Study on Logistics Capability of Manufacturing Enterprise via AHP and Fuzzy Evaluation

Xianming Liu, Shujie Yun, Xiaorong Huang, Jingyuan Xing and Yazhou Xiong
School of Economics and Management, Hubei Polytechnic University, Huangshi, 435003, China
Department of Basic, Henan Mechanical and Electrical Engineering College, Xinxiang, 453000, China

Abstract: Logistics is called as a source of the third profit and it is also one of the most important and difficult factors in the successful implementation of the supply chain. The logistics capability is summarized as a comprehensive logistics ability, including the logistics cost controlling, logistics service, logistics elements and logistics organization and management. After analyzing the fundamental connotation of logistics capability, this study establishes an evaluation system of logistics capability from the above four aspects. The model of AHP and fuzzy evaluation are comprehensively used to assess the logistics capability of manufacturing enterprise. And a case of manufacturing enterprise in 2011 is analyzed to prove that the method is valid.

Key words: Logistics capability, analytic hierarchy process (AHP), fuzzy evaluation

INTRODUCTION

Regarded as the third profit source, logistics is playing an extremely important role in the process of the modern industrial production. At present it becomes more and more difficult that the enterprises only rely on the ability to create ways to obtain the sustainable competitive advantage. Therefore, the enterprises begin to turn their attention to the logistics field, which is called "the third profit source" of the enterprises.

In the past decades, a lot of research on the logistics capability had been made by many experts and scholars at home and abroad. Shang et al. (2009) summarized the logistics capability from four aspects and evaluated the logistics capability of a case based on the fuzzy evaluation method. Logistics capability should include processing ability and the value-added capacity and the relationship between them was analyzed (Kumar, 2008). Morash et al. (1996) made a study on strategic logistics capabilities for competitive advantage and firm success. Huang (2008) put forward some problem-solving measures to improve the logistics capability. Daugherty and Pittman (1995) studied the logistics capability from the speed of product distribution, information exchange and flexibility. Daugherty et al. (1998) thought that logistics capability should be studied from five performance measures, including the response speed of the customer, the level of customer service, delivery on time, stability of the quality and advance notice of delay or shortage.

Generally speaking, a lot of experts and scholars performed some empirical studies on logistics capabilities via some evaluation methods, including the Analytic Hierarchy Process (AHP), fuzzy evaluation, Principal Component Analysis (PCA) and entropy theory and so on (Shi et al., 2009; Yu et al., 2010). At the same time, every evaluation method has its advantages and disadvantages. Using the model of AHP and fuzzy evaluation, the study establishes logistics capability evaluation system from four aspects and tests it via a case study in the manufacturing enterprise.

TO CONSTRUCT THE EVALUATION SYSTEM OF LOGISTICS CAPABILITY

Different industries have different priorities about the evaluation indicator of logistics capability. Based on the results of previous research, according to the comparison and summary, this study intends to establish a more scientific indicator system from the following five aspects and every aspect can be divided into different components.

Ability to control the logistics cost:

- Supply logistics cost: It mainly refers to forecast cost of logistics, projected cost of logistics and preparation cost of logistics
- Production logistics cost: It mainly refers to a variety of productive logistics cost, including loading and unloading, transportation, processing, storage and transportation, etc
- Sales logistics cost: It mainly refers to the sales service cost of the logistics, including the storage, packaging, service fees, etc

Corresponding Author: Yazhou Xiong, School of Economics and management, Hubei Polytechnic University, Huangshi, 455003, China
Return logistics cost: It mainly refers to the logistics cost for the return and exchange
Abandoned logistics cost: It mainly refers to the logistics cost produced by waste, substandard products

Ability of logistics service:
- Time efficiency elements: It mainly refers to order processing speed, delivery accuracy and flexibility
- Information elements: It mainly refers to informatization level, complete information and visibility
- Customer element: It mainly refers to the goods availability, complaint handling, personalized response

Ability of logistics elements:
- Logistics equipment: It mainly refers to the machinery and equipment needed for various logistics activities and logistics operations
- Logistics facilities area: It mainly refers to the facilities area needed for various logistics activities and logistics operations
- Logistics capital: It mainly refers to the capital needed for various logistics activities and logistics operations

Ability of logistics organization and management:
- Management ability: It mainly refers to the management ability of logistics administrators
- Operation ability: It mainly refers to the operation ability of logistics activity operators
- Technical level: It mainly refers to the technical level of logistics technical personnel

Considering the principles of purpose, scientific, adaptability, comparability and overall system about indicators, an evaluation indicator system of logistics capabilities that contains 4 first-level indicators, 14 second-level indicators is established (Table 1).

