Social Impact Assessment of Laos-China Transnational Hydropower Projects in View of the Fuzzy Comprehensive Evaluation

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Abstract

Having been considered as clean energy, hydropower plays an important role in the energy strategy. Laos is rich in hydropower resources, attracting a large number of Chinese companies to invest in the construction of hydropower stations in Laos. While promoting the economic development of Laos, it also has a non-negligible impact on the regional social system. The objective of this study was to evaluate the social impact of Laos-China transnational hydropower projects which is of great significance for further improving its social benefits and promoting development. This paper constructed a social impact evaluation index for hydropower project investment projects from four aspects: social people's livelihood, social culture, environment, and

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the impact of transnational factors on the social system, employing cascade hydropower projects in the Nam Ou river basin in Laos as a sample to conduct empirical analysis. The research results show that the overall evaluation of the Nanoujiang cascade hydropower station on the social impact was at a good level, indicating that it had a great effect on improving the overall social benefits. Among them, the social impact of the project was mainly reflected in social cultural of Laos, with the highest degree. In addition, the impact of the project on the transnational factors in the construction took the second place, and the impact on social environment and livelihood were relatively low.

Keywords: Transnational hydropower projects, social impact evaluation, fuzzy comprehensive evaluation; Nanoujiang cascade hydropower station

Introduction

Because economic globalization, rapid population growth, and accelerated industrialization have continuously promoted economic and social development, all regions of the world are facing the real problem of power supply shortages. As an environment-friendly energy source, hydropower has received high attention worldwide due to its low price and relatively clean characteristics. In the context of global energy interoperability, the investment and implementation of transnational water conservancy and hydropower projects are

becoming the focus of all countries (Zhou Xingbo, 2017).

The Lancang-Mekong River is an international river that originated in China and flows through Myanmar, Laos, Thailand, Cambodia, and Vietnam. In recent years, with the continuous economic development of the countries in the basin, the demand for energy and electricity has increased. To develop the economy and ease the shortage of water resources and energy, the development of hydropower resources has become an inevitable choice for all countries in the Lancang-Mekong River Basin. Laos is the country with the most abundant hydropower resources in the lower Mekong River. It has abundant hydropower reserves and favorable conditions, making it very suitable for the construction of large-sized hydropower projects (Wang Zhigang & Huang, 2018).

As a country along with the Belt and Road initiative, Laos and China have continuously deepened friendly exchanges and cooperation in the fields of politics, economy, military, culture, and health. The abundant hydropower resources in Laos have attracted investment from many Chinese companies in recent years. China has become the largest hydropower construction investor in Laos. A large number of Chinese-funded enterprises have invested, constructed, and operated a large number of hydropower projects. For example, the cascade hydropower stations in Nam Ou River were the first time a Chinese company has obtained overseas development. The direct investment in these hydropower projects, on the one hand, gave full play to the local hydropower advantages of Laos and brought new

opportunities for hydropower development. On the other hand, it also promoted the construction of domestic infrastructure in Laos, improved the level of social and people's livelihood, and contributed to Laos. Hydropower construction and social and economic development have made great contributions (Yu et al., 2016).

Hydropower is now seen as the basic industry of Laos. The transnational hydropower project has further improved the economic development of Laos based on solidifying the friendship between Laos and China. This paper takes into account the important impact of Laos-China transnational hydropower projects on the regional social system, as well as the long construction period of the project itself, large investment scale, complex related stakeholders, and wide range of influence to make a scientific and reasonable social impact on hydropower projects.

Objective

The purpose of this paper was to explore the content of social impact evaluation of Laos-China transnational hydropower projects, establish a representative index system, and use a combination of directional and quantitative methods to obtain the degree of influence of various factors on social system in order to better grasp the social impact of the project on this region. It's of great significance to the promotion of cross-border hydropower cooperation between Laos and China.

Literature Review

The coverage of multinational engineering projects is wide, and it has various impacts on the neighborhood of the project location. Judging from the literature, many scholars have studied the impact of multinational engineering investment projects on the economy, society, and nature. Regarding the social impact of multinational engineering projects, the current paper is mainly developed from two dimensions, one is the method of evaluating the social impact of engineering projects, and the other is the content of the social impact evaluation of engineering projects. In the research of social impact evaluation, there are many comprehensive evaluation methods applicable to multinational hydropower projects.

From different perspectives, scholars have conducted studies using the Data envelopment analysis (DEA) model (Zhou Xun, 2018), cloud model (Chen Song, 2015), analytic hierarchy process (Ren Rong, 2016), and system dynamics (Zhang Shu et al., 2014), to name but a few. To overcome the subjectivity of artificial empowerment of traditional index methods, some scholars use variable analysis to evaluate the social impact of engineering projects (Zhao Liqi et al., 2014). The evaluation results produced by different methods may be different, but the principles followed are roughly the same. That is, to conduct social impact evaluation on transnational engineering projects, the engineering projects must emphasize the overall national economic and social system. Social impact evaluation cannot be simply embedded in national economic evaluation. Instead, it is
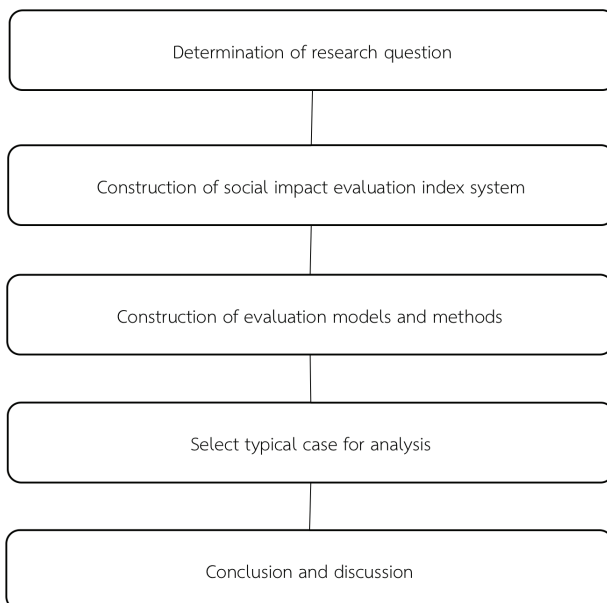
necessary to make full use of an interdisciplinary framework such as sociology and economics to comprehensively investigate and analyze the social impact of engineering projects (Jia Guangshe et al., 2013). For the social impact evaluation, the social impact evaluation code published by the International Association for Impact Evaluation (1994) includes five aspects: demographic characteristics, social and institutional structure, political and social resources, individual and family changes, and community resources.

Regarding the social impact of engineering projects, scholars mainly focused on agriculture, forestry, water conservancy, transportation infrastructure, and other industries (Jiang Xishan, 2010; Chen Yan, 2011; Wang Zhengbing, 2012), and most of them studied the social impact evaluation system of engineering projects. Hu Yongquan (2006) reviewed the development of social evaluation of construction projects at home and abroad, analyzed the social evaluation system of various projects, combined to build a harmonious society in China, and proposed the content of the social evaluation system of construction projects in China; Shi Na Ke (2007) constructed the social impact evaluation index of agricultural technology projects according to the characteristics of agricultural engineering projects; Jia Guangshe (2010) constructed the social impact evaluation index of large-scale projects based on the theoretical framework of construction engineering sociology; Teng Minmin (2014) constructed a social impact evaluation index system for large-scale infrastructure projects in China and found the seven aspects of family, political and social

structure, the direct impact of the project, public resources, ecological environment, social adaptability, and community and infrastructure.

In general, the literature mostly concentrates on the social impact evaluation of general engineering projects, and there are few studies on the social impact evaluation of transnational hydropower project investment projects. Given the urgency and importance of the current global hydropower development, the global hydropower resources to be developed are mostly concentrated in the countries along with the Belt and Road cooperation (Wu Shang & Shi Guoqing, 2018), especially the Lancang-Mekong River Basin, which is rich in hydropower resources. Therefore, this article takes the Lao-Chinese transnational hydropower projects as samples, analyzes, and evaluates the social impact based on the fuzzy comprehensive evaluation method to enrich the knowledge on the impact of transnational hydropower projects.

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│  Construction of social impact evaluation index  │
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│            Conclusion and discussion             │
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The specific research conceptual framework is as follows:

Research Methodology

    1. Index selection

    The impact of the construction of transnational hydropower projects in Laos is mainly manifested in the four aspects: people's livelihood, social culture, environment, and system. The following indicators, thus, are selected to measure the impact of the Laos-China transnational projects on the local social system.

    1.1) People's livelihood refers to the basic survival and living conditions of Laotian people, including development opportunities, development capabilities, and protection of human rights. Society and people's livelihood is the core work of the government, including food, clothing, housing, transportation, birth, old age, sickness, and death. This paper selects infrastructure satisfaction, social security level, etc. as evaluation indicators of social people's livelihood. First, an appropriate infrastructure construction can improve people's living standards, and people's satisfaction with infrastructure reflects the level of the local social environment. Second, the level of social security. Social security is an important indicator that reflects the livelihood of the society and people, and it is closely related to the living standards of the local people.

    1.2) The social culture refers to various cultural phenomena and cultural activities that are closely related to the production of the broad masses of the grassroots which have distinctive characteristics. This article selects social culture evaluation

indicators such as the training of industrial skills and the introduction of emerging cultures. First, the cultivation of industrial talent skills refers to the process of education and cultivation of talents, that is to train people with good humanities, scientific qualities, and a sense of social responsibility. Second, the introduction of emerging culture is a concept opposite to traditional culture. The attitude of the Laotian people towards emerging culture reflects the social and cultural atmosphere of Laos.

1.3) The social environment, in a narrow sense, refers to the direct environment of human life. This article selects social security status and medical and health technology as social environment evaluation indicators. First, social security refers to a stable and orderly state of society under the constraints of certain laws, regulations, and systems. Second, medical and health technology is a manifestation of the level of medical security in Lao society and can indirectly reflect the social environment of the region.

1.4) Due to the Laos-China transnational hydropower projects, transnational factors will inevitably have an impact on the social system. This article selects the degree of social integration as a measure. The degree of social integration refers to the degree of intimacy between personnel of the two countries.

2. The weights of indicators determination

As the social impact evaluations in this article are all qualitative indicators, the analytic hierarchy process combined with Delphi Method was used to determine the weight of each evaluation index. Taking

the social impact evaluation of Laos Nanoujiang cascade hydropower stations as the goal, a social impact evaluation system with 4 first-level indicators and 7 second-level indicators was constructed, through the construction of a two-level judgment matrix, matrix standardization processing, eigenvectors, and maximum characteristics. Mathematical calculations such as root solution and consistency deviation tests possess the weight of each index.

3. Fuzzy Evaluation method

3.1 Determining fuzzy objects, factors, and comments Objects: o = {o1, o2, ..., on}, nis the number of evaluated objects. Factors: u = {u1, u2, ..., um}, mis the number of evaluation factors; factors are indicators. Comments: c = {c1, c2, ..., ck}, respectively expressed as: very good, good, fair, poor, and bad. Among them, k is the number of comments.

3.2 Establishing the weight distributions of the evaluation indexes Different evaluation factors play different roles in the evaluation indicators, that is, the weights that each evaluation factor occupies in the comprehensive evaluation are different. The w can be obtained by an improved analytic hierarchy process, so that the weight distribution matrix w = (w1, w2, ..., wm) of m factors is obtained, and the weights

$$R = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_m \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

In the formula, rijis the index of the comments of the objects noi on the factor uj, which is called the degree of membership, sorij [0,1].

3.4 Comprehensive evaluation result matrix

$$S = W*R = (S_1, S_2, ..., S_n) = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_m \end{bmatrix} * \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

This paper uses the maximum degree of membership method to deal with the evaluation index and takes the comments information corresponding to the maximum evaluation index Smax = max {Si} (i=1, 2,..., m) as the judgment situation.

Research Findings

Brief Introduction of Cascade Hydropower Station in Nam Ou River Basin is described below:

The Laos cascade hydropower stations in the Nam Ou river basin is the first overseas project that a Chinese enterprise has invested overseas with the BOT investment. As a key project of Laos' national energy strategy, the power station was constructed in two phases with a total installed capacity of 1272 MW and an average annual power generation of about 5 billion kWh. In May 2016, all 9 units of the first phase (second, fifth, and sixth-level hydropower stations) were put into production for power generation. In December 2017, the second phase (first, third, fourth, and seventh-level hydropower stations) completed the river closure, and the first one was planned

to be achieved by the end of 2019. The first phase of the Nam Ou river project is generating greater comprehensive economic and social benefits, allowing the integrated advantage of the entire industrial chain of power construction to be fully demonstrated in international competition, becoming a bright spot in the practice of China's Belt and Road projects. At the same time, it represents a new model of China-Laos power and energy cooperation. After the completion of the cascade hydropower stations in the Nam Ou river basin, they would provide stable and high-quality electric energy, guaranteeing 12% of the country's electricity supply in Laos and promoting the upgrade of the northern power grid and transmission interconnection. The project would help Laos become the Battery of Asia and accelerate the process of Laos' electricity export and regional integration of electricity. The seven power stations are like a string of jewels, transforming the rich water resources of the Nam Ou river into the source of economic and social development.

