determined and described in this section. Epistemology deals with the issues of what should be considered as acceptable knowledge and whether social science studies should apply the same research principles and methods as natural science (ibid.). Two predominate and contrasting epistemological positions are positivism and interpretivism (also referred to as anti-positivism). Basically, positivism advocates the use of natural science research methods in the social field, so that the observation and analysis of objects must be objective; on the contrary, interpretivists suggest that we should respect the fundamental differences between social science and natural science, thus social scientists are required to explain social phenomena subjectively (ibid.). Similarly, ontology is also briefly composed of two distinctive positions: objectivism and constructionism (also called constructivism). Ontology deals with the issue of the nature of social entities (ibid.). The core conflicts between the two positions are relationship social phenomena and social actors. Objectivists believe that phenomena are independent of social actors and are external facts to researchers; while constructionism asserts that phenomena are accomplished by social actors and are always evolving through time.

In the case of evaluating GBS, first of all, the task is not to test a theory or generate a law but rather to sketch out the state of a building assessment tool under the phenomenon of sustainability. Secondly, the notion of sustainability is quite subject to the understanding of different people. The meaning is continuously reviewed and revised as the society and mindsets are developing. Moreover, GBS is a tool that created and utilized by stakeholders. It has to fit the needs of users and will gradually approach the essence of sustainability along with the building industry. Based on the considerations above, an interpretivist and constructionist strategy of research is adopted.

As for issue of applying a qualitative or quantitative research approach, the two approaches are mutually involved and cannot be simply distinguished (Holliday, 2007). From its epistemological and ontological basis, it seems that a qualitative approach should be used. Nevertheless, Holliday (2007) argues that we cannot simply divide the two approaches into hard categories, because social research is complex. A feature of quantitative research is that it always reduces the effects of variables and controls the factors, while qualitative research tends to collect more unpredictable information (Silverman, 2013), which is more suitable for the task of this paper. Thus the paper will primarily apply a qualitative research approach with assistance of some quantitative data.

4.2 Data Collection Methods

4.2.1 Literature Review

Literature Review is a crucial process of doing social research because the researcher needs to ensure that he or she is knowledgeable in the field of interesting in order to 1) avoid repeating studies or reinvent theories that have already been done in the field, as well as 2) use ideas from other scholars to support arguments or viewpoints (Bryman, 2008). Massive literature review was conducted through the whole process of this research on GBS. In the beginning, domestic academic articles, conference proceedings and governmental official documents were reviewed to draw a general picture of the current state of green building and GBS development in China. A literature review on the hotspots of green building assessment worldwide was also conducted after research questions were raised, which helped the understanding of the gaps between the world trend and the research stage of China. The formulation of methodological basis of the paper, i.e. using PICABUE as a general framework, occurred after a review on books and articles on sustainability indicators and building assessment tool construction. Literature review is at the same time an important source of data (Bryman, 2008). Arguments on the merits and limitations of GBS as well as other building assessment tools are collected from academic articles, newspapers, magazines, and documents from private entities, etc.

4.2.2 Participant Observation

A participant observation method is applied as the main approach of data collection. A participant observer immerses him/herself in a social setting in a relatively long period of time. The observer doesn't solely make observations as an outsider but engages in conversations and even activities (Bryman, 2008). The observation was conducted by working in a group of stakeholders of who played an important role in green building industry in China, i.e. green building consultants. The function of green building consultancy is helping potential green building projects to apply for and acquire a GBS certification (sometimes other certifications as well, e.g. LEED). The tasks include pre-evaluation of the design, providing modification suggestions, tracking and supervising the construction phase and preparing the application portfolio. The consulting process goes through the design, construction and occupation phases of the projects until they get the certification. The researcher spent two and a half months working as an intern in the Green Building Department of Walton Design & Consulting Engineering Co., Ltd. with 14 members in the green building consulting team. According to Gold (1958), the role of a participant observer can be classified by the degree of involvement ranging from complete participant to complete observer (Figure 9). In this case, the author is a participant-as-observer, who is a fully functioning member of the group of study and the identity as a researcher is known by the others. The author got in touch with several undergoing projects of a variety of stages, checking items and doing computer simulating of energy consumption and so on, in the mean time having conversation with colleagues, clients and green technology providers. The main conflicts originated by GBS were realized and the opinions of GBS regarding its shortcomings were collected. This deeply involving observation also helped the researcher to access project cases and massive information, and sometimes even confidential documents of private companies.

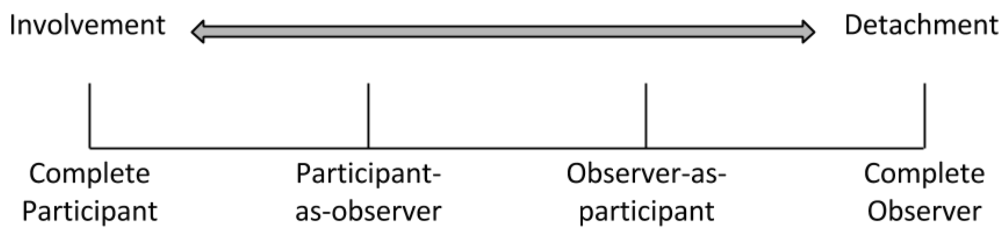

Figure 9 Classification of Participant Observer Roles by Degree of Involvement (Adapted from Bryman, 2008)

Additionally, some other observations are conducted as supplement. The author visited several green building projects that have already been certified in Tangshan Bay Eco-City and Beijing. The direct on-site observation offered an intuitive impression of certified green buildings and provided opportunity to interview some developers and city managers in government.

4.3 Data Analysis Methods

Thematic Analysis

Qualitative data analysis is not as straightforward as quantitative analysis because qualitative data are obtained from participant observations and interviews, which are mainly textual documents, field notes and interview transcripts (Bryman, 2008). Despite containing numerous useful information and patterns, it is difficult to find a path through massive fragments to explore and interpret these data into meaningful arguments (Miles, 1979). There aren't any agreements on explicit rules how to analysis qualitative data, but some strategies are widely applied by social researchers such as Analytic Induction and Grounded Theory (Glaser & Strauss, 2009). For the analysis of data collected for GBS evaluation, Thematic Analysis suggested by Bryman (2008) is used. Thematic analysis is approach that requires researchers to summarize themes and subthemes from the data and categorize all the data under each theme or sub theme. This approach has something in common with the "coding" step of Grounded Theory, which analyses interview transcripts and documents to derive what concepts and topics are keys to the research. In this paper, themes are defined according to the seven steps of PICAQUE. Critiques are allocated to each theme so that it is clear to trace which steps of constructing indicators have caused these problems. Table 3 shows the main critiques about GBS under thematic analysis, where the theme "Augmentation" has three subthemes to incorporate three of the four principles of sustainability: futurity, equity and environment. The fourth principle "public participation" will be frequently mentioned in several themes, since public participation should be addressed during the whole process. It is important to note that some issues can be put into more than one theme but are not listed separately here. The interrelation of different steps of PICABUE will be discussed in the next section.

