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Original Research Article

Agility Evaluation of Rail Transit Equipment Supply Chain Based on Fuzzy Hierarchy Theory

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Abstract: Under the economic globalization, the competition between the enterprises has evolved into the competition between the supply- chains. In this situation, the agile supply-chain is more competitive than the lean supply-chain. This article is about a new method to evaluate the agility of supply-chain, which is combined with the fuzzy logic and analytic hierarchy process. This method can not only evaluate the agility of supply-chain, but also find the weakness and urgentimprovement direction of agile supply-chain through the result analysis, which provides a theoretical basis for the optimization and development of supply-chain.

Keywords: Agile supply chain; Fuzzy-logic; Analytic hierarchy process.

1. Introduction

1.1 Motivation of the Paper

China has proposed the Made in China 2025 Action Plan to achieve the strategic goal of becoming a manufacturing powerhouse. As a brand enterprise made in China, CRRC needs to be at the forefront of innovative development. In the current situation of rapid technological innovation, global market competition, and increasing recognition of the importance of data, manufacturing enterprises need to face increased instability and uncertainty. This leads to higher costs, more intense competition, and higher requirements for research and development. At the same time, the requirements of customers for manufacturing enterprises have also changed, no longer just for batch production, but also reflect individual customized customer needs. In order to meet the needs of these customers and the high level of information in market competition, it is necessary for enterprises to cooperate with the supply chain composed of customers and suppliers. Manufacturing enterprises need to realize that competition is no longer a competition between enterprises, but a competition between supply chains. The understanding of supply chain by enterprises has become a very important survival ability and competitiveness for themselves. The agility of the supply chain is an important indicator. The understanding of the driving forces of agility in Table 1 can also help correct the actual development strategy of the company.

1.2 Lean Supply Chain (LSC) and Agile Supply Chain (ASC)

For supply chain management, lean supply chain is more well-known and widely used.

Mason Jones et al. (2000) discussed the differences between the two using four indicators, which are still the most obvious standard to this day. As shown in Figure 1, the qualifications for entering the market for lean supply chain are quality, time, and service level, but the core competitiveness of the market is cost. For agile supply chains, service level is the core competitiveness, and customers do not care about costs. What they need is customized services to meet personalized needs.

2. Evaluation Method Based on Fuzzy Analytic Hierarchy (FAH) Process

The key to evaluating supply chain agility is to evaluate qualitative indicators and determine the proportion of all indicators. In many cases and literature, these issues are typically addressed through the experience of

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experts and decision-makers. Personal opinions are subjective. In order to evaluate the supply chain as accurately as possible, it is necessary to minimize subjectivity in the methods. In the ordinary Analytic Hierarchy Process, qualitative indicators can be assigned accurate numbers through expert experience. However, qualitative indicators are difficult to measure and compare with precise numbers. Based on this situation, it is difficult to compare the qualitative evaluations of different experts in numerical form with each other. Although monitoring consistency can reduce subjectivity, it is not sufficient to make it a feasible method for evaluating supply chain agility.

Table 1 Driving forces for agility.

Driving force	content
Changes in the market	● Growth in niche markets ● Changes in national and international politics ● Improvement of product models ● Shortening of product lifespan
Changes in competitiveness	● A rapidly changing market ● Increased cost pressure ● Increased frequency of innovation ● The Response of Shortening the Leading Cycle of New Products to Competitor Changes under Global Competitive Pressure
Changes in customer needs	● The demand for customized products and services ● Faster delivery and lead times ● Higher expectations for quality ● Sudden changes in ordering requirements and quantities
Technological changes	● More efficient, faster, and cost-effective equipment ● New software technologies, such as software and methods ● Integrating information technology and new hardware technologies
Changes in social factors	● Environmental pressure ● Political and legal pressures ● Cultural issues ● Changes in social contracts ● Workplace and Labor Expectations

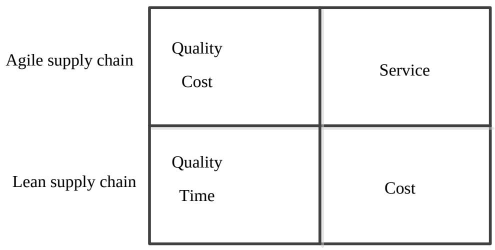

Figure 1 Market for agile and lean supply chains.

At this point, it is necessary to apply fuzzy logic. Through fuzzy logic, the textual expressions of qualitative indicators by experts can be transformed into fuzzy numbers. By calculating the fuzzy numbers, the evaluation and proportion of indicators can be obtained. By doing so, the subjectivity in qualitative evaluation can be reduced.

This evaluation method consists of four steps. Firstly, it is necessary to select appropriate evaluation indicators based on the project's own supply chain situation. The selection of indicators can be based on previous project experience. In order to ensure the correctness and comprehensiveness of indicator selection, experts or employees from different departments should be selected for indicator selection. The second step is to use the fuzzy analytic hierarchy process to construct a hierarchical structure for existing problems. At the same time, the proportion between indicators is determined through fuzzy analytic hierarchy process. The third step is to calculate the fuzzy agility index. The fuzzy agility index calculated can determine the current level of supply chain agility. Finally, by calculating and analyzing the fuzzy importance index, the fuzzy importance indices of all indicators are de fuzzified and the obtained values are arranged. By sorting them in order, weaknesses in the supply chain can be identified. This also provides a basis and direction for optimizing the supply chain in the future.

2.1 Selection of Evaluation Indicators

For the selection of indicators, it is necessary to have a comprehensive understanding of the entire supply chain. Seeking the opinions of specific experts on specific issues should not be generalized, but rather focused. Because the supply chains of different industries and even different enterprises are not the same, the experts selected must be very clear about their own supply chains, and also have an understanding of competitors or other supply chains that can be referenced. This means that the selection of indicators must be based on a comprehensive consideration of both internal and external factors.

2.2 Fuzzy Analytic Hierarchy Process

The use of fuzzy analytic hierarchy process is similar to that of ordinary analytic hierarchy process. After checking the consistency of the comparison matrix, fuzzy logic will be substituted into the Analytic Hierarchy Process. The elements of the comparison matrix will be transformed from numerical form to fuzzy numerical form. This transformation can be obtained through fuzzy equations, and all fuzzy logic models in this article are discussed using triangular fuzzy numbers.

Qualitative indicators are difficult to express in numerical form, so experts usually use textual evaluations for these indicators. For example, experts may use words such as “very high” or “very low” to evaluate the proportion of indicators. However, this textual evaluation is not intuitive enough and cannot be directly used for calculation. Therefore, it is necessary to clarify the relationship between textual evaluation and fuzzy numbers.

In this article, textual evaluation will use a level 5 textual evaluation. The performance of the indicators will be evaluated verbally by “very poor” (SS), “poor” (S), “average” (N), “good” (G), and “very good” (SG). Each evaluation level corresponds to a corresponding triangular fuzzy function. The value of each fuzzy function is either 0.25 or 0.3. The specific relationship between fuzzy numbers and textual descriptions is shