

Fuzzy Analytical Hierarchy Process Approach of Attracting Investment Capital into Industrial Parks in Hai Duong Province, Vietnam

Thi-Kim-Lien Nguyen*, Quang-Minh Le, Thi-Hong-Diep Vu

Abstract—This study focuses on the application of the Fuzzy Analytical Hierarchy Process (FAHP) approach to find strategies to attract investment capital in Hai Duong Province, Vietnam. A set of evaluations for attracting investment capital is tested in the FAHP approach through the evaluation of five experts. First, there are four main criteria and 16 subcriteria used based on the function of objective identification. Second, the score of each criterion and overscore of criteria are determined. The empirical result revealed that the weight of the main criteria and integrated weight of subcriteria achieve the highest scores as the state's support policy (0.44384) and applying the free tax (0.11328), respectively. These weights recommend the importance and rank of the main and sub criteria to attract investment capital to industrial parks. The empirical result suggests strategies to increase the investment capital of all enterprises into industrial parks in Hai Duong Province, Vietnam.

Index Terms—Fuzzy Analytical Hierarchy Process, attract investment capital, main criteria, sub- criteria

I. INTRODUCTION

THE development of industrial parks in Vietnam is a crucial element to innovate and enhance related industry and international trade. According to the Ministry of Planning and Investment of the Socialist Republic of Vietnam (2020) [1], there are 330 industrial parks with 97.000 ha in Vietnam. Whereas, according to the Hai Duong industrial parks authority (2020) [2], there are 21 industrial parks with 3,684.12 ha in Hai Duong province. Nowadays, there is 2,020.58 ha that has been registered, built, and operated; further, planned area has been empty for about 1,663.3 ha. Therefore, the establishment of industrial parks is a sturdy foundation in which to expand and develop the industrial area and attract investors; as such, the empty land should utilize strategies to attract these investors.

Attracting investment capital has a direct impact on the construction, expansion, and modernization of industrial parks. Investment projects will create new jobs and stabilize

income and increase quality of life for laborers. Investors own new technologies, which means laborers can use to innovate and increase science and technology. Besides, the construction of transportation, electricity, water, and telecommunication has expanded and upgraded demands for high quality as requirements of the enterprises. Moreover, investors contribute tax to the government's budget. Therefore, attracting investment capital into industrial parks has an important meaning for a nation's industrialization and modernization process.

Every nation typically wants to attract investment capital; as such, nations need to maintain standard conditions for construction, policies, humans, society, and economy that investors will appreciate. There are many previous studies that have studied and published articles on attracting investment. For example, factor evaluation of the condition of existing enterprise and development research of attracting investment was presented via the statistical analysis method [3]. The special economic zone model, for example, was used to discover regional features of attracting investment into the Russian economy [4] and a decision-making method was applied to identify suitable development orientations for attracting investment in Southwest China [5]. The influential factors behind investment decisions in Vietnam's economic zones were explored via the probit regression model [6]. These papers were concerned with attracting investments; however, each paper has used a different method for access and analysis. In this study, we used the fuzzy analytical hierarchy process (FAHP) in multi-criteria decision-making (MCDM) to evaluate effectiveness factors that attract investment capital.

MCDM is a subdiscipline of operation research to evaluate various indicators, i.e., multiple conflicting objectives. The MCDM offers many methods, including the weight sum method, analytical hierarchy process (AHP), technique for order preference by similarity to ideal solution (TOPSIS), etc., which are applied in various aspects [7]. The Fuzzy – AHP – TOPSIS method, for example, was applied to investigate the problem of human resource selection [8]. The application of an adaptive fuzzy mechanism was used to improve the performance of a standard Mean Shift to Indonesian vehicles license plate tracking [9]. The AHP approach was used to determine the email author identification system [10].

In MCDM, the FAHP is used to define the parameter weights by decision-makers, the objective into a hierarchical model, and calculate scores of each alternative consideration criteria and the overall score of each alternative [7] [11]. It

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also evaluated and conducted the sawability classification for ranking criteria [12]. Thus, the FAHP is a useful tool that has been applied to various aspects in previous research. For instance, evaluation of gemstone quality was analyzed via FAHP algorithm [13]. An FAHP approach was used, for example, to choose the best location for a gilsonite processing plant in Kermanshah Province, Iran [14]. The application of FAHP assessed the domino effects in the coal gasification process [15]. Further, an earthquake risk assessment in Sanandaj Province in Iran was discovered by the FAHP approach [16].

