Hindawi
Mathematical Problems in Engineering
Volume 2019, Article ID 3985673, 9 pages
https://doi.org/10.1155/2019/3985673

Research Article

A Method for Selecting Enterprise's Logistics Operation Mode Based on Ballou Model

Feng Li,[1] Zhi-Ping Fan ,[1,2] Bing-Bing Cao ,[3] and Ze Wang[4]

[1] *School of Business Administration, Northeastern University, Shenyang 110169, China*
[2] *State Key Laboratory of Synthetical Automation for Process Industries, Northeastern University, Shenyang 110819, China*
[3] *School of Management, Guangzhou University, Guangzhou 510006, China*
[4] *Neusoft Group Co., Ltd., Shenyang 110179, China*

Correspondence should be addressed to Bing-Bing Cao; bbcao_neu@163.com

Received 7 October 2018; Accepted 19 June 2019; Published 2 July 2019

Academic Editor: Sitek Paweł

The right choice of logistics operation mode is not only the foundation for improving the comprehensive operation level of an enterprise, but also an important way to improve the management performance. Nevertheless, the study on this aspect is still lacking. In this paper, we develop a novel method for selecting enterprise's logistics operation mode. First, we give the analysis of main types and characteristics of the logistics operation modes. According to the two dimensions of the Ballou model, i.e., the importance of logistics to enterprise success and the enterprise operation logistics capacity, we set up an evaluation index system for selecting enterprise's logistics operation mode through literature analysis. Then, the each index is evaluated using the fuzzy language assessment method, and evaluation value of each index in the two dimensions is calculated using the 2-tuple fuzzy linguistic representation model. Furthermore, a two-dimensional matrix model for selecting enterprise's logistics operation mode selection is built. According to the model, the right logistics operation mode can be selected. Finally, an example is used to illustrate the practicality and validity of proposed method.

1. Introduction

The management performance is an important index for the operation level of the enterprise [1, 2]. In many related influence factors of the enterprise management performance, the logistics operation mode is an important factor which cannot be ignored [3]. It plays an important role in improving the enterprise management performance [4–6]. Logistics operation mode refers to a way, a policy, or an operation standard adopted by the enterprise during the process of the production and the operation. The suitable logistics operation mode can help to improve the information processing ability of the enterprise logistics operation. It can also improve the enterprise operation level in many aspects such as the cost and the service capacity [7, 8]. Therefore, how to select enterprise's logistics operation mode is a valuable and important research topic.

So far, some related research results on the logistics operation mode can be seen. For example, Yao gave the classification of the logistics operation modes and analyzed the advantages and disadvantages of each kind of logistics operation mode. He also developed a method for selecting the logistics operation mode based on the AHP and the Petri net modelling method [9]. Su et al. studied the influence factors for selecting the logistics operation mode for the manufacturing enterprise based on the interpretive structure mode (ISM). They analyzed the hierarchy and relationship of the influence factors and determined the important factors which can influence the logistics operation mode selection [10]. Cui and Hertz proposed the concept of the logistics mode selection based on the network development and the core competence and provided the logistics mode selection method for three different types of enterprises [11]. Gong and Da analyzed two types of the logistics modes, i.e., the logistics outsourcing mode and the logistics self-supporting mode. On this basis, considering different dominant model, they gave the selection methods and the logistics modes for four kinds of logistics combination modes [12]. Yu studied the problem

of the logistics operation mode selection of the construction enterprises and offered the corresponding solutions [13]. Mcfarlane et al. proposed the "customer-oriented" concept model in intelligence logistics and helped further research on the method for selecting the logistics operation mode [14].

It can be seen from the existing research results that the study on logistics operation mode selection mainly contains the three aspects: the types of logistics operation modes and the reasons for their existence, the relationships among the logistics operation mode, the logistics management performance and the enterprise competence advantage, and the method for selecting enterprise's logistics operation mode. However, the research on the influence factors or evaluation index system of enterprise's logistics operation mode is still lacking. Although the studies of [15, 16] involve the influence factors of logistics operation modes selection, they did not give the specific analysis of the index evaluation system. They did not also give the method for selecting enterprise's logistics operation mode based on the evaluation results. Based on this, it is necessary to further study the method for selecting enterprise's logistics operation mode.

To select the right logistics operation mode, this paper is to refer to the thought of the two-dimensional matrix model proposed by Ballou [17] and determines the evaluation index sets of two dimensions (i.e., the importance of logistics to enterprise success and the enterprise operation logistics capacity) through literature analysis. Then, the method for selecting enterprise's logistics operation mode is developed based on the fuzzy linguistic assessment method and the 2-tuple fuzzy linguistic representation model.

The remainder of this paper is organized as follows. Section 2 introduces the Ballou model. In Section 3, we set up an evaluation index system for logistics operation mode selection. Section 4 presents the method for selecting enterprise's logistics operation mode. In Section 5, a numerical example is given to illustrate the use of the proposed method. Finally, Section 6 summarizes and highlights the main features of the proposed method.

2. Ballou Model

The logistics operation mode mainly includes three kinds: the self-run logistics, the third party logistics, and the logistics alliance [9, 11, 12, 18]. The self-run logistics mode refers to the operation mode that the enterprise meets independently the logistics demand of the internal and external product supply by independently forming a logistics center and constructing the basic hardware facilities such as transport equipment, warehouse, information platform, and so on [9, 11]. The third party logistics operation mode refers to the operation mode that the enterprise outsources their own logistics business to the professional logistics enterprises. In the mode, the enterprise will outsource the logistics business which is not within the core business to a more professional logistics enterprise [9, 12]. Thus, the use of this mode can help to not only reduce the enterprise's capital investment, but also to let the enterprise put its energies into professional fields. This can further improve the market competitiveness of the enterprise. The logistics alliance operation mode refers to

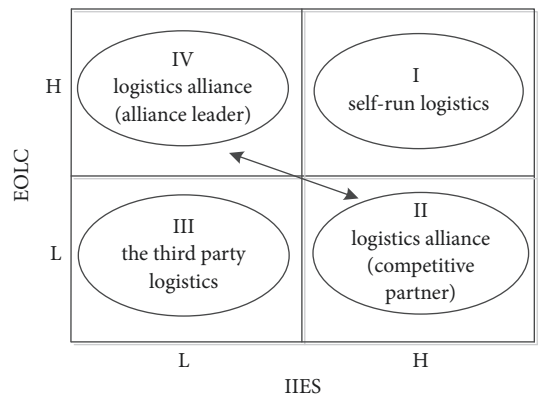

Figure 1: Ballou model.

the operation mode that two or more enterprises carry out long-term cooperation to meet the specific logistics demands [18]. It is a cooperation form which is independent from the transaction relationship between the enterprise and the market. It is also a relatively stable and long-term contractual relationship between the enterprises with the purpose of realizing win-win.

