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## Evaluating the sustainable development of urban built environment: Case study of Ningbo, China

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# Evaluating the sustainable development of urban built environment: Case study of Ningbo, China

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**Abstract.** Currently, Chinese urban planning experts and academic organizations have developed evaluating methods to assess the sustainable development of the urban built environment of Chinese cities. However, these methods have common disadvantages, such as costly, time-consuming, and difficulties of gathering data. This study develops an evaluating method, which using the China statistic yearbooks as a data source, to assess the sustainable development of the urban built environment of Chinese cities during the past decades. The China Statistic Yearbooks are annually statistical publications, which reflect comprehensively the economic and social development of the last year. They can be accessed easily through government official websites or yearbook platform. Therefore, using China Statistic Yearbooks as a data source is cost-effective and time-saving. The case study city used in this study is Ningbo, a sub-provincial city located in the east part of Zhejiang Province. A general idea of the sustainable development profile of the urban built environment of Ningbo is provided and may help in the decision making of urban managers.

## 1. Introduction

### 1.1. Urban environment's definition and influence

Currently, the global urbanization rate is around 54%, and it is predicted that this number will increase to 66% by 2050 [1]. In order to accommodate the expanded population in urban areas, a large number of construction activities has been conducted. In particular, buildings, which significantly determined the performance of the urban built environment, have occupied the biggest portion of these activities [1]. The massive scale of the construction activities already has led to the deterioration of the urban built environment throughout the world [2]. For example, buildings currently account for 30-41% of the total resource consumption and over one-third of carbon emissions in the US, China, and EU [3][4] [5]. And they will continue to shape the form of the urban built environment in the further.

Urban built environment has been defined as “man-made space in which people live, work, and recreate on a day to day basis” [6]. Recently, more social dimensions have been covered, such as the medical service, transport, technologies, policies, communities, and food safety, etc. Therefore, a tight relationship between the urban built environment and human physical and mental health has been established [7][8]. In view of this relationship, the sustainable development of the urban built environment has been a key determinant of the sustainability of whole urban system. Sustainable development was first defined by Brundtland Report in 1987 as development that meets the human needs of the present without compromising the ability of the future generations. In other words, the development of the urban built environment should not only meet human development needs, but also



sustain the ability of the natural systems to provide the natural resources and ecosystem services for the whole society.

China has obtained a rapid development regarding the urbanization rate during the last decades since the implementation of the policy of Reform and Opening-up in the 1980s. The urbanization rate has increased from 26.4% to 57.4% between 1991 and 2017 [9]. To accommodate the increased population, the built-up urban areas have expanded from 12856 square kilometers to 65869 square kilometers over the same period [9]. Moreover, this increasing tendency is expecting to continue since urbanization is a main development strategy for the Chinese government to maintain the long-term economic growth. The urbanization rate of China has been predicted to reach around 65% by 2035, resulting in a huge of loads for the urban environment, including land deterioration, ambient air pollution, food supply, and safety, etc. China Society for Urban Studies (CSUS) [10] claimed that the global sustainable development will be largely determined by the sustainable development of the China's urban built environment.

### 1.2. Development of urban evaluating system

Urban evaluating systems were initial developed to assess the sustainable development in the building sector, such as the Leadership in Energy and Environmental Design (LEED) from the US and the Building Research Establishment Environmental Assessment Method (BREEAM) from the UK. However, Jones et al [11] suggested that broader issues should be addressed since only evaluating individual building cannot reflect the sustainable development of the urban environment. Alberti [12] also stated that the whole urban system should be evaluated rather than solely on the technologies development and the design principles used for individual building. Therefore, the above-mentioned evaluating systems have been expanded to cover more social dimensions [13]. For example, LEED published Leadership in Energy and Environmental Design for Neighbourhood Development (LEED-ND) around 2009. Similar expansions also were observed in BREEAM (BREEAM-Communities).