This study will determine the effect factors for attracting investment capital into industrial parks in Hai Duong Province, Vietnam; as such, the FAHP is used to calculate the scores of each criterion and overall scores of criteria. Notably, the FAHP helps to clarify the important meaning of criteria. The empirical results present the weights of the main criteria, sub-criteria, integrated criteria, and position of integrated criteria. The research recommends the important level of effect factors to attract investment capital.

The rest of this paper is organized as follows: Section 1 introduces a general review of attracting investment capital and FAHP method; Section 2 establishes the structure of the FAHP and equations of the modified FAHP and gives the basic concept of criteria; Section 3 reviews the empirical results and discusses the main finding; Section 4 recaptures important results and suggests future research.

II. RESEARCH METHOD

A. Modified Structure of Fuzzy Analytical Hierarchy Process

Based on the literature review in Section 2, this study found that attracting investment for industrial parks requires the coordination of various resources. Hence, it is suitable to use FAHP to attract investment in industrial parks in Hai Duong Province in Vietnam. The hierarchical analysis method can analyze the weight of each factor and integrate the factors of high importance to plan strategies for attracting investment for the industrial park. Therefore, the study establishes a model for attracting investment strategies for industrial parks. The FAHP structure of attracting investment is modified as shown in Figure 1. The study constructs four main criteria and 16 subcriteria. The main

criteria include infrastructure of industrial park, support policy of the state, human resource, and social and economic condition. Each of main criteria has four subcriteria, which clearly explain the characteristics of the main criteria.

B. Concept of Factors

In this study, questionnaires for experts in the Hai Duong Industrial Parks Authority were distributed for direct interviews. These experts are managers and have degrees above master. Every expert was directly surveyed; then, we collected responses to the questionnaires as well. Classifications and concepts of the main criteria and subcriteria are shown in Table I.

TABLE I
MAIN AND SUB CRITERIA FOR ATTRACTING INVESTMENT STRATEGIES

Main criteria	Subcriteria	Definition
C1: Infrastructure of industrial park	S11: Transportation system	The infrastructures of transportation, electricity, wastewater, and telecommunication systems in industrial parks.
	S12: The electricity and water systems fully meet the requirement of production and business activities	
	S13: Standard wastewater treatment system	
	S14: High quality telecommunication system	
C2: Support policy of the state	S21: Fast and apparent administrative procedures	Policies that the state supports for enterprises
	S22: Supporting enterprises to access banks loans	
	S23: Applying the free tax	
	S24: Support training of highly skilled human resources	
C3: Human resources	S31: Number of persons of working age	The potential human resource and training school in Hai Duong Province
	S32: Number of vocational training schools	
	S33: High-quality vocational training school	
	S34: Labor with professional working style	
C4: Social and economic condition	S41: Regional economic development	Current social and economic status in Hai Duong Province
	S42: Cost of rent land	
	S43: Securities and social assurance	
	S44: Environment is under good control	

