Journal of Cleaner Production 276 (2020) 124303

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Assessing the low-carbon tourism in the tourism-based urban destinations

Jiekuan Zhang [a, *], Yan Zhang [b]

[a] Asean Tourism Research Centre of China Tourism Academy, Guilin Tourism University, China
[b] School of Tourism Management, Guilin Tourism University, China

ARTICLE INFO

Article history:
Received 2 August 2019
Received in revised form
22 March 2020
Accepted 16 September 2020
Available online 19 September 2020

Handling Editor. Yutao Wang

Keywords:
Low-carbon tourism
Evaluation of low-carbon tourism
Tourismbased urban destination
Fuzzy delphi-analytic network process approach

ABSTRACT

Climate change problems have become a worldwide concern. In response to containing global climate change, there has been a proliferation of theories and policies aimed at driving tourism towards 'low-carbon tourism'. The problem becomes even greater if turning to cities. Constructing a low-carbon tourism city requires a comprehensive understanding of urban low-carbon tourism development rather than solely focusing on targets limited to CO_2 emissions and energy reduction. However, much of the focus of research to date has not been on this key issue. Here this study constructed indicators to evaluate low-carbon tourism development in a tourism-based urban destination. A total of 33 indicators were identified using the fuzzy Delphi method. Then, the weights of these indicators were determined using the analytic network process. The evaluation model made it possible to convert the subjective qualitative characteristics of low-carbon tourism, the implied mutual influences between the numerous indicators, and development demands into integrated quantitative values to guide actual low-carbon tourism development. The presented research process and results could provide a reference for relevant policy making in tourism-based urban destinations worldwide.

1. Introduction

Climate change problems have become a worldwide concern. A low-carbon economy is an unavoidable choice for realizing sustainable development (Yang and Li, 2018). In response to this recognition, there has been a proliferation of theories and policies aimed at driving tourism towards 'low-carbon tourism'. The problem becomes even greater if turning to cities. Numerous urban tourism destinations have been significantly affected by carbon dioxide (CO_2) emissions and the resulting climate policies (Cho et al., 2016; Dwyer et al., 2013; Seetaram et al., 2018; Zhang and Zhang, 2018). In this respect, low-carbon development in urban tourist destinations — a key challenge and a substantial aspect of low-carbon tourism strategies — has recently been acknowledged as an essential pattern for improving the sustainability, liveability, competitiveness and brand image of those destinations (Shen, Wu, Wang, Lv and You, 2015; Xu et al., 2011).

Considering cities' significance in palliating future energy consumption and CO_2 emissions, in 2010 the Chinese government selected five low-carbon pilot provinces and eight pilot cities to promote low-carbon cities' construction (Khanna et al., 2014). Subsequently, the construction of low-carbon cities began to grow vigorously (Su et al., 2013; Shen et al., 2018). Currently, almost all urban tourism destinations have set targets for low-carbon development. However, constructing a low-carbon tourism city requires a comprehensive understanding of urban low-carbon tourism development, as indicated by Hodson and Marvin (2010), Liu and Qin (2016) and Tan et al. (2017), rather than solely focusing on targets limited to CO_2 emissions and energy reduction in those destinations. In addition to CO_2 emissions and energy consumption, the construction of low-carbon cities must involve economic, environmental and social aspects such as economic growth, water quality, waste management, technology and policy indicated by Liu and Qin (2016), Zhou et al. (2015) and Tan et al. (2017). It is thus worthwhile to develop a reasonable indicator framework competent to assess the low-carbon level of tourism cities. Under the premise that a development status cannot be determined under an evaluation framework, the rationality and feasibility of any target formulation are also doubtful. However, to our knowledge, much of the focus of research to date has not been on these key issues. Given this background, the main research question was put forward to

* Corresponding author. No.26, Liangfeng Road, Guilin, Guangxi, China.
E-mail address: zhangjiekuan@126.com (J. Zhang).

https://doi.org/10.1016/j.jclepro.2020.124303
0959-6526/

drive this study as follows: how to evaluate the low-carbon development of an urban tourism destination.

This study attempted to implement an evaluation model of tourism-based urban destinations (TBUDs). It is hoped that this model will be instrumental in guiding their low-carbon and, even, sustainable management. Numerous scholars have conducted extensive research on evaluation frameworks for low-carbon cities (see section Literature review). However, those frameworks may be seen as inappropriate for the purpose of evaluating the low-carbon development of TBUDs. Given that almost all cities have some degree of tourist attraction/s, in this sense, all cities can be considered as tourist destinations. Thus, the concept of general urban tourism destinations becomes extensive, meaning that there can be deemed to be no significant difference between the low-carbon evaluation of urban tourism destinations and cities in general. Yet, in the context of TBUD, the tourism industry occupies a prominent proportion of the economy, and most of these cities' resources will be arranged around the tourism industry. Hence, TBUDs' low-carbon development contains certain unique characteristics which distinguish them from general urban destinations. Researching how best to evaluate low-carbon development in TBUDs is thus a distinct endeavor and embodies significant "tourism" characteristics.

For addressing the aforesaid research question, this study aims to analyze the following issues: 1) How to identify evaluation indicators to assess a TBUD's level of low-carbon development. 2) How should these evaluation indicators be weighted? 3) What is the level of low-carbon tourism development? By engaging with these aims, the main contribution of this paper is the implementation of a system of evaluation indicators and weightings to assess a TBUD's low-carbon development employing a combination of qualitative and quantitative fuzzy Delphi method (FDM) and analytic network process (ANP) approaches, so as to meet the multi-level, multi-objective characteristics of a TBUD evaluation index. This reminder of this paper includes section two presenting the literature review, section three outlining the theoretical framework for evaluating low-carbon tourism, section four presenting the results, section five providing a case study, and section six providing the conclusions.

2. Literature review

As highlighted in numerous studies, low-carbon tourism is highly relevant to low-carbon economies, sustainability, and tourism (Gössling et al., 2007; Lee and Brahmasrene, 2013; He et al., 2018). Having a low-carbon city has been consistently linked with the ultimate goal of sustainability (Tan et al., 2017). Therefore, this section reviews evaluations of city sustainability, low-carbon cities, and a city's tourism sustainability. This section also reviews studies on the evaluation of low-carbon tourism, so as to provide a reference framework for constructing low-carbon evaluation indicators for TBUDs.

2.1. Evaluation of city sustainability

Camagni et al. (1998) and Whitehead (2003) argued that the aim of urban sustainable development is to coordinate the economic environment, social environment and physical environment (or the so-called ecological environment). Mori and Christodoulou (2012) also indicated that a sustainable city is a synchronous social, economic and political construct. Regarding the evaluation of sustainable cities, index setting has always been a dominant paradigm. Gagliardi, Roscia, and Lazaroiu (2007) evaluated indicators affecting urban sustainable development based on the four criteria of the economy, environment, energy and urban planning. Chang and Dong (2016) evaluated the sustainable development level of resources-based cities, constructing indicators with respect to economic and social factors, resources, and the environment. In addition to the common economic and environmental indicators, Zinatizadeh et al. (2017) identified numerous social indicators measured through the per capita occupancy of public facilities. The authors also assert that urban sustainable development is ultimately a balancing act between economic, environmental and social issues.

Likewise, Braulio-Gonzalo, Bovea, and Ruá (2015), Ghalib et al. (2017), Oregi et al. (2016) and Shen, Zhou, Skitmore, and Xia (2015) respectively identified varieties of evaluation indicators in terms of environmental, economic and social development, in order to assess the progress of urban sustainability strategies. Furthermore, Hara et al. (2016) established a smart evaluation indicator system based on sustainability. The latter study highlights the importance of information technology within an economic-environmental-social framework. Additionally, Theodoridou et al. (2012) indicated the importance of energy consumption/planning and energy conservation measures in building a sustainable city; Tian et al. (2018) and Yang et al. (2018) highlighted the importance of CO_2 emissions in the city-level sustainability. Prior research indicates that evaluation indicators of city sustainability are clearly classified among the economic-environmental-social framework. Meanwhile, low-carbon environment (i.e. CO_2 emissions reduction and energy conservation) construction has become a key construct of city sustainability.

2.2. Evaluating the low-carbon city

Compared with sustainable cities, the concept of the 'low-carbon city' a term that was later introduced in the literature. There are a variety of terms used effectively as synonyms for low-carbon city such as eco-city, smart city, carbon neutral city and zero carbon city (Tan et al., 2017). The concept of the low-carbon city has been well defined by Hodson and Marvin (2010): as a system with resource and energy security constraints where decision makers set their targets from the perspective of achieving low carbon. Likewise, Liu and Qin (2016) argued that the aim of building a low-carbon city is to reduce CO_2 emissions and improve the environment, both of which require the cooperation of numerous social and governmental sectors. Thus, similar to a sustainability assessment, an evaluation of the low-carbon city also involves economic, environmental and social indicators.