Principles of Sustainability, Objectives
1. Lack of participation of all stakeholders: occupants & developers 2. Architects, designers and developers haven't changed minds toward sustainability 3. How to interpret sustainability of a building 4. Intention: GDP growth? Business values? 5. GBS doesn't apply to existing buildings, while existing buildings are energy inefficient in China 6. Entire life cycle: Design Label vs. Operation Label
Issues of Concern
1. Convenience to get to work 2. Accessibility to services - hospitals, schools, etc. 3. Concerning geographical differences; localization of GBS should respect traditional experiences. 4. Public participation: more information of certified projects should be exposed to the public
Construction of Indicators - 1. There aren't any simplified indicators for public demonstration 2. Too many requirements on specific technologies which constrained innovation 3. Items concerning construction phase of building were allocated in Land Saving category 4. Why not use existing mature indicators? 5. Should emphasize on effectiveness rather than which specific methods are used, e.g. utility of renewable energy
Augmentation by Broader Sustainability Principles
Futurity 1. Lifespan of a building is significantly shorter than European buildings 2. Life cycle analysis of energy consumption and the incremental cost: does it worthwhile? **Equity** 3. Some construction sites are obtained through forced demolition: social conflicts 4. Working condition of employees of property management **Environment** 5. Contribution to urban ecosystem, biodiversity 6. Care for the source of raw materials - local material, labelled timber
Boundary Issues
1. Green building as a part of bigger system of city: reclaimed water, decomposable wastes 2. Wastes are sorted at residential end, but facilities to treat them haven't been built up 3. Building's impacts on building user (intra-system) and the environment (inter-system)
Uncertainties
1. Different habits and behaviours of occupants 2. Education of building users
Evaluation and Modification
1. It should be the indicator users who review the indicators 2. Target values don't have scientific basis 3. Some items are vague and immeasurable 4. Some items overlapped with existing regulations or standards

Table 3 The Main Critiques about GBS under Thematic Analysis

5. FINDINGS AND ANALYSIS

In this section, findings will be presented and analysed according to the seven steps that building up the PICABUE framework, which is also the order of seven main themes of data categorizing.

5.1. Principles of Sustainability and Objectives of Indicators

5.1.1 Dearth of Stakeholder Participation

The GBS claims that the evaluation of green buildings should consider the integration of environmental, social and economic effects (Article 1.0.5) and promoting sustainable development concerning buildings' life cycle is one of the objectives (Article 1.0.1). However, sustainability along with its three pillars and life cycle are merely presented as ambiguous concepts without any explanations. It is crucial to inform what is sustainable development and how life cycle is to be considered to all practitioners in building industry, otherwise the concepts and findings of scientific researches will never be transformed into practice, as Bell and Morse argues "bad application of good science" (Bell & Morse, 1999, p.1). And without a distinct understanding of sustainability as a guide, construction of indicator system and selection of indicators could be driven off the track and detached from the goal of sustainable development. Therefore, coming to a consensus around all stakeholders is fairly important, which calls for extensive incorporation of stakeholders through the whole process of GBS formulation, including government, scientific institutes, developers, architects, construction engineers, constructors, green building consultants, management operators, building users and NGOs.

The current version of GBS was formulated by China Academy of Building Research and Shanghai Research Institute of Building Science along with 6 other institutes and China State Construction Engineering Corporation, who is the only entity that is engaged in real estate development (MOHURD & GAQSIQ, 2005). Before GBS is proclaimed an exposure draft was sending around for comments from professionals in the building industry as a supplementary method of a broader inclusion of stakeholders. One of the most important stakeholders, the building users, i.e. the public is completely excluded from the whole procedure and the opinions of NGOs are not heard. Moreover, there is apparently lack of involvement of representatives other than research institutes during the formulation of concepts and objectives.

Architects and engineers are only able to make technical comments on indicators that are already generated. Barely any adjustments on the structure and framework could be suggested.

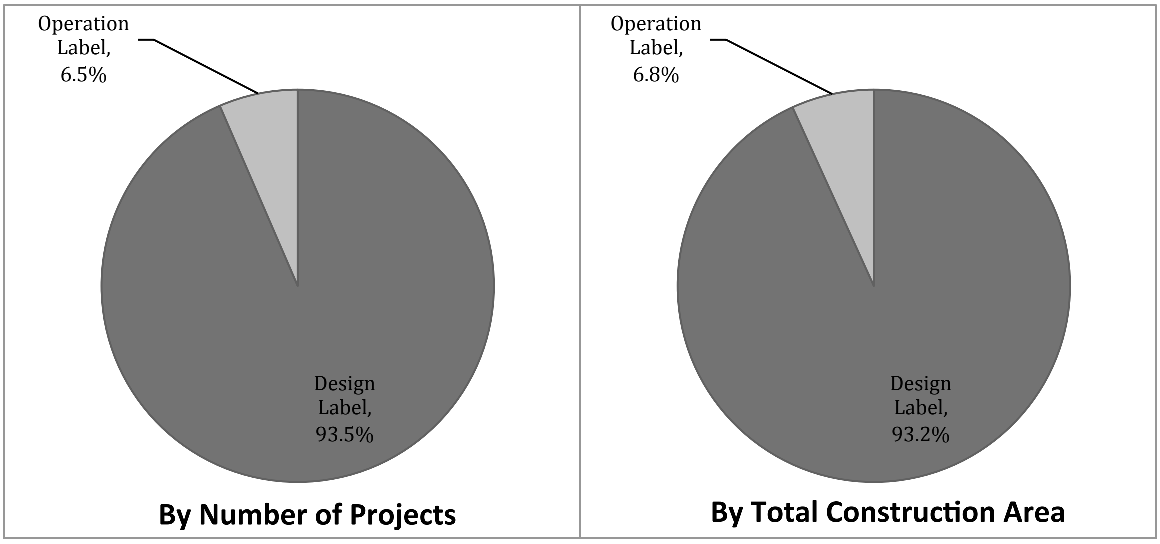

Figure 10 Ratio of Design Label and Operation Label Projects Certified by GBS by the End of 2012 (Data Source: Wang et al., 2012)

Another detriment of dearth of discussion around principles of sustainability is that most architects, developers and local government officials haven't change their minds of traditional understanding of green buildings, which still regard green buildings as conceptual hypes and labels (Wu, 2011). In some cases, GBS certifications are pursued as highlights of projects by developers and are used as means of marketing purpose and raising house price. Similarly, some municipalities and new eco-cities need the concept of green building as a signature. This may one of the causes of the following interest phenomenon. As a means of considering the whole life cycle, *Management Regulation of Green Building Label* was enforced by MOHURD in 2007 to assist the implementation of GBS, saying that a building project two kinds of certifications: the Design Label and the Operation Label. The design label could be pursued right after the design is finished and the evaluation is based on the blueprints and drawings of the project. Index such as energy consumption and noise pollution are assessed through computer simulation reports instead of actual measured values. In contrast, the operation label could be pursued after one year of operation and are evaluated based on the actual performance. From Figure 10 we can see that by the end of 2012 only 6.5% of the projects have acquired the operation label, which is 48 out of 742 projects (Wang, Gao, Song, Li, et al., 2013). And this ratio of 2011 is 23 out of 353 (Wang et al., 2012). Although considering the rapid growth of numbers of green building projects and a usually 1-2 years' lag between design label and operation label, the figures can still imply that a large number of projects didn't applied for a operation label. It is contradictory that customers buy their apartments influenced by the design label while the living condition and green performance of their shelters are in accordance with operation label, which may never be acquired. Nominally it takes care of the whole life cycle but turned out to be just a strategy of selling.