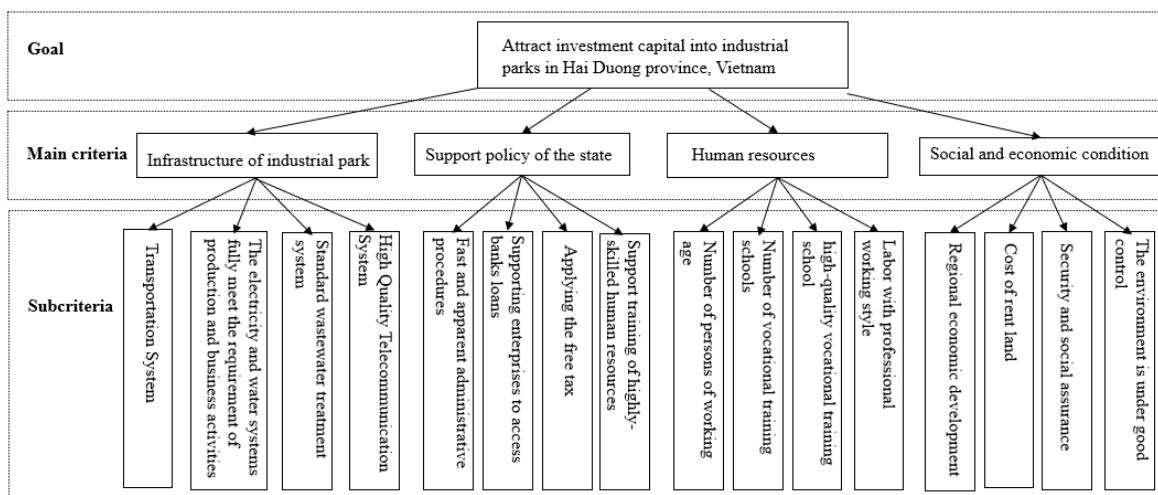


Fig. 1. The research framework of attracting investment capital into industrial parks.

C. Fuzzy Analytical Hierarchy Process

Triangular Fuzzy Number

The fuzzy number is a normalized and convex completion of real numbers with segmental continuity. The fuzzy numbers in this study are from $\tilde{1}$ to $\tilde{9}$. Experts were asked to determine the performance of main criteria and subcriteria. Linguistic variables of pairwise comparison are shown in Table II.

TABLE II
TRIANGULAR FUZZY NUMBER

Linguistic variable	Triangular fuzzy scale	Positive reciprocal triangular fuzzy scale
Little strong	(1,1,1)	(1,1,1)
Equally strong	(2,3,4)	(1/2,1/3,1/4)
Strong	(4,5,6)	(1/4,1/5,1/6)
Very important	(6,7,8)	(1/6,1/7,1/8)
Extremely important	(9,9,9)	(1/9,1/9,1/9)
Moderately Intermediate	(1,2,3); (3,4,5); (5,6,7); (7,8,9)	(1,1/2,1/3); (1/3,1/4,1/5); (1/5,1/6,1/7); (1/7,1/8,1/9)

Source: Saaty (2001) [17]

Table II denotes the triangular fuzzy number with three characteristics values, then these values are reversed and called as the reciprocal fuzzy number [18].

Modified Fuzzy AHP Algorithm

Fuzzy AHP algorithm is modified as the following steps:

Step 1. Construct a hierarchical analysis framework of attracting investment based on the triangular number $D_{ij} = (a_{ij}, b_{ij}, c_{ij})$. The equation of fuzzy numbers is calculated:

$$\begin{aligned} a_{ij} &= \left(\sum_{h=1}^m a_{ij}^h \right) / m \\ b_{ij} &= \left(\sum_{h=1}^m b_{ij}^h \right) / m \\ c_{ij} &= \left(\sum_{h=1}^m c_{ij}^h \right) / m \end{aligned} \quad (1)$$

Step 2. Construct a fuzzy pairwise comparison matrix.

$$D = \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} \\ a_{21} & 1 & a_{23} & a_{24} \\ a_{31} & a_{32} & 1 & a_{34} \\ a_{41} & a_{42} & a_{43} & 1 \end{bmatrix} \quad (2)$$

Step 3. Inverse the fuzzy numbers $D_{ij}^{-1} = (a_{ij}, b_{ij}, c_{ij})^{-1}$.

$$D^{-1} = \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} \\ 1/a_{12} & 1 & a_{23} & a_{24} \\ 1/a_{13} & 1/a_{23} & 1 & a_{34} \\ 1/a_{14} & 1/a_{24} & 1/a_{34} & 1 \end{bmatrix} \quad (3)$$

Step 4. Calculate the fuzzy geometric mean value.

$$\begin{aligned} g_{ij} &= D_1 \otimes D_2 \otimes D_3 \otimes D_4 = (a_{11}, b_{11}, c_{11}) \\ &\otimes (a_{12}, b_{12}, c_{12}) \otimes (a_{13}, b_{13}, c_{13}) \otimes (a_{14}, b_{14}, c_{14}) \\ &= \left(a_{11} * a_{12} * a_{13} * a_{14}, b_{11} * b_{12} * b_{13} * b_{14} \right. \\ &\quad \left. * c_{11} * c_{12} * c_{13} * c_{14} \right) \end{aligned} \quad (4)$$