**Table 1.** 11 evaluating systems in China.

Chinese Society for Urban Studies (CSUS)
China City Sustainable Development Indicators developed by China Academic of Science (CCSDI-CAS)
Indicator system developed by Research Center for Eco-Environmental Science (IS-RCEES)
Indicator system developed by China Academic of Social Science (IS-CASS)
Indicator system developed by Renmin University of China (RUC) and Tsinghua University (IS-RUC and TU)
Eco-Garden City from MoC (Eco-Garden City-MoC)
State Environmental Protection Administration (SEAP)/MEP Ecological Province City, County
Tianjin Eco-City (controlled indicators)
Caofeidian
Turpan New District
Guiyang Eco-Civilization City

In China, evaluating systems were initially designed for cities and programs initiated by the governments. For example, in 2003, the Ministry of Environmental Protection (MEP) started the Eco-city program. In 2004, the Ministry of Construction (MoC) initiated the National Garden City program, which is based on the National Garden City program of 1992. In 2009, the National Development and Reform Commission (NDRC) started the Low-carbon city program. Apart from these programs from central governments, local governments also initiated their own programs. For example, the Tianjin government developed the Sino-Singapore Eco-City program in 2008. Tangshan government started their Eco-City program in 2007. Currently, more than 230 cities in China have claimed to establish themselves as “eco-cities” and around 46.3% of these cities have set up their targets to develop

specifically as “low-carbon cities”. All these programs introduced their own evaluating systems and set criteria for the cities involved. By 2011, the 11 major evaluating systems have been widely adopted by researches, planners, and policymakers to assess various “low-carbon”, “eco”, or “sustainable” cities programs in China [14]. Table 1 summarized these 11 evaluating systems.

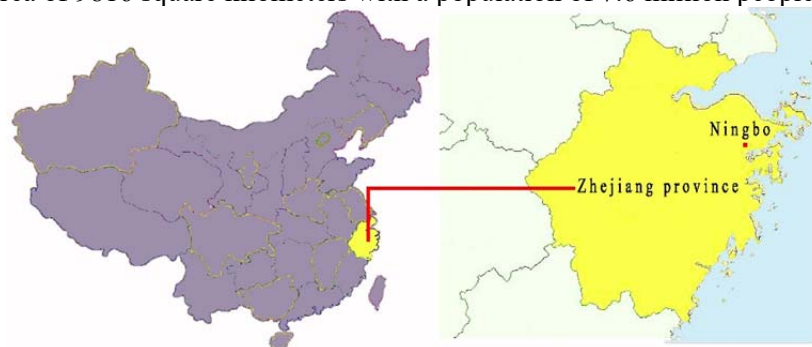
### 1.3. Research gap identified

Although the international evaluating systems (LEED and BREEAM) have been widely implemented for many years. However, they have drawbacks in application and adaptation for specific local context [15]. The 11 evaluating systems used for Chinese cities also have limitations. For example, too many indicators were involved (such as Caoheidian, 141 indicators in total) have complicated the data collection and the evaluating process. Zhou et al. [14] indicated that all the 11 Chinese evaluating systems suffer from the time-consuming and difficulties of collecting data.

Therefore, a new time-saving and cost-effective evaluating method is needed for urban managers to obtain a snapshot of the sustainable development of their cities and provides help in making the decision for the further development. The data for this method should be easily collected and the analysis results based on these data should be practical and reliable. In this study, a sole data source, i.e. the China Statistic Yearbooks published by the governments annually were employed. China Statistic Yearbooks record and highlight the past year, covering various aspects of the city, such as population, transportation, energy, environment, food, water, and so on. They provide a clear and coherent overview of present-day of cities through statistic. Data in yearbooks was collected by the Statistic Bureaus and they are normally from principal statistical publications available from governments and leading academic sources. Thus, the data is authentic and reliable. Furthermore, yearbooks can be accessed free and easily through government official website or yearbook online platform. Therefore, using Yearbooks as a data source can save time and cost.

## 2. Case study city: Ningbo

Ningbo is a sub-provincial city in northeast Zhejiang province in China (Figure 1). It comprises the urban districts of Ningbo proper, three satellite cities, and a number of rural counties including islands in Hangzhou Bay and the East China Sea. According to the 2010 census, Ningbo has an entire administration area of 9816 square kilometers with a population of 7.6 million people.