As the obedience of GBS is mainly monitored and controlled by green building consultants, architects and designers don't have to contribute much effort to apply with the standards. Furthermore, in the current consulting mechanism the consultants intervene a project after the design is completed, which magnifies the designers' ignorance of sustainability. For example, in the project of the New Pavilion of Fujian Science and Technology Museum, in which the author engaged at Walton, the consultant found that the natural sunshine of a hall is not sufficient in accordance with GBS. The consultant provided a scheme to solve the problem, which is adding skylight windows on the ceiling. This idea was strongly refused by the architect, because the entirety design would be damaged. And the hall could be used as classroom or conference room, which prefers a darker environment for projectors. Therefore, so as to meet the standards, the final design will be a compromise of harming the entirety and giving up some functions rather than a thoughtful and comprehensive design in the very beginning. Such examples can also be noticed when projects wants to meet the Article 4.2.9 of GBS, a requirement of over 5% of renewable energy out of overall energy consumption. Some projects have to attach photovoltaic solar panels on the surfaces of buildings, which could significantly impact the aesthetics of the building.

5.1.2 Existing Buildings Overlooked

The objectives determine the scope and effectiveness of an indicator system. For building sector, existing buildings should be equally drawn attention to newly built buildings, because newly built buildings only comprise a small proportion of the total amount. Taking China as an example, by 2011 the total construction area of urban residential building is 22.59 billion m^2, while the increment rate is 1.42 billion m^2 per year (Xu, 2013). Chinese buildings didn't focus too much on energy efficiency in the past. Compared to Western developed countries, the average energy efficiency is much lower, especially lacking external envelope with good thermal performance (Wu, 2011). However, via refurbishment of existing in-use buildings, the energy consumption could be significantly reduced. Study shows that for Beijing climate an instalment of 5cm insulation layer could possibly cut down 60% of heating energy use as well as the CO_2 and SO_2 emission, since coal is the major primary energy for heating in China (Glicksman, 2006). Other aspects than energy such as greenery and water consumption also have room for improvement. Many countries have started to lay emphasis on existing buildings, e.g. LEED and CASBEE have specialized evaluation methods for renovation of existing buildings. GBS should make efforts as well to promote the development of green refurbishment of existing buildings.

5.2 Issues of Concern

5.2.1 Quality of Life

Quality of human life is the foundation of issues to be addressed. Unlike most green building assessment tools emphasizing on the "green", i.e. environmental protection and resource saving, the starting point of PICABUE framework is quality of life. Quality of life is described as "individual's happiness or satisfaction with life and environment including needs and desires and other tangible and intangible factors which determine overall well-being" (Cutter, 1985) We should know that there isn't a consensus what quality of life is or what should be regarded as quality of life. Following the approach suggested by Mitchell et al. (1995) the building related quality of life is subdivided into smaller components. Figure 11 is just an example developed by the author. There could be dozens of ways to subdivide it.

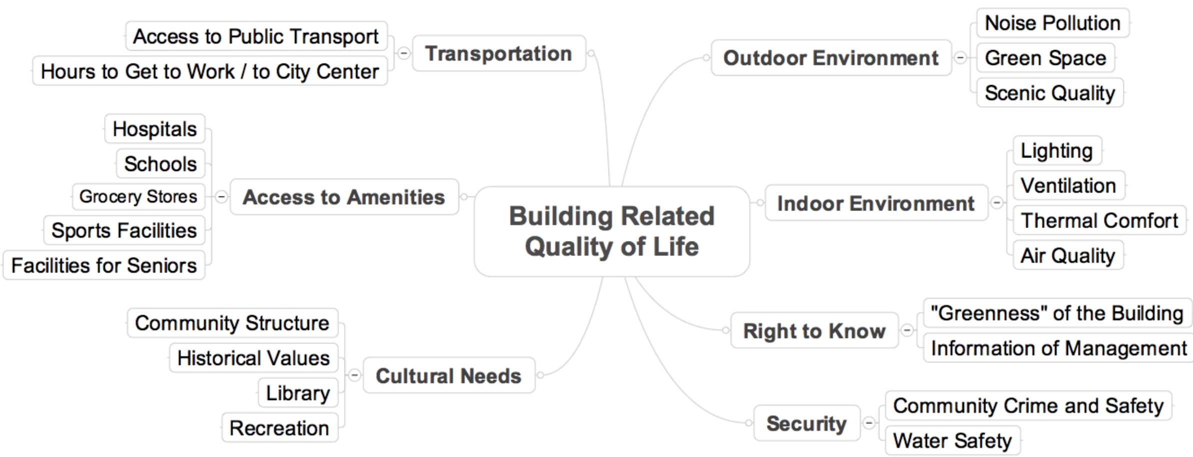

Figure 11 Subdivision of Building Related Quality of Life

Among the listed components of building related quality of life in Figure 11, outdoor and indoor environments are relatively well addressed by GBS. And indoor environment is even one of the six main categories of indicators. However, the other issues are more or less neglected. Only the transportation issue is discussed here as an example. The only item about transportation is Article 4.1.15, which requires that the nearest public transport station to the building entrance should be no greater than 500 meters. This item is assumed to guarantee residents' transportation convenience and encourage the use of public transport, but the real situation might be far from expectation. Distance from a bus stop or a subway station is not the only factor to influence people's commuting behaviours. For instance, in some suburban areas of mega-cities a commuter may have to transfer several times or the transport capacity in rush hours is gravely insufficient, so that it is painful to take public transport. Thus the residents in those areas have no choice but to use private cars. At the same time, GBS doesn't have any complementary requirements to constrain the use fossil fuel vehicles, e.g. limiting parking spaces, or ways to encourage using energy efficient cars, electric cars or car pooling. All of the factors above make the Article 4.1.15 an easy item to reach but ineffective at all.

5.2.2 Localization of GBS

Another issue that needs to be discussed is the respect of geographical differences. China is a big country in terms of its territorial area and contains several distinct climatic zones. Differences of ethnicities, culture and economic development are also considerable. GBS is a general tool for the entire country but it allows provinces and municipalities to develop their localized version of green building standard referring to the national GBS, which is a very smart merit compared to many other building assessment tools worldwide. 19 provinces and municipalities have compiled local GBS by the end of 2012 (Wang et al., 2013). The intention is to be flexible with local conditions and make good use of traditional experiences on building green performance. However, the implementation doesn't always goes as expected. Some local GBSs haven't shown many localized characters and some others go too far away from the original aims of establishing green building standards (Wu, 2011). The formulation of local GBS should also comply with the principles of sustainability and a methodological framework as guidance.