In the existing related study on logistics service, Ballou pointed out that the choice of the logistics operation mode for enterprises to develop logistics business mainly depends on the comprehensive evaluation results of two dimensions, i.e., the importance of logistics to enterprise success (IIES thereafter) and the enterprise operation logistics capacity (EOLC thereafter) [17]. IIES refers to the importance of the logistics to the ultimate goal in the process of the desired goal of an enterprise. EOLC refers to the skill level and the hardware level of control, coordination, and operation with respect to all aspects of services provided by the enterprise when the enterprise aims to meet various logistics demands of participants. Ballou proposed a two-dimensional decision matrix model (Ballou model thereafter) [17], as shown in Figure 1. This figure has four regions, i.e., I, II, III, and IV. Region I shows that the enterprise can adopt the self-run logistics mode, regions II and IV show the logistics alliance mode, and region III shows the third party logistics mode. Obviously, the suitable logistics operation model can be determined according to the enterprise's position in the two-dimensional decision matrix.

It should be pointed out that the two-dimensional matrix model better reflects the theoretical basis of enterprise's logistics operation mode selection. Obviously, the two dimensions (IIES and EOLC) have practical significance; that is, the key of logistics operation to promoting enterprise performance is to attach importance to the enterprise's own logistics operation ability and the importance of logistics to the expected enterprise strategic objectives.

3. An Evaluation Index System for Logistics Operation Mode Selection

In this section, we will present an evaluation index system for logistics operation mode selection. First of all, the related literature is collected, sorted, and analyzed. Then, according

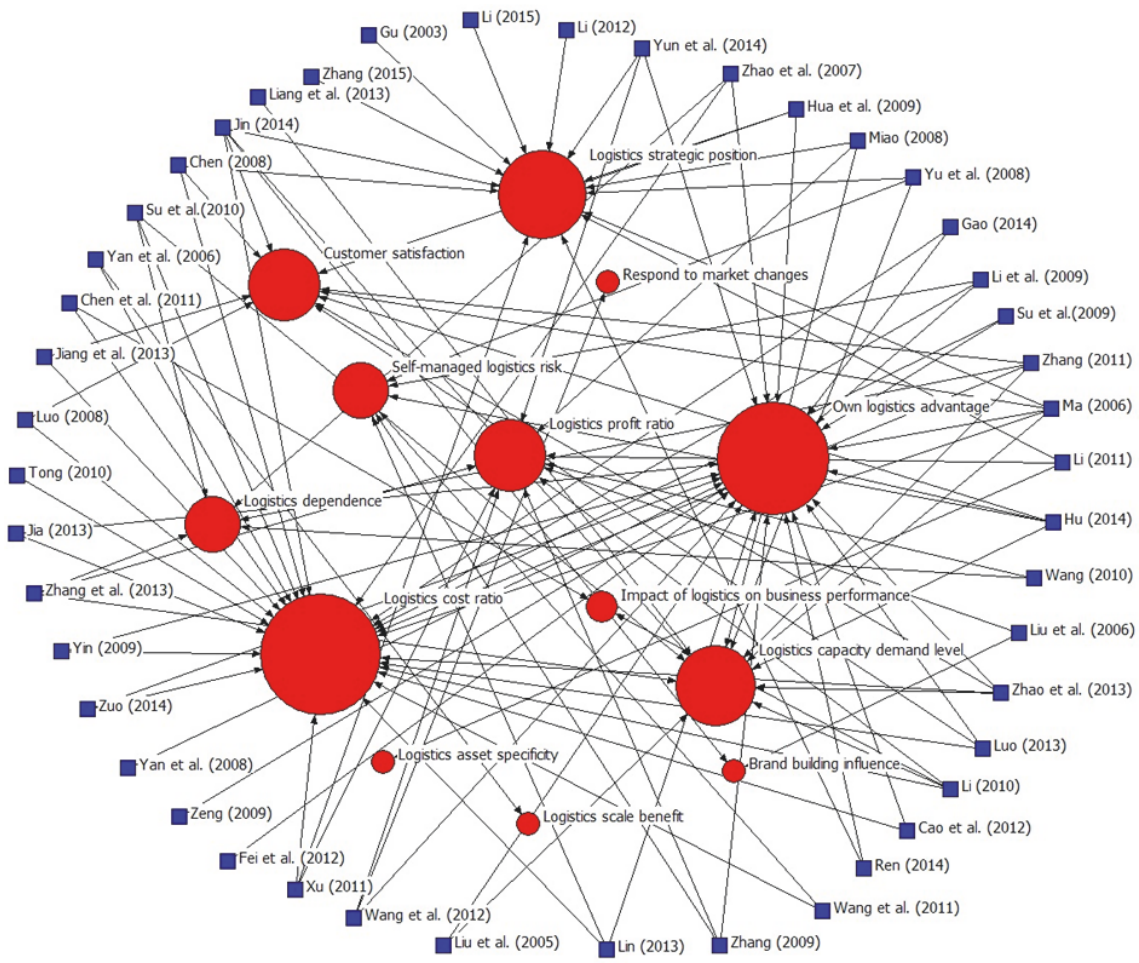

Figure 2: The network diagram of relationships among evaluation indices and scholars with regard to the importance of logistics to enterprise success (IIES).

to the steps of keywords determination, literature retrieval and analysis, evaluation index summarization, sorting and merging, name determination and relation diagram drawing, etc., evaluation indices of the IIES dimension and the EOLC dimension can be determined using the literature metrology [19].