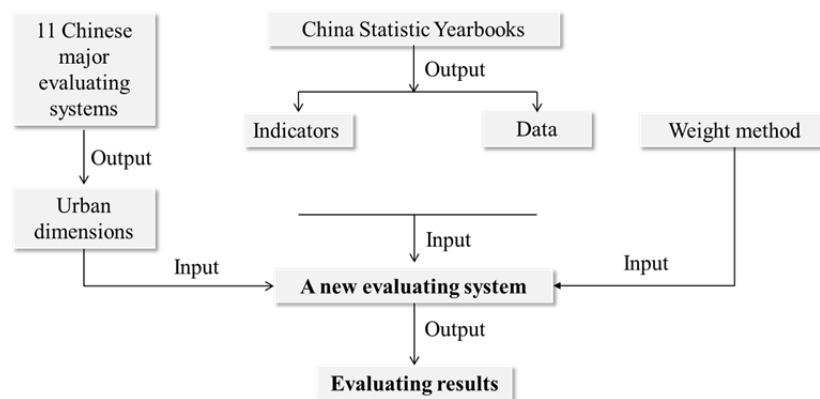
**Figure 1.** Location of Ningbo.

In 2003, Ningbo has implemented its own Eco-Development Plan, aiming to improve the sustainable development of its urban environment, in particular in the areas such as society, transport, culture, and policy innovation, etc. In 2010, Ningbo government published its new city development strategy, i.e. Ningbo Development Strategy 2030, aiming to further promote its sustainable development in the following two decades. Currently, it has been around 10 years since the implementation of these two plans, the sustainable development of Ningbo is not well identified. Only several reports gave their evaluating results recently. For example, the report from the China Centre for Economic Exchange (CCEE) [16] stated that Ningbo ranked 16 in the ranking of City Sustainability Index 2016 of Chinese cities. The Study conducted by the National Development and

Reform Commission's Development Planning Department and the Cloud River Urban Research Institute (NDRC-DPD and CRURI) [17] indicated that Ningbo is one of the top ten cities in terms of the sustainable development in China.

### 3. Research methodology

The diagram in the Figure 2 indicated the research method used in this study. Urban dimensions were derived from the 11 Chinese evaluating systems since they have been widely adopted by Chinese cities. The China Statistic Yearbooks provided indicators and data that corresponding each dimension. A weighting method was introduced to establish a numerical index to describe the evaluating results.



**Figure 2.** Research method used in this study.

#### 3.1. Defining evaluating dimensions and indicators

Temple [18] defined the sustainability dimensions as Building and Facilities, Natural Environment, People Satisfaction, and Transport Systems. However, dimensions from the 11 evaluating methods were categorized into eight groups, they are Transport, Air Quality, Economy, Land Use, Social Aspects, Waste, Water and Energy [14]. It can be seen that dimensions from the 11 evaluating methods are more specific and cover more details of Chinese cities. Therefore, the 8 dimensions from the 11 evaluating systems are used in this study. Yearbooks in China normally contains 27 chapters and each chapter has indicators which have a strong relationship with the urban built environment. Based on the covering aspects of the urban built environment, indicators which are relevant to the urban built environment were selected from the yearbooks. Table 2 has summarized the selected indicators for each dimension.

The data of yearbooks published in 2000, 2005, 2010 and 2015 was collected for analysis since these years are the ends of the ninth, tenth, eleventh, and twelfth Five-Year Plan of China. China's Five-Year plans are a series of social and economic development initiatives issued by the central governments since 1953. They are the most important role in mapping strategies for social development, setting an economic growth target, and launching reforms. Thus, choosing the end years of the Five-Year Plan would make the evaluating results have more contrastive for different periods of time of a city.

