Research on the Harmonization Evaluation of Regional Logistics Ecosystem Based on Entropy Weight and DEA

Ya-chao WU¹, Ling-yun ZHOU²,*, Jun-jie FAN³, Qin-man FAN¹ and Xiao-fan ZHOU¹

¹School of Management Engineering, Huaiyin Institute of Technology, Huaian, China 223003
²Key Laboratory for Traffic and Transportation Security of Jiangsu Province, Huaiyin Institute of Technology, Huaian, China 223003
³School of Economics and Management, Beijing Jiaotong University, Beijing, China, 100044

*Corresponding author

Keywords: Regional logistics, Ecosystem, Harmonization evaluation, Data envelopment analysis.

Abstract. The harmonization evaluation of ecosystem is useful to accurately reveal the development status and problems. Based on the theory of ecology and complex adaptive system, the connotation and characteristics of the harmonization of regional logistics ecosystem were analyzed from the perspective of the ecological health. The harmonization evaluation index system of regional logistics ecosystem was constructed according to the structure, function, ecological economics and development environment. Moreover, the harmonization evaluation model of regional logistics ecosystem was built base on entropy weight and data envelopment analysis (DEA) methods. The proposed methodology can evaluate the harmonization development status of regional logistics ecosystem and provide new ideas and new methods for regional logistics industry management.

Introduction

With the emphasis on ecology and environment, the healthy development of ecosystem has become an important research hotspot. At present, there is no general definition of ecosystem harmonization, but some scholars have studied and explored the harmonization of ecosystem from their respective subject background and case, so as to produce different concepts and thoughts of ecological harmonization. Ecosystem harmonization can be understood as a state of ecosystem, whose research began in the 1940s. In the context of the widespread degradation of the global ecosystem, the concept of "ecosystem harmonization" began to receive widespread attention in the late 1970s. On the whole, there is no consensus on the current understanding of the harmonization of industrial ecosystems at home and abroad, but this does not prevent it from being widely used in practice [¹,²]. Mark et al. (2002) argued that ecosystem harmonization was determined based on functional processes, and its assessment should include the integrity of ecosystems, adaptability and efficiency [³]. Konghongmei (2002) argued that environmental management was closely related to the harmonization of ecosystems. Xiao Jingcheng and Li Bihong (2016) thought that industrial cluster ecosystem’s harmonious development played a strong role in promoting the sustainable development of the regional economy, and it should be analyzed based on the characteristics of industrial clusters, self-organized from the system harmonization [⁴].

Ecosystem harmonization is the purpose of environmental management. Ecosystem harmonization provides accurate development information and decision making basis for achieving regional sustainable development [⁵]. The evolution of regional logistics ecosystem is a process of transforming from low orderly structure to higher orderly structure. The significance of its evaluation of harmonization is to reveal the status of system development accurately and discover the problems in regional logistics, and the government departments can put forward the corresponding suggestions and countermeasures to further improve the development environment of regional logistics, which helps it develop to a higher basic stable statue of ecosystem.
Connotation of Harmonization of Regional Logistics Ecosystem

According to the theory of ecology and complex adaptive system, ecosystem harmonization refers to that ecosystem could maintain its vitality, organizational structure and autonomy, have the ability of resisting interference and recovering in the external stress. Considering the characteristics of ecosystem harmonization and regional logistics industry cluster, the regional logistics ecosystem harmonization should have the following characteristics: having a reasonable structure of logistics population; maintaining internal self-organizing process; having the logistics output with a high level; having a strong capacity for logistics sustainable development; having a good logistics industry development environment.

Evaluation Index System of Regional Logistics Ecosystem Harmonization

The Principle of Establishing Index System

Regional logistics ecosystem is a complex multi-dimensional, multi-level, dynamic organic whole, whose harmonious development is commonly impacted by the internal and external elements. Therefore, the evaluation of the regional logistics ecosystem harmonization must proceed from the whole system, taking into account the system structure, characteristics and the relationship with the external environment, establishing comprehensive evaluation index system from a number of scales on the system vitality, organization, resilience and others, so as to make a comprehensive measure and evaluation of its harmonious development. The evaluation index of regional logistics ecosystem harmonization should not only ensure the rationality, but also ensure that the information contained in the evaluation index is effective and comprehensive, which can reflect the characteristics of the system. In the specific research process, if the research focus is different, the choice of research angles will change. The study of urban location and logistics industry cluster characteristics is different, then the evaluation index system is bound to be different. In this paper, the principle of constructing the evaluation index system includes system, scientific, universal comparability, data availability, quantitative index and practicality.

Index System Construction

Because of the complexity of the regional logistics ecosystem, it is difficult to simply summarize the evaluation of the harmonization of the urban logistics industry cluster. According to the structure, function and harmonization characteristics of the regional logistics ecosystem, the comprehensive harmonization evaluation index system of regional logistics ecosystem is shown in Table 1.