Step 5. Compute the fuzzy weights [19].

$$w_i = g_i \otimes (g_1 \otimes g_2 \otimes g_3 \otimes g_4)^{-1} \quad (5)$$

Step 6. Conduct the weights.

$$w_i = \left(\frac{a_{ij} + b_{ij} + c_{ij}}{3} \right) \quad (6)$$

MCDM is a statistic method to evaluate an object or an event in many fields such as athletic competitions, questionnaire-based surveys, and performance appraisal [20]. In this study, we utilize FAHP method to analyze the questionnaire-based survey. This calculation process computes weights and integrated weights of criteria by using the above steps. The finding results evaluate the influence level of impacted factors for attracting investment capital in industrial parks in Hai Duong Province.

III. RESULTS

Industrial parks in Hai Duong Province have been established and developed over the past 20 years; however, attracting investment capital for business in these areas has limitations. Therefore, this study examines attracting investment capital in industrial parks in Hai Duong Province via questionnaire survey of experts in Hai Duong Industrial Zones Authority.

The questionnaire survey was delivered to five experts in the Hai Duong Industrial Parks Authority who have more than 10 year's related work experience and an undergraduate degree. The analysis process of the questionnaire survey was computed particularly.

In this study, four main evaluation aspects use the fuzzy AHP algorithm, as explained in Section 2.2. According to the four evaluation aspects and 16 sub-criteria, the structure of attracting investment capital into industrial parks was divided into three levels, as shown in Figure 1. The goal of attracting investment capital was the first level. The second level of the hierarchical structure comprised four main criteria under the goal. The third level of the hierarchical structure was constructed with 16 sub-criteria under the four main criteria. Hence, this study constructed three levels of the hierarchical structure. The main criteria were used for illustration.

Set a pairwise comparison matrix based on the triangular fuzzy number.

$$D = \begin{bmatrix} (1,1,1) & (1/8,1/7,1/6) & (6,7,8) & (6,7,8) \\ (6,7,8) & (1,1,1) & (6,7,8) & (6,7,8) \\ (1/8,1/7,1/6) & (1/8,1/7,1/6) & (1,1,1) & (6,7,8) \\ (1/8,1/7,1/6) & (1/8,1/7,1/6) & (1/8,1/7,1/6) & (1,1,1) \end{bmatrix} \quad (7)$$

Calculate the fuzzy geometric mean value.

$$\begin{aligned} g_{ij} &= D_1 \otimes D_2 \otimes D_3 \otimes D_4 \\ &= \left[\begin{aligned} &(1*0.125*6*6), (1*0.143*7*7), (1*0.167*8*8) \\ &(6*1*6*6), (7*1*7*7), (8*1*8*8) \\ &(0.125*0.125*1*6), (0.143*0.143*1*7), (0.167*0.167*1*8) \\ &(0.125*0.125*0.125*1), (0.143*0.143*0.143*1), (0.167*0.167*0.167*1) \end{aligned} \right]^{-1/4} \\ &= \begin{bmatrix} 1.5732, 1.7389, 1.9168 \\ 3.8337, 4.3035, 4.7568 \\ 0.5533, 0.6148, 0.6866 \\ 0.2101, 0.2325, 0.2609 \end{bmatrix} \end{aligned} \quad (8)$$

Conduct the fuzzy weights.

$$w_i = \begin{bmatrix} 0.2064, 0.2524, 0.3106 \\ 0.5030, 0.6246, 0.7709 \\ 0.0726, 0.0892, 0.1113 \\ 0.0276, 0.0337, 0.0423 \end{bmatrix} \quad (9)$$

Compute the weights.

$$w_i = \begin{bmatrix} 0.2527 \\ 0.6236 \\ 0.0897 \\ 0.0340 \end{bmatrix} \quad (10)$$

Based on the above steps, the weights for all main criteria and subcriteria and integrated weights for all subcriteria are conducted, these weights are shown particularly in Table III.