China's Low-carbon Economy Media Federation (CLEMF) (2011) issued the publication, *Evaluation System for China's Low-carbon Cities,* which included indicators with respect to planning, communication, products, new energy utilization, green coverage rate, low-carbon travel, buildings, air quality, CO_2 emissions reduction behavior, and public attitudes. This provided a relatively systematic definition of China's low-carbon city and has become a benchmark for low-carbon development in many cities. Following this, the Lawrence Berkeley National Laboratory (LBNL) implemented several evaluation indicators to low-carbon eco-cities by adding in the concept of ecology to that of low-carbon, ultimately constructing 33 indicators (Zhou et al., 2012). Subsequently, Zhou et al. (2015) provided benchmarks for LBNL's indicators, as well as a detailed guide on tool applications.

Additional examples include the following: Yang and Li (2018), who set 14 indicators to evaluate the level of low-carbon, urban economic development; Zhou et al. (2015), who used the driving forces-pressures-state-impacts-responses causal-effect framework to investigate the low-carbon city, particularly highlighting the importance of technical and policy responses to reduce emissions pressures; Tan et al. (2017), who constructed indicators from the perspectives of the economy, the environment (including energy patterns, carbon and environment, solid waste and water), and society (including factors related to urban living and mobility). Other evaluations of low-carbon city planning (Khanna et al., 2014), low-carbon city management (Wang et al., 2015), and low-carbon urban competitiveness (Guo et al., 2018), were also examined from these three perspectives.

In addition to the latter holistic evaluation, other studies have, respectively, focused on energy policy making (Phdungsilp, 2010; Chen and Zhu, 2013), policy implementation (Lo, 2014), low-carbon planning (Liu and Qin, 2016), transport policy (Trappey et al., 2012), technology and climate legislation (Tsai and Chang, 2015), and low-carbon industrial park (Fang et al., 2017) in the context of developing the low-carbon city.

2.3. Evaluating urban tourism sustainability

Assessing the sustainability of tourism destinations has always been a key element of sustainable tourism research (Tseng et al., 2018). Given that they are major destinations, evaluations of urban tourism destinations have also commanded a great deal of the academic community's efforts. For example, Savage et al. (2004) argued that taking a holistic view is conducive to gauging the sustainability of urban tourism development, which consists of environmental, economic, social and cultural sustainability. Lee, Huang, and Yeh (2010) pointed out that achieving long-term sustainability requires ensuring the sustainable use of the ecological environment, increasing the reliability of destination corridors, and improving the quality of tourism services. Pérez et al. (2016) constructed a set of indicators (11 social, 14 economic and 14 environmental) to measure the sustainability of urban tourism. Unlike the traditional static evaluation, Blancas et al. (2016) built a dynamic evaluation index through a goal planning approach, composed of a total of 85 indicators, namely 29 social indicators, 36 economic indicators, and 20 environmental indicators. In addition, Ben-Dalia et al. (2013) evaluated a city's tourism product and the relevant macro environment, while Zamfir and Corbos (2015) disclosed some key success factors for achieving sustainable tourism development in urban areas.

2.4. Evaluating low-carbon tourism

Cheng et al. (2013) established a system of indicators to evaluate the low-carbon development of tourist attractions. Although there are significant differences between tourist attractions and urban tourism destinations, the dimensions of the eco-environment, tourist facilities, management system and participant attitudes harnessed by Cheng et al. (2013) could still provide an adequate indicator framework for evaluating the low-carbon development of a TBUD. With respect to urban tourism destinations, Yao et al. (2014) evaluated the degree of urban low-carbon industrialization. It is noteworthy that the authors proposed indicators focusing not on CO_2 emissions and energy consumption, but on traditional environmental indicators such as solid waste, exhaust gas and sewage. Cho et al. (2016) constructed 53 indicators to evaluate the level of Yilan County's low-carbon tourism development from six perspectives. Zhang (2017) evaluated regional low-carbon tourism strategies. The limitations of the latter research lie in that, compared with the evaluation of low-carbon and sustainable tourism cities, the system of indicators is not comprehensive enough. Juvan and Dolnicar (2016) highlighted the importance of transportation related greenhouse gas emissions for measuring the environmentally sustainable tourist behavior. In addition, Hsiao (2016) investigated the low-carbon evaluation index with regard to travel agencies' products.

Other scholars have analyzed the low-carbon tourism system, such as the low-carbon tourist attractions system (Luo et al., 2014) and the low-carbon urban tourism system (He et al., 2018; Xu et al., 2011). Despite the simulation rather than evaluation in these studies, all of the latter low-carbon tourism systems refer to the key elements or variables affecting low-carbon tourism development. These elements or variables can be converted into corresponding evaluation indicators in the context of evaluating low-carbon tourism. These low-carbon tourism systems consist of three subsystems: the economic subsystem, the environmental subsystem and the social subsystem.

3. Theoretical framework for evaluating low-carbon tourism

The proposed evaluation framework to be applied to TBUDs (Fig. 1) is presented in four parts, as follows:

- Evaluation dimensions
- Evaluation indicators
- Interdependence between evaluation indicators
- Weights of evaluation indicators

3.1. Evaluation dimensions of low-carbon tourism in an urban tourist destination

When collating viewpoints in the literature review, all the evaluation indicators of low-carbon development essentially distil into economic, environmental and social aspects. Therefore, the current study also takes as its starting point that the low-carbon evaluation indicators for TBUDs consist of three subsystems; namely, the low-carbon economic subsystem, low-carbon environmental subsystem and low-carbon social subsystem, as demonstrated in Fig. 1. The process of evaluating the current TBUD's low-carbon framework involves the researchers' interpretations and an understanding of low-carbon development.

In the context of a low-carbon economic subsystem, first, this study measured the low-carbon tourism product, which includes catering, accommodation, transport, sightseeing and shopping. Low-carbon input measures tourism enterprises' business philosophies against a low-carbon background. The CO_2 emissions and energy consumption growth, along with the rapid growth of tourism, can be seen as not conducive to the construction of a low-carbon tourism destination (Zhang, 2017). Therefore, with respect to tourism development, evaluation indicators need to include the static tourism scale and dynamic tourism changes. Fig. 1 illustrates that a low-carbon environmental subsystem includes a low-carbon environment, an ecological environment and low-carbon facilities. The indicators involved in a low-carbon environment should be closely related to low-carbon such as CO_2 emissions, energy consumption and carbon sink. The ecological environment is consistently a critical factor in the evaluation of low-carbon development or sustainable development. The notion of low-carbon facilities is used to measure the low-carbon input (except for tourism enterprises) of a tourist destination. The notion of a low-carbon social subsystem reflects the humanistic environment in which low-carbon tourism is developed. As revealed by numerous studies mentioned in the literature review, low-carbon planning, legislation, technology, communication and literacy are all the facilitators of low-carbon tourism development.

3.2. Identifying the evaluation indicators through FDM

The Delphi method is widely used in selecting evaluation indicators (e.g. Cho et al., 2016; Cheng et al., 2013). Accordingly, this

