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A Survey of Isfahan among Low Carbon Cities in the World

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ABSTRACT

Cities consume a considerable amount of fusil fuels energy and as a result emit carbon dioxide significantly. Developing a carbon emission assessment system for low carbon urban planning has become an important approach for reducing carbon emissions and achieving low carbon eco-city development goals. Analysis of LCC (Low Carbon City) indices of the city of Isfahan and its comparison, via TOPSIS algorithm, with the cities of Beijing and Stockholm shows that this city is not in a good position regarding its ranking among the industrial low-carbon cities. Excessive use of fossil fuels and not utilizing renewable energies are the main reasons for the low rank of Isfahan among the other cities in the world. Dealing with the challenges ahead of developing of an Iranian low carbon Eco-city discussed in this paper is critical. However, the results of this study indicate that the occurrence of some of these challenges is inevitable in the process of achieving a low carbon and sustainable urban development. Moreover, a basic understanding of LCC not only minimizes energy use and natural resources but also contributes to social development, environmental protection and improving the quality of life in Isfahan.

Keywords: *Keywords: Eco-City – Carbon emission- Urban Energy Management-TOPSIS algorithm*

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1. INTRODUCTION

Nowadays, cities consume two-thirds of the world's energy and emit more than 70 % of the world's energy-related carbon dioxide (Rudolph and Kawakatsu, 2012). In other words, cities as the main economic development unit and the stimulus to future growth should play an important role in low carbon development. Climate change has destructive effects on cities as these changes affect a large proportion of urban assets and populations (Su et al., 2013; Gomi and Shimada, 2010). Hence, cities play an important role in achieving sustainable development worldwide (Shuai et al., 2017). Concerns over the lack of sustainability of contemporary urban patterns have increased in several directions and raised significant questions about the connections existing between urban regeneration and the transformation of societies, economies, and environmental systems (Cugurullo, 2016).

Over time, with the development of understanding the social changes and the impact of human on health, environmental and economic, the term "eco-city" and similar concepts like the "green city" and "sustainable city" have been presented (Zhou et al., 2015). However, there are no precise definitions and descriptions on the eco-city (De Jong et al., 2013). The Eco-city concept was first proposed by Register and suggestions were presented for "urban regeneration in balance with nature" (Register, 1993). Sustainable cities should minimize the use of energy resources, water, and other natural resources and reduce waste and pollution (Wong and Yuan, 2011). Less use of fossil fuels and reducing carbon emissions is the way to achieve a sustainable city (Kline, 2000). Low Carbon City (LCC) has been proposed in response to the growing carbon footprint and climatic changes in cities (Tan et al., 2016). In recent years, the construction of low carbon cities has attracted governments. Examples of this are Shenzhen in China (Shenzhen's Development and Reform Commission, 2012) and Stockholm in Sweden (Örjan et al., 2010).

Eco-cities and low carbon cities have gradually emerged in academic and political discourse since the 1990s (Fu and Zhang, 2017; de Jong et al., 2015). The urban epitaxial growth model cannot meet the developmental requirements under the new conditions; therefore, the urban development model needs to be amended. The low carbon model and the ecological concept has become the most significant and important issue of sustainable human development in the 21st century and has become a new development approach to deal with climate change, resource constraints, and ecological environmental challenges. Meanwhile, developing a carbon emission assessment system for low carbon urban planning has become an important approach for reducing carbon emissions and achieving the low carbon eco-city development goals. Several studies have been conducted on low carbon cities and carbon emissions in cities, and the present study has essentially examined all the influential aspects such as political theory and technical operations. At the political level, research mainly focuses on the meaning, pattern, and correlation between a low carbon city and a low-carbon economy (An et al., 2018). Recently, with the advent of eco-cities and low carbon cities as the new branches of the "sustainable city", various dimensions have been investigated in the planning of low carbon cities and eco-cities to ensure environmental compatibility. This makes the principles of sustainability associated with low carbon cities and eco-cities to be more intelligible. At present, the policy of a low carbon city has become an important development strategy at the national and local levels. In the Urban Development Guidebook, the new national urban planning by the state council in some countries is that the urbanization process should follow the "Comprehensive, Intelligent, Green, and Low-carbon" principle (Conroy and Berke, 2004). Therefore, the concept of LCC refers not only to the dissemination of GHG but also to the development of its economic, social and environmental aspects.