#### 3.2. Quantification method

A weighting method should be established in order to represent the sustainable development through statistic numbers. In this study, equal weighting is used to quantify the sustainability of the urban built environment of Ningbo. Basically, the weight (1) will be divided equally for eight dimensions and assigned equally to each indicator selected from yearbooks. The overall weight for each dimension is 1. Dimensions were considered equally important and within each dimension, the indicators are also equally important. Moreover, a positive sign (+) was assigned to the weight of indicators if the bigger value of

that indicator has a positive effect on the sustainable development of the urban built environment. While the negative sign (-) was assigned to the weight of indicators which will decrease the sustainable development level of the urban built environment. A summary of weights was shown in Table 3.

There is no doubt that equal weighting method may underestimate indicators which play a more important role in shaping the sustainable development of the urban built environment. However, considering the aim of this study is to take a snapshot of the sustainable profile, this method still may provide an initial evaluating result for urban managers to identify any specific areas that need further improvement.

#### 4. Quantification results and discussion

Table 4 summarized the quantification results of the sustainable development of the urban built environment of Ningbo. The values have been obtained for each indicator and the overall score for each dimension also has been calculated. It should be noticed that the bigger value of the dimensions or the indicators in Table 4 means that Ningbo has a higher level of sustainable development in these areas.

**Table 2.** Indicators selected from yearbooks for each dimension

Dimensions	Indicators	Unit
Energy	Total energy uses per capita	(tons of SCE/person)
	Energy use for construction activities	(kg of SCE/sqm)
	Energy use per capita for living	(kg of SCE/person)
	Electricity consumption for living	kWh/person
Water	Water consumption for living	(kg/person)
	Water storage	Billion cube meters
Social Aspects	Life expectancy	Years
	Illiteracy rate	%
	Road stock on average	(m <sup>2</sup> /person)
	Number of public parks	
	Number of primary schools per 10000 residents	/10000 residents
	Number of hospitals per 10000 residents	/10000 residents
	Number of beds in health care institutions per 1000 residents	/1000 residents
Waste	Reutilization rate of solid waste	%
	Built-up area to total land area	%
Land Use	City green areas per capita	m <sup>2</sup>
	The coverage rate of the conservation area	%
	The rate of wetland areas to city land areas	%
Economy	GDP per capita	Yuan
	Unemployment rate	%
	Average wage level	Yuan
Air Quality	Percentage of days above AIP level 2	%
Transport	Number of public bus per 10000 people	/10000 people
	Number of underground trains per 10000 persons	/ per 10000 persons

**Table 3.** Weights for dimensions and indicators.

Dimensions	Weight for dimensions	Indicators	Weight for indicators	Sign
Energy	0.125	Total energy uses per capita	0.03125	-
		Energy use for construction activities	0.03125	-
		Energy use per capita for living	0.03125	-
		Electricity consumption for living	0.03125	-
Water	0.125	Water consumption for living	0.0625	-
		Water storage	0.0625	+
Social Aspects	0.125	Life expectancy	0.0179	+
		Illiteracy rate	0.0179	+
		Road stock on average	0.0179	+
		Number of public parks	0.0179	+
		Number of primary schools per 10000 residents	0.0179	+
		Number of hospitals per 10000 residents	0.0179	+
		Number of beds in health care institutions per 1000 residents	0.0179	+
Waste	0.125	Reutilization rate of solid waste	0.0125	+
Land Use	0.125	Built-up area to total land area	0.03125	-
		City green areas per capita	0.03125	+
		The coverage rate of the conservation area	0.03125	+
		The rate of wetland areas to city land areas	0.03125	+
Economy	0.125	GDP per capita	0.0417	+
		Unemployment rate	0.0417	-
		Average wage level	0.0417	+
Air Quality	0.125	Percentage of days above AIP level 2	0.125	+
Transport	0.125	Number of public bus per 10000 people	0.0625	+
		Number of underground trains per 10000 persons	0.0625	+