(1) Industrial organization structure. As a complex or polymer industry, urban logistics industry cluster is assembled by a variety of types of logistics industry cluster. The industrial organization structure mainly refers to the core logistics service sub-industry of the regional logistics ecosystem, the diversity and related index of the supporting service organization or organization, including the number of logistics industry activity units, the number of legal persons above the domestic trade limit, the industrial diversity and the dominant Coordination, R & D and technical services, the diversity of logistics enterprises and so on.

(2) Industrial development vitality. The vitality of the regional logistics ecosystem represents its activity, metabolism and primary productivity, which comprehensively reflects the service function, operational efficiency and efficiency of a city logistics industry cluster. We can use the best economic benefits, input-output ratio indicators to measure the regional logistics ecosystem vitality, including the total social logistics, logistics industry, the value of the logistics industry, fixed asset investment, corporate logistics outsourcing level, freight volume, freight turnover quantity and other output indicators.

(3) Industrial ecological resilience. It mainly refers to that the regional logistics ecosystem improves self-maintenance and update capacity through scientific and technological progress, industrial cooperation, ecological protection and other ways, including: logistics cost ratio of GDP, logistics
information level, logistics and energy consumption, green logistics development, the level of convergence of different transport, logistics and technological innovation level, the linkage situation of logistics industry and manufacturing.

Table 1. Evaluation index system of regional logistics ecosystem harmonization.

<table>
<thead>
<tr>
<th>target layer</th>
<th>criteria layer</th>
<th>index layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>cluster organization structure</td>
<td>the unit quantity of logistics industry activity</td>
<td>the number of legal persons above domestic trade limit</td>
</tr>
<tr>
<td></td>
<td>the coordination degree of industry diversity and dominance</td>
<td>the number of cooperative R &amp; D and technical services</td>
</tr>
<tr>
<td></td>
<td>the diversity of logistics enterprises</td>
<td></td>
</tr>
<tr>
<td>industrial developing vitality</td>
<td>total social logistics</td>
<td>the gross product of logistics industry</td>
</tr>
<tr>
<td></td>
<td>investment in fixed assets of logistics industry</td>
<td>the number of cooperative R &amp; D and technical services</td>
</tr>
<tr>
<td></td>
<td>enterprises’ logistics outsourcing level</td>
<td></td>
</tr>
<tr>
<td></td>
<td>freight volume</td>
<td></td>
</tr>
<tr>
<td></td>
<td>freight turnover</td>
<td></td>
</tr>
<tr>
<td></td>
<td>logistics cost to GDP ratio</td>
<td>the level of logistics information</td>
</tr>
<tr>
<td></td>
<td>the level of logistics information</td>
<td>the consumption of logistics energy</td>
</tr>
<tr>
<td></td>
<td>the consumption of logistics energy</td>
<td>green logistics development</td>
</tr>
<tr>
<td></td>
<td>green logistics development</td>
<td>the convergence level of different transports</td>
</tr>
<tr>
<td></td>
<td>the innovation Level of logistics science and technology</td>
<td>the linkage of logistics and manufacturing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>industrial ecological resilience</td>
<td>regional total production</td>
<td>railway mileage</td>
</tr>
<tr>
<td></td>
<td>railway mileage</td>
<td>highway mileage</td>
</tr>
<tr>
<td></td>
<td>highway mileage</td>
<td>inland waterway mileage</td>
</tr>
<tr>
<td></td>
<td>inland waterway mileage</td>
<td>the total retail sales of social goods consumed</td>
</tr>
<tr>
<td></td>
<td>the total retail sales of social goods consumed</td>
<td>the total amount of goods purchased for wholesale and retail trade</td>
</tr>
<tr>
<td></td>
<td>the total amount of goods purchased for wholesale and retail trade</td>
<td>total import and export of goods</td>
</tr>
<tr>
<td></td>
<td>total import and export of goods</td>
<td>the level of logistics standards and policy system</td>
</tr>
<tr>
<td></td>
<td>the level of logistics standards and policy system</td>
<td></td>
</tr>
</tbody>
</table>

(4) Industrial development environment. It mainly refers to the basic conditions, economic needs, technical standards and policy support environment for the development of eco-system of urban logistics industry cluster, specifically including the total amount of regional production, railway mileage, highway mileage, inland waterway mileage, total retail sales of social consumer goods, the total amount of goods purchased, the total import and export of goods, logistics standards and policy system level.

Evaluation Criteria and Method Selection of Regional Logistics Ecosystem Harmonization

Evaluation Criteria

In order to make an accurate assessment of the harmonization of ecosystems, it is necessary to develop the corresponding standards according to the concept of ecosystem harmonization. Because the research of the harmonization of industrial ecosystem just starts and the research on the harmonization of industrial cluster ecosystem is scarce, the evaluation standard of harmonization has
not yet formed a unified consensus. At present, some scholars divide the natural ecosystem harmonization evaluation criteria into harmonization, sub-harmonization and disease these three kinds of standards. In order to describe this metric result more concisely, it is possible to divide the evaluation grades of regional logistics ecosystem harmonization into five states: harmonious state (V), harmonious state (IV), Basic harmonization (III), disharmonization (II), harmonization state difference (I) in the light of the general level of industrial ecosystem harmonization.