For evaluation indices of the dimension IIES, the search keywords can be determined, i.e., "logistics operation mode selection" and "importance of logistics to enterprise success". According to the determined keywords, 783 articles are first searched out in Elsevier database, China national knowledge infrastructure (CNKI), and Google Scholar. Then, 45 related articles can be determined by removing the invalid articles. Further, by refining the evaluation indices involved in the 45 articles, 124 evaluation indices are determined. Finally, by merging same or similar items, 13 evaluation indices are obtained. After determining the name of each evaluation index, according to the frequency of the evaluation indices involved in related articles, a network diagram of relationships among evaluation indices and scholars can be mapped using the UCINET 6 software, as shown in Figure 2. In the figure, blue squares denote the scholars who propose the evaluation indices in the dimension IIES, and red dots denote the evaluation indices in the dimension IIES. It is necessary to note that the size of red dot represents the frequency of the evaluation index in the literature. The larger the red dot is, the higher the approval degree of the evaluation index is. According to Figure 2, the evaluation indices with frequency of 10 times or more in the literature can be determined to set up the evaluation index set of the dimension IIES, i.e., the logistics costs ratio (I_{s1}), the own logistics advantage (I_{s2}), the logistics strategic position (I_{s3}), the logistics demand level (I_{s4}), the customer satisfaction (I_{s5}), and the logistics profits ratio (I_{s6}).

Similarly, for evaluation indices of the dimension EOLC, the search keywords are determined, i.e., "logistics competence", "logistics capacity", and "logistics capability". According to the determined keywords, 935 articles are first searched out in Elsevier database, China national knowledge infrastructure (CNKI), and Google Scholar. Then, 47 related articles can be determined by removing the invalid articles. Further, by refining the evaluation indices involved in the 45 articles, 403 evaluation indices are determined. Finally, by merging same or similar items, 32 evaluation indexes are

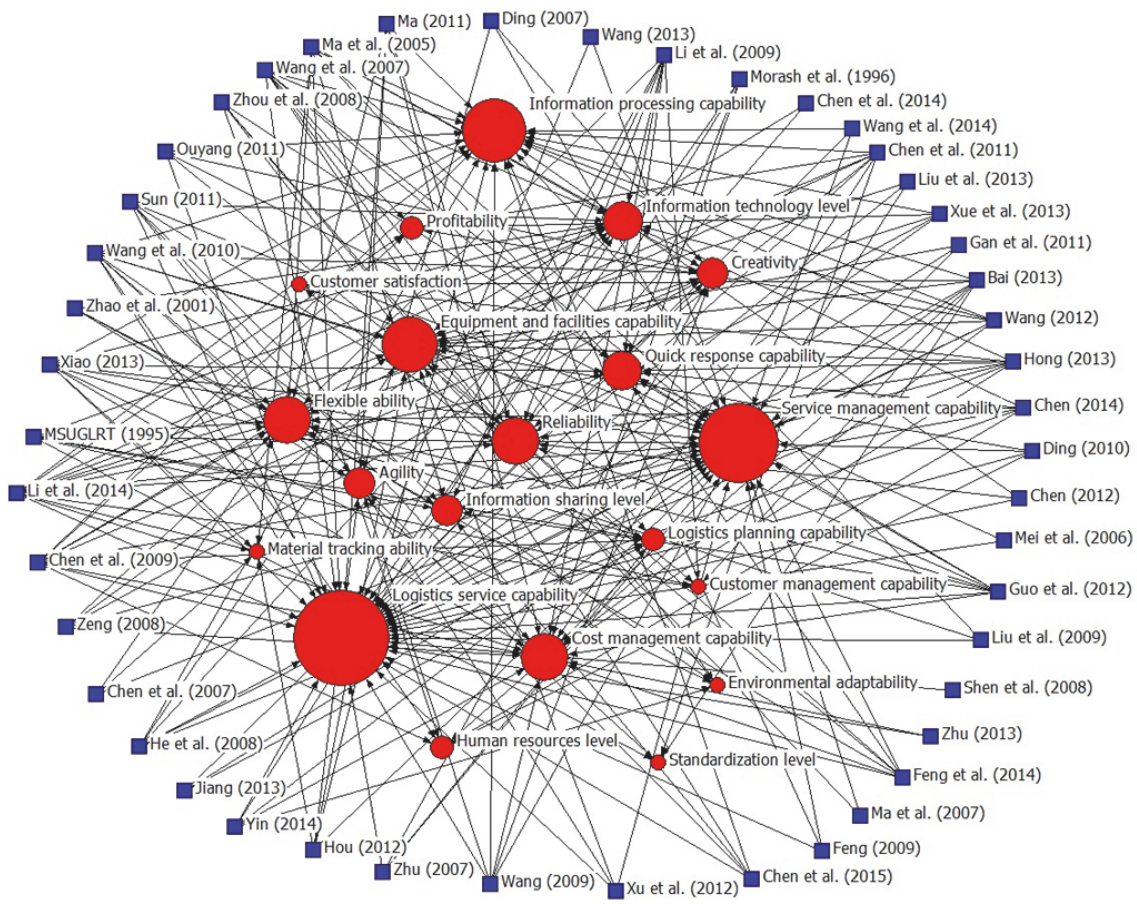

Figure 3: The network diagram of relationships among evaluation indices and scholars with regard to the enterprise operation logistics capacity (EOLC).

obtained. After determining the name of each evaluation index, a network diagram of relationships among evaluation indices and scholars can be mapped using the UCINET 6 software, as shown in the Figure 3. According to Figure 3, the evaluation indices with frequency of 10 or more in the literature can be determined to set up the evaluation index set of the dimension EOLC, i.e., the logistics service capability (I_{c1}), the service management capability (I_{c2}), the information processing capability (I_{c3}), the equipment and facility capability (I_{c4}), the cost management capability (I_{c5}), the logistics flexibility (I_{c6}), the logistics reliability (I_{c7}), the information technology level (I_{c8}), the quick response ability (I_{c9}), and the innovation ability (I_{c10}).

It is necessary to note that there are more literatures about evaluation indices of logistics operation mode selection. Due to limited space, this paper focuses on citing the literature which describe the evaluation indexes comprehensively [16, 20–23]. In addition, the above evaluation index sets are not fixed. In the process of practical application, the indices in the sets can be appropriately added or removed according to the internal and external environment of the enterprise.

To sum up, logistics operation mode selection should be based on the two dimensions and extending indices. According to the above determined two evaluation index sets, the evaluation index system for logistics operation mode selection is shown as Table 1. The grades of importance of these indices in Table 1 depend on the industry to which an enterprise belongs and the strategy that the enterprise implements. To obtain weights or importance of these indices, we can consider inviting experts to provide precise judgments.