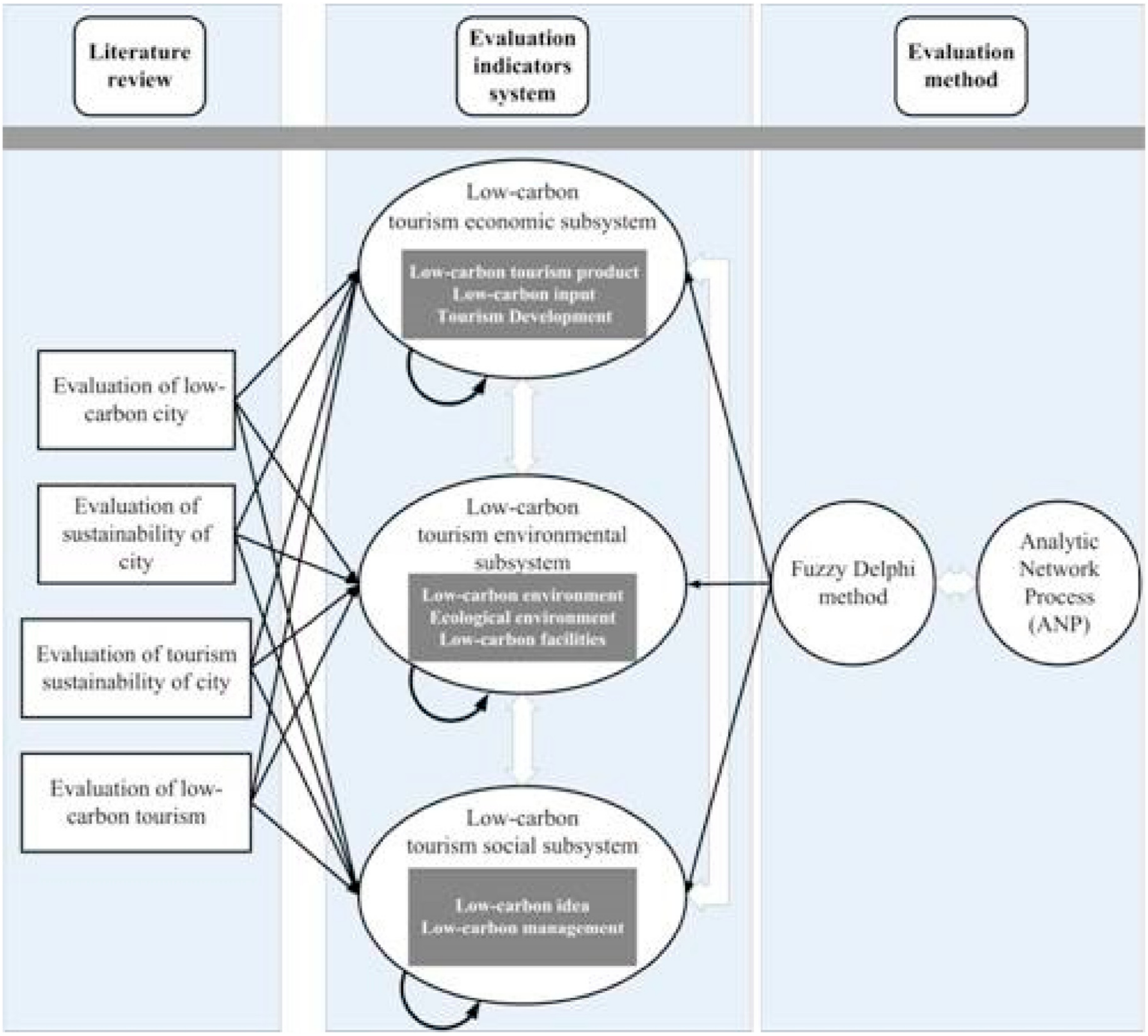

Fig. 1. Theoretical framework for evaluating low-carbon tourism in a TBUD.

study also adopted a Delphi approach to identify the evaluation indicators for the low-carbon tourism development of a TBUD. However, in order to overcome the shortcomings of the traditional Delphi method, such as nondeterminacy, ambiguity and time-consuming features (Wang et al., 2010, 2013; Zhang, 2017), this study adopted the FDM, which was developed by Murray et al. (1985), based on fuzzy theory. As asserted by Murray et al. (1985) and Zhang (2017), the FDM has two main advantages: (1) the FDM comprehensively take into account the uncertainty and ambiguity of the subjective thinking of experts, so that the opinion of every expert can be fully involved in the decision-making. Therefore, the results obtained are objective and reasonable. (2) The final decision can be made through only a round of FDM-based surveys so that the several rounds of survey employed in the traditional Delphi method can be avoided. This thus reduces the research time and costs. The FDM procedure was as follows:

Step i. Collect all n possible evaluation indicators based on the above literature review and experts' judgments: $\mathbf{U} = (u_1, u_2, \cdots, u_n)$.

Step ii. Collect the estimated score of each indicator u_n from all the m experts according to the triangular fuzzy number (Zhang, 2017), as shown in Table 1. Each expert's judgment of each indicator is obtained using the semantic variables in a questionnaire. The score of u_n given by the *ith* expert is denoted as $\omega_{in} = (a_{in}, b_{in}, c_{in})$, $i = 1, 2, \cdots, m$. Concretely, the score of each expert on each indicator is a set of numbers, so that the decision

Table 1
Fuzzy evaluation scale.

Step iii. The final fuzzy weight S_n of u_n is defuzzified using Eq. (2), a simple arithmetic average methodw.

$$S_n = \frac{\alpha_n + \beta_n + \gamma_n}{3} \tag{2}$$

Step iv. Extract critical evaluation indicators from **U**. Set the threshold value ρ; if $S_n \geq \rho$, select indicator n; if $S_n < \rho$, eliminate indicator *n*. Generally, this study determined the threshold value subjectively according to requirements (Kuo and Chen, 2008). If fewer indicators are required, $\rho$is determined as a larger value while, conversely, $\rho$is determined as a smaller one (Zhang, 2017).

Fuzzy scale	Evaluation fuzzy set	Triangular fuzzy numbers (a,b,c)
$\tilde{9}$	Extremely important	(7,9,9)
$\tilde{7}$	Very important	(5,7,9)
$\tilde{5}$	Important	(3,5,7)
$\tilde{3}$	Somewhat important	(1,3,5)
$\tilde{1}$	Not important	(1,1,3)

of each expert is better fault tolerant. For example, if one expert judges that indicator C1 is very important, he or she can score (7, 7, and 9) instead of traditionally scoring 7 or 8 or 9 using the Delphi method. The fuzzy weight of the *nth*indicator is defined as:

$$\omega_n = (\alpha_n, \beta_n, \gamma_n), \tag{1}$$

where$\alpha_n = \min(a_{in})\beta_n = \frac{1}{m}\sum_{i=1}^{m} b_{in}, \gamma_n = \max(c_{in})$.

A total of 11 experts in the fields of low-carbon tourism management were invited to participate. For ensuring credibility to the FDM results, all the selected experts are knowledgeable in the research field of low-carbon city (three experts), low-carbon tourism (five experts) and sustainable development (three experts). In addition, the panel of experts is internationalized within which there are five Chinese, two Australians and four Europeans. The FDM was then applied to obtain the final evaluation indicators.

3.3. Weighting the evaluation indicators using the analytic network process

The analytic network process (ANP) was proposed by Saaty (1996). This enables interdependence or feedback in a network system and replaces hierarchies with networks, and is the generalization of the analytic hierarchy process (AHP). Inevitably, there exists a large amount of interdependence between numerous evaluation indicators (Zhang, 2017); thus, there is a certain limitation in determining the weight of each indicator using the traditional AHP method. This study obtained the weights of the evaluation indicators through the ANP method. Since the detailed ANP process can be found in Saaty (1996) or numerous relevant studies, such as Wang et al. (2010), Zhang (2016) and Zhang (2017), the current study does not cover this in detail but gives a simple description. The ANP process consists of first, building the ANP network model, second, establishing all the pair-wise comparison matrices, third, determining the unweighted super-matrix, fourth, calculating the weighted super-matrix, and finally, obtaining the limit super-matrix. After the evaluation indicators were obtained, a face-to-face survey was conducted to collect experts' opinions on the relative importance of these indicators. The selected experts were asked to use Saaty's 1–9 scale to compare any pair of indicators. Finally, all the pair-wise comparison matrices were obtained by calculating the mean of each expert's decision.

4. Results

4.1. Evaluation indicators

By referring to previous studies, this study obtained the possible evaluation indicators (see Table S1 in the online supplementary material). Then the FDM is applied to identify the final indicators, which can also be found in Table S1. It is noteworthy that the expert group was given the right to set indicators in addition to the indicators we provided. However, they all agreed on our initial indicators and made a selection within the scope of these indicators. In the current study, the threshold value ρ was subjectively set as 5 because first, enough indicators should be obtained. As shown in Table S1, the value 5 is a good threshold. second, the importance of these indicators should be simultaneously guaranteed because the value 5 indicates "important" as shown in Table 1. The final list of 33 evaluation indicators derived through the FDM and their units and references are shown in Table 2.

In order to ensure the robustness of evaluation results, this study additionally performed a sensitivity test for threshold ρ by setting it to 3 and 2, respectively. When the threshold is 2, all initial indicators are included. Then the ANP method was used to respectively calculate the weight of the indicators in these two cases, and the results are shown in Table S2 in the online supplementary material. Table S2 shows that the weights of the newly added indicators are very small, thus their impact on low-carbon tourism in a TBUD can be ignored. Therefore, the selected indicators and their corresponding weights are robust.