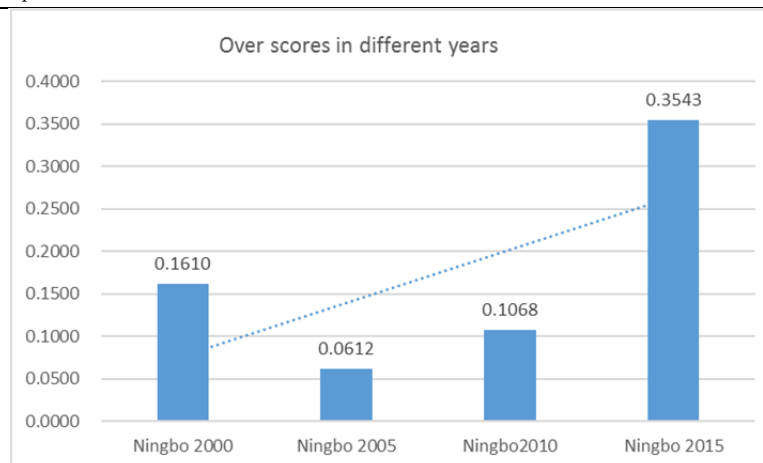
Figure 3 indicates the overall scores for Ningbo in studied years. It can be seen that the sustainability of the urban built environment of Ningbo has a decrease between 2000 and 2005, while an increase has been achieved in the following decade. Especially from 2010 to 2015, the scores have been significantly increased from 0.1057 to 0.3426.

Figure 4 provides a detailed changing tendency of the sustainability of each dimension in studied years. It is clear that Ningbo has been constantly improved in the sustainability area of Social Aspects and Transport due to the increasing level of health conditions and public service conditions. For example, more roads and more public parks have been constructed, as the scores increased from 0 to 0.0179. Moreover, the life expectancy and the number of beds in health care institutions per 1000 residents also have significantly increased, as scores increased from 0 to 0.0205 and 0.0270 respectively. In the Transport system, more and more public buses are running on the road to provide convenience for people's traveling. And in 2014, underground trains were put into service in Ningbo and this has significantly increased the sustainability of the urban built environment regarding the public transport system. On the contrary, Ningbo has a constant decrease in the area of Energy. This is largely caused due to the increased energy consumption for people's living, as the scores of energies use and electricity consumption for the living has constantly declined from 0 to -0.0313. The reason to explain this decrease might be the improved living standard during the past 15 years, as more and more families can afford more domestic appliance.

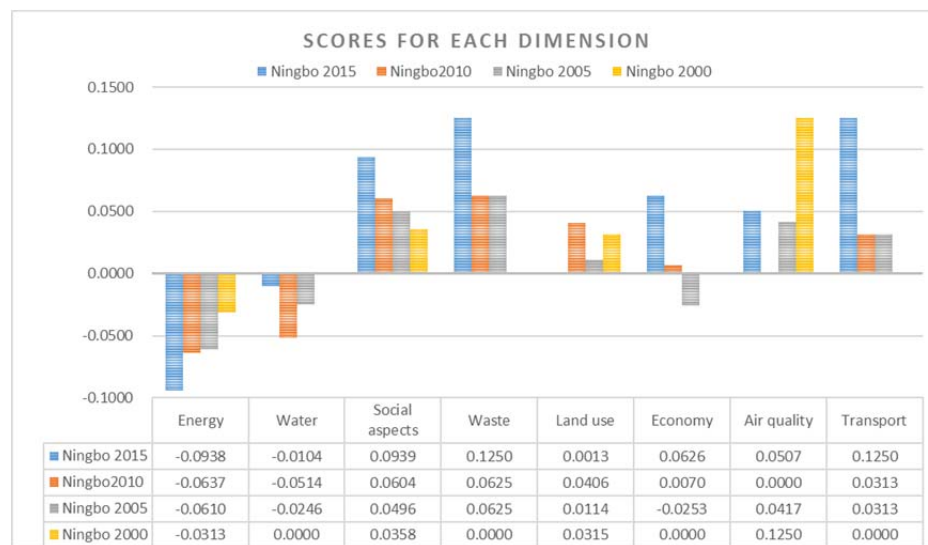
In the areas of Water and Air Quality, a constant decrease can be observed between 2000 and 2010, while an increase was obtained between 2010 and 2015. The area of Waste maintained a stable level between 2005 and 2010, and then an increase was achieved in the following 5 years.

