# Study on Ecological Development of Petrochemical Park Based on AHP

Sheng Chang, Siyi Wei

North China University of Science and Technology, Tangshan 063000, China.

## Abstract

**There are many factors that influence the development of the ecological development of the petrochemical park. According to the theory of circular economy and the characteristics of the petrochemical park, the analytic hierarchy process is used to evaluate the development of the ecological development of the petrochemical park. The study found that the pace of development of each aspect of the ecological development of petrochemical parks is not consistent, among which the material reduction and recycling development level are the best.**

## Keywords

**Ecological, Analytical hierarchy process, Circular economy.**

## 1. Introduction

Eco-industrial parks refer to industrial parks that are guided by the theory of industrial ecology and circular economy, and form a virtuous circle of production development, resource utilization, and environmental protection [1]. It is an efficient, stable, coordinated and sustainable integrated ecosystem petrochemical industry that can maximize people's enthusiasm and creativity. It is a pillar industry in China and a key industry for long-term development in the future. Its sustainable development is an important guarantee for the healthy development of the national economy [2]. According to data from the National Bureau of Statistics, as of 2018, there were 676 industrial parks with petroleum and chemical industries as the leading industries in the country, of which 57 were national level (including economic and technological development zones and high-tech zones); 351 provincial; 268 municipalities; 27813 enterprises above the scale of the oil and chemical industry. The added value of the year increased by 4.6 % year-on-year, an increase of 0.6 percentage points over the previous year; The main business revenue was 12.4 trillion yuan, an increase of 13.6 % year-on-year; The total profit was 839.38 billion yuan, an increase of 32.1 % year-on-year, accounting for 12.1 % and 12.7 % of the total revenue and profits of the country's large-scale industries. At the same time, the petrochemical industry is a "high consumption, high pollution, and high emission" industry. It not only consumes a large amount of fossil fuels, water resources and chemical raw materials, but also has a huge impact on the ecological environment. The waste water discharge in the petrochemical industry exceeds 4 billion tons, accounting for 20 % of the country's industrial volume, and the exhaust gas emission is 600 million cubic meters. The VOCs emissions alone account for about 40 % of the total industrial source emissions in China, and the waste emission is 370 million tons, which is the second largest in industry.

To solve the problem of pollution in petrochemical parks, this research is guided by the evaluation of the ecological development of petrochemical park, combining with the characteristics of petrochemical park, establishing the evaluation index system of ecological development of petrochemical park with reference to relevant standards, and evaluating it by analytic hierarchy process. It is of great significance to improve production and management in order to promote the development of recycling economy in petrochemical industry.

## 2. The construction of ecological development evaluation index system of petrochemical park

Ecological park is a complex system involving social, economic and environmental aspects. This study takes the ecological development of petrochemical parks as the target layer, and combining the characteristics of the petrochemical park. Referring to relevant standards: "National Ecological Industry Model Park Standard"(HJ274-2015), "Industry Ecological Industrial Park Standard"(HJ/T273-2006), based on material flow analysis, ecological industry and circular economy theoretical basis, Starting from the basic connotation of circular economy, a comprehensive evaluation index system for the eco-development of multi-factor petrochemical parks is established, which is based on the criteria of economic development, material reduction and recycling, pollution control, and park management. See Table 1.

Table 1 evaluation index system of ecological development of petrochemical park.

| Level 1 indicators | Level 2 indicator |
|---|---|
| Economic development | Growth rate of industrial added value（%） |
| Substance reduction and recycling | Integrated energy consumption per unit of industrial added value(tons of standard coal / 10,000 yuan) |
| | Unit industrial added value fresh water consumption(m3/million yuan) |
| | Production of wastewater per unit of industrial added value(T / million yuan) |
| | Industrial water reuse（%） |
| | Integrated utilization of industrial solid waste（%） |
| Pollution control | COD emissions per unit of industrial added value(kg/10000 yuan) |
| | SO2 emissions per unit of industrial added value(kg/10000 yuan) |
| | Disposal rate of hazardous waste |
| | Oil, volatile phenols emission compliance rate |
| | Waste collection system |
| | Waste centralized disposal facilities |
| Park management | Environmental Management System |
| | Process technical level |
| | Perfection of the information platform |

## 3. Research technique

AHP is a simple method for making decisions on some more complex and vague issues. It is a simple, flexible and practical multi-criteria decision-making method [4-5]. The biggest difficulty in evaluating the ecological development of petrochemical parks is the multi-index nature. Due to the influence of various factors such as economic development, material reduction and recycling, comprehensive utilization of resources, pollution control, and park management, many factors within each factor are intertwined. Interaction forms a complex relationship. Therefore, using the analytic hierarchy process, it can express the influence degree of various factors accurately and evaluate the development of the target object namely the zoology of the petrochemical park according to the actual situation of the influencing factors.

### 3.1 Establish a ladder hierarchy model.

The ecological development evaluation index system of the petrochemical park is a hierarchical system composed of the target layer (A), the criterion layer (B), and the indicator layer (C). See Figure 1.