The explanation based on the Fuzzy Evaluation method

1.Fuzzy evaluation matrix calculation

The index level standards are set based on the social impact evaluation system of Lao-Chinese transnational hydropower projects, combined with the actual implementation of the Nanoujiang cascade hydropower project. 30 experts from Laos and China were invited to conduct a single-factor evaluation of each indicator.

The fuzzy evaluation matrix obtained is as follows:

$$R_1 = \begin{bmatrix} 0.17 & 0.23 & 0.5 & 0.1 & 0 \\ 0.07 & 0.27 & 0.4 & 0.2 & 0.07 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0.3 & 0.37 & 0.23 & 0.07 & 0.03 \\ 0.1 & 0.33 & 0.5 & 0.03 & 0.03 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0.07 & 0.17 & 0.4 & 0.3 & 0.07 \\ 0.17 & 0.4 & 0.33 & 0.1 & 0 \end{bmatrix}$$

$$R_4 = [0.23 \quad 0.4 \quad 0.3 \quad 0.03 \quad 0.03]$$

2. Single-factor evaluation

The degree of membership of a single factor for each evaluation level is as follows:

$$S_1 = W_1{}^*R_1 = [0.1004 \quad 0.2578 \quad 0.4304 \quad 0.1696 \quad 0.0487]$$
$$S_2 = W_2{}^*R_2 = [0.2669 \quad 0.3634 \quad 0.2747 \quad 0.0634 \quad 0.03]$$
$$S_3 = W_3{}^*R_3 = [0.1533 \quad 0.3617 \quad 0.3417 \quad 0.1333 \quad 0.0117]$$
$$S_4 = W_4{}^*R_4 = [0.23 \quad 0.4 \quad 0.3 \quad 0.03 \quad 0.03]$$

According to the principle of the maximum degree of membership (s_k = max {s_i} (1≤i≤m)), it is concluded that the impact of the Nanoujiang cascade hydropower station on society and people's livelihood is at a normal level, and the impact on social culture and social environment is at a good level. The impact of transnational factors on the social system in project construction is also at a good level.

3. Comprehensive evaluation

According to the principle of maximum membership degree (ck = ma x {ci}(1≤i≤m)) and (cmax=0.3558), it can be determined that the impact of the Nanoujiang cascade hydropower station project on the overall social system is at a good level.

$$C = W{}^*S = [0.1518 \quad 0.4200 \quad 0.1908 \quad 0.2375] \begin{bmatrix} 0.1004 & 0.2578 & 0.4304 & 0.1696 & 0.0487 \\ 0.2669 & 0.3634 & 0.2747 & 0.0634 & 0.0300 \\ 0.1533 & 0.3617 & 0.3417 & 0.1333 & 0.0117 \\ 0.2300 & 0.4000 & 0.3000 & 0.0300 & 0.0300 \end{bmatrix} = [0.2112 \quad 0.3558 \quad 0.3172 \quad 0.0849 \quad 0.0294]$$

4.Results and Analysis

The social and people's livelihood indicators of the cascade hydropower project in the Nanoujiang River Basin account for 43.04%, which is the largest of all levels. According to the max-membership principle, the comprehensive evaluation result of the project's impact on society and people's livelihood is general. On the one hand, the impact of hydropower projects on the regional infrastructure is mainly reflected in the impact on drainage and sewage. For example, the implementation of flood control projects will help reduce the pressure on regional drainage, but the impact on the overall urban infrastructure is general. On the other hand, hydropower projects can promote regional economic development by stimulating employment, thereby increasing local government finances and ultimately improving the level of social security. Therefore, the impact of hydropower projects on the level of social security is also general.