TO DETERMINE THE MODEL INDICATORS VIA AHP

The Analytic Hierarchy Process (AHP) is a functional decision process proposed and gradually improved by the American mathematician Saaty T. L. in the 1970's (Saaty, 1990). It is appropriate to use the AHP method to determine weights among the second-level indicators and weighted calculation. Finally, this study uses the AHP method to establish a model, whose main steps are as follows (Duan et al., 2011).

To construct the judgment matrices of each level: After the model of AHP is established, the judgment matrices of each level will be easily constructed. According to the questionnaires survey and expert opinion, the relative important each other will be easily expressed. Then the data matrices that represent respectively the judgment matrices of the second-level indicators will be constructed (Chen and Li, 2011).

To perform hierarchical single sorting and consistency check: As some program can be written simply and run in the Matlab software, the hierarchical single sorting and the consistency check can be easily solved. And the equation of the consistency check is as follows:

\[ CI = \frac{\lambda_{max} - n}{n-1} \]  \hspace{2cm} (1)

\[ CR = \frac{CI}{RI} \] \hspace{2cm} (2)

Where:
- \( \lambda_{max} \) = The maximum eigenvalue
- \( n \) = The rank of judgment matrix

Table 1: Evaluation indicator system of logistics capabilities

<table>
<thead>
<tr>
<th>First-level indicators</th>
<th>No.</th>
<th>Second-level indicators</th>
<th>No.</th>
<th>Relative weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to control the logistics cost</td>
<td>U1</td>
<td>Supply logistics cost</td>
<td>u1</td>
<td>w1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Production logistics cost</td>
<td>u2</td>
<td>w2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sales logistics cost</td>
<td>u3</td>
<td>w3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Return logistics cost</td>
<td>u4</td>
<td>w4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Abandoned logistics cost</td>
<td>u5</td>
<td>w5</td>
</tr>
<tr>
<td>Ability of logistics service</td>
<td>U2</td>
<td>Time efficiency elements</td>
<td>u6</td>
<td>w6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Information elements</td>
<td>u7</td>
<td>w7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Customer element</td>
<td>u8</td>
<td>w8</td>
</tr>
<tr>
<td>Ability of logistics elements</td>
<td>U3</td>
<td>Logistics equipment</td>
<td>u9</td>
<td>w9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Logistics facilities area</td>
<td>u10</td>
<td>w10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Logistics capital</td>
<td>u11</td>
<td>w11</td>
</tr>
<tr>
<td>Ability of logistics organization and management</td>
<td>U4</td>
<td>Management ability</td>
<td>u12</td>
<td>w12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operation ability</td>
<td>u13</td>
<td>w13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Technical level</td>
<td>u14</td>
<td>w14</td>
</tr>
</tbody>
</table>
Consistency of judgment matrix deviation
Random consistence rate
The average random consistence of different rank
judgment matrix

To adjust the judgment matrix and hierarchical ranking model: After the calculation of the judgment matrix via the Matlab software, CI and CR will be easily obtained. If necessary, the judgment matrix and hierarchical ranking model may be corrected and adjusted. If CR is less than 0.1, the results of hierarchical sorting will satisfy the requirement for consistency, otherwise the judgment matrix will need to be adjusted.

TO ESTABLISH EVALUATION SYSTEM OF LOGISTICS ABILITY VIA FUZZY EVALUATION

To determine the evaluation set: In the model of the fuzzy evaluation, the evaluation set of the logistics capability is \( C_i \) (i = 1, 2, 3, 4, 5) that express, respectively five grades, including the higher, high, general, low and lower. And the above five grades are given the assignment \( V = \{95, 85, 75, 65, 30\} \).