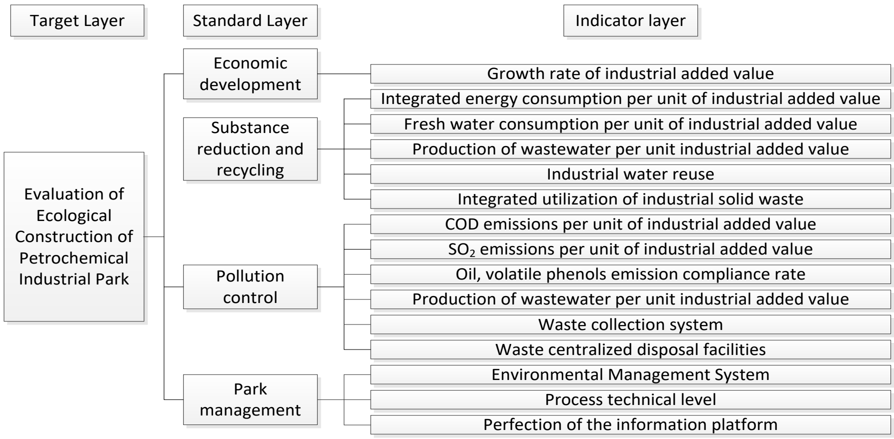


Fig. 1 Hierarchy Analysis Model of Ecological Development in Petrochemical Park

### 3.2 Construct judgement matrix and check consistency.

In order to compare the influence of each factor on a certain factor, a comparison matrix is established by comparing the factors in two pairs. The judgment Matrix has the following properties:

$$a_{ij} > 0 \tag{1}$$

$$a_{ji} = \frac{1}{a_{ij}} \, (i, j = 1, 2, \ldots, n) \tag{2}$$

$$a_{ii} = 1 \, (i = 1, 2, \ldots, n) \tag{3}$$

In order to obtain a quantitative judgment Matrix, a 1-9 scale method is used to determine the relative importance of indicators. According to the judgment principle of each element of the judgment Matrix, the importance of each factor in the evaluation at all levels is compared by expert consultation, and the judgment matrix is constructed [6].

Table 2 Meaning of scales

| Scales | meaning |
|---|---|
| 1 | Have the same importance compared with the two factors |
| 3 | Compared with the two factors, the former is slightly more important than the latter |
| 5 | Compared with the two factors, the former is obviously more important than the latter |
| 7 | Compared with the two factors, the former is more important than the latter |
| 9 | Compared with the two factors, the former is extremely important than the latter |
| 2,4,6,8 | Represents the middle value of the above adjacent judgment |
| reciprocal | If the ratio of the importance of factor I to factor J is aij, the ratio of factor J to factor I is $a_{ji} = 1/a_{ij}$ . |

When experts establish a judgment Matrix, it is more likely that the judgment results will be inconsistent. In general, we use the consistency ratio CR value to verify the consistency of the judgment matrix: $CR = CI/RI$ , where consistency refers to $CI = \lambda_{\max} - n/n-1$. The value of RI varies depending on the order of the matrix, as shown in table 3 [6]. If $CR \le 0.10$, it is considered that the consistency test of the judgment matrix is passed, otherwise the judgment matrix must be modified until satisfactory consistency is obtained.

Table 3 Average random consistency indicators

| Order | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 | 1.51 | 1.48 |

Through expert consultation, the criteria layer judgment matrix A and the indicator layer judgment matrices B1, B2, B3, B4 can be obtained. See Table 4-8.

Table 4 A-B judgement matrix

| A | $B_1$ | $B_2$ | $B_3$ | $B_4$ | CR |
|---|---|---|---|---|---|
| $B_1$ | 1 | 1/5 | 1/4 | 1/3 | CR=0.067≤0.1 |
| $B_2$ | 5 | 1 | 3 | 4 | |
| $B_3$ | 4 | 1/3 | 1 | 3 | Satisfactory consistency |
| $B_4$ | 3 | 1/4 | 1/3 | 1 | |

Table 5 $B_1$-C judgement matrix

| $B_1$ | $C_{11}$ | CR |
|---|---|---|
| $C_{11}$ | 1 | CR=0≤0.1 Satisfactory consistency |

Table 6 $B_2$-C judgement matrix

| $B_2$ | $C_{21}$ | $C_{22}$ | $C_{23}$ | $C_{24}$ | $C_{25}$ | CR |
|---|---|---|---|---|---|---|
| $C_{21}$ | 1 | 5 | 4 | 1/2 | 1/3 | CR=0.023≤0.1 |
| $C_{22}$ | 1/5 | 1 | 1/2 | 1/6 | 1/8 | |
| $C_{23}$ | 1/4 | 2 | 1 | 1/5 | 1/7 | |
| $C_{24}$ | 2 | 6 | 5 | 1 | 1/2 | Satisfactory consistency |
| $C_{25}$ | 3 | 8 | 7 | 2 | 1 | |