Several studies examined LLC from a variety of perspectives. These studies are macro-scale, such as the establishment of a comprehensive assessment system and a low-carbon city construction and development assessment model (Tan, 2017) or micro-scale, such as the relationship between carbon emissions and city economic growth (Khanna et al. 2014; Liu and He 2015; Liu et al., 2011). In a report by C40 Cities Climate Leadership, which was published as a C40 report, about 93 percent of C40 cities were responsible for climate change at the highest level. More than half of these cities were pursuing specific goals for reducing GHG. For example, the GHG emissions by 60 % in 2025 were compared to its level in 1990 (Carbon Disclosure Project (CDP), 2011).

Skea and Nishioka have shown the consensus on LCC as a city in which low carbon development has been accepted in developmental planning and satisfies the needs of all groups of society. Wie stated that LCC should be considered in planning for sustainable development and implementation. LCC, as a part of a global ecology system, requires coordinated activities on local and global scales, but its orientation should be on local governance in a global framework. Therefore, the introduction of an indicator system is essential because the goal of this system is to promote low carbon strategy, urban planning and implementation in a policy framework. The purpose of this study was to evaluate the LLC's criteria in Isfahan and comparing the obtained results with Stockholm and Beijing.

1.1. Studied area

Isfahan is a city in central Iran and is the third-most-populous Iranian city by population, with the coordinates of 32° 39' 40.8348'' N and 51° 40' 49.3464'' E. Isfahan province covers an area of approximately 107,090 km^2 (Figure1) and is the fifth largest province of Iran. Isfahan ranks first in the country in terms of industrial cities and ranks second in the industrial Gross Value Added (GVA) (Isfahan Municipality Portal, 2019).

Figure 1. Isfahan map

2. METHODOLOGY

While the eco-city evaluation methods vary, it is crucial to select the most operational method for planners and decision-makers and addressing climate change (Dong et al., 2016; Yu, 2014). For instance, four systems were utilized in Europe, with two applied to cities across the EU region (EU Green Capitals Program, 2011; Hakkinen, 2007). Also, there are four systems that have been implemented in cities across North America (Karlenzig and Marquardt, 2007; Marchington, 2011). Two national indicator systems were applied (MEP, 2007; MOHURD, 2004).

In this study, LCC criteria were considered including economic growth, energy design and patterns, living and social conditions, environmental changes, carbon intensity, urban transport, waste management, and water resource management (Figure 2). It is absolutely essential that LCC assessment criteria deal with resource conservation, environmentally friendly, sustainable economy and harmonious society (Aimin and Li, 2012). The determination of quality indicators is to improve the performance of urban growth and development and reduce carbon emissions. The selection of these indices is based on the availability of data resources and the main factors in LCC development. The higher the values of these indices are, the better the performance of the system. Table 1 has summarized the LLC indices for the cities of Stockholm, Beijing, and Isfahan.

The next step was the weighting of LCC indicators. The relative importance of each indicator has been determined by the Shannon entropy method. Tan et al. (2016) calculated the weighing of indicators using Shannon entropy, based on international standards and the ecological cities' performance, proposed by Siemens (Table 1). The city of Stockholm ranked highest and Beijing ranked lowest among the several cities in the world in terms of LCC indicators. Therefore, these cities were classified as the index of comparison.