4.2. Interdependence between evaluation indicators

In the FDM work, only the evaluation indicators were identified. However, before weighting the evaluation indicators in the ANP process, the interdependence between economy, environment and society as asserted by (Zhang, 2017) must be considered. For example, the ratio of investment in low-carbon (C7) has, of course, negative impacts on tourism carbon intensity (C11) and tourism carbon footprint (C12) and positive impacts on water-saving technology adoption (C23) and low-carbon guiding signs (C24) (Cheng et al., 2013). Besides, low-carbon policy & legislation (C31) and special plans for low-carbon tourism (C32) theoretically influence each other (Zhang, 2017). Therefore, there is substantial interdependence between the total 33 evaluation indicators in Table 2. This study investigated the interdependence through expert team surveys using a two-dimensional table (see Table S3). The experts were required to identify the interdependence between different evaluation indicators. For example, it is well known that green hotel construction is conducive to reducing tourism-related CO_2 emissions (Zhang, 2017); therefore, the interdependence between C1 and C12 could be determined. Likewise, there is the interdependence between C1 and C11. The interdependence that was found is shown in Table S3 in the online supplementary material.

4.3. ANP process

Fig. 2 illustrates the ANP network model for assessing the development level of low-carbon tourism in a TBUD according to Table S3. Here all the arrows indicate the interdependence between different indicators. The ANP model was written using the decision tool, Super Decisions. Fig. 2 actually illustrates the results that are detailed in Table S3. There are 299 pair-wise comparison matrices in the proposed ANP model, with all matrices having passed the consistency test (inconsistency<0.1) (see Table S4 in the online supplementary material). The maximum inconsistency of all the pair-wise comparison matrices was 0.0909. All the priorities of the 33 indicators as well as the low-carbon tourism economy, low-carbon tourism environment and low-carbon tourism society were calculated, and form the initial super-matrix (unweighted super-matrix), as shown in Table S5 in the online supplementary material. Following this, this study transformed the initial super-matrix into a weighted super-matrix and raised the weighted super-matrix to have limiting powers, in order to obtain the limit super-matrix, in which all the relationships converged. Through this process, this study eventually obtained the integrated weights of all of the evaluation indicators. The results are presented in Table 2.

Columns 5 and 6 of Table 2 respectively show the integrated weights and integrated ranking of all of the evaluation indicators. Table 2 shows that the monitoring system of ecological environment (C21) has the highest weight (0.0968), followed by the air pollution index (C16) (0.0781), surface water quality (C17) (0.0666), and proportion of low-carbon transport (C5) (0.0632). The ranking of the indicators shows that in the low-carbon tourism development in a TBUD, prevention (environmental monitoring) is more important than governance (e.g. trash management (C19) (0.0280), and sewage treatment (C20) (0.0465)). This highlights the importance of preventing problems before they happen rather than

Table 2
Evaluation indicators for low-carbon urban tourism.

Dimensions (weights)	Second-level indicators (weights)	Third-level indicators	References	Unit	Integrated weights	
					Weights	Ranking
Low-carbon tourism economy (A1) (0.2725)	Low-carbon tourism product supply (B1) (0.1697)	Proportion of green hotel (C1)	Zhang (2017)	%	0.0349	11
		Proportion of green catering enterprise (C2)	Zhang (2017)	%	0.0121	25
		Proportion of green building (C3)	CLEMF (2011)	%	0.0200	20
		Low-carbon shopping (C4)	Expert interviews	% of simple packing and degradable packaging bag	0.0106	28
		Proportion of Low-carbon transport (C5)	CLEMF (2011), Zhang (2017)	%	0.0632	4
		Proportion of low-carbon tourism attractions (C6)	Expert interviews	%	0.0289	14
	Low-carbon input (B2) (0.0633)	Ratio of investment in low-carbon (C7)	Cheng et al. (2013)	%	0.0426	10
		Low-carbon marketing (C8)	Expert interviews	% of network marketing expenditure	0.0207	18
	Tourism Development (B3) (0.0395)	Tourist growth rate (C9)	Expert interviews	% of tourist volume growth	0.0317	12
		Tourism congestion index (C10)	Expert interviews	Ratio of tourist volume to population	0.0078	30
Low-carbon tourism environment (A2) (0.6086)	Low-carbon environment (B4) (0.1929)	Tourism carbon intensity (C11)	Xu et al. (2011), Zhou et al. (2015), Zhang (2017)	Ton CO_2/1000 USD tourism revenue	0.0620	5
		Tourism carbon footprint (C12)	Expert interviews	Ton CO_2/thousand visitor days	0.0448	7
		Renewable energy usage (C13)	CLEMF (2011), Cheng et al. (2013), Chen and Zhu (2013), Zhou et al. (2015), Tan et al. (2017)	% of total renewable energy usage	0.0437	9
		Tourism energy intensity (C14)	Guo et al. (2018), Chen and Zhu (2013)	10^3MJ/1000 USD tourism revenue	0.0243	17
		Ratio of green space (C15)	CLEMF (2011), Cheng et al. (2013), Guo et al. (2018), Y. He et al. (2018), Yao et al. (2014)	%	0.0181	21
	Ecological environment (B5) (0.3310)	Air pollution index (C16) 85.75%	Zhou et al. (2015), CLEMF (2011), Zhang (2017)	percentage of total days with excellent[1] air quality per year	0.0781	2
		Surface water quality (C17)	Cheng et al. (2013), Zhou et al. (2015), Zhang (2017)	Percentage of total surface water meeting Chinese Grade III or above	0.0666	3
		Noise pollution level (C18)	Guo et al. (2018)	Ratio of average nose value meeting Chinese Level II	0.0150	22
		Trash management (C19)	Yao et al. (2014), Chang, and Dong (2016), Zhang (2017), Tan et al. (2017)	% of total trash	0.0280	15
		Sewage treatment (C20)	Zhou et al. (2015), Yao et al. (2014), Chang, and Dong (2016), Zhang (2017), Tan et al. (2017)	% of total sewage	0.0465	6
		Monitoring system of ecological environment (C21)	Cheng et al. (2013), Gagliardi et al. (2007)	Percentage of working environmental monitoring stations per year	0.0968	1
	Low-carbon facilities (B6) (0.0847)	Public infrastructure construction for low-carbon (C22)	Luo et al. (2014), Zinatizadeh et al. (2017)	% of investment of GDP	0.0444	8
		Water-saving technology adoption (C23)	Zhou et al. (2015), Zhang (2017)	% of recycled water use	0.0207	19
		Low-carbon guiding signs (C24)	Cheng et al. (2013)	% of signs coverage in destination	0.0077	31
		Usage of low-carbon materials (C25)	Cheng et al. (2013)	% of energy-saving and environmental-protecting materials	0.0119	26
Low-carbon tourism society (A3) (0.1192)	Low-carbon idea (B7) (0.0662)	Education of low-carbon environment (C26)	Cheng et al. (2013), Zhang (2017)	0-100 scores	0.0272	16
		Communication of low-carbon (C27)	CLEMF (2011),	0-100 scores	0.0144	23
		Carbon literacy of residents (C28)	Cheng et al. (2013), Expert interviews	0-100 scores	0.0052	33
		Carbon literacy of tourists (C29)	Cheng et al. (2013), Expert interviews	0-100 scores	0.0075	32
		Carbon literacy of tourism enterprises (C30)	Cheng et al. (2013), Horng et al. (2013)	0-100 scores	0.0119	27
	Low-carbon management (B8) (0.0530)	Low-carbon policy & legislation (C31)	Wang et al. (2015), Zhang (2017), Lo (2014), Liu and Qin (2016)	0-100 scores	0.0316	13
		Special plans for low-carbon tourism (C32)	CLEMF (2011), Cheng et al. (2013), Zhou et al. (2015), Zhang (2017)	0-100 scores	0.0131	24
			Tsai and Chang (2015)	0-100 scores	0.0083	29

Table 2 (*continued*)

Dimensions (weights)	Second-level indicators (weights)	Third-level indicators	References	Unit	Integrated weights	
					Weights	Ranking
		Low-carbon technology (C33)				

Note: 1 “Excellent” means that the PM2.5 (i.e., particulate matter< 2.5 mm in diameter) index is less than 50.