Form evaluation indices of the two dimensions extracted, their practical significance is obvious. For the IIES dimension, extracted evaluation indicators, such as logistics costs ratio, logistics strategic position, logistics demand level and logistics profits ratio, etc., better reflect the importance of the logistics to the ultimate goal in the process of the desired goal of an enterprise. For the EOLC dimension, extracted evaluation indicators, such as logistics service capability, service management capability and information technology level, etc., better reflect the enterprise's own logistics operation ability. In addition, these can also be seen in practice. For example, in China, *Jingdong* has higher performance of the two dimensions, so it adopts the self-run logistics operation mode; *Tmall* has lower performance of the two dimensions, so this enterprise adopts the third party logistics operation mode; for *SF Express*, the difference between performances

Table 1: The evaluation index system for logistics operation mode selection.

Dimensions	Indices
Importance of logistics to enterprise success (IIES)	Logistics costs ratio (I_{s1})
	Own logistics advantage (I_{s2})
	Logistics strategic position (I_{s3})
	Logistics demand level (I_{s4})
	Customer satisfaction (I_{s5})
	Logistics profits ratio (I_{s6})
Enterprise operation logistics capacity (EOLC)	Logistics service capability (I_{c1})
	Service management capability (I_{c2})
	Information processing capability (I_{c3})
	Equipment and facility capability (I_{c4})
	Cost management capability (I_{c5})
	Logistics flexibility (I_{c6})
	logistics reliability (I_{c7})
	Information technology level (I_{c8})
	Quick response ability (I_{c9})
	Innovation ability (I_{c10})

of the two dimensions is large, so this enterprise adopts the logistics alliance operation mode through cooperation with UPS.

4. The Method of Selecting Enterprise's Logistics Operation Mode

Generally, the logistics operation mode selection requires group opinions from multiple experts. They are responsible for providing evaluation information for the performance and importance of each index. From Table 1, it is obvious that all indices for logistics operation mode selection are qualitative, so the easiest way for experts to express their opinions is to use fuzzy linguistic terms such as "Very High", "High", or "Middle". Therefore, the situation that experts express their opinions by use of linguistic evaluation information is considered in this study. Since the preference information delivered by linguistic terms is fuzzy, we consider using a fuzzy linguistic assessment method to conduct the logistics operation mode selection.

In this study, we use the method based on the 2-tuple fuzzy linguistic representation model [24, 25] to deal with linguistic information since this method can overcome the weakness that evaluation results usually do not exactly match any of the initial linguistic terms and the information loss often occurs.

In this section, we first present the approach to determine weights of the evaluation indices and then give the approach to comprehensive evaluation for two dimensions.

4.1. The Determination of Weights of the Evaluation Indices. With respect to the evaluation index system of the two dimensions as shown in Table 1, determinations of weights of the indices can be obtained using the expert group evaluation method. In the process of using the of the evaluation method, the characteristics of experts from the different areas or departments and the function distribution of expert groups members should be considered. The composition of expert group members should cover every department as much as possible so as to obtain more comprehensive evaluation results. Usually, expert group members can be from the enterprise's related department and mainly include enterprise senior managers and department managers who is responsible for the logistics, sales, etc.

According to the fuzzy language assessment theory proposed by Zadeh [26], let $S = \{S_0, S_1, \ldots, S_T\}$ be a preestablished finite and totally ordered set with odd cardinalities, where S_i denotes the ith language term, $S_i \in S$. In this study, we choose a linguistic term set with seven elements (language term) according to real needs, i.e., $S = \{S_0$=DL: Definitely Low, S_1 = VL: Very Low, S_2 = L: Low, S_3 = M: Medium, S_4 = H: High, S_5 = VH: Very High, S_6 = DH: Definitely High$\}$.

Let $E = \{E_1, E_2, \ldots, E_m\}$ be a finite expert set, $m \geq 2$, where E_k denotes the kth expert who is invited by the decision maker to make the evaluation. Let $I_s = \{I_{s1}, I_{s2}, \ldots, I_{sp}\}$ be the evaluation index set in the dimension IIES, where I_{si} denotes the ith evaluation index, $i = 1, 2, \ldots, p$; let $U_P = \{u_1, u_2, \ldots, u_p\}$ be the index weight set corresponding to the set $I_s = \{I_{s1}, I_{s2}, \ldots, I_{sp}\}$, where u_i denotes the weight of the ith index, $i = 1, 2, \ldots, p$. Let $I_c = \{I_{c1}, I_{c2}, \ldots, I_{cq}\}$ be the evaluation index set in the dimension EOLC, where I_{cj} denotes the jth evaluation index, $j = 1, 2, \ldots, p$; let $V_Q = \{v_1, v_2, \ldots, v_q\}$ be the index weight set corresponding to the set $I_c = \{I_{c1}, I_{c2}, \ldots, I_{cq}\}$, where v_j denotes the weight of the jth index, $j = 1, 2, \ldots, p$.

In this paper, we assume that the experts' assessment information on index weights and index evaluation values in the two dimensions is in the form of fuzzy linguistic term. Suppose $W_E = (w_{ks1}, w_{ks2}, \ldots, w_{ksp})^T$ and $W_O = (w_{kc1}, w_{kc2}, \ldots, w_{kcq})^T$ be evaluation index weight vectors in the IIES dimension and the EOLC dimension provided by

the expert E_k, respectively, where w_{ksi} and w_{kcj} are linguistic assessments on the importance of the indices I_s and I_c given by the expert E_k, respectively, and $W_{ksi}, W_{kcj} \in S$. Let $U = [u_{ki}]_{m\times p}$ and $V = [v_{kj}]_{m\times q}$ be the evaluation matrices in the IIES dimension and the EOLC dimension, respectively, where u_{ki} and v_{kj} denote the fuzzy language assessments with respect to the indexes I_{si} and I_{cj} provided by the expert E_k, $u_{ki}, v_{kj} \in S$.