TABLE III
THE WEIGHT OF MAIN CRITERIA AND SUBCRITERIA

Main Criteria	Weight	Sub-criteria	Weight	Integrated weight	Rank
C1	0.2760	S11	0.4438	0.11096	2
		S12	0.2888	0.07219	8
		S13	0.2232	0.05579	9
		S14	0.0443	0.01106	15
C2	0.4362	S21	0.3024	0.07561	7
		S22	0.1608	0.04021	12
		S23	0.4531	0.11328	1
		S24	0.0836	0.02091	13
C3	0.1996	S31	0.4256	0.10640	4
		S32	0.0502	0.01254	14
		S33	0.1974	0.04936	10
		S34	0.3268	0.08170	6
C4	0.0882	S41	0.1805	0.04513	11
		S42	0.4407	0.11018	3
		S43	0.3440	0.08599	5
		S44	0.0348	0.00870	16

Source: Author's calculation

The weight of criteria represents the ratio of how much more important one criterion is than another. Table III indicates the weight of each criterion. For the main criteria, the C2 has the highest weight at 0.43617 (the strongest); the weight of industrial park's infrastructure is 0.27602, which is lower than the support policy of the state; next, the weight of the human resources is 0.19963; the weight of the social and economic condition is the lowest at 0.08818. Therefore, the ranking of the main criteria regarding attracting investment into industrial parks is as follows: Support policy of the state > Infrastructure of industrial park > Human resources > Social and economic condition. Investors will receive good support policies from the state when investing in industrial parks in Hai Duong Province.

Each main criterion has many subcriteria; each subcriterion is also reviewed and evaluated by the positive expert's opinions. For an industrial park's infrastructure, park, the weight of each subcriteria is in a range: S11 > S12 > S13 > S14. This result indicates that the transportation system has the strongest effect on the industrial park's infrastructure. For the state's support policy, the rank of the

weight is organized: S23 > S21 > S22 > S24, which means that applying the free tax is very important. For human resources, the weight of each subcriterion is ranked: S31 > S34 > S32 > S33; thus, the number of persons of working age has an important and strong effect. For social and economic conditions, the weight of each criterion is in a range: S42 > S43 > S41 > S44; this result denotes that the cost of rent land is evaluated to be the most important for investors.

After conducting all subcriteria of the main criteria, these weights of sub-criteria are integrated and computed for the integrated weight; further, the weights and position of sub-criteria in Table III are in a range: S23 > S11 > S42 > S31 > S43 > S34 > S21 > S12 > S13 > S33 > S41 > S22 > S24 > S32 > S14 > S44. Therefore, the analyzed result shows that applying the free tax is critical for attracting investment capital in Hai Duong Province; the second, third, and fourth ranks are transportation system, cost of rent land, and the number of working persons, respectively. S44 with the integrated weight is 0.0087; its importance is the lowest criterion in the integrated weights.

The empirical results reveal that the government in Hai Duong Province should focus on the state's support policies for investors such as free tax application of prioritized enterprises. Although the transportation of industrial parks is typically convenient and good, upgrading quality will lead to a better transportation system. Unnecessary administrative procedures should be removed to increase procedure quality. Moreover, labor needs to improve its skills to have highly skilled human resources. Increasing the quality of administrative procedures and structures will inspire the government to further in industrial parks.

In generally, weights of main criteria and subcriteria recommend their valuable meaning in different comparisons of groups, each separate group can explore its important criterion. Besides, the integrated weights and ranks of all subcriteria exhibit not only values but also positions. These evaluated results help both enterprises and government to determine the importance levels of each group to investment attraction into industrial parks in Hai Duong Province. Especially, the government can identify and create better policy to increase the investment capital in the future. When the government has a clear evidence of meaning level for all criterion, they can have an exact identification to improve the policies and enhance the development of industrial parks.