Table 7 $B_3$-C judgement matrix

| $B_3$ | $C_{31}$ | $C_{32}$ | $C_{33}$ | $C_{34}$ | $C_{35}$ | $C_{36}$ | CR |
|---|---|---|---|---|---|---|---|
| $C_{31}$ | 1 | 2 | 1/3 | 5 | 5 | 1/5 | CR=0.065≤0.1 |
| $C_{32}$ | 1/2 | 1 | 1/4 | 4 | 4 | 1/7 | |
| $C_{33}$ | 3 | 4 | 1 | 7 | 7 | 1/4 | |
| $C_{34}$ | 1/5 | 1/4 | 1/7 | 1 | 1 | 1/9 | |
| $C_{35}$ | 1/5 | 1/4 | 1/7 | 1 | 1 | 1/9 | Satisfactory consistency |
| $C_{36}$ | 5 | 7 | 4 | 9 | 9 | 1 | |

Table 8 $B_4$-C judgement matrix

| $B_4$ | $C_{41}$ | $C_{42}$ | $C_{43}$ | CR |
|---|---|---|---|---|
| $C_{41}$ | 1 | 1/4 | 2 | CR=0.007≤0.1 |
| $C_{42}$ | 4 | 1 | 6 | |
| $C_{43}$ | 1/2 | 1/6 | 1 | Satisfactory consistency |

Table 9 Index Weight of Ecological Development of Petrochemical Park

| Level B of the guidelines | | Indicator layer C | | Composite weights | sort |
|---|---|---|---|---|---|
| index | weight | index | weight | | |
| Economic development $B_1$ | 0.069 | Growth rate of industrial added value $C_{11}$ | 1 | 0.069 | 6 |
| | 0.529 | Integrated energy consumption per unit of industrial added value $C_{21}$ | 0.178 | 0.094 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| Substance reduction and cycling $B_2$ | | Unit industrial added value Fresh water consumption $C_{22}$ | 0.041 | 0.022 | 11 |
| | | Production of wastewater per unit industrial added value $C_{23}$ | 0.059 | 0.031 | 9 |
| | | Industrial water reuse rate $C_{24}$ | 0.275 | 0.146 | 2 |
| | | Integrated utilization of industrial solid waste $C_{25}$ | 0.447 | 0.236 | 1 |
| Pollution control $B_3$ | 0.268 | COD emissions per unit of industrial added value $C_{31}$ | 0.122 | 0.033 | 8 |
| | | $SO_2$ emissions per unit of industrial added value $C_{32}$ | 0.081 | 0.022 | 12 |
| | | Disposal rate of hazardous waste $C_{33}$ | 0.234 | 0.063 | 7 |
| | | Oil, volatile phenol emission compliance $C_{34}$ | 0.031 | 0.008 | 14 |
| | | Waste collection system $C_{35}$ | 0.031 | 0.008 | 15 |
| | | Waste centralized disposal facility $C_{36}$ | 0.501 | 0.134 | 3 |
| Park Management $B_4$ | 0.134 | Environmental Management System $C_{41}$ | 0.193 | 0.026 | 10 |
| | | Process level $C_{42}$ | 0.701 | 0.094 | 5 |
| | | Perfection of the information platform $C_{43}$ | 0.106 | 0.014 | 13 |

## 4. Conclusion

This study uses AHP to evaluate the ecological development of the petrochemical park. From the ecological development of the petrochemical park, the maximum weight of the standard layer index affected by material reduction and circulation is 0.529, then the pollution control weight is 0.268, the weight of the park management is 0.134, and the least affecting economic development is 0.069. However, the waste collection system in pollution control has the least impact on the ecological development of petrochemical parks, with a weight of 0.008, ranking 15th among the indicator levels. The level of process technology in the management of the park has a great influence on the ecological development of the petrochemical park, with a weight of 0.094, ranking 5 in the index level.

It can be seen that in the ecological development of petrochemical parks, it is also necessary to increase the development of the economy and ensure economic growth while improving the ecology. Secondly, the development pace of ecological development of the park is not consistent, and there is room for improvement.

## References

[1] E. Liwarska-Bizukojc, M. Bizukojc, A. Marcinkowski, et al. The conceptual model of an eco-industrial park based upon ecological relationships, Journal of Cleaner Production, 2009, 17(8):732-741.

[2] M. Lei, S.H. Zhong: Review on the Evaluation Study of Ecological Industrial Park in Foreign Countries. Management of scientific research. 2010, 31(2):178-184. (In Chinese)

[3] P. Xiao: Construction of Circular Economy Evaluation Model for Petrochemical Industrial Park: Based on Hierarchy Analysis, Journal of Beijing Institute of Administration, 2013(1): 79-83. (In Chinese)

[4] Y. J. Qi. Comparative Study of Petrochemical Recycling Economy, Petrochemical Technology and Economics, 2007(03): 8-12.

[5] Y.H. Xiao, X.W. Zhang: An Evaluation Study on Innovation Ability of High-tech Zone in China Based on AHP, Economic issues, 2012(1): 31-34. (In Chinese)

[6] M. Li, J.F. Wang: Construction of Circular Economy Evaluation Model for Petrochemical Industrial Park: Based on Hierarchy Analysis, Journal of Beijing Institute of Administration, 2013(1): 79-83. (In Chinese)