According to the related properties of the fuzzy language assessment term set and the calculation method based the 2-tuple fuzzy linguistic representation model [24, 25, 27], the index weight w_{ksi} and the index evaluation value u_{ki} in the IIES dimension can be converted into the 2-tuple linguistic evaluation information, respectively, i.e., $(w_{ksi}, 0)$ and $(u_{ki}, 0)$. Likewise, the evaluation matrix $U = [u_{ki}]_{m\times p}$ can be converted into the 2-tuple linguistic evaluation matrix $\widehat{U} = [\widehat{u}_{ki}]_{m\times p}$, where $\widehat{u}_{ki} = (\widehat{u}_{ki}, 0)$. Similarly, the index weight w_{kcj} and the index evaluation value v_{kj} in the EOLC dimension can be also converted to the 2-tuple linguistic evaluation information, respectively, i.e., $(w_{kcj}, 0)$ and $(u_{kj}, 0)$, respectively, and the evaluation matrix $V = [v_{kj}]_{m\times q}$ can be converted into the 2-tuple linguistic evaluation matrix $\widehat{V} = [\widehat{v}_{kj}]_{m\times q}$, where $\widehat{v}_{kj} = (\widehat{v}_{kj}, 0)$.

By the existing calculation method [28, 29], the index weight vector in the IIES dimension, i.e., $(u_i, \alpha_{si}{}')$, can be obtained by integrating the index weight information $(w_{ksi}, 0)$ and index evaluation information $(u_{ki}, 0)$. It calculation formula is as follows:

$$\left(u_i, \alpha_{si}{}'\right) = \Delta\left(\frac{\sum_{k=1}^{p} \Delta^{-1}\left(w_k, 0\right) \times \Delta^{-1}\left(u_{ki}, 0\right)}{\sum_{k=1}^{p} \Delta^{-1}\left(w_k, 0\right)}\right), \quad i = 1, 2, \ldots, p. \tag{1}$$

In the same way, the index weight vector in the EOLC dimension, i.e., $(v_i, \alpha_{cj}{}')$, can be obtained by integrating the index weight information $(w_{kcj}, 0)$ and the index evaluation information $(v_{kj}, 0)$. Its calculation formula is as follows:

$$\left(v_i, \alpha_{cj}{}'\right) = \Delta\left(\frac{\sum_{k=1}^{q} \Delta^{-1}\left(w_k, 0\right) \times \Delta^{-1}\left(v_{kj}, 0\right)}{\sum_{k=1}^{q} \Delta^{-1}\left(w_k, 0\right)}\right), \quad j = 1, 2, \ldots, q. \tag{2}$$

4.2. Comprehensive Evaluation of Two Dimensions. Using the fuzzy language term set $S = \{S_0, S_1, \ldots, S_T\}$, experts $E = \{E_1, E_2, \ldots, E_m\}$ can provide their evaluation information of the performance with respect to the each index in the evaluation index set I_s; thus the evaluation matrix $X = [x_{ki}]_{m\times p}$ with respect to the evaluation index set I_s can be built, where x_{ki} is a fuzzy language term selected by the expert E_k, $x_{ki} \in S$, i.e., the evaluation for the performance with respect to the index I_{si}. In the same way, experts $E = \{E_1, E_2, \ldots, E_m\}$ can provide their evaluation information of the performance with respect to the each index in the evaluation index set I_c; thus the evaluation matrix $Y = [y_{kj}]_{m\times q}$ with respect to the evaluation index set I_c can be built, where y_{kj} is an evaluation language term selected by the expert E_k, i.e., the evaluation of the performance with respect to the index I_{cj}, $y_{kj} \in S$.

By the calculation method based on the 2-tuple fuzzy linguistic representation model, evaluation matrices $X = [x_{ki}]_{m\times p}$ and $Y = [y_{kj}]_{m\times q}$ can be converted into the 2-tuple fuzzy linguistic form, i.e., $\widehat{X} = [\widehat{x}_{ki}]_{m\times p}$ and $\widehat{Y} = [\widehat{y}_{kj}]_{m\times q}$, where $\widehat{x}_{ki} = (\widehat{x}_{ki}, 0)$ and $\widehat{y}_{kj} = (\widehat{y}_{kj}, 0)$.

By aggregating the weight evaluation information (i.e., $(w_k, 0)$) and the performance evaluation information (i.e., $(x_{ki}, 0)$) with respect to the indices in the dimension IIES provide by each expert, the expert group's evaluation index value of the dimension IIES, (x_i, α_{si}), can be determined, and its calculation formula is given by

$$\left(x_i, \alpha_{si}\right) = \Delta\left(\frac{\sum_{k=1}^{m} \Delta^{-1}\left(w_k, 0\right) \times \Delta^{-1}\left(x_{ki}, 0\right)}{\sum_{k=1}^{m} \Delta^{-1}\left(w_k, 0\right)}\right), \quad i = 1, 2, \ldots, p. \tag{3}$$

where $x_i \in S$ and $\alpha_{st} \in [-0.5, 0.5)$. Further, by (3), the comprehensive evaluation value of the dimension IIES, (x, α_s), can be determined, and its calculation formula is given by

$$\left(x, \alpha_s\right) = \Delta\left(\frac{\sum_{i=1}^{p} \Delta^{-1}\left(u_i, \alpha_{si}{}'\right) \times \Delta^{-1}\left(x_i, \alpha_{si}\right)}{\sum_{i=1}^{p} \Delta^{-1}\left(u_i, \alpha_{si}{}'\right)}\right), \tag{4}$$

where $x \in S$ and $\alpha_s \in [-0.5, 0.5)$.

In the same way, by aggregating the weight evaluation information (i.e., $(w_k, 0)$) and the performance evaluation information (i.e., $(y_{kj}, 0)$) with respect to the indices in the dimension EOLC provided by each expert, the expert group's evaluation index value of the dimension EOLC, (y_j, α_{cj}), can be determined, and its calculation formula is given by

$$\left(y_j, \alpha_{cj}\right) = \Delta\left(\frac{\sum_{k=1}^{m} \Delta^{-1}\left(w_k, 0\right) \times \Delta^{-1}\left(y_{kj}, 0\right)}{\sum_{k=1}^{m} \Delta^{-1}\left(w_k, 0\right)}\right), \quad j = 1, 2, \ldots, q. \tag{5}$$

where $y_j \in S$ and $\alpha_{cj} \in [-0.5, 0.5)$. Further, by (5), the comprehensive evaluation value of the dimension EOLC, (y, α_c), can be determined, and its calculation formula is given by

$$\left(y, \alpha_c\right) = \Delta\left(\frac{\sum_{i=1}^{q} \Delta^{-1}\left(v_j, \alpha_{cj}{}'\right) \times \Delta^{-1}\left(y_i, \alpha_{cj}\right)}{\sum_{i=1}^{q} \Delta^{-1}\left(v_j, \alpha_{cj}{}'\right)}\right), \tag{6}$$

where $y \in S$ and $\alpha_c \in [-0.5, 0.5)$.