5.3 Construction of Indicators

5.3.1 Specific Indicators and Composite Indicators

The step of indicator construction is a process to precisely interpret issues of concern into measurable and illustrative indicators. Mitchell et al. (1995) summarized three commonly applied approaches to structure indicators (see Figure 12), which are 1) many separated specific indicators used by most of the current green building assessment tools, 2) composite indicators that combine issues and data to result in one or a few figures, e.g. a batch of development index such as Human Development Index (HDI) and Happiness Index (HI), and 3) key indicators whereas representative components are expected to explain the whole system, e.g. the population of key species or endangered species to represent the ecosystem stability. It is not surprising that building assessment tools invariably choose non-composite indicates since the tools are designed to discover where exactly the problems are and to guide the green building practitioners in details. Composite indicators are also frequently applied, which is the final scores usually in the form of "labelling". For example, LEED offers "Silver", "Gold" and "Platinum" awards for certified projects based on the summation of all satisfied points. BREEAM has a five-level rating system as well, which is "Pass", "Good", "Very Good", Excellent" and "Outstanding" (Kajikawa et al., 2011). GBS also applies a three-star labelling system and it goes even further by clarifying how many items should be satisfied in each of the six categories. A general composite indicator is necessary because it is more understandable for the public and publicity, although the reduced resolution leads to loss of details. GBS has the advantage of keeping balance among categories but this advantage hasn't been made full use of. More details of green buildings should be exposed to the public. Nevertheless, at the moment customers are solely informed that the property is an one/two/three-star green building (probably just a design label). This problem is interconnected with quality of life discussed in section 5.2.1 where residents have the right to know more about the performance of their buildings.

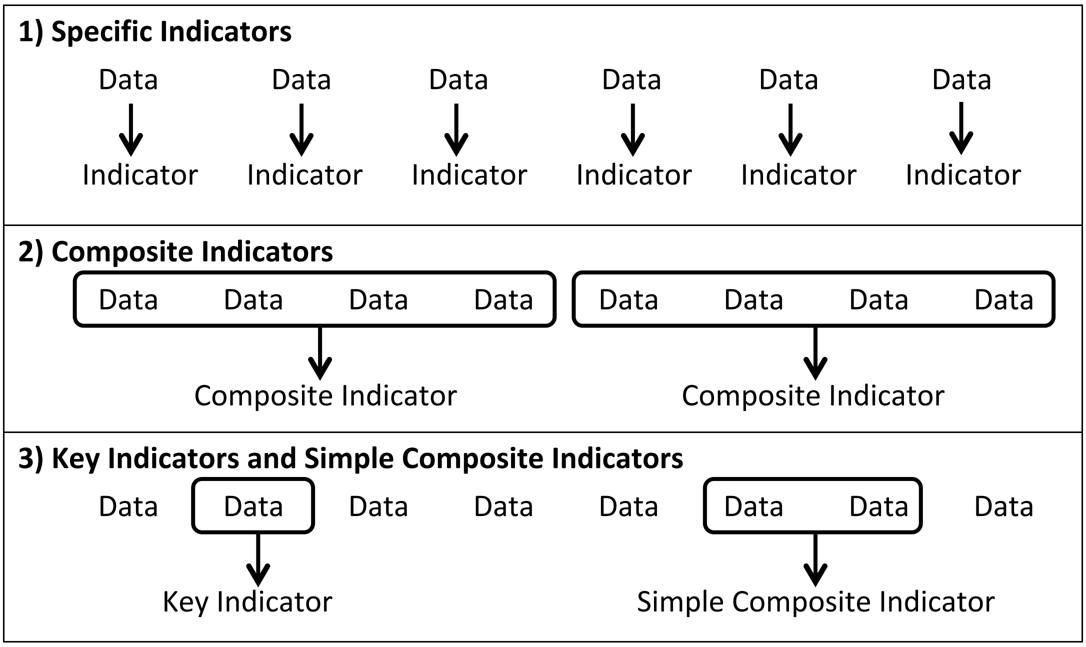

Figure 12 Three Common Approaches to Structure Indicators

A good model of public information on this case is the Miljöbyggprogram SYD (Environmental Construction Program: Southern Sweden, MBP SYD), which is a building assessment tool developed by Municipalities of Malmö and Lund and Lund University in 2009. MBP SYD is a local tool only available in Malmö and Lund, Sweden. However the tool explicitly underlines that the assessment results of all of the three phases, including ambition contract, result protocol and operation report, should be published on the website accessible to the public (Malmö Stad et al., 2012). Rose diagrams (Figure 13) are also required to put on the webpage as well to clearly illustrate which aspects of environmental performance a project is doing excellent or falling behind (please refer to http://www.miljobyggprogramsyd.se/ for more examples). This method intuitively and sufficiently exposes information of green building projects and is ready for the public to track the progress of these projects. This is a good experience that GBS should learn from.

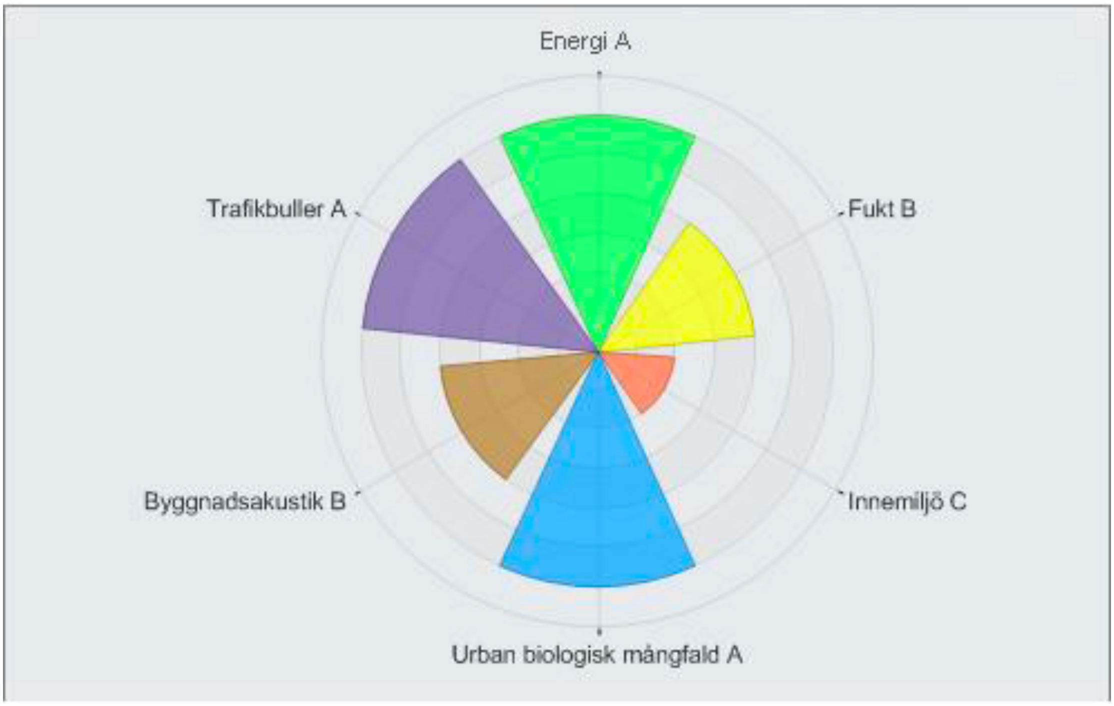

Figure 13 A Sample of Rose Diagram Illustrating Green Building Performance in Six Aspects of MBY SYD (Source: Miljöbyggprogram SYD version 2, 2012)