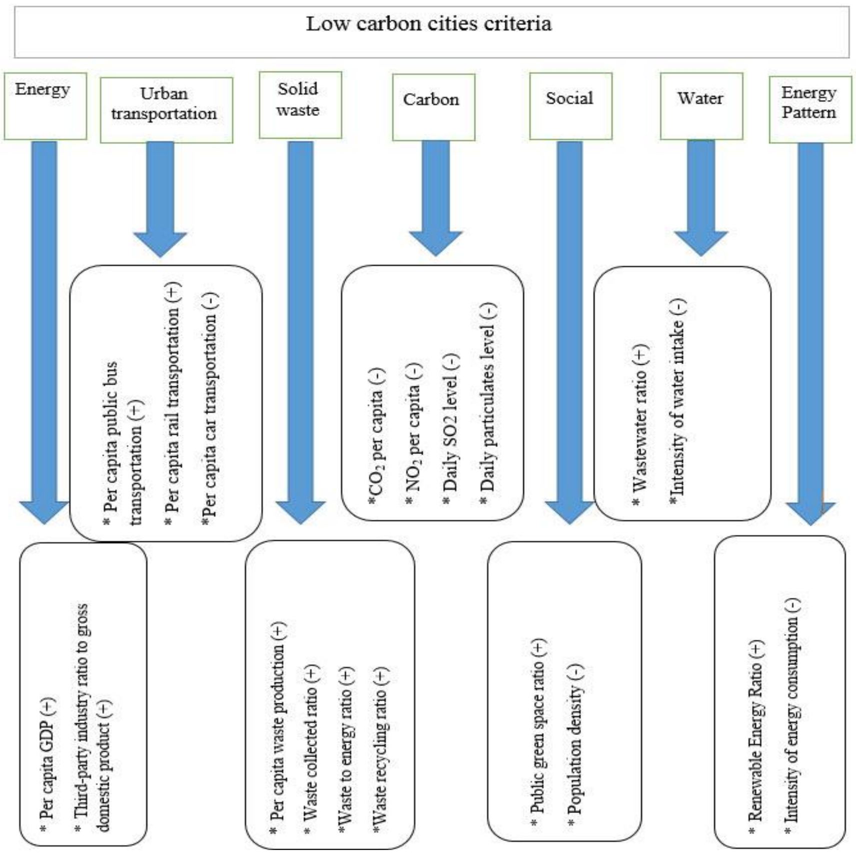

Figure 2: Low Carbon City (LCC) Criteria

The third step was comparing the Isfahan indexes with Stockholm and Beijing using Fuzzy TOPSIS Technique . The TOPSIS algorithm is based on the shortest distance from the positive ideal solution (PIS) and the furthest distance from the negative ideal solution (NIS) (Patil and Kant, 2014).

Although it is often difficult for decision-makers to assign an accurate assessment score to an alternative, the advantage of using fuzzy methods is to overcome ambiguity in human judgment and to capture the relative importance of attributes. The following steps represent the fuzzy TOPSIS method:

1. **Assign scores to alternatives according to each criterion:**

Assume an evaluation matrix consisting of m alternatives A={A_1, A_2, … .,A_m}, and n evaluation criteria C={C1,C2, … ,Cn}. The weight of the criteria is determined by W_j(j=1.2. … . … n). Performance ratings of each decision maker D_k = (k = 1.2 … … .k) for each alternative A_i (i = 1.2 … … m) according to the criteria C_j (j = 1.2 … … n) is equal to (Table 1 Decision Matrix):

$$\widetilde{R_k} = \widetilde{X_{IJk}}(i = 1.2\ldots\ldots m\,;\, j = 1.2\ldots\ldots n\,;\, k = 1.2\ldots\ldots k\,)$$

Table 1. Bench Mark Values of cities (Decision Matrix

Matrix	E1	E2	U1	U2	U3	SW1	SW2	SW3	SW4	C1	C2	C3	C4	S1	S2	W1	W2	EP1	EP2
Stockholm	53941	80.2	994	51.7	0.39	0.28	100	0.49	25	2.96	13.32	2.45	15	0.4	4800	100	69.3	48	2.2
Bejing	20275	77.3	1071	38	0.25	0.52	95.4	0.1	37	8.2	52	28	121	0.56	1261	80.3	218.1	4.5	7.94
Isfahan	23427.14	40	1150	20	0.58	0.57	95	0.01	55	14	84.1	11.1	66	0.27	18326.621	80	154	6.36	39.5
Criteria Type	Positive	Positive	Positive	Positive	Negative	Negative	Positive	Positive	Positive	Negative	Negative	Negative	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Benchma k value	0.03916	0.016	0.07957	0.10521	0.03176	0.04668	0.0449	0.0673	0.04909	0.04068	0.04703	0.03296	0.04223	0.05429	0.03735	0.03543	0.04968	0.07503	0.04421

2. Calculate aggregate fuzzy importance for alternatives

Suppose that the fuzzy ranking of all decision-makers in terms of criteria is triangular fuzzy numbers $\widetilde{R_k} = (a_k . b_k . c_k)$ and k = 1.2. … .k is as follows:

$$a = \min\{a_k\}. \quad b = \frac{1}{k}\sum_{k=1}^{k} b_k . c \;\; = \max\{c_k\} \qquad (8)$$