**Table 4.** Scores for indicators and dimensions.

Dimension	Indicators	Scores for each indicator				Total scores for each dimension			
		2000	2005	2010	2015	2000	2005	2010	2015
Energy	Total energy uses per capita	0.0000	-0.0121	0.0270	-0.0313	-0.0313	-0.0610	-0.0637	-0.0938
	Energy use for construction activities	-0.0313	-0.0280	-0.0021	0.0000				
	Energy use per capita for living	0.0000	-0.0004	-0.0009	-0.0313				
	Electricity consumption for living	0.0000	-0.0205	-0.0261	-0.0313				
Water	Water consumption for living	-0.0625	-0.0610	-0.0514	-0.0625	0	-0.0246	-0.0514	-0.0104
	Water storage	0.0625	0.0365	0.0000	0.0521				
Social Aspects	Life expectancy	0.0000	0.0026	0.0077	0.0205	0.0358	0.0496	0.0604	0.0939
	Illiteracy rate	0.0179	0.0107	0.0054	0.0000				
	Road stock on average	0.0000	0.0047	0.0104	0.0179				
	Number of public parks	0.0000	0.0060	0.0060	0.0179				
	Number of primary schools per 10000 residents	0.0000	0.0016	0.0179	0.0105				
	Number of hospitals per 10000 residents	0.0179	0.0175	0.0000	0.0002				
	Number of beds in health care institutions per 1000 residents	0.0000	0.0066	0.0131	0.0270				
Waste	Reutilization rate of solid waste	0.0000	0.0313	0.0313	0.1250	0	0.0625	0.0625	0.1250
Land Use	Built-up area to total land area	0.0000	-0.0038	-0.0015	-0.0313	0.0315	0.0114	0.0406	0.0013
	City green areas per capita	0.0002	0.0113	0.0313	0.0000				
	The coverage rate of the conservation area	0.0313	0.0005	0.0000	0.0013				
	The rate of wetland areas to city land areas	0.0000	0.0035	0.0243	0.0313				
Economy	GDP per capita	0.0000	0.0060	0.0226	0.0417	0	-0.0253	0.0070	0.0626
	Unemployment rate	0.0000	-0.0417	-0.0417	-0.0209				
	Average wage level	0.0000	0.0104	0.0261	0.0417				
Air Quality	Percentage of days above AIP level 2	0.1250	0.0417	0.0000	0.0507	0.1250	0.0417	0.000	0.0507
Transport	Number of public bus per 10000 people	0.0000	0.0313	0.0313	0.0625	0	0.0313	0.0313	0.1250
	Number of underground trains per 10000 persons	0.0000	0.0000	0.0000	0.0625				

**Figure 3.** overall scores for Ningbo in different years.





**Figure 4.** Scores for each dimension.

Ningbo's economy performed not good during the first 5 years of the 21<sup>st</sup> century. However, it was much improved in the following 10 years. Especially in the areas of wage level and the GDP per capita, the scores have increased from 0.0060 and 0.0104 to 0.0417 respectively. In the area of Land Use, only the rate of wetland areas to city land areas has a constant increase while other three indicators have different levels of decrease in different periods.

Overall, the sustainable development of the urban built environment of Ningbo has been improved between the ninth and twelfth Five-Year Plan, in particular in the areas of Social Aspects, Transport, Economy, and Waste. While in other areas, such as Energy, Water, and Land Use, measures should be taken to stop the decline of the sustainability. For example, more city green areas should be provided to the public. And the utilization of the energy-effective household appliances should be encouraged.

## 5. Conclusions

This study develops an evaluating method to take a snapshot of the sustainable development of the urban built environment of cities. The strength and weakness of the cities' development can be identified and this helps urban managers to make the decision for the further development. It should be noticed that the method proposed is based on the sole data source, i.e. China Statistic Yearbooks, which are published annually by the government. Thus, lots of time can be saved from gathering data.