The social culture indicators of cascade hydropower projects in the Nam Ou river basin account for 36.34%. According to the max-membership principle, the comprehensive evaluation result of the project's social culture impact is at a good level. For transnational hydropower projects, the operation and construction of projects are guaranteed by technology, which will inevitably promote the skills of industrial talents. In addition, regarding the common construction goals, the personnel of Laos and China continue to deepen the exchanges. While promoting the smooth implementation of the project, it also promotes the spread of the culture of both sides,

especially the emerging culture that is promoted by modern science and technology.

The social environment indicators for cascade hydropower projects in the Nam Ou river basin account for 36.17%. According to the max-membership principle, the comprehensive evaluation result of the project's impact on the social environment is at a good level. In addition to stimulating local employment, the implementation of hydropower projects has also played a huge role in regional flood control, silt reduction, water supply, irrigation, and power generation. These benefits have played an important role in maintaining social stability and improving medical and health standards. Therefore, the hydropower project in the Nam Ou river basin has a better impact on the social environment of the region.

The impact index of transnational factors on the social system accounts for 40%. According to the principle of maximum subordination, the comprehensive evaluation of the project's transnational factors' influence on the social system is at a good level. Among the transnational factors, the familiarity of Lao and Chinese personnel continues to deepen within the construction of transnational hydropower projects, leading to an increase in the sense of social integration of both parties. Therefore, transnational factors have a great impact on the social system.

Conclusion and discussion

The development and construction of Laos-China transnational hydropower projects have positive impacts on the local society, people's livelihood, social culture, and social environment. The purpose of social impact assessment is to analyze and predict the possible social impact of the project implementation on the region. This paper establishes the social impact evaluation system of Laos-China transnational hydropower project investment projects, employing the analytic hierarchy process to determine the index weights, and using the Laos Nanoujiang cascade hydropower station as a sample to analyze the impact of the project on the social system of Laos in view of the fuzzy comprehensive evaluation method.
It is found that:

First, the fuzzy comprehensive evaluation method was adopted to evaluate the social impact of the Lao-Chinese transnational hydropower projects, which combines qualitative and quantitative methods to directly reflect the impact of the project on various indicators. The evaluation results are in line with reality. Second, on the whole, the overall evaluation of the impacts of the cascade hydropower stations in Laos on the regional social system is at a good level. Among them, the impact on the society and people's livelihood is at an average level, while the impact on social culture, social environment, and the transnational factors on the social system are all at a good level. Third, the impact of transnational hydropower projects on the social system is mainly reflected in the impacts on

social culture and social environment, especially on the industrial skills and medical and health technology. The impact of transnational factors on the social system cannot be ignored. In further construction and management, the social benefits of the project should be more inclined to the people's livelihood to improve the overall social benefits of the project.

Recommendation

AAccording to the evaluation results, in order to further optimize the social impact of hydropower projects construction and promote sustainable development of the project and society, this paper puts forward the following suggestions:

Firstly, we should strengthen the social impact evaluation of the whole process. The social impact of transnational hydropower projects should be evaluated throughout the entire process of the project, so as to link the various processes of project implementation with the impact. The paper believes that the social impact assessment of projects can be carried out from the three aspects of the project's decision-making, implementation and operation stages, and the project content and possible impacts of each stage can be analyzed and evaluated, so that the project construction can be carried out better.

Secondly, we should pay attention to the shortcomings. Compared with other indicators, the impact of the construction of the Laos Nanoujiang cascade hydropower station on society and people's

livelihood is "general". Therefore, in the subsequent operation and construction of hydropower projects, more attention should be paid to the impact on society and people's livelihood. On the one hand, hydropower stations should provide necessary assistance for the government to establish related infrastructure and improve people's satisfaction with the level of infrastructure; On the other hand, hydropower stations can expand the number of employees to create more employment opportunities. The increase in people's income means the increase in government revenue, which indirectly increases the level of social security.

For future research, due to the wide range of social impact assessment, the research needs to be continuously improved. First of all, theoretical research needs to be further improved. At present, the existing research has not deep enough on the social impact of transnational hydropower projects and related theories are lacking. It is necessary to in-depth exploration of theoretical foundations and related research methods. Secondly, the indicator system needs to be further improved. The social factors involved in the project's social impact evaluation are constantly changing, and the evaluation index system should be revised and improved according to changes in actual conditions. Finally, only by strengthening the applied research on the social impact assessment of transnational hydropower projects can we have an in-depth understanding and analysis of the social impact of projects construction.

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