If the fuzzy ranking of the k[th] decision maker is $\tilde{X}_{ijk} = (a_{ijk} . b_{ijk} . c_{ijk})$, j = 1.2 … .n and i = 1.2 … … m, then the integrated fuzzy ranking of the X substitutes according to each criterion is given by $\tilde{X}_{IJ} = (a_{ij} . b_{ij} . c_{ij})$ and is as follows:

$$a = \min\{a_{ijk}\}. \qquad b = \frac{1}{k}\sum_{k=1}^{k} b_{ijk} . c = \max\{c_{ijk}\} \qquad (9)$$

3. Calculate the fuzzy decision matrix

The fuzzy decision matrix for alternatives (D) is formed as follows:

$$\tilde{D} = \begin{bmatrix} \widetilde{X_{11}} & \widetilde{X_{12}} & \cdots & \widetilde{X_{1n}} \\ \widetilde{X_{21}} & \widetilde{X_{22}} & \cdots & \widetilde{X_{2n}} \\ \vdots & \vdots & \vdots & \vdots \\ \widetilde{X_{m1}} & \widetilde{X_{m2}} & \cdots & \widetilde{X_{mn}} \end{bmatrix}$$

$$i = 1.2. \dots . m$$
$$j = 1.2. \dots . n \qquad (10)$$

4. Normalize raw data for each criterion using linear scale conversion

The normalized decision matrix is given as follows:

$$\tilde{R} = [\widetilde{r_{IJ}}]_{m\times n}. \quad i = 1.2. \dots \dots . m. \quad j = 1.2. \dots \dots . n \qquad (11)$$

$$\widetilde{r_{IJ}} = \left(\frac{a_{ij}}{c_j^+} . \frac{b_{ij}}{c_j^+} . \frac{c_{ij}}{c_j^+}\right). \quad c_j^+ = Max_i C_{ij} \quad positive\ criterion \quad (12)$$

$$\widetilde{r_{IJ}} = \left(\frac{a_j^-}{c_{ij}} . \frac{a_j^-}{b_{ij}} . \frac{a_j^-}{a_{ij}}\right). \quad a_j^- = Min_i a_{ij} \quad negative\ criterion \quad (13)$$

5. Calculate normalized weight matrix

Normalized weight matrix $\tilde{V}$ for criteria is calculated by multiplying evaluation criteria weights $\widetilde{W_J}$ in the normalized fuzzy decision making $\widetilde{r_{IJ}}$.

$$\tilde{V} = [\widetilde{v_{IJ}}]_{m\times n}. \quad i = 1.2. \dots \dots . m . \quad j = 1.2. \dots \dots . n \qquad (14)$$

$$\widetilde{v_{IJ}} = \widetilde{r_{IJ}} * W_j \qquad (15)$$

Note that $\widetilde{v_{IJ}}$ is a TFN represented by $(a_{IJK} . b_{IJK} . c_{IJK})$.

6. Determine the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution for alternatives

$$A^+ = (\widetilde{v_1^+} . \widetilde{v_2^+} \dots \dots . \widetilde{v_n^+}). \quad \widetilde{v_J^+} = Max_i\{v_{ij}\}$$
$$i = 1.2. \dots \dots . m . \;\; j = 1.2. \dots \dots . n \qquad (16)$$

$$A^- = (\widetilde{v_1^-} . \widetilde{v_2^-} \dots \dots . \widetilde{v_n^-}). \quad \widetilde{v_J^-} = Min_i\{v_{ij}\}$$
$$i = 1.2. \dots \dots . m . \;\; j = 1.2. \dots \dots . n \qquad (17)$$

7. Calculate the distance of each alternative from FPIS and FNIS

Distances (d_i^+, d_i^-) of each weighting criterion i = 1.2 …... m is calculated from FPIS and FNIS as follows:

$$d_i^+ = \sum_{j=1}^{n} dv\left(\tilde{v}_{ij} . \tilde{v}_j^+\right). \quad i = 1.2. \dots \dots . m \qquad (18)$$

$$d_i^- = \sum_{j=1}^{n} dv\left(\tilde{v}_{ij} . \tilde{v}_j^-\right). \quad i = 1.2. \dots \dots . m \qquad (19)$$

Where $dv(a.b)$ is the distance between the two fuzzy numbers $\tilde{a}$ and $\tilde{b}$.

