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The low carbon development (LCD) levels' evaluation of the world's 47 countries (areas) by combining the FAHP with the TOPSIS method

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ABSTRACT

The low carbon economy (LCE) is considered as a kind of development mode (low carbon development, LCD) in this paper. So several problems appear, e.g., what kind of development is LCD? And, how to evaluate the level of LCD? The aim of this study is just to answer these questions. Firstly, the indicators' system of the LCD level was constructed, which contains five main indicators and 10 sub-indicators. Then, 47 representative countries (areas) worldwide were taken as the numerical case. In the empirical research process, a two step methodology of combining the Fuzzy Analytic Hierarchy Process (FAHP) with the Technique for Order Performance by Similarity to Ideal Solution method (TOPSIS) is proposed. FAHP was used to determinate the main and sub-indicators' weights of the 47 countries' (areas') LCD level, then the TOPSIS method used these weights as its own input weights to complete the whole calculation process. The results indicate that the method proposed can be successfully used in the study and the concept of the LCD level be considered as a very useful tool because the conclusions related to it have some certain directive significances when we have to take decisions on some items. In the end, some reasonable policy suggestions are proposed and some directions for future studies are put forward.

1. Introduction

Since this concept of low carbon economy (LCE) was, firstly, put forward by British Department of Trade and Industry in a book (Energy White Paper: Our Energy Future-Creating a Low Carbon Economy) in 2003, it has been attracted more and more attention. A LCE is an economy which has a minimal output of greenhouse gas (GHG) emissions into the biosphere, specifically refers to the greenhouse gas carbon dioxide from the burning of coal, oil and gas (Ding, Dai, & Zhao, 2008).

So far, this LCE concept has been become one of the most hottest issues in the world. However, different people may have different research perspectives about it such as technology, policy, market and fuel standard, etc. Omer (2008) thought that the use of renewable energy sources (RES) is a fundamental factor for a possible energy policy. Promoting innovative low carbon technologies (LCT) and reinforcing corresponding market about RES will significantly contribute to energy saving in the LCE future. Xydis (2009) examined the availability of different LCT using the method of Exergy Analysis and found that a wider LCT utilization is needed because of the increased energy consumption in all sectors over the last decades. Yeh, Lutsey, and Parker (2009) investigated the potential for carbon dioxide reductions from electrification and expanded use of biofuels and used a portfolio approach to design a LCE future. Bataille, Tu, and Jaccard (2008) simulated the developing scenario of levying the carbon taxes in Canada and China and found a global low carbon society (LCS) is feasible, on condition that policy makers are willing and able to impose long-term, credible policy packages with carbon pricing policy as the core element. Sperling and Yeh (2009) thought a low carbon fuel standard (LCFS) is a promising approach to decarbonize transportation fuels. Andress, Nguyen, and Das (2009) reviewed the major characteristics of the LCFS implemented in California and summarizes two principal alternative approaches to regulate greenhouse gas emissions, the cap-and-trade and the carbon tax.

However, it is worth noting that the research of considering LCE as a kind of development mode is still few. Urban (2010) argued that we need to link up pro-poor policy with the low carbon development (LCD) policy. Phdungsilp (2010) used the Long-range Energy Alternatives Planning System (LEAP) model to simulate many scenarios for Bangkok's LCD from 2000 to 2025 in Thailand. The result found the most significant way for energy savings was in the transport sector. Zhu (2009) used some quantitative indicators

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such as carbon productivity and per capita carbon emissions and so on to evaluate some cities' LCD level in China, and explored their corresponding roadmap to a LCS. Using Zhu's method, Li and Zhong (2010) evaluated the LCD level of Heilongjiang Province in China, and presented some policy recommendations for its development in the future. In addition, there were some other researches try to evaluate the LCD level and provide corresponding countermeasures by constructing a regional LCE index system (Fu, Zhuang, & Gao, 2010; Zhu, Zhou, & Yuan, 2009). All in all, we can see that people, so far, have no unified and common understandings about the LCD (e.g., what a kind of development is LCD? And, how to evaluate a country or regional LCD level?).

Thus, this paper tries to answer these questions from a globe scale. Firstly, The AHP, fuzzy set theory, the FAHP, the TOPSIS method and the integration process of these methods for LCD level's evaluation were described in the Part 2. Then, the empirical research process for evaluating the worldwide 47 countries' (areas') LCD level was explained in the Part 3, which included the location of 47 major countries (areas) in the world, the data sources, the selection of the indicators' system and the results' analysis and discussion. In the Part 4, the conclusions were summarized and some policy suggestions were proposed.