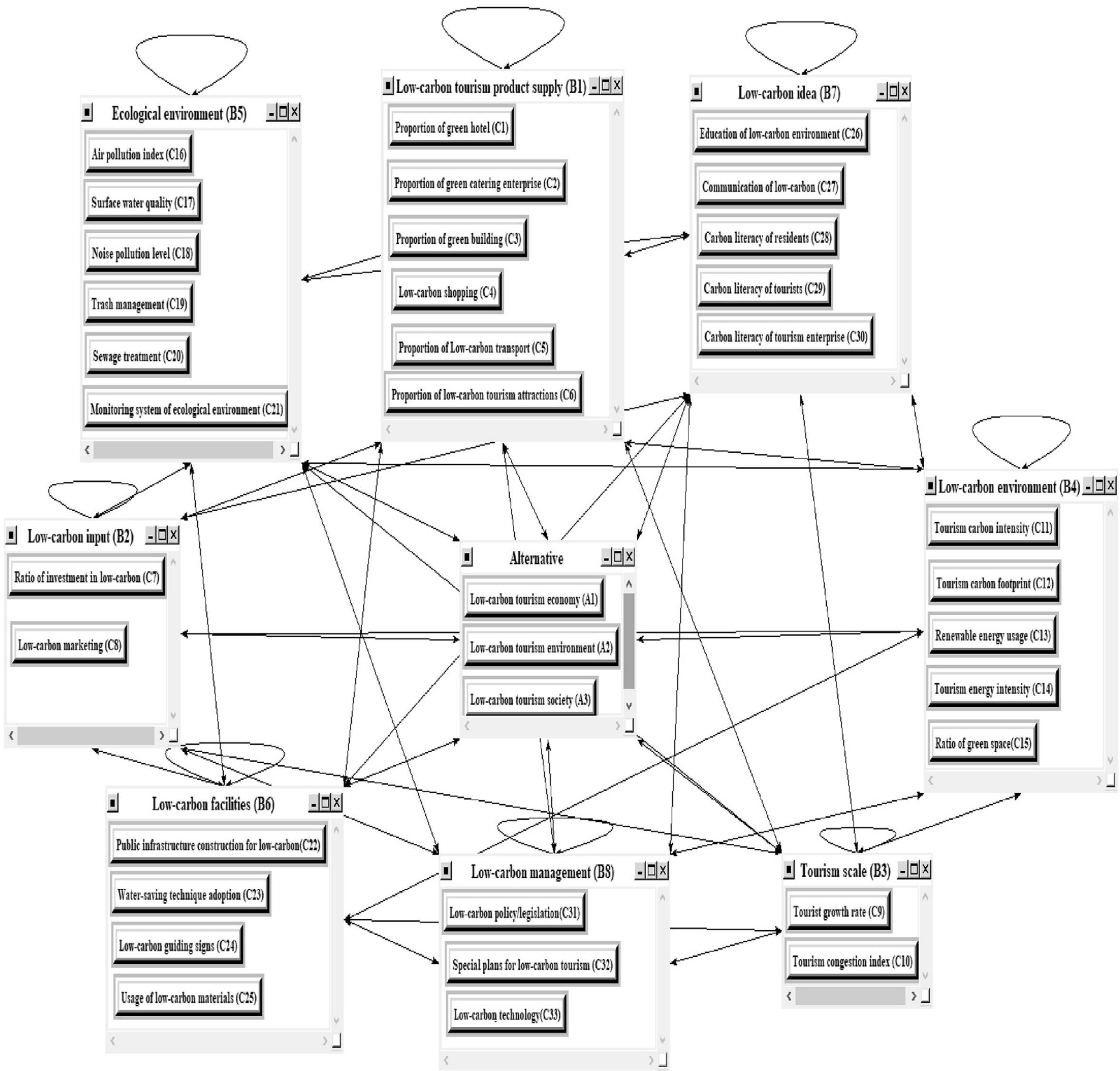

Fig. 2. ANP network model for evaluating low-carbon tourism.

governance after pollution has already occurred (Zhang, 2017). The relatively high weight of the air quality index highlights the importance attached by experts to air quality. Similarly, surface water quality is also assigned a higher weight. The weights allocated to trash management (0.0280) and sewage treatment (0.0465) are higher than those of the majority of indicators. All of these weights indicate that the panel of experts is concerned with the fact that TBUD’s natural environment may be endangered in the process of low-carbon tourism development. Transport, the important component CO_2 emissions in tourist destinations is, of course, attached to a higher weight.

As simultaneously shown in Table 2, the average weight of the indicators involved in a low-carbon society is lower than that in a low-carbon economy and low-carbon environment. It would appear that the development of low-carbon tourism should be more driven by the government, as reflected in the relatively high weights of economic and environmental indicators. In this context, and at the current stage of development, social indicators cannot work significantly. That is to say, most of the social indicators are not a priority for the development of low-carbon tourism in a TBUD. However, considering the functional mechanism of the social indicators themselves (whether the popularization of education, dissemination of ideas or improvement of literacy, which are all long-term processes), in the long run, these social indicators are expected to have more positive impacts on TBUD's low-carbon tourism development. With respect to the eight indicators pertaining to a low-carbon society, education of low-carbon environment (C26) (0.0272) possesses the highest weight, ranking 16th out of all 33 evaluation indicators, while residents' carbon literacy (C28) (0.0052) and the carbon literacy of tourists (C29) (0.0075) rank last. Therefore, in terms of the current humanistic environment in which low-carbon tourism is being developed, the experts consulted preferred to acknowledge the role of low-carbon education.

5. Case studies

5.1. Study area

This study takes Lhasa and Guilin in China as the case study regions. Lhasa is a city with the ambition of becoming an important world tourism center (Zhang, 2017). Lhasa has vigorously promoted its image as a clean energy 'demonstration city' and build a low-carbon tourism city as soon as possible. Guilin is a China's Sustainable Development Agenda Innovation Demonstration Area, the National Tourism Innovation and Development Pioneer Zone, the Demonstration Area Built as a World-Class Tourism Destination, and is also the permanent host of the UNWTO (United Nations World Tourism Organization)/APTA (Asia Pacific Tourism Association) International Forum on Tourism Trends and Prospects. Both Lhasa and Guilin are the representative TBUDs. Given that Lhasa's tourism activities and the resulting CO_2 emissions and energy consumption are concentrated in the urban area, where tourist reception accounted for 92.7% of Lhasa's total reception in 2016 according to Lhasa Tourism Development Commission, this study selected the urban area of Lhasa, namely Chengguan District, Doilungdeqen District and Dagze District, and Guilin to explore the evaluation of low-carbon development in the typical TBUDs.

5.2. Evaluation results and policy implications

In order to directly score every evaluation indicator in Table 2, this study applied the benchmarks to the selected 33 final indicators; see columns 2, 3, 5 and 6 of Table 3. Columns 2 and 5 represent the benchmark values and columns 3 and 6 indicate the source. Out of all 33 indicators, the tourist growth rate (C9), tourism congestion index (C10), tourism carbon intensity (C11), tourism carbon footprint (C12), and tourism energy intensity (C14) were negative.

Additional opinions of the 11 experts had been used to evaluate the progress of Lhasa and Guilin in each indicator to obtain the normalized scores. Each indicator was divided into four levels: poor low-carbon tourism development, moderate low-carbon tourism development, good low-carbon tourism development, and excellent low-carbon tourism development. Referring to the chosen benchmark values, the normalized score presented by the experts associated with the respective levels are as follows: [0, 0.25), [0.25, 0.5), [0.5,0.75), [0.75,1]. The final normalized score for each indicator was set to be the average of the 11 experts' judgments.

All the original scores, normalized score and data source of the 33 evaluation indicators can be seen in Table S6 in the online supplementary material.

For measuring the development level of low-carbon tourism in Lhasa's urban area, this study referred to Cheng et al. (2013) to divide the development of low-carbon urban destinations into four levels: excellent low-carbon tourism development, relatively good low-carbon tourism development, insufficient low-carbon tourism development, and poor low-carbon tourism development. These levels of development respectively correlate with the maturity stage, development stage, involvement stage, and exploration stage, as proposed by Cho et al. (2016). These four levels were found to be successively in line with the composite scores range (0.85, 1], (0.7, 0.85], (0.5, 0.7], and (0, 0.5].

Supposing that the composite score of low-carbon tourism development is G, the weight of the nth evaluation indicator is W_n and the final score of the *nth* evaluation indicator is F_n, then

$$G = \sum_{n=1}^{33} W_n F_n \tag{3}$$

Using the data collection method for each indicator given in Table 3, this study obtained the raw data pertaining to each indicator in 2016. Following this, the normalized scores of all the indicators (see Table S6) were calculated based on the 11 experts' judgments. Eventually, the composite scores of the level of low-carbon tourism development in Lhasa and Guilin were obtained using Eq. (3). The results are shown in columns 4 and 7 of Table 3.

The composite score 0.6375 of Lhasa and 0.7510 of Guilin were finally obtained, respectively. These figures mean that the current level of development of Lhasa's low-carbon tourism is insufficient, or is at the involvement stage, while Guilin's low-carbon tourism is good. Concretely speaking, Lhasa's "*eco-environment has started gaining attention, as has low-carbon tourism. An active transformation towards a green economy is publicly gaining momentum*" (Cho et al., 2016). Table S6 indicates that the six indicators with respect to the ecological environment had higher normalized scores. Specifically, the noise pollution level (C18) (1) and the monitoring system of ecological environment (C21) (1) emerged as having the highest scores. It is noteworthy that Lhasa's official position has always been as an ecotourism focused city geographically located on a plateau, with its ecological environment being relatively fragile (Zhang et al., 2015); thus, the ecological environment has always been a key focus of Lhasa's urban development. However, this study found the performance of some of the indicators closely related to CO_2 emissions to be generally poor. Specially, the normalized score with respect to the ratio of investment in low-carbon was only 0.09, the proportion of green hotels (C1) was 0.28, the proportion of green catering enterprises (C2) was 0.13, and the proportion of low-carbon tourism attractions (C6) was 0.25.