5.3.2 Suitable Existing Indicators

When setting up an indicator system, it is not necessary to construct every indicator from scratch. Many suitable indicators that already exist but used to serve for other purposes can be borrowed as bricks. Greenery of surrounding area is one of this type of issues. Article 4.1.14 of GBS restricts that a multi-layer ecological community of flora, i.e. a combination of grass, shrubs and trees should be planted for greenery and there must be at least 3 trees per 100 m^2 green space. However, a sustainable urban landscape requires its ecological functions, which are habitats for plants and animals, ecological connections (corridors) between green spaces, microclimate regulation and water absorption, etc. (Sandström et al., 2006). It's apparently not appropriate to evaluate sustainability of green spaces just by counting trees. Actually there are already some tools or indices used by urban ecologists for a long time. Traditional ones are biodiversity indices. For example, Shannon-Wiener index is a most famous one, who doesn't only consider number of species but also the evenness (Hermy & Cornelis, 2000). Some recently developed tools are also contributing to build ecologically friendly urban ecosystems. Biotope Area Factor (BAF) is such kind of index adopted by some European cities such as Berlin, Germany and Malmö, Sweden (Kazmierczak & Carter, 2010; Böhme, 2013). BAF counts in green roofs, green walls, ponds, and even permeable surface, any type of surface that contributes to the ecosystem (Böhme, 2013). MBP SYD even has restrictions on bird nests and lairs for animals (Malmö Stad et al., 2012). To sum up, it would be better for GBS to adopt existing and relatively mature indicators at least for greenery assessment. Indeed, it needs collaboration with specialist on urban ecology. And if possible ecological modeling could be conducted through GIS and other computer technologies.

5.3.3 Technocentric Perspective

GBS tends to formulate its indicators from a more technocentric perspective. Many items of GBS explicitly require the application of specific methods, techniques or even equipment. It's questionable whether these indicators could interpret the issues of concern. Energy saving and water saving are evaluated according to a checklist of techniques and equipment, rather than absolute values of energy and water consumption. Therefore the indicator design of GBS doesn't really emphasize on the actual effects but foci on technology. In this way, we could never measure how much resource is saved exactly or how much impact is imposed to the environment. Moreover, a checklist-like approach is an obstacle to technical innovation, since limited investments have to be used on technologies that are on the list of GBS. Article 4.4.5 is a typical example, which requires the buildings to use high-performance concrete and high-strength steel as structural materials. This has constrained the implementation of new design based on other structural materials. A world tallest 34-story wooden skyscraper will be built up soon in Stockholm, Sweden (Osborne, 2013). The skyscraper will give up using any concrete or steel for the structure (ibid). Even though wooden buildings cost much less energy embedded in producing process, they wouldn't be considered "green" in terms of material saving from GBS perspective. The concepts of Energy Efficient House, Passive House and Zero-Energy House which are popular in Europe are based on the absolute values of kilowatt-hours of total energy consumption per year (IPHA, 2010). For GBS, absolute-value indicators could be combined with specific technical requirements and an encouragement mechanism of innovation.

5.4 Augmentation by Broader Sustainability Principles

The indicators formulated from Step 2 and Step 3 of PICABUE are originated from the start point of human needs of current generation. In order to build a sustainably sound indicator system, the sustainability principles "futurity", "equity" and "Environment" needs to be integrated to the system. The formulated indicators are thus modified or new indicators are generated considering intra-generational and inter-generational equity, as well as the ecosystem. The augmentation by the three principles will be discussed respectively.

5.4.1 Futurity (Inter-Generational Equity)

The idea of futurity is bonded in the notion of sustainability on the first day it became a worldwide concern. Futurity, also explained as "no cheating on our kids" (Bell & Morse, 2008), considers the impacts of activities of current generation to the future generations to meet their needs. It is highly related to the pace we exploit the environment that should not exceed the threshold of ecological recovery and the capital we store for our descendants. The issues related to the ecosystem will be mentioned in section 5.4.3. In this part the futurity of buildings are analysed.

The lifespan of a building is a neglected issue of GBS. The average building life expectancy in China is 30 years, which is much shorter than Western countries (Q. Wang, 2010). For example, the average lifespan of British buildings is 132 years and the number in the US is 74 years (ibid.). The huge disparity is supposed to result from the poor quality of China's building and the poor city planning. Only in 2003, 161 million m^2 of buildings were demolished in the country, which was 41.6% of the newly-built construction area of that year (Wu, 2011). The shorter life expectancy causes tremendous construction waste generation and the resources as well as energy spent on the construction phase are twice or thrice it should be, let alone the dust and noise pollution. GBS should pay attention to this special condition of China, otherwise the efforts of saving energy and materials made from other approaches would be wasted. However, a building's lifespan is difficult to predict. Smart methods need to be found and this task should coordinate with legislation.

Another problem embedded in GBS is that LCA is not fully implemented. Energy utility should be calculated dependent on the entire life cycle of buildings. This problem is prominent on the application of renewable energy techniques. Projects, especially those who want to pursue Three-Star Label, often invests plenty of money on the instalment of solar energy, wind energy or biogas generating facilities. The incremental costs derived from renewable energy technology could take up 40% to 80% of the total incremental costs (Ye et al., 2011). However the efficiency of these techniques are yet to be tested. It is questionable whether they are cost-benefit balanced during the whole life cycle. The other solution to the energy issue is using more passive energy technologies, focusing on improvements on insulation and ventilation performance, which needs to be addressed by GBS.

5.4.2 Intra-Generational Equity

Building related quality of life refers to living satisfaction of building occupants but also other people directly or indirectly connected to buildings. In China the acquisition of construction land is either through reconstruction of old parts of the city or through city expansion, which means turning rural land into urban land. Both ways involves conflict between indigenous residents and developers. The conflict is more severe at the borders of cities, i.e. the frontier of urbanization. The special situation of China is that urban land is state-owned, while some of the rural land is collectively owned by rural communities. Therefore when rural land is transformed to build urban buildings, the villagers' wills are often violated, although they can get some compensation. These years, violent incidents resulted from forced demolition of indigenous buildings are increasing according to Amnesty International (Jacob, 2012). The government leads the enforcement of land grabbing process but developers also participate in the actions. Social equality is the weak point of sustainable building assessment methods, including GBS. However if a "green" building were built on the sacrifice of right of innocent people, it would go the opposite direction from its intentions. Further improvement of GBS should consider the relationship between the buildings and the surrounding people influenced by them.