Ningbo, as the second largest and one sub-provincial city of Zhejiang province, was selected as a case study. A consistency has been identified between the evaluating results of this research and the prior published studies from the CCEE [16] and the NDRC-DPD and CRURI [17]. For example, Ningbo obtained relatively high scores in the areas of Social Aspects, Transport, and Economy in all these three evaluating studies. While in the areas of Energy and Natural Environment, a low level of sustainable development has been observed.

Although the proposed method in this study can provide a snapshot of cities' sustainable development during a certain period. However, it cannot evaluate the sustainability in all areas due to the limited indicators available in the statistic yearbooks. Moreover, the equal weighting method may overlook areas which are more important for the sustainability of the urban built environment, therefore, a more accurate method should be found in case a more accurate and specific result is required.

## Reference

- [1] United Nations Dept of Economic and Social Information 2014 *World urbanization prospects: The 2014 revision, highlights* Department of Economic and Social Affairs Population Division, United Nations
- [2] Turner B L 1988 The earth as transformed by human action *The Professional Geographer* **40(3)** 340-341
- [3] Liu Y, Prasad D, Li J, Fu Y, Liu J 2006 Developing regionally specific environmental building tools for China *Building Research & Information* **34(4)** 372-386
- [4] Cao X, Dai X, Liu J 2016 Building energy-consumption status worldwide and the state-of-the-art technologies for zero-energy buildings during the past decade *Energy and Buildings* **128** 198-213
- [5] Zhang X, Wang F 2016 Hybrid input-output analysis for life-cycle energy consumption and carbon emissions of China's building sector *Building and Environment* **104** 188-197
- [6] Roof K, Oleru N 2008 Public health: Seattle and King County's push for the built environment *Journal of environmental health* **71(1)** 24-27
- [7] Gao M, Ahern J, Koshland C P 2016 Perceived built environment and health-related quality of life in four types of neighbourhoods in Xi'an, China *Health & place* **39** 110-115
- [8] Graham P 2003 *Building ecology: first principles for a sustainable built environment*, Blackwell Publishing, Oxford
- [9] China National Statistical Bureau 2017 China Statistic Yearbook 2017 *China Statistical Press, Beijing* [online] Available at: <http://www.stats.gov.cn/tjsj/ndsj/2013/indexch.htm> [Accessed 28 Apr 2018]
- [10] Chinese Society for Urban Studies (CSUS) 2008 Green Building: 2008 *China Architecture & Building Press, Beijing* [online] Available at: <http://www.chinasus.org/chinasus/> [Accessed 29 Apr 2018] (In Chinese)
- [11] Jones P, Patterson J, Lannon S 2007 Modelling the built environment at an urban scale—Energy and health impacts in relation to housing *Landscape and Urban Planning* **83(1)** 39-49
- [12] Alberti M 1996 Measuring urban sustainability *Environmental impact assessment review* **16(4-6)** 381-424
- [13] Sharifi A, Murayama A 2013 A critical review of seven selected neighbourhood sustainability assessment tools *Environmental Impact Assessment Review* **38** 73-87
- [14] Zhou N, He G, Williams C 2012 China's development of low-carbon eco-cities and associated indicator systems (No LBNL--5873E) *Lawrence Berkeley National Lab (LBNL)*, Berkeley, CA (United States)
- [15] Vakili-Ardebili A, Boussabaine A H 2007 Application of fuzzy techniques to develop an assessment framework for building design eco-drivers *Building & Environment* **42(11)** 3785-3800
- [16] China centre for economic exchange (CCEE) 2016 *Research on Assessment Indicators System for China's Sustainable Development: Rankings of the Provincial and Mega Cities* (1<sup>st</sup> ed) Beijing
- [17] National Development and Reform Commission's Development Planning Department & Cloudy River Urban Research Institute (NDRC-DPD and CRURI) 2016 *China Integrated City Index 2016* (1st ed) Beijing: People press
- [18] Temple M 2004 *Studying the built environment* New York: Palgrave Macmillan, Basingstoke