Although the tourism carbon intensity (C11) (0.81), tourism carbon footprint (C12) (0.69) and tourism energy intensity (C14) (0.70) showed a relatively good performance, there is still a big gap evident (26.11%, 24.43% and 25.90% gap, respectively) between the current values and 2020 target values. Bridging this gap may generate huge economic costs, especially given estimates that a 20% or 30% carbon emissions reduction in China would lead to a 6.11% or 14.86% fall in nominal GDP, respectively (Guo et al., 2014). Lhasa's urban area is also sure to encounter this kind of problem. As such, it will be very difficult to achieve the carbon intensity target by 2020. The same difficulty will be involved in tourism carbon footprint and energy intensity. In addition, the normalized scores of those indicators in terms of low-carbon facilities, low-carbon ideas and low-carbon management, which are conducive to the improvement of low-carbon tourism development, are far lower than those of indicators with respect to the ecological environment. Therefore, the level of Lhasa's low-carbon tourism development seems extremely poor if limiting the evaluation indicators to pure "low-carbon" criteria. More efforts should thus be made in all aspects of developing low-carbon tourism in Lhasa's urban area.

Table 3
Benchmarks of evaluation indicators and evaluation results.

Indicators	Lhasa			Guilin			Properties
	Benchmark		Final scores	Benchmark		Final scores	
	Value	Source		Value	Source		
Proportion of green hotel[1](C1)	100%	Expert team decision	0.0098	100%	Expert team decision	0.0171	Positive
Proportion of green catering enterprise (C2)	100%	Expert team decision	0.0016	100%	Expert team decision	0.0042	Positive
Proportion of green building[2] (C3)	40%	Lhasa Energy Development Plan, 2020 target	0.0034	60%	The 13th Five-year Plan for Energy Development in Guilin, 2020 target	0.0110	Positive
Low-carbon shopping (C4)	100%	Expert team decision	0.0086	100%	Expert team decision	0.0074	Positive
Proportion of Low-carbon transport (C5)	90%	Lhasa Energy Development Plan, 2020 target	0.0228	95%	The 13th Five-year Plan for Energy Development in Guilin, 2020 target	0.0575	Positive
Proportion of low-carbon tourism attractions (C6)	100%	Expert team decision	0.0072	100%	Expert team decision	0.0136	Positive
Ratio of investment in low-carbon (C7)	10%	Expert team decision, 2020 target	0.0038	20%	Expert team decision, 2020 target	0.0166	Positive
Low-carbon marketing (C8)	60%	Expert team decision, 2020 target	0.0110	80%	Expert team decision, 2020 target	0.0143	Positive
Tourist growth rate (C9)	≤10%	Expert team decision, 2020 target	0.0231	≤10%	Expert team decision, 2020 target	0.0114	Negative
Tourism congestion index (C10)	≤10	Expert team decision, 2020 target; Zhang (2016)	0.0045	≤20	Expert team decision, 2020 target	0.0078	Negative
Tourism carbon intensity (C11)	≤0.150	Zhang (2017)	0.0502	≤0.200	Expert team decision	0.0453	Negative
Tourism carbon footprint (C12)	≤30	Expert team decision, 2020 target	0.0309	≤30	Expert team decision, 2020 target	0.0251	Negative
Renewable energy usage (C13)	55%	Lhasa Energy Development Plan, 2020 target	0.0315	60%	The 13th Five-year Plan for Energy Development in Guilin, 2020 target	0.0284	Positive
Tourism energy intensity (C14)	≤5	Expert team decision, 2020 target	0.0170	≤6	Expert team decision, 2020 target	0.0180	Negative
Ratio of green space (C15)	42%	Lhasa 13th Five-Year Plan, 2020 target	0.0129	70%	Guilin 13th Five-Year Plan, 2020 target	0.0167	Positive
Air pollution index (C16)	100%	Expert team decision	0.0711	100%	Expert team decision	0.0734	Positive
Surface water quality (C17)	100%	Expert team decision	0.0639	100%	Expert team decision	0.0639	Positive
Noise pollution level (C18)	100%	Expert team decision	0.0150	100%	Expert team decision	0.0150	Positive
Trash management (C19)	100%	Expert team decision	0.0171	100%	Expert team decision	0.0224	Positive
Sewage treatment (C20)	100%	Expert team decision	0.0377	100%	Expert team decision	0.0423	Positive
Monitoring system of ecological environment (C21)	100%	Expert team decision	0.0968	100%	Expert team decision	0.0968	Positive
Public infrastructure construction for low-carbon (C22)	5%	Expert team decision, 2020 target	0.0004	8%	Expert team decision, 2020 target	0.0240	Positive
Water-saving technology adoption (C23)	30%	Expert team decision	0.0058	50%	Expert team decision	0.0095	Positive
Low-carbon guiding signs (C24)	100%	Expert team decision	0.0028	100%	Expert team decision	0.0060	Positive
Usage of low-carbon materials (C25)	100%	Expert team decision	0.0049	100%	Expert team decision	0.0062	Positive
Education of low-carbon environment (C26)	100	Expert team decision	0.0160	100	Expert team decision	0.0237	Positive
Communication of low-carbon (C27)	100	Expert team decision	0.0101	100	Expert team decision	0.0108	Positive
Carbon literacy of residents (C28)[3]	100	Expert team decision	0.0043	100	Expert team decision	0.0042	Positive
Carbon literacy of tourists (C29)[4]	100	Expert team decision	0.0056	100	Expert team decision	0.0056	Positive
Carbon literacy of tourism enterprise (C30)[5]	100	Expert team decision	0.0098	100	Expert team decision	0.0090	Positive
Low-carbon policy & legislation (C31)	100	Expert team decision	0.0218	100	Expert team decision	0.0262	Positive
Special plans for low-carbon tourism (C32)	100	Expert team decision	0.0086	100	Expert team decision	0.0098	Positive
Low-carbon technology (C33)	100	Expert team decision	0.0076	100	Expert team decision	0.0077	Positive

By contrast, Guilin's low-carbon tourism is in the development stage as Cho et al. (2016) mentioned. Table S6 shows that nine indicators are having higher normalized scores that are more than 0.9. Specifically, the tourism congestion index (C10), noise pollution level (C18) (1.0000) and monitoring system of ecological environment (C21) (1.0000) emerged as having the highest scores. As a China's Sustainable Development Agenda Innovation Demonstration Area, Guilin's ecological environment has always been a key focus of urban development as well. This study found the performance of the indicators closely related to the natural environment to be generally high. Most of these indicators score higher than those in Lhasa. Also, some indicators score relatively low in Guilin. For instance, the normalized score with respect to the proportion of green hotel (C1)was only 0.49, the proportion of green catering enterprise (C2) was 0.35, the ratio of investment in low-carbon (C7) was 0.39, the tourist growth rate (C9) was 0.36, and the water-saving technology adoption (C23) was 0.46. It is noteworthy that although the development level Guilin's low-carbon tourism is good, it still scored poorly on several indicators closely associated with low carbon including the tourism carbon intensity (C12) (0.73), tourism carbon footprint (C13) (0.56), renewable energy usage (C13) (0.65), and tourism energy intensity (C14) (0.73).

Taken together, this study addresses some key policy implications as follows:

First, on the basis of the traditional investment in the ecological environmental protection, it is recommended to increase investment in low-carbon infrastructure as well as popularize low-carbon materials and low-carbon labels in the tourism industry and even all walks of life. Second, it is suggested to spread low-carbon ideas among the stakeholders of tourism development and in turn improve the low-carbon literacy of these groups. Furthermore, tourism practitioners, including administrators, especially employees of tourism enterprises, should be continuously educated on low-carbon, and the negative effects of climate change on tourism development, so as to form a low-carbon cultural atmosphere in the whole society. Third, it is required to formulate and especially implement relevant policies and legislations and regulations for low-carbon development as soon as possible, and draw up low-carbon tourism development plan or revise the current tourism plans to reflect the ideas of low-carbon development, so as to guide low-carbon behavior. In addition, low-carbon technologies should be actively promoted in tourism carbon-intensive sectors such as accommodation and transportation, as well as new and sustainable energy such as solar energy, wind energy and hydro-energy should be popularized.