4.3. The Selection of Logistics Operation Mode. In the Ballou model as shown in Figure 1, the abscissa x and the ordinate y denote the comprehensive evaluation values of dimensions IIES and EOLC, respectively. Scopes of the abscissa and the ordinate are the continuous closed interval from DL to DH, and they take the abscissa $x = M$ and the ordinate $y = M$ as the dividing lines. Thus, the whole feasible region in Figure 1 can be divided into four regions. If the point

corresponding to the comprehensive evaluation values of dimensions IIES and EOLC is marked out in the figure, then we can know which region the decision point of logistics operation mode selection of the enterprise falls. Further, according to the Ballou model shown in Figure 1, the suitable logistics operation mode of the enterprise can be selected.

5. Case Analysis

To illustrate the use of the above method, this section gives a case analysis. Enterprise A from Inner Mongolia in China is a manufacturer which produces "Mongolian hot pot soup" products; its distributors can be found in more than twenty provinces in China. In selling process, enterprise A needs to deliver the products to the distributors. To improve the quality of logistics service and ensure that the products can be delivered safely and efficiently to the distributors, enterprise A needs to select the better logistics operation mode. For this, the enterprise selects the experts from the related departments to form an expert committee. They include the senior manager (E_1), the logistics manager (E_2), the sales manager (E_3), the customer manager (E_4), and the outside expert (E_5). According to the method given above, the weight vector of the five experts can be determined, i.e., $W = (w_1, w_2, w_3, w_4, w_5)^T = (\mathrm{H}, \mathrm{DH}, \mathrm{UH}, \mathrm{M}, \mathrm{M})^T$.

According to the real situation of enterprise A, the evaluation indexes in IIES dimension and EOLC dimension are screened, respectively.

According to the method for the selection of the language evaluation set S, this expert group will be responsible to all the evaluation work of enterprise A's logistics operation mode.

Firstly, the five experts give the fuzzy assessment matrix with respect to the weights of the six evaluation indices in the dimension IIES, i.e.,

$$U = [u_{ki}]_{5\times 6} = \begin{bmatrix} \mathrm{DH} & \mathrm{M} & \mathrm{UH} & \mathrm{H} & \mathrm{DH} & \mathrm{UH} \\ \mathrm{UH} & \mathrm{DH} & \mathrm{DH} & \mathrm{UH} & \mathrm{M} & \mathrm{DH} \\ \mathrm{M} & \mathrm{M} & \mathrm{H} & \mathrm{UH} & \mathrm{UH} & \mathrm{DH} \\ \mathrm{UH} & \mathrm{L} & \mathrm{M} & \mathrm{UH} & \mathrm{DH} & \mathrm{UH} \\ \mathrm{UH} & \mathrm{L} & \mathrm{UH} & \mathrm{H} & \mathrm{UH} & \mathrm{UH} \end{bmatrix}. \quad (7)$$

Also, the five experts give the fuzzy assessment matrix with respect to the weights of the ten evaluation indices in the dimension EOLC, i.e.,

$$V = [v_{kj}]_{5\times 10} = \begin{bmatrix} \mathrm{UH} & \mathrm{UH} & \mathrm{L} & \mathrm{H} & \mathrm{H} & \mathrm{L} & \mathrm{UH} & \mathrm{UL} & \mathrm{M} & \mathrm{UL} \\ \mathrm{DH} & \mathrm{UH} & \mathrm{H} & \mathrm{DH} & \mathrm{M} & \mathrm{H} & \mathrm{H} & \mathrm{UH} & \mathrm{UH} & \mathrm{H} \\ \mathrm{UH} & \mathrm{H} & \mathrm{M} & \mathrm{H} & \mathrm{UH} & \mathrm{UH} & \mathrm{DH} & \mathrm{L} & \mathrm{H} & \mathrm{UH} \\ \mathrm{UH} & \mathrm{UH} & \mathrm{M} & \mathrm{H} & \mathrm{UH} & \mathrm{H} & \mathrm{DH} & \mathrm{M} & \mathrm{DH} & \mathrm{DH} \\ \mathrm{DH} & \mathrm{DH} & \mathrm{UH} & \mathrm{UH} & \mathrm{UH} & \mathrm{M} & \mathrm{H} & \mathrm{M} & \mathrm{UH} & \mathrm{M} \end{bmatrix}. \quad (8)$$

Then, according to the evaluation indices in dimensions IIES and EOLC, the five experts undertake evaluates of the enterprise A and, respectively, determine the corresponding fuzzy assessment matrices as follows:

$$X = [x_{ki}]_{5\times 6} = \begin{bmatrix} \mathrm{M} & \mathrm{UL} & \mathrm{M} & \mathrm{H} & \mathrm{M} & \mathrm{L} \\ \mathrm{DH} & \mathrm{L} & \mathrm{DH} & \mathrm{UH} & \mathrm{L} & \mathrm{DH} \\ \mathrm{L} & \mathrm{L} & \mathrm{M} & \mathrm{H} & \mathrm{UL} & \mathrm{M} \\ \mathrm{M} & \mathrm{M} & \mathrm{M} & \mathrm{UH} & \mathrm{DL} & \mathrm{H} \\ \mathrm{M} & \mathrm{L} & \mathrm{H} & \mathrm{M} & \mathrm{M} & \mathrm{L} \end{bmatrix},$$

$$Y = [y_{kj}]_{5\times 10} = \begin{bmatrix} \mathrm{M} & \mathrm{L} & \mathrm{UL} & \mathrm{M} & \mathrm{M} & \mathrm{H} & \mathrm{H} & \mathrm{UL} & \mathrm{UL} & \mathrm{L} \\ \mathrm{H} & \mathrm{UH} & \mathrm{M} & \mathrm{UL} & \mathrm{H} & \mathrm{UH} & \mathrm{UH} & \mathrm{M} & \mathrm{M} & \mathrm{M} \\ \mathrm{M} & \mathrm{M} & \mathrm{L} & \mathrm{M} & \mathrm{L} & \mathrm{M} & \mathrm{H} & \mathrm{M} & \mathrm{L} & \mathrm{L} \\ \mathrm{L} & \mathrm{M} & \mathrm{L} & \mathrm{M} & \mathrm{M} & \mathrm{UL} & \mathrm{L} & \mathrm{L} & \mathrm{M} & \mathrm{DL} \\ \mathrm{M} & \mathrm{M} & \mathrm{M} & \mathrm{L} & \mathrm{M} & \mathrm{L} & \mathrm{H} & \mathrm{M} & \mathrm{L} & \mathrm{L} \end{bmatrix}, \quad (9)$$