IV. DISCUSSION

The industrialization and modernization are key elements to convert agricultural economy to industrial economy in many provinces in Vietnam, including Bac Giang, Bac Ninh, Hai Phong, etc. These provinces have mostly attracted large foreign-invested companies in the world such as Samsung corporation in Bac Ninh province and Thai Nguyen province, Foxconn technology group in Bac Ninh province and Bac Giang province. Hai Duong Province has established and developed industrial parks for more than 10 years, which attracts many foreign enterprises in various aspects. In recent years, attracting investment capital into industrial parks in Hai Duong Province has gained some good signals because the attracting investment capital

increased smoothly from 2015 to June 2020 [21], as shown

TABLE IV
TOTAL INVESTMENT CAPITAL FROM 2015 TO 2019

Type of capital	FDI (Millions in USD)	DDI (Trillions in VND)
2015	324.94	2,194.03
2016	267.28	741.14
2017	260.36	335.93
2018	494.83	791.80
2019	541.20	1,431.95
06/2020	296.00	1,107.00

Source: Hai Duong industrial parks authority [21]

in Table IV.

Table IV indicates that there are two types of investment capital for industrial parks, including FDI and DDI. Total investment capital of FDI and DDI over 2015–2019 was 1,888.61 million (USD) and 3,300.82 trillion (VND), respectively. The highest investment capital for FDI and DDI was 541.20 million (USD) in 2019 and 2,194.03 trillion (VND) in 2015, respectively. Thus, the total investment capital achieved positive values, the FDI investment capital increased consecutively from 267.28 million USD in 2016 to 541.20 million USD in 2019; the DDI investment capital increased within three continual years from 335.93 trillion VND in 2017 to 1,431.95 trillion VND in 2019. In the first six months of 2020, although COVID-19 has a sharp impact on economics development, attracting investment capital for industrial parks in Hai Duong Province sent good signals for total investment capital of FDI as 296 million USD and DDI as 1.107 trillion VND. Further, industrial parks in Hai Duong Province are good environmental investments for domestic and cosmetic investors.

Moreover, attracting investment capital in these industrial parks in Hai Duong Province introduced important value that contributed to increase the labor and develop the economy. However, it has existed limitations; as such, investment capital has not achieved excellence value. Thus, an investigation into attracting investment capital in the industrial parks proceeds to take the ideas of experts and evaluate the effect factors that have a direct impact to attract investment capital; these experts also offered their opinions to increase investment capital. The empirical result and valuable investigation indicated difficult issues of attracting investment capital in the industrial parks based on overall score of criteria through the FAHP method, a long with complicated administrative procedures and shortage of the highly skilled laborers. Based on expert evaluations, attracting investment capital into industry parks should increase the quality of their infrastructure, simply do the administrative procedures, have better policy of tax for investors, raise the quality of human resources.

The above analysis indicated that total investment capital will increase when the government uses the particular strategies. The government gives priority to the policies of tax and administrative procedures to create an attractive environmental investment; enhances building and maintaining transportation systems; has a strategy to train skilled labors; and establishes the investment promotion activities to introduce strength. Thus, industrial parks in Hai Duong Province will attract large investment, thereby raising total investment capital.

V. CONCLUSION

In this study, the FAHP method is a useful tool that defines the effect factors to invest capital into industrial parks. The analysis explores the importance level of four main criteria and 16 subcriteria and then determines the position of each sub-criteria based on their integrated weight. With the function of defining the objective in the hierarchical model, the study sets up the research framework with four main criteria and 16 subcriteria. Next, the weights for each criterion are conducted. Finally, the integrated weights of criteria are calculated based on the separate weight of each criterion.

The FAHP method helps this research to determine the objectives and estimate the weights and integrated weights of the criteria. In this study, we set up three types of weights, including weights of main criteria, weights of subcriteria, and integrated weights of subcriteria, these weights exhibit their impact levels. The empirical result recommends a plan to increase attracting investment capital into industrial parks in Hai Duong Province. Local governments in Hai Duong Province should contribute to increase the quality of administrative procedures and support state policies for enterprises. The transportation system should also be improved to alleviate waiting in traffic jams. Vocational school and universities should set up courses that train skilled labor with practical activities.

Although this study discovers the importance of effect factors in investing capital into industrial parks in Hai Duong Province, it still has limitations. The study only determines the importance level of effect factors and recommends a plan to upgrade attracting investment capital; thus, further research should evaluate the operating performance of these industrial parks based on the previous data via data envelopment analysis method. To develop clear strategies for the future, further study should apply the forecasting method to predict the ability to invest capital over the short and long terms.

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