6. Conclusions and discussion

Previous studies have indicated that the construction of low-carbon tourism cities is an important move if the tourism industry is to achieve the goal of reducing CO_2 emissions or play an important role in the process of achieving a low-carbon society (Shen et al., 2015; Xu et al., 2011). Based on the evaluation of sustainable cities, low-carbon cities, sustainable urban tourism and low-carbon tourism, this study constructed an evaluation index that could be applied to TBUDs. This paper has arguably demonstrated some pioneering work in both the selection and the weight-setting of evaluation indicators. In the cases of Lhasa and Guilin, the results indicate different levels of low-carbon tourism development.

Regarding the selection of evaluation indicators, although as the review above, there are a large number of evaluation studies on low-carbon and sustainable cities, this study focuses more on highlighting the performance of tourism-related indicators due to the difference in emphases, namely that this study mainly focuses on low-carbon tourism, while other studies cover the entire economic system. Moreover, the evaluation indicators in this study are limited to tourism-based urban destinations, rather than being more general in the same way as existing studies that consider cities in the general sense. It is precisely because of the tourism characteristics that this study highlights the importance of CO_2 emissions and energy consumption in hotels, tourist attractions and other tourism enterprises in terms of low-carbon economic and environmental indicators. Similarly, this study highlights the low-carbon literacy of tourism stakeholders including residents, tourist and tourism enterprises in a low-carbon society.

Compared with studies on urban sustainable tourism evaluation such as Pérez et al. (2016) and Blancas et al. (2016), the indicators presented in this study highlight low-carbon characteristics, which are reflected in carbon intensity, energy intensity and low-carbon literacy. As indicated in the review section, few studies have focused on the evaluation of low-carbon tourism. An exceptional example is Zhang (2017) who evaluated the low-carbon tourism development strategy. The author finally ranked the priorities of regional low-carbon tourism strategies through the setting of evaluation indicators. This study further pioneered in terms of indicators through expanding the 15 indicators of Zhang (2017) to 33 indicators and emphasizes the importance of economic development for low-carbon tourism, thus more comprehensively reflecting the level of urban low-carbon tourism development.

Regarding the weight determination method, in the evaluation of low-carbon development and sustainability, the most popular approaches are AHP (Cho et al., 2016; Hsiao, 2016) and Entropy method (Chang and Dong, 2016; Shen et al., 2015b; Zinatizadeh et al., 2017). However, this study takes into account the network relationships among the indicators and the adjacent levels as shown in Table S3, thus choosing the ANP method to define the weight of each indicator. The Entropy method tends to ignore the importance of the indicator itself, as well as the interdependence between the different indicators. As an evolutionary version of AHP, ANP possesses the great advantage that considers the interdependence between different indicators or adjacent levels and could use super-matrix to comprehensively analyze all the indicators so as to obtain the integrated weights of these indicators.

The main contribution of the current study is that, for the first time, an index system has been implemented that evaluates the low-carbon development of a TBUD using a combination of the qualitative and quantitative FDM-ANP approach. The network evaluation model constructed for this research enabled the conversion of the abstract concept of low-carbon tourism city development into concrete indicators. The evaluation model also made it possible to convert the subjective qualitative characteristics of low-carbon tourism, the implied mutual influences between the numerous indicators, and development demands into integrated quantitative values to guide actual low-carbon tourism development.

The research process shows that the constructed indicators (and weightings) have a wider relevance than China. Because, for one thing, the initial indicators system was determined referring to the research worldwide; for another, the selected experts of FDM are from multi countries and regions including Australia, European Union, and China. The ANP process was also carried out by the same panel of experts. Therefore, without loss of generality, the evaluation model could be applicable for not only China but also all the tourism-based urban destinations worldwide.

Some limitations are highlighted here and some improvements are possible for future studies. First, the choice of triangular fuzzy numbers is based on experience. However, changing such numbers would change the final results of selecting the evaluation indicators for low-carbon urban tourism. Therefore, future sensitivity analysis should have been performed to ensure the robustness of indicator selection. Second, More empirical research is needed to prove the applicability of our model in future studies. Of course, this requires re-determining the benchmarks based on comprehensive data analysis in other regions, so as to obtain the evaluation results suitable for the particular case.

CRediT authorship contribution statement

Jiekuan Zhang: Writing - original draft, Conceptualization. **Yan Zhang:** Writing - original draft, Conceptualization, Data curation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was financially supported by the National Natural Science Foundation of China under Grant (71764027, 41801137) and Improvement Project of Young and Middle-aged Teachers' Research Ability in Guangxi's Colleges under Grant (2020KY22018).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2020.124303.

References

Ben-Dalia, S., Collins-Kreiner, N., Churchman, A., 2013. Evaluation of an urban tourism destination. Tourism Geogr. 15 (2), 233–249.
Blancas, F.J., Lozano-Oyola, M., González, M., Caballero, R., 2016. Sustainable tourism