Further, the matrices U, V, X, and Y can be converted into the 2-tuple fuzzy linguistic form. On this basis, by (1) and (3), the weights and the performance evaluation values of each expert with respect to each index in the dimension IIES can be obtained; i.e., the weights are $(u_1, \alpha_{s1}{}') = (\mathrm{UH}, -0.29)$, $(u_2, \alpha_{s2}{}') = (\mathrm{H}, -0.43)$, $(u_3, \alpha_{s3}{}') = (\mathrm{UH}, -0.24)$, $(u_4, \alpha_{s4}{}') = (\mathrm{UH}, -0.33)$, $(u_5, \alpha_{s5}{}') = (\mathrm{UH}, -0.24)$, and $(u_6, \alpha_{s6}{}') = (\mathrm{DH}, -0.48)$; the performance evaluation values are $(x_1, \alpha_{s1}) = (\mathrm{H}, -0.38)$, $(x_2, \alpha_{s2}) = (\mathrm{L}, -0.05)$, $(x_3, \alpha_{s3}) = (\mathrm{H}, 0)$, $(x_4, \alpha_{s4}) = (\mathrm{H}, 0.29)$, $(x_5, \alpha_{s5}) = (\mathrm{L}, 0.19)$, and $(x_6, \alpha_{s6}) = (\mathrm{H}, -0.33)$. In the same way, by (2) and (5), the weights and the performance evaluation values of each expert with respect to each index in the dimension EOLC can be obtained; i.e., the weights are $(v_1, \alpha_{c1}{}') = (\mathrm{UH}, 0.43)$, $(v_2, \alpha_{c2}{}') = (\mathrm{UH}, -0.10)$, $(v_3, \alpha_{c3}{}') = (\mathrm{M}, 0.38)$, $(v_4, \alpha_{c4}{}') = (\mathrm{UH}, -0.29)$, $(v_5, \alpha_{c5}{}') = (\mathrm{UH}, -0.29)$, $(v_6, \alpha_{c6}{}') = (\mathrm{H}, -0.29)$, $(v_7, \alpha_{c7}{}') = (\mathrm{UH}, 0.05)$, $(v_8, \alpha_{c8}{}') = (\mathrm{M}, -0.05)$, $(v_9, \alpha_{c9}{}') = (\mathrm{UH}, -0.48)$, and $(v_{10}, \alpha_{c10}{}') = (\mathrm{H}, -0.19)$; the performance evaluation values are $(y_1, \alpha_{c1}) = (\mathrm{M}, 0.14)$, $(y_2, \alpha_{c2}) = (\mathrm{M}, 0.38)$, $(y_3, \alpha_{c3}) = (\mathrm{L}, 0.24)$, $(y_4, \alpha_{c4}) = (\mathrm{L}, 0.29)$, $(y_5, \alpha_{c5}) = (\mathrm{M}, 0.05)$, $(y_6, \alpha_{c6}) = (\mathrm{M}, 0.33)$, $(y_7, \alpha_{c7}) = (\mathrm{H}, 0)$, $(y_8, \alpha_{c8}) = (\mathrm{L}, 0.48)$, $(y_9, \alpha_{c9}) = (\mathrm{L}, 0.24)$, and $(y_{10}, \alpha_{c10}) = (\mathrm{L}, 0)$.

Finally, by (4) and (6), we can obtain the comprehensive evaluation value of enterprise A the expert group, i.e., $(x, \alpha_s) = (\mathrm{M}, 0.29)$ and $(y, \alpha_c) = (\mathrm{M}, -0.13)$, which is shown as the point P in region II in Figure 4. The point P shows that the importance of logistics to enterprise success A is higher, but the enterprise operation logistics capacity is lower. According to the two-dimensional decision matrix model shown in Figure 1, enterprise A may select the logistics alliance mode and should need to seek the strong partner in the logistics alliance.

6. Conclusions

This paper presents a method for selecting the enterprise logistic operation mode based on the Ballou model. According to the Ballou model, the evaluation index sets of two

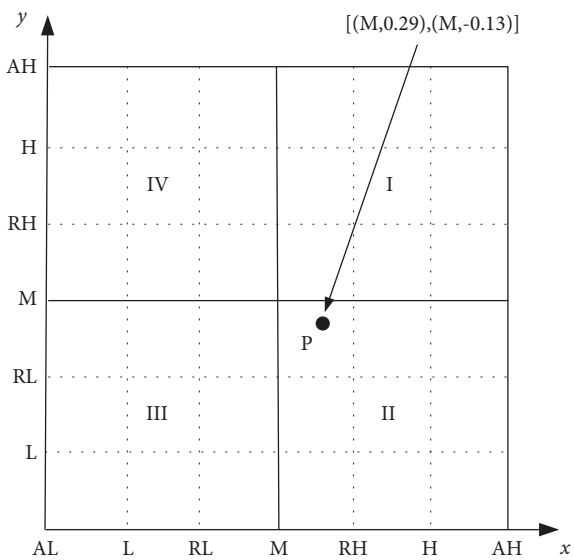

Figure 4: The two-dimensional decision matrix of logistics operating mode selection.

dimensions IIES and EOLC for selecting enterprise logistics operation mode are first determined through literature analysis. Then, the method for selecting enterprise's logistics operation mode is given based on the fuzzy linguistic assessment method and the 2-tuple fuzzy linguistic representation model. Compared with the existing methods, the proposed method has distinct characteristics as discussed as follows.

First, the proposed method is based on the Ballou model. It has a solid theoretical foundation.

Second, in the proposed method, the evaluation index sets of two dimensions IIES and EOLC for selecting enterprise's logistics operation mode are based on literature analysis. This is based on a large number of existing research results.

Third, the proposed method is simple and easy to operate. It can be used to guide the management practice of enterprises.