To establish evaluation membership matrix \( \mu_i \):

\[
\mu_i = \begin{pmatrix}
\mu_{i1} & \mu_{i2} & \cdots & \mu_{in}
\end{pmatrix}
\]

Where:
\( i \) = No. of the first-level indicators
\( n \) = No. of evaluation grades in the evaluation set
\( m \) = No. of the evaluated factors

To make the fuzzy comprehensive evaluation:

- To make the second-level fuzzy comprehensive evaluation:

\[
T = \sum_{i=1}^{n} \mu_i \times u_i = (w_1, w_2, ..., w_n)
\]

Where:
\( i \) = Number of the first-level indicators
\( w_i \) = Internal weight of the first-level evaluation index \( U_i \) (i = 1, 2, 3)
\( \mu_i \) = Evaluation matrix of level i

To make the first-level fuzzy comprehensive evaluation:

\[
A = w \times T
\]

Where:
\( w \) = Relative weights among the first-level indicators
\( T \) = Membership vector of the factor \( U \) corresponding to the evaluation set \( V \)
\( A \) = Comprehensive evaluation vector

To determine the grade of comprehensive evaluation:

\[
F = A \times d
\]

Where:
\( F \) = Final evaluation score
\( d \) = Rating scores matrix
\( A \) = Comprehensive evaluation vector

Case study: In this study, the logistics capability of a manufacturing enterprise in 2011 is evaluated by the models of AHP and fuzzy evaluation.

To determine weights among the second-level indicators via AHP: According to the expert scoring and results of the questionnaires, the hierarchical analysis matrix will be built so as to determine the internal weights of evaluation index level. The maximum eigenvalue of all judgment matrices is as follows and all the results of hierarchical sorting can satisfy the requirement for consistency check:

- The calculation of the judgment matrix \( U_i \) (Table 2)

**Remarks:** \( \lambda_{max} = 5.2826, CI = 0.0706, CR = 0.0631<0.10 \)

\( w_i \) = Relative weights of the first-level indicators \( U_i \).

- The calculation of the judgment matrix \( U_j \) (Table 3)

**Remarks:** \( \lambda_{max} = 3.0385, CI = 0.0193, CR = 0.0332<0.10 \)

\( w_j \) = Relative weights of the first-level indicators \( U_j \).

- The calculation of the judgment matrix \( U_k \) (Table 4)

**Remarks:** \( \lambda_{max} = 3.0383, CI = 0.0091, CR = 0.0158<0.10 \)

\( w_k \) = Relative weights of the first-level indicators \( U_k \).

- The calculation of the judgment matrix \( U_n \) (Table 5)

**Remarks:** \( \lambda_{max} = 3.0765, CI = 0.0368, CR = 0.0634<0.10 \)

\( w_n \) = Relative weights of the first-level indicators \( U_n \).
Table 2: Judgment matrix U1

<table>
<thead>
<tr>
<th>Ability to control the logistics cost (U1)</th>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
<th>w5</th>
<th>w6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply logistics cost (u1)</td>
<td>1</td>
<td>1/3</td>
<td>1/5</td>
<td>2</td>
<td>3</td>
<td>0.1140</td>
</tr>
<tr>
<td>Production logistics cost (u2)</td>
<td>3</td>
<td>1</td>
<td>1/3</td>
<td>5</td>
<td>7</td>
<td>0.2711</td>
</tr>
<tr>
<td>Sales logistics cost (u3)</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>8</td>
<td>0.5016</td>
</tr>
<tr>
<td>Return logistics cost (u4)</td>
<td>1/3</td>
<td>1/5</td>
<td>1/6</td>
<td>1</td>
<td>3</td>
<td>0.0708</td>
</tr>
<tr>
<td>Abandoned logistics cost (u5)</td>
<td>1/2</td>
<td>1/7</td>
<td>1/8</td>
<td>1/3</td>
<td>1</td>
<td>0.0425</td>
</tr>
</tbody>
</table>

Table 3: Judgment matrix U2

<table>
<thead>
<tr>
<th>Ability of logistics service (U2)</th>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
<th>w5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time efficiency elements (u1)</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>0.6370</td>
<td></td>
</tr>
<tr>
<td>Information elements (u2)</td>
<td>1/3</td>
<td>1</td>
<td>3</td>
<td>0.2883</td>
<td></td>
</tr>
<tr>
<td>Customer element (u3)</td>
<td>1/5</td>
<td>1/3</td>
<td>1</td>
<td>0.1047</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Judgment matrix U3

<table>
<thead>
<tr>
<th>Ability of logistics elements (U3)</th>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
<th>w5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistics equipment (u1)</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>0.5584</td>
<td></td>
</tr>
<tr>
<td>Logistics facilities area (u2)</td>
<td>1/2</td>
<td>1</td>
<td>3</td>
<td>0.3196</td>
<td></td>
</tr>
<tr>
<td>Logistics capital (u3)</td>
<td>1/4</td>
<td>1/3</td>
<td>1</td>
<td>0.1220</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Judgment matrix U4