8. Calculate closeness coefficient CC_i of each alternative

The closeness coefficient represents the distances from both fuzzy positive ideal solution and fuzzy negative ideal solution. The closeness coefficient of each alternative is obtained as below:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+} \qquad i = 1.2. \dots \dots . m \qquad (20)$$

9. Rank the alternatives

At the final step, the alternatives are ranked according to the closeness coefficient.

3. RESULTS AND DISCUSSION

The use of the TOPSIS algorithm in assessing Isfahan showed that this city does not have a good ecological status compared with major industrial cities in the world. Although some indicators of LCC are satisfactory, energy management efforts can make Isfahan one of the world's low carbon cities (Figure 3). Energy management in countries like Iran where cheap and affordable fossil fuels are permanently available should be based on the development of renewable energies. In order to achieve low carbon and sustainable development in Isfahan, investment in the transportation sector is required to reduce air pollution and fossil fuel consumption. The main reason for the distance between the cities of Isfahan and low carbon cities is the availability of convenient and inexpensive fossil fuels, which leads to untapped consumption of these fuels in the industrial and urban sectors. However, it is possible to improve the position of Isfahan in the LCC ranking by managing fuel consumption and utilizing renewable energy. Figure and Table 2 compared Stockholm, Beijing, and Isfahan in terms of energy consumption. Development management and planning in the city of Isfahan should focus on reducing the consumption of fossil fuels and the use of clean renewable energy, air quality control and reuse of waste. Dealing with the challenges ahead of the development of an Iranian low carbon Eco-city discussed in this paper is critical. However, the results of this study indicated that the occurrence of some of these challenges is inevitable in the process of achieving a low carbon and sustainable urban development. There are many uncertainties in the process of urban development. Even if a number of primary goals are achieved, due to the emergence of new innovative technologies and other socio-economic changes, other objectives may need to be revised. However, what is certain is that humans must strive to create high-quality cities in terms of environment, economy and social factors that prove the value of these cities for life.

Table 2. LCC ranking for the cities

Results	Proximity coefficient
Stockholm	0.8385
Bejing	0.3826
Isfahan	0.2112

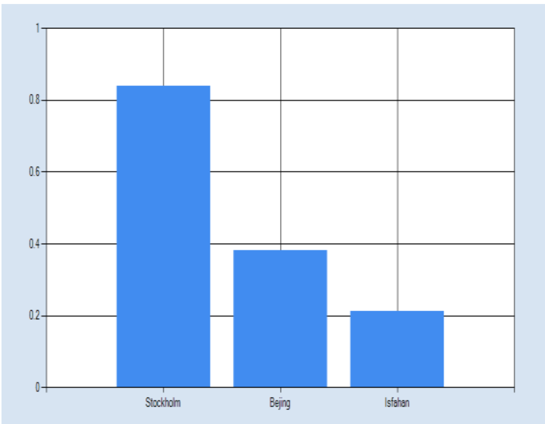

Figure 3. LCC ranking for Stockholm, Beijing, and Isfahan and their proximity coefficients

An attempt to achieve eco-city is a process designed to transport sustainable integrated social, economic and environmental development to highlight the coordinated relationships between humans and their natural environment. Development without regarding the three pillars of sustainable development will not result in the formation of an eco-city. Although with our current knowledge, it is impossible to build a perfect eco-city, we have to follow a path that will ultimately lead us to this goal. Planning, evaluation, and implementation of eco-city should be done in different stages. In each of these steps, the development priorities can be changed. These varied priorities could include the application of low carbon innovative technologies, social equity, adoption of more equal opportunity policy, ecological and environmental improvement, and the reduction of carbon emissions and the use of fossil fuels.

From this point of view, it should be emphasized that the transformation of the existing development model and the changing of the current lifestyle into a simple, sustainable and healthy lifestyle should be part of the main short-term development activities of the low carbon eco-cities. In this process of transformation, the use of creativity is essential. Eco-City needs an initiative not only in related technologies but also in organizational development. The development of low-carbon eco-city needs innovation in low-carbon and renewable energy technologies to promote environmental economics. The application of green and environmental technologies can help reduce fossil fuel consumption in economic development, which creates job opportunities and boosts GDP. However, LCC not only minimizes energy use and natural resources but also contributes to social development, environmental protection and improving the quality of life. Despite the myriad problems facing the development of low-carbon eco-cities in Iran, the low carbon model can and must become the main method of urbanization and industrialization in Iran and the Middle East.

Conflict of Interest:

There is no conflict to declare.

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