It is necessary to point out that, for the different types of enterprises, the evaluation indexes and their weights may be different. In the practical application of the method, we can adjust the evaluation index sets according to the actual situation of enterprises.

In terms of future research, to facilitate better application of the proposed method, the decision support system for selecting enterprise logistics operation mode needs to be developed.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

This work was partly supported by the National Natural Science Foundation of China (Project no. 71871049) and the 111 Project (B16009).

References

[1] J. G. Nell, *A Standardization Strategy That Matches Enterprise Operation*, Springer, Berlin, Germany, 1997.

[2] P. Xing, C. H. Zhang, Y. L. Wang, and J. Jiang, "Logistics service quality control considering risk aversion under supply disruption," *Journal of Northeastern University (Natural Science)*, vol. 37, no. 4, pp. 604–608, 2016.

[3] A. S. Safaei, S. Farsad, and M. M. Paydar, "Robust bi-level optimization of relief logistics operations," *Applied Mathematical Modelling*, vol. 56, pp. 359–380, 2018.

[4] A. Gunasekaran, Z. Irani, K. Choy, L. Filippi, and T. Papadopoulos, "Performance measures and metrics in outsourcing decisions: A review for research and applications," *International Journal of Production Economics*, vol. 161, pp. 153–166, 2015.

[5] H. Hsiao, R. Kemp, J. van der Vorst, and S. (Onno) Omta, "A classification of logistic outsourcing levels and their impact on service performance: Evidence from the food processing industry," *International Journal of Production Economics*, vol. 124, no. 1, pp. 75–86, 2010.

[6] T. Liao, "Reverse logistics network design for product recovery and remanufacturing," *Applied Mathematical Modelling*, vol. 60, pp. 145–163, 2018.

[7] W. Ho, T. He, C. K. M. Lee, and A. Emrouznejad, "Strategic logistics outsourcing: an integrated QFD and fuzzy AHP approach," *Expert Systems with Applications*, vol. 39, no. 12, pp. 10841–10850, 2012.

[8] D.-F. Li and S.-P. Wan, "Fuzzy heterogeneous multiattribute decision making method for outsourcing provider selection," *Expert Systems with Applications*, vol. 41, no. 6, pp. 3047–3059, 2014.

[9] K. Yao, *Regional E-commerce enterprise logistics distribution mode selection and process optimization design research [Doctoral, thesis]*, Nanjing University of Science and Technology in China, Nanjing, China, 2015.

[10] J. N. Su and C. F. Shi, "ISM-based impact factor analysis in the selection of logistics mode in manufacturing enterprises," *Industrial Engineering Journal*, vol. 12, no. 4, pp. 6–10, 2009.

[11] L. Cui and S. Hertz, "Networks and capabilities as characteristics of logistics firms," *Industrial Marketing Management*, vol. 40, no. 6, pp. 1004–1011, 2011.

[12] Y. D. Gong and Q. L. Da, "Research on combinations of closed-loop supply chain dominant mode and logistics mode," *Journal of Management Sciences in China*, vol. 18, no. 10, pp. 14–25, 2015.

[13] P. Yu, *Research for logistics operation mode selection of construction enterprises [Doctoral, thesis]*, Chongqing Jiao tong University in China, Chongqing, China, 2015.

[14] D. McFarlane, V. Giannikas, and W. Lu, "Intelligent logistics: Involving the customer," *Computers in Industry*, vol. 81, pp. 105–115, 2016.

[15] A. Awasthi, "Evaluating new business operation models for small and medium size logistics operators within low emission zones," *Transportation Research Procedia*, vol. 12, pp. 707–717, 2016.

[16] Y. F. Wang and W. Liu, "The blind number model of evaluating regional logistics capability under information chaos," *Chinese Journal of Management*, vol. 7, no. 3, pp. 418–422, 2010.

[17] R. Ballou, "Business logistics management: Planning, organizing, and controlling the supply chain," *Instructors ManuaPrentice-Hall*, pp. 37–40, 1999.

[18] W. Feng, "Enterprise benefit game model of collaborative supply chain in logistics industry park," *Journal of Computational Science*, vol. 27, pp. 469–475, 2018.

[19] Y. F. Wang, *A synthetic research of bibliometric method and content analysis method [Doctoral, thesis]*, Nanjing University of Science and Technology in China, Nanjing, China, 2007.

[20] F. Li, "A study on the forming mechanism of retailers' logistic modes," *Management Review*, vol. 22, no. 10, pp. 14–25, 2010.

[21] Y. P. Zhao and L. Yan, "Study on the choice of logistics delivery model in small and medium-sized manufacturing enterprises," *Operations Research and Management Science*, vol. 18, no. 5, pp. 163–167, 2009.

[22] L. Xu and S. Wang, "Empirical research on construct of chain store logistics capability system," *Ibusiness*, vol. 04, no. 01, pp. 10–17, 2012.

[23] W. Shen and S. H. Ma, "A scheduling model for logistics capability in a time-based multi-stage supply chain," *Surveys in Operations Research and Management Science*, vol. 16, no. 3, pp. 20–25, 2007.

[24] F. Herrera and L. Martínez, "A 2-tuple fuzzy linguistic representation model for computing with words," *IEEE Transactions on Fuzzy Systems*, vol. 8, no. 6, pp. 746–752, 2000.

[25] F. Herrera and L. Martínez, "A model based on linguistic 2-tuples for dealing with multi-granular hierarchical linguistic contexts in multi-expert decision-making," *IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics)*, vol. 31, no. 2, pp. 227–234, 2001.

[26] L. A. Zadeh, "The concept of a linguistic variable and its application to approximate reasoning I," *Information Sciences*, vol. 8, pp. 199–249, 1975.

[27] L. Martínez and F. Herrera, "An overview on the 2-tuple linguistic model for computing with words in decision making: extensions, applications and challenges," *Information Sciences*, vol. 207, pp. 1–18, 2012.

[28] Z. P. Fan, B. Feng, Y. H. Sun, and W. Ou, "Evaluating knowledge management capability of organizations: a fuzzy linguistic method," *Expert Systems with Applications*, vol. 36, no. 2, pp. 3346–3354, 2009.

[29] Y. Liu, J.-W. Bi, and Z.-P. Fan, "Ranking products through online reviews: A method based on sentiment analysis technique and intuitionistic fuzzy set theory," *Information Fusion*, vol. 36, pp. 149–161, 2017.