<table>
<thead>
<tr>
<th>Ability of logistics organization and management (U4)</th>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management ability (u1)</td>
<td>1</td>
<td>1/3</td>
<td>1/4</td>
<td>0.1172</td>
</tr>
<tr>
<td>Operation ability (u2)</td>
<td>3</td>
<td>1</td>
<td>1/3</td>
<td>0.2684</td>
</tr>
<tr>
<td>Technical level (u3)</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>0.1444</td>
</tr>
</tbody>
</table>

Table 6: Judgment matrix U5

<table>
<thead>
<tr>
<th>Comprehensive logistics ability (U5)</th>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
<th>w5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to control the logistics cost (U1)</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>0.5292</td>
</tr>
<tr>
<td>Ability of logistics service (U2)</td>
<td>1/3</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>0.2682</td>
</tr>
<tr>
<td>Ability of logistics elements (U3)</td>
<td>1/4</td>
<td>1/3</td>
<td>1</td>
<td>3</td>
<td>0.1542</td>
</tr>
<tr>
<td>Ability of logistics organization and management (U4)</td>
<td>1/5</td>
<td>1/4</td>
<td>1/3</td>
<td>1</td>
<td>0.0694</td>
</tr>
</tbody>
</table>

- The calculation of the judgment matrix U (Table 6)

Remarks: λmax = 4.1807, CI = 0.0602, CR = 0.0669<0.10

w = Relative weights among the first-level indicators.

To make the fuzzy comprehensive evaluation of logistics capability: According to questionnaires survey and Eq 3, the membership of indicators μi (i = 1, 2, 3, 4) will be obtained which is as follows:

\[ w_i = (0.1140, 0.2711, 0.5016, 0.0708, 0.0425) \]

d = (0.2366, 0.2591, 0.3072, 0.1129, 0.0841)

Similarly:

\[ T_1 = w_i \mu_i = (0.3154, 0.2339, 0.2927, 0.0871, 0.0710) \]

\[ T_2 = (0.3756, 0.2680, 0.2122, 0.0721, 0.0721) \]

\[ T_3 = (0.3117, 0.3161, 0.2275, 0.0816, 0.0631) \]

According to the Eq 5, the evaluation values of the first-indicator can be obtained:

\[ T = \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \end{bmatrix} = \begin{bmatrix} 0.2366 \\ 0.3154 \\ 0.3756 \\ 0.3117 \end{bmatrix} \begin{bmatrix} 0.2591 \\ 0.2339 \\ 0.2680 \\ 0.3161 \end{bmatrix} \begin{bmatrix} 0.3072 \\ 0.2927 \\ 0.2122 \\ 0.2275 \end{bmatrix} \begin{bmatrix} 0.1129 \\ 0.0871 \\ 0.0721 \\ 0.0816 \end{bmatrix} \begin{bmatrix} 0.0841 \\ 0.0710 \\ 0.0721 \\ 0.0631 \end{bmatrix} \]

\[ A = w \times T = (0.5292, 0.2682, 0.1342, 0.0684) \]

According to the Eq 6, value of logistics capabilities of every level can be obtained:

\[ \text{The score of the first-level indicator: } F_1 = T_1 \times (95 \ 85 \ 75 \ 65 \ 30)^T = 77.402 \]

Similarly:

\[ F_2 = 79.588 \]

\[ F_3 = 81.226 \]

\[ F_4 = 80.739 \]

The score of comprehensive evaluation of logistic capability in manufacturing enterprise:

\[ F = A \times d = A \times (95 \ 85 \ 75 \ 65 \ 30)^T = 78.73 \]

The evaluation of calculation results: By the above calculation, all of the final evaluation score is between 85 and 75. So the conclusion can be drawn that the comprehensive evaluation of logistic capability in manufacturing enterprise is at the secondary level and all of the capability of four aspects is in general, which is consistent with the actual situation.

CONCLUSION

In this study, an evaluation system of logistics capabilities is established from four aspects. A model of AHP and fuzzy evaluation is used to analyze the logistics capabilities of manufacturing enterprise. And the result of an empirical analysis proved to be valid.
ACKNOWLEDGMENTS

The study is supported by the outstanding Youth Science and Technology Innovation Team funded projects of Hubei Polytechnic University under Grant No. 13xtr03 and the Laboratory Open Foundation of Hubei Polytechnic University Grant No. 201343.

REFERENCES