2. Methodology

2.1. AHP, fuzzy set theory and FAHP

2.1.1. AHP

The Analytic Hierarchy Process (AHP), proposed by Saaty (1980), is a structured qualitative and quantitative technique for helping people deal with complex decisions. The fundamental principle of the analysis is the possibility of connecting information, based on knowledge, to take decisions or previsions; the knowledge can be taken from experience or derived from the application of other tools (Naghadehi, Mikaeil, & Ataei, 2009; Saaty, 1980; Saaty & Vargas, 1990). Nowadays, many researchers have used AHP in the personnel evaluation problems (Islam & Rasad, 2006; Taylor, Ketcham, & Hoffman, 1998).

The flowchart of AHP is shown in Fig. 1. When the problem is put forward, the corresponding AHP model should be, firstly, constructed. Then, through the comparison of pair-wise matrixes in the questionnaire table (Fig. 1), the expert's knowledge or understanding about this problem can be captured. In the end, the result can be concluded and analyzed when the expert's views can be sorted and pass the consistence test. The sorting contains the monolayer sorting and the overall sorting. To do the consistence test, Saaty and Vargas (1990) provides a consistency index to measure any inconsistency within the judgments in each pair-wise comparison matrix as well as for the entire hierarchy. The consistency index (CI) is formulated as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

In which λ_{max} is the maximum eigenvalue and n is the dimension of the matrix.

Accordingly, the consistency ration (CR) can be computed with the use of following equation:

$$CR = \frac{CI}{RI} \quad (2)$$

If the calculated CR of a pair-wise comparison matrix is less than 0.1, the consistency of the pair-wise judgment can be thought of as being acceptable. Moreover, if the consistency is not passed, the original values in the pair-wise comparison matrix must be revised by the evaluator.

However, this method still cannot really reflect the human thinking style (Kahraman, Cebeci, & Ulukan, 2003). For instance, it uses an exact value to express the decision maker's opinion in a comparison of a pair-wise matrix, which is problematic (Wang & Chen, 2007). Another, it is often criticized due to its use of unbalanced scale of judgments and its inability to adequately handle the inherent uncertainty and imprecision in the pair-wise comparison process (Deng, 1999). Therefore, fuzzy AHP (FAHP) was developed to overcome these shortcomings, which is a combination of fuzzy sets theory and AHP.

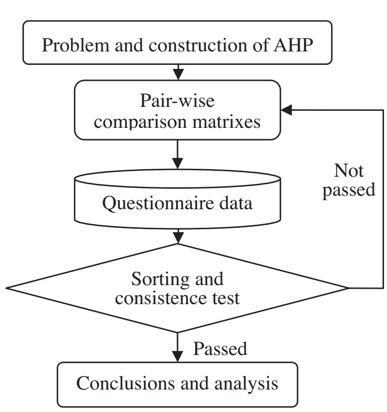

Fig. 1. AHP flowchart.

2.1.2. Fuzzy set theory

The imprecision or fuzziness arising from mental phenomena is a common characteristic of decision making problems, which are neither random nor stochastic (Mikhailov & Tsvetinov, 2004; Vahidnia, Alesheikh, & Alimohammadi, 2009). If the imprecision or fuzziness of human decision making is not taken into account, the results in our studies can be misleading (Naghadehi et al., 2009; Tsaur, Chang, & Yen, 2002). Fuzzy set theory is a better means for modeling this imprecision or fuzziness. This theory was introduced by Zadeh (1965) and provides a more widely frame than classic set theory. It has been contributing to capability of reflecting human thinking style and real world (Ertugrul & Tus, 2007). When some complex phenomena cannot be described by traditional mathematical methods, especially when the goal is to find a good approximate solution, this capability is important and significant (Bojadziev & Bojadziev, 1998). In fact, decision makers usually find that it is more confident of giving interval judgments (fuzzy set) than fixed value judgments (Kahraman, Ruan, & Dogan, 2003).

2.1.3. FAHP

By using fuzzy number and membership function, FAHP combines the fuzzy set theory with AHP (Erensal, Oncan, & Demircan, 2006; Feng, 1995; Wang, Luo, & Hua, 2008). In literature, different authors propose different fuzzy AHP methods. Van Laarhoven and Pedrcyz (1983) initiated triangle fuzzy numbers to express the decision maker's evaluation on alternatives with respect to each criterion. Buckley (1985) used trapezoidal fuzzy numbers to do that. Chang (1996) introduced the extent analysis method of handling triangular fuzzy numbers for the pair-wise comparisons. Deng (1999) presented a fuzzy approach for tackling qualitative multi-criteria analysis problems in a simple and straightforward manner. Zhu, Jing, and Chang (1999) proved the basic theory of the triangular fuzzy number and improved its formulation. Leung and Cao (2000) proposed a fuzzy consistency definition with consideration of a tolerance deviation. Chou and Liang (2001) proposed a fuzzy multi-criteria decision making model by combining fuzzy set theory, AHP and concept of entropy, for shipping company perfor-