The rights of people who work for the construction and management of green buildings should be paid attention to as well. Working condition and stress of builders, cleaners and maintainers are relatively low nowadays in China. While visiting a luxurious residential district "Vanke Hongjun Community" in the City of Tangshan, the author found that during the demonstration of waste management the workers were pick up plastics and metals from organic wastes by hand, because the residents didn't sort their wastes well. And the workers' working condition was poor and without sufficient protection. Ironically, this district was a good model of waste management advocated by the local government.

5.4.3 Environment

The issues of environment from sustainability point of view are supposed to take a broader ecosystem into account, considering the capacity of ecosystems to resist impacts of human activity and the environmental stock we can leave for the future. So here the principle of environment is so called the ecological dimension of futurity (Mitchell et al., 1995). As a matter of fact, environmental principle has already been repeatedly discussed in the previous sections, but here an extended view of ecosystem and the notion of thresholds are highlighted. One of the advantages of GBS is that it puts a lot of efforts on material, water and energy saving and particularly addresses recycling and reuse, for example the instalment of energy recovering units (Article 4.2.8), using reclaimed grey water (Article 4.3.9) and using materials from recycled construction wastes (Article 4.4.6 & 4.4.9). However, the disadvantage is that the GBS certified green buildings don't care about the source of raw materials, which in fact comprise the majority of material consumption. For instance where does the water supply come from? Does it exceed the turnover rate of the groundwater aquifer? Or is the timber used causing deforestation? Some other existing tools are doing better in this sense. LEED has strict requirements on using labelled timber to ensure wood is produced by sustainable way (USGBC, 2009). GBS needs to start thinking of a wider concern of the ecosystem.

5.5 Boundary Issues

Building is a system that interact with its surrounding environment and other systems. A building system highly depends on continuous input of energy and resources and meanwhile the massive output considerably impacts its externality. As we mentioned in section 2.3, there are two types of indicators, one describing intra-systemic features and the other dealing with inter-systemic interactions. Transboundary indicators are an important component of indicator systems. As an indicator system for building performance, GBS is expected to deliberate the well-being of people inside the target building as well as rights of people who are outside the system but directly or indirectly affected by it through the environment. Aforementioned examples show the needs to track the sources of inputs such as water, construction materials, energy and air, etc., and destinations of outputs such as municipal solid wastes, construction waste and sewage. These considerations are suggested to be undertaken through LCA and environmental impact analysis (Mitchell et al., 1995).

Indicators also need to be aware of the limitations of what issues can be solved within the system and what cannot. Waste management and water supply and discharge are greatly dependent on the supporting infrastructure in the area. For instance, residential project called the "Orange Glow Waterfront Neighbourhood" in Tangshan Bay Eco-City was pursuing a Two-Star GBS Label in 2013. The waste sorting facilities were equipped in the community including trash bins labelled with different colours and a waste transfer station. The solid wastes were supposed to be collected and handled separately, however, there was neither a recycling center nor an incinerator in the city to treat the wastes. An incinerator and waste management plant were on the masterplan of the eco-city but no one knew when they would be built. This kind of phenomena is not occasional but very popular in China. At this point, the developers would be happy to establish waste sorting facilities no matter whether the wastes could be separately recycled, because a point from Article 4.6.10 (i.e. 90% households sort wastes) can get be easily obtained.

5.6 Uncertainties

The uncertainties embodied in the measurement of green building indicators include mainly the unpredictable behaviour of building users. The occupants of buildings have different habits on energy consumption, waste sorting and facility using, etc. Researches have shown that many energy efficient houses cannot reach their expected energy performance because household behaviours are a major uncertainty (Karresand, 2006). Although GBS has clarified that separate meters of water, gas and electricity consumption should be installed for every household, the residents may not significantly reduce their consumption apart from monetary cost concerns. Household renovation and decoration are also regarded as uncertainties that may damage insulation layer of walls and then affect the overall energy performance of a building. Technical measures should be coupled with guidance and education to the public to raise the awareness and knowledge of building users on how to live sustainably with the building. This should definitely be regularized in GBS.

5.7 Evaluation and Modification

The final step of PICABUE is reviewing and evaluating the finished indicator system in order to discover inappropriate indicators to be modified. The reviewers should be the ones who intend to actually use the indicators (Mitchell et al., 1995). During the process of compiling GBS, the intended users of GBS could provide suggestion to the draft that released by MOHURD, but the main review and evaluation process was conducted by institutes and the government, which is not considered a complete participative evaluation. Some rules of indicators are to checked during the evaluation, as mentioned earlier, which are relevance and scientific validity, sensitivity to change over time and space, consistent and measurable data, understandability, appropriate data transformation, and possible target or threshold values. Amongst these criteria, two problems of GBS are fairly prominent. The first problem is that many target values don't have scientific basis. Many expressions such as "reduce by 30%", "shall not be less than 10%" can be found in GBS. It seems that these values were not set through rigorous scientific reasoning. They should be connected to the threshold of ecosystem. The other problem is that some indicators are too ambiguously expressed and immeasurable. Words such as "properly", "reasonably", "make full use of", etc. are frequently used without any specific figures or explicit ways to measure. This results in that some requirements are too easy to reach and some others have different standards by different evaluators.

6. DISCUSSION

6.1 Further Suggestions to GBS

The limitations of GBS from a sustainability point of view have been demonstrated and a number of suggestions have been made through analysis using PICABUE framework. Apart from the points that needs to be considered via sustainability principles and partially located problems that could be adjusted with relatively tiny changes, suggestions on systematic problems of GBS are proposed.

The systematic problem embedded in GBS and many other building assessment tools is that the notion of "green building" or sustainability is not penetrated throughout the whole process of building production from the appraisal phase till construction phase after occupation. Building assessment tools are expected to undertake the mission of promoting the whole building industry towards sustainability as a pioneer. However, the existing GBS hasn't broken the conventional building planning and design patterns. It is just applied as a supplementary tool hoping to fix the current unsustainable state. Absence of ideology of sustainable principles and insufficient guidance and supervision from green building experts cause an information delay for architects and engineers that weaken the optimization of designing sustainable buildings (Lutzkendorf & Lorenz, 2006). It has been analysed in section 5.1 that the consultancy of green building only fit into the conventional building production process after the design has been completed and tendering has been done. And there are merely two positions where GBS can perform its functions (illustrated in Figure 14 on the left). A more integrated approach is suggested that GBS can play a role at every stage of building production including appraisal, design, tendering, and construction (Figure 14, right). In order to achieve the integrated approach, firstly GBS should undertake the responsibility to require establishment of database that documents the detailed information of certified green buildings. Thus experiences can be analysed and provided to later architects and engineers. It should also become a rule that a project should declare that it would pursue GBS certification at the appraisal stage before a final design is chosen, so that green building assessment experts could intervene the process of building design and plan selection. Last but not least, at the construction phase, it is not enough to control the construction process by self-inspection. Experts and evaluating officials should take part in the phase to offer advice and monitor the process to make sure the accomplished building would reach the design goals.