At present, there are two major methods for industrial ecosystem-related evaluation: qualitative evaluation and quantitative evaluation. Among quantitative evaluation, there are Analytic Hierarchy Process (AHP), energy analysis, target planning, optimization method, gray system evaluation, fuzzy comprehensive evaluation, rough set, data envelopment analysis (DEA), etc. we need to make a reasonable choice based on specific target, object, and the main body evaluated.

Because the regional logistics ecosystem health assessment has many characteristics such as multi-scale, multi-objective, uncertainty and fuzziness, the harmonization evaluation of regional logistics ecosystem can be treated as a comprehensive evaluation problem. A DEA model with entropy weight constraint (E-DEA model) can be constructed by the combination of entropy method and DEA method so as to evaluate the harmonization degree of regional logistics ecosystem.

**Determination of Entropy Weight**

The value of the entropy is an intuitive representation of the effective information expressed by the index, so the entropy can reflect the importance of the index relative to the object evaluated. If there are \( m \) evaluation indicators and \( n \) decision-making objects, the decision matrix is:

\[
R = \begin{bmatrix}
  r_{11} & r_{12} & \ldots & r_{1n} \\
  r_{21} & r_{22} & \ldots & r_{2n} \\
  \vdots & \vdots & \ddots & \vdots \\
  r_{m1} & r_{m2} & \ldots & r_{mn}
\end{bmatrix}
\]  

(1)

In the evaluation of \( m \) decision-making indicators and \( n \) decision-making objects, the entropy of the order of decision-making index \( i \) is defined as:

\[
Hi = -k \sum_{j=1}^{n} f_j \ln f_j \quad (i=1,2,\ldots,m)
\]

(2)

where \( f_j = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}} \), \( k = \frac{1}{\ln n} \). If \( f_j = 0 \), then \( f_j \ln f_j = 0 \)

In the decision-making problem, the entropy weight of the order of decision-making index \( i \) is defined as:

\[
\omega_i = \frac{1 - Hi}{m - \sum_{i=1}^{m} Hi}
\]

(3)

**Construction of DEA Model**

DEA as a nonparametric method, can effectively measure the relative effectiveness of decision making unit with multi-inputs and multi-outputs. The two most basic methods of the DEA method are the \( C^2R \) and \( BC^2 \) models. \( BC^2 \) model can only evaluate whether the technical efficiency is the most effective state, ignoring the impact of scale efficiency; \( C^2R \) model can simultaneously measure the scale efficiency and technical efficiency, and reveal their relationship.
If there are \( n \) regional logistics ecosystems, \( m \) input indicators and \( s \) output indicators, the evaluation model based on the \( C^2R \) model is:

\[
\begin{align*}
\min_{\lambda} & \quad \theta \\
\text{s.t.} & \quad \sum_{j=1}^{n} \lambda_j x_j - \theta x_0 \leq 0 \\
& \quad \sum_{j=1}^{n} \lambda_j y_j - \theta y_0 \geq 0 \\
& \quad \sum_{j=1}^{n} \lambda_j = 1, \lambda_j \geq 0, j = 1, 2..., n \\
\end{align*}
\]

(4)

where \( X_j = (x_{j1}, x_{j2}, ..., x_{jn}) \) denotes the input index set, \( Y_j = (y_{j1}, y_{j2}, ..., y_{jn}) \) denotes the output indicator set, \( \lambda_j \) denotes weight factor and \( \theta \) denotes the target value.

According to the linear programming technology, we can get the optimal solution \( \theta^* \), if the optimal solution of a project is \( \theta^* = 1 \), then the project construction investment is efficient, otherwise the project investment is relatively inefficient.

**Conclusion**

The harmonization plays an important role in promoting the sustainable development of regional logistics ecosystem. This paper proposed a comprehensive methodology to accurately evaluate the harmonization status of regional logistics industrial ecosystem. The main results are as follows.

1. The harmonization connotation of regional logistics ecosystem was put forward from the ecological health perspective, and its characteristics were analyzed based on the ecologic theory.

2. According to the structure, function, ecological economics and development environment, the harmonization evaluation index system of regional logistics ecosystem was constructed, which consisted of cluster structure index, industrial development vitality index, industrial ecological restoring force index and industrial development environment index.

3. The harmonization evaluation criteria of regional logistics ecosystem were analyzed, and the harmonization evaluation model was built base on entropy weight and DEA methods to evaluate the harmonization development status.

The research provides a new method and tool for the health and sustainable development study of regional logistics ecosystem, and a reference to the decision of regional logistics industry management.

**Acknowledgments**

This work was supported by the National Natural Science Foundation of China (Granted No. 71403096) and University Philosophy and Social Science Foundation in Jiangsu Province.

**References**