composite indicators: a dynamic evaluation to manage changes in sustainability. J. Sustain. Tourism 24 (10), 1403–1424.
Braulio-Gonzalo, M., Bovea, M.D., Ruá, M.J., 2015. Sustainability on the urban scale: proposal of a structure of indicators for the Spanish context. Environ. Impact Assess. Rev. 53, 16–30.
Camagni, R., Capello, R., Nijkamp, P., 1998. Towards sustainable city policy: an economy-environment technology nexus. Ecol. Econ. 24 (1), 103–118.
Chang, Y.Z., Dong, S.C., 2016. Evaluation of sustainable development of resources-based cities in Shanxi Province based on unascertained measure. Sustainability 8 (6), 585.
Chen, F., Zhu, D., 2013. Theoretical research on low-carbon city and empirical study of Shanghai. Habitat Int. 37, 33–42.
Cheng, Q., Su, B., Tan, J., 2013. Developing an evaluation index system for low-carbon tourist attractions in China– A case study examining the Xixi Wetland. Tourism Manag. 36 (3), 314–320.
China Low-carbon Economy Media Federation, 2011. Evaluation system of China low-carbon cities (in China). http://www.clemf.com/productshop.asp?id=2117.
Cho, Y.J., Wang, Y., Hsu, L.L.I., 2016. Constructing Taiwan's low-carbon tourism development suitability evaluation indicators. Asia Pac. J. Tourism Res. 21 (6), 658–677.
Dwyer, L., Forsyth, P., Spurr, R., Hoque, S., 2013. Economic impacts of a carbon tax on the Australian tourism industry. J. Trav. Res. 52 (2), 143–155.
Fang, D., Chen, B., Hayat, T., Alsaedi, A., 2017. Emergy evaluation for a low-carbon industrial park. J. Clean. Prod. 163, S392–S400.
Gagliardi, F., Roscia, M., Lazaroiu, G., 2007. Evaluation of sustainability of a city through fuzzy logic. Energy 32 (5), 795–802.
Ghalib, A., Qadir, A., Ahmad, S.R., 2017. Evaluation of developmental progress in some cities of Punjab, Pakistan, using urban sustainability indicators. Sustainability 9 (8), 1473.
Gössling, S., Broderick, J., Upham, P., Ceron, J.P., Dubois, G., Peeters, P., Strasdas, W., 2007. Voluntary carbon offsetting schemes for aviation: efficiency, credibility and sustainable tourism. J. Sustain. Tourism 15 (3), 223–248.
Guo, H., Yang, C., Liu, X., Li, Y., Meng, Q., 2018. Simulation Evaluation of Urban Low-Carbon Competitiveness of Cities within Wuhan City Circle in China. Sustainable Cities and Society. https://doi.org/10.1016/j.scs.2018.04.030.
Guo, Z., Zhang, X., Zheng, Y., Rao, R., 2014. Exploring the impacts of a carbon tax on the Chinese economy using a CGE model with a detailed disaggregation of energy sectors. Energy Econ. 45, 455–462.
Hara, M., Nagao, T., Hannoe, S., Nakamura, J., 2016. New key performance indicators for a smart sustainable city. Sustainability 8 (3), 206.
He, P., He, Y., Xu, F., 2018. Evolutionary analysis of sustainable tourism. Ann. Tourism Res. 69, 76–89.
He, Y., Huang, P., Xu, H., 2018. Simulation of a dynamical ecotourism system with low carbon activity: a case from western China. J. Environ. Manag. 206, 1243–1252.
Hodson, M., Marvin, S., 2010. World Cities and Climate Change: Producing Ecological Security. McGraw Hill.
Horng, J.S., Hu, M.L.M., Teng, C.C.C., Hsiao, H.L., Liu, C.H.S., 2013. Development and validation of the low-carbon literacy scale among practitioners in the Taiwanese tourism industry. Tourism Manag. 35, 255–262.
Hsiao, T.Y., 2016. Developing a dual-perspective low-carbon tourism evaluation index system for travel agencies. J. Sustain. Tourism 24 (12), 1604–1623.
Juvan, E., Dolnicar, S., 2016. Measuring environmentally sustainable tourist behaviour. Ann. Tourism Res. 59, 30–44.
Khanna, N., Fridley, D., Hong, L., 2014. China's pilot low-carbon city initiative: a comparative assessment of national goals and local plans. Sustain. Cities Soc. 12, 110–121.
Kuo, Y.F., Chen, P.C., 2008. Constructing performance appraisal indicators for mobility of the service industries using Fuzzy Delphi Method. Expert Syst. Appl. 35 (4), 1930–1939.
Lee, C.F., Huang, H.I., Yeh, H.R., 2010. Developing an evaluation model for destination attractiveness: sustainable forest recreation tourism in Taiwan. J. Sustain. Tourism 18 (6), 811–828.
Lee, J.W., Brahmasrene, T., 2013. Investigating the influence of tourism on economic growth and carbon emissions: evidence from panel analysis of the European Union. Tourism Manag. 38, 69–76.
Liu, W., Qin, B., 2016. Low-carbon city initiatives in China: a review from the policy paradigm perspective. Cities 51 (12), 131–138.
Lo, K., 2014. China's low-carbon city initiatives: the implementation gap and the limits of the target responsibility system. Habitat Int. 42, 236–244.
Luo, Y., Jin, M., Ren, P., Liao, Z., Zhu, Z., 2014. Simulation and prediction of decarbonated development in tourist attractions associated with low-carbon economy. Sustainability 6 (4), 2320–2337.
Mori, K., Christodoulou, A., 2012. Review of sustainability indices and indicators: towards a new City Sustainability Index (CSI). Environ. Impact Assess. Rev. 32 (1), 94–106.
Murray, T.J., Pipino, L.L., van Gigch, J.P., 1985. A pilot study of fuzzy set modification of Delphi. Hum. Syst. Manag. 5 (1), 76–80.
Oregi, X., Pousse, M., Mabe, L., Escudero, A., Mardaras, I., 2016. Sustainability assessment of three districts in the city of Donostia through the NEST simulation tool. Nat. Resour. Forum 40 (4), 156–168.
Pérez, V., Hernández, A., Guerrero, F., León, M.A., Da Silva, C.L., Caballero, R., 2016. Sustainability ranking for Cuban tourist destinations based on composite indexes. Soc. Indicat. Res. 129 (1), 425–444.
Phdungsilp, A., 2010. Integrated energy and carbon modeling with a decision support system: policy scenarios for low-carbon city development in Bangkok. Energy Pol. 38 (9), 4808–4817.
Saaty, T.L., 1996. Decision Making with Dependence and Feedback: the Analytical Hierarchy Process. RWS Publications, Pittsburgh.
Savage, V.R., Huang, S., Chang, T.C., 2004. The Singapore River thematic zone: sustainable tourism in an urban context. Geogr. J. 170 (3), 212–225.
Seetaram, N., Song, H., Ye, S., Page, S., 2018. Estimating willingness to pay air passenger duty. Ann. Tourism Res. 72, 85–97.
Shen, L., Wu, Y., Lou, Y., Zeng, D., Shuai, C., Song, X., 2018. What drives the carbon emission in the Chinese cities?—a case of pilot low carbon city of Beijing. J. Clean. Prod. 174, 343–354.
Shen, L., Zhou, J., Skitmore, M., Xia, B., 2015b. Application of a hybrid Entropy–McKinsey Matrix method in evaluating sustainable urbanization: a China case study. Cities 42, 186–194.
Shen, P., Wu, C., Wang, Z., Lv, T., You, H., 2015a. The influence factor of low-carbon urban construction land use in tourism city based on PCA analysis: a case study of hangzhou city. In: Proceedings of the 19th International Symposium on Advancement of Construction Management and Real Estate. Springer Berlin Heidelberg.
Su, M., Li, R., Lu, W., Chen, C., Chen, B., Yang, Z., 2013. Evaluation of a low-carbon city: method and application. Entropy 15 (4), 1171–1185.
Tan, S., Yang, J., Yan, J., Lee, C., Hashim, H., Chen, B., 2017. A holistic low carbon city indicator framework for sustainable development. Appl. Energy 185, 1919–1930.
Theodoridou, I., Papadopoulos, A.M., Hegger, M., 2012. A feasibility evaluation tool for sustainable cities–A case study for Greece. Energy Pol. 44 (5), 207–216.
Tian, J., Andraded, C., Lumbreras, J., Guan, D., Wang, F., Liao, H., 2018. Integrating sustainability into city-level CO2 accounting: social consumption pattern and income distribution. Ecol. Econ. 153, 1–16.
Trappey, A.J., Trappey, C., Hsiao, C., Ou, J.J., Li, S., Chen, K.W., 2012. An evaluation model for low carbon island policy: the case of Taiwan's green transportation policy. Energy Pol. 45, 510–515.
Tsai, M.S., Chang, S.L., 2015. Taiwan's 2050 low carbon development roadmap: an evaluation with the MARKAL model. Renew. Sustain. Energy Rev. 49, 178–191.
Tseng, M.L., Wu, K.J., Lee, C.H., Lim, M.K., Bui, T.D., Chen, C.C., 2018. Assessing sustainable tourism in Vietnam: a hierarchical structure approach. J. Clean. Prod. 195, 406–417.
Wang, W.M., Lee, A.H., Chang, D.T., 2010. An integrated FDM–ANP evaluation model for sustainable development of housing community. Optim. Lett. 4 (2), 239–257.
Wang, W.M., Lee, A.H., Peng, L.P., Wu, Z.L., 2013. An integrated decision making model for district revitalization and regeneration project selection. Decis. Support Syst. 54 (2), 1092–1103.
Wang, Y., Song, Q., He, J., Qi, Y., 2015. Developing low-carbon cities through pilots. Clim. Pol. 15 (Suppl.1), S81–S103.
Whitehead, M., 2003. (Re) analysing the sustainable city: nature, urbanisation and the regulation of socio-environmental relations in the UK. Urban Stud. 40 (7), 1183–1206.
Xu, J., Yao, L., Mo, L., 2011. Simulation of low-carbon tourism in world natural and cultural heritage areas: an application to Shizhong District of Leshan City in China. Energy Pol. 39 (7), 4298–4307.
Yang, X., Li, R., 2018. Investigating low-carbon city: empirical study of Shanghai. Sustainability 10 (4), 1054.
Yang, Y., Zhang, H., Xiong, W., Zhang, D., Zhang, X., 2018. Regional power system modeling for evaluating renewable energy development and CO_2 emissions reduction in China. Environ. Impact Assess. Rev. 73, 142–151.
Yao, L., Xu, J., Li, Y., 2014. Evaluation of the efficiency of low carbon industrialization in cultural and natural heritage: taking Leshan as an example. Sustainability 6 (6), 3825–3842.
Zamfir, A., Corbos, R.A., 2015. Towards sustainable tourism development in urban areas: case study on Bucharest as tourist destination. Sustainability 7 (9), 12709–12722.
Zhang, J.K., 2016. Weighing and realizing the environmental, economic and social goals of tourism development using an analytic network process-goal programming approach. J. Clean. Prod. 127, 262–273.
Zhang, J.K., 2017. Evaluating regional low-carbon tourism strategies using the fuzzy Delphi-analytic network process approach. J. Clean. Prod. 141, 409–419.
Zhang, J.K., Zhang, Y., 2018. Carbon tax, tourism CO_2 emissions and economic welfare. Ann. Tourism Res. 69, 18–30.
Zhang, J.K., Ji, M., Zhang, Y., 2015. Tourism sustainability in Tibet–Forward planning using a systems approach. Ecol. Indicat. 56, 218–228.
Zhou, G., Singh, J., Wu, J., Sinha, R., Laurenti, R., Frostell, B., 2015. Evaluating low-carbon city initiatives from the DPSIR framework perspective. Habitat Int. 50, 289–299.
Zhou, N., He, G., Williams, C., 2012. China 's Development of Low-Carbon Eco-Cities and Associated Indicator Systems. Lawrence Berkeley National Laboratory.
Zhou, N., He, G., Williams, C., Fridley, D., 2015. ELITE cities: a low-carbon eco-city evaluation tool for China. Ecol. Indicat. 48, 448–456.
Zinatizadeh, S., Azmi, A., Monavari, S.M., Sobhanardakani, S., 2017. Evaluation and prediction of sustainability of urban areas: a case study for Kermanshah city, Iran. Cities 66, 1–9.