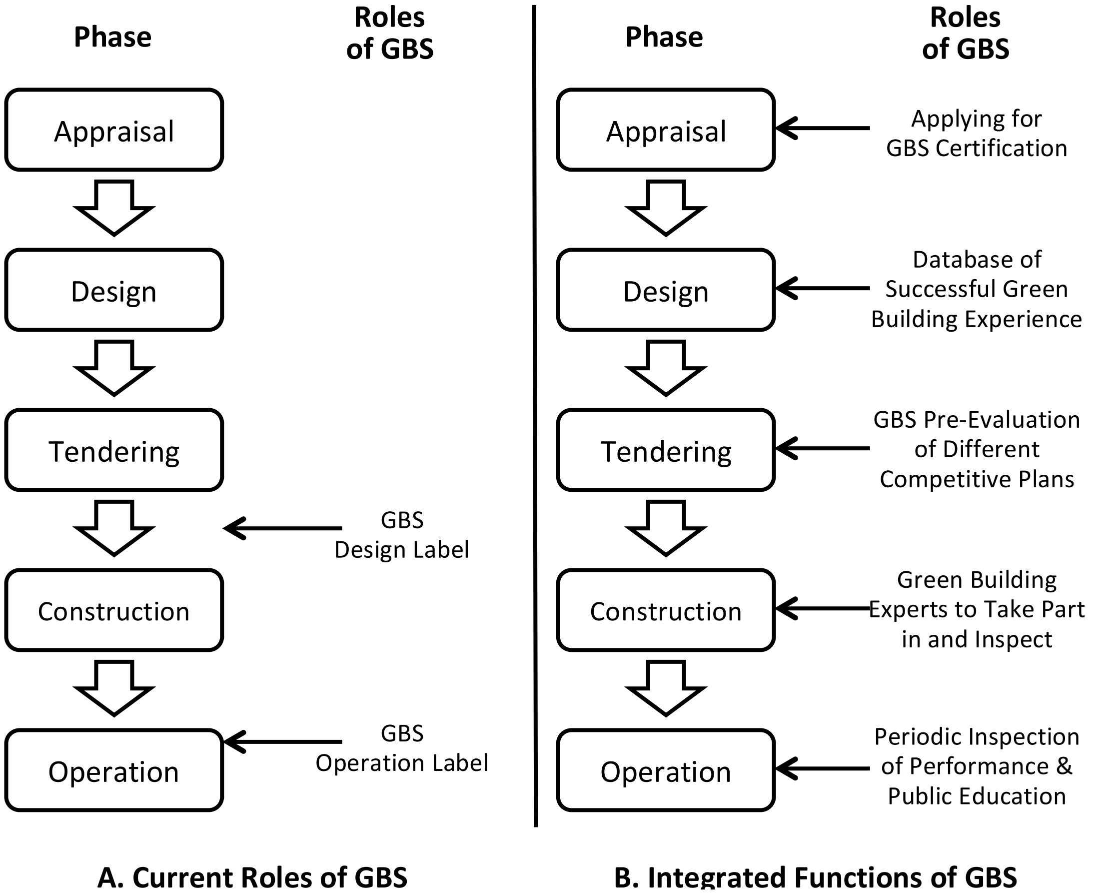

Figure 14 Suggestions of Integrated Functions of GBS Compared to the Current Roles of GBS

6.2 Modification of PICABUE Framework for Building Assessment Tools

While using PICABUE as a methodological framework to evaluate GBS, some problems of PICABUE that are inappropriate for the needs of building assessment tools have been found. First of all, PICABUE has made a great leap from a technocentric starting point shared by many building assessment tools to the well-being of human, which is frequently mentioned as "quality of life" in this paper. However, environmental issues and resource saving form the majority part of these mainstreaming tools. In another word, environment is the central concern of contemporary assessment tools. PICABUE puts the principle of environment in the fourth step as augmentations of quality of life along with futurity and equity, which diminishes the importance of environmental concerns in green building development. A modification is suggested that the principle of environment should be brought forward to the second step of PICABUE, i.e. "issues of concern". Consequently, quality of life and environmental concerns consist a dual-core foundation for building assessment tool formulation, considering from both ecocentric and anthropocentric perspectives.

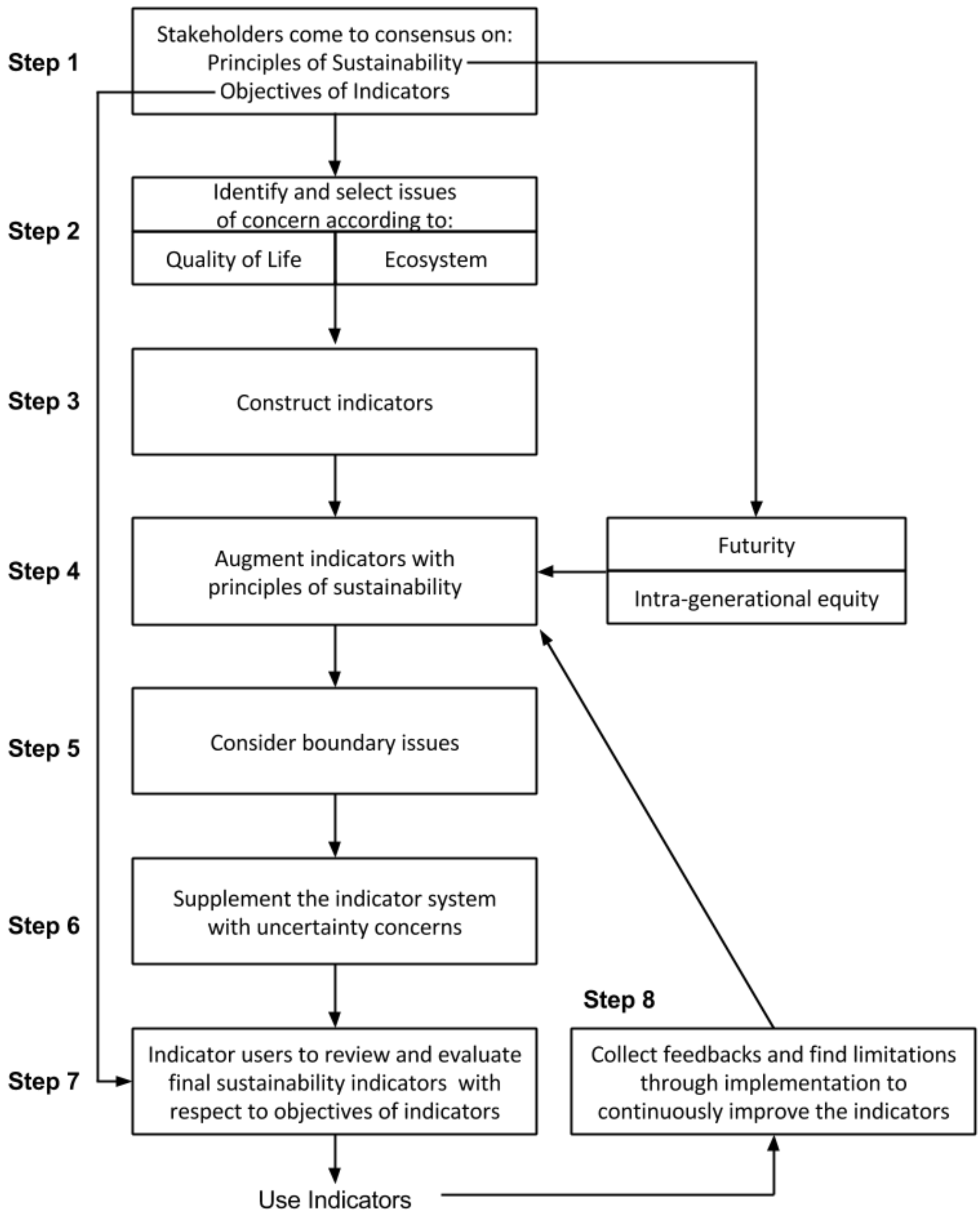

Figure 15 Modification of PICABUE for Sustainable Building Indicators

The other problem of PICABUE is that it overlooks the circulative process of indicator generation (Bell & Morse, 2008). Sustainable building assessment tools are still at early stage of development and far from mature. And the notion of sustainability is expanding and shifting both in academia and building sector. Therefore the tools are in a constant process of revision and evolution by the time they are implemented and practiced. It has been 7 years since the first version of GBS was released. In comparison, BREEAM and LEED are revised every 2 to 3 years (Wu, 2011). The updating speed of GBS cannot match the pace of green building development. Thus, PICABUE is not fully competent for the task if the indicators are only reviewed and evaluated before a large-scale implementation. Another additional step is suggested after the use of indicators to form a loop that can continuously offer feedbacks and strengthen the indicators. Figure 15 shows how PICABUE can be improved by some modification.

6.3 Research Limitations

Limitations of this research exist in several aspects. First, a participant observation research method was applied but not comprehensively. During the participation and observation, some key informants that emerge from the target group should be paid particular attention (Bryman, 2008). These key informants have relatively important position and are willing to offer information. The research hasn't made much effort to organize more targeted or deeper interviews to them, such as the Green Building Department Manager of Walton Company. Second, consultants are only the main users of GBS. Nevertheless, due to limitations of social connections, the GBS creators, i.e. the experts from institutes and officials from government are not directly contacted. The opinions of these people are crucial to understand the current progress of green building development in China and the difficulties lies in compiling GBS. Third, for qualitative researches, data collection and data analysis are not independent to each other. Via data analysis, theories are proposed and more questions are raised. Therefore supplementary data collection is needs to improve the theories or confirm the findings. The data collection and analysis is an iterative process (Bryman, 2008). However, duo to time constraint, further data collection and analysis is left for future research.

This research has focused on the design of GBS, which is an institutional tool for promoting green building development in China. Yet the development of green building is an extremely complicated issue dependent on institutional structure, policymaking, economic development, technology progress, mass media, and many other factors. Without assistance of institutional transformation, new policies and legislations such as subsidies on green buildings and enforcement of GBS certification, GBS cannot fully realize its functions. How to evaluate the whole set of institution rather than just the GBS is the next task urgently needed to study.

PICABUE is a quite theoretical framework to construct indicator systems, which is contradictory to the practical character of building assessment tools. It is still unknown to what extent the application of PICABUE can impact the development of building industry toward sustainability. A long period of recording and research should be conducted to learn the idea change and behaviour change of green building practitioners in relation to theoretical bases of GBS generation.

7. CONCLUSION

As environmental degradation and resource, energy and land scarcity as well as the tensions emerging with development, it has become a consensus that human should change the ways and goals of development from a sustainability point of view. The rising concept of green building or sustainable building in the last few decades is one of the efforts made in the building industry. China is facing the double pressure of urbanization and upgrading overall living condition, which forces China to value the importance of developing green buildings in recent years, although a bit late than developed countries. On one hand China is falling behind in green building technology, theoretical study and institutional construction, but on the other hand the China has the advantage to learn successful and failing experiences from other countries worldwide. The release and implementation of National Evaluation Standard for Green Building is a good attempt and important step of green building development, since its design has amended many problems occurred in earlier green building assessment tools. And duo to the core role GBS is play in promotion of China's green building industry, a comprehensive methodological assessment of GBS from sustainability perspective is urgently needed.

In this paper, the methodological framework of PICABUE is introduced to assess to what extent the GBS meets the principles of sustainability. Through analysis following the seven steps of PICABUE, it is found that GBS considers some criteria of sustainability but not comprehensively. First of all, GBS is generated from a technocentric view, which emphasizes too much on technical requirements. However, PICABUE suggests a both anthropocentric and ecocentric starting point, taking quality of human life and ecological robustness as fundamental judgement. GBS hasn't select or formulate indicators in coalition with the thresholds and regeneration rate of ecosystem but mainly offers a checklist of technologies to use. Quality of life especially for people outside the building system and the future generation is not fully addressed. The evaluation of existing buildings and the problem of short lifespan of Chinese building are not well considered. Secondly, GBS generation and revision neglect the involvement of all stakeholders of building sector. Currently, technical experts and policymakers have predominated the establishment of GBS evaluation system, which has blocked the opinions from others and weakened the communication to come to agreement on the notion of sustainability. Thirdly, GBS hasn't perfectly played its role on design guidance, decision-making and public education. The architects and engineers haven't keep the green building requirements in mind while they are designing. The developers fail to choose the most sustainable plan and GBS certification are sometimes used as marketing means. The real performance greatly dependent on users' behaviours is also neglected. Lastly, public participation should be addressed not only at every stage of building life cycle but also on formulating and reviewing GBS. Building users have got enough detailed information of their buildings. The voice of their needs are seldom heard either.

Some suggestions have been offered in the paper. For systemic problems, it is suggested that a broader integration of stakeholders including developers, architects, engineers, consultants, builders and occupants should participate in standard building and policymaking. Database of information of certified green buildings is advised to establish, which could be used for public exposure as well as aggregation of samples and experience for forthcoming projects. Other minor suggestions have also been raised, such as modifying implicitly described indicators, considering limitations of building projects under the local context, using life cycle assessment for indicator design, etc.

This paper offers a different way of analysing GBS compared to other studies in China hoping to provide inspirations for researchers in this field. Nonetheless, this is just a start, more studies with thinking of sustainability is needed, so that the development of green buildings in China could move forward in the right direction and positively help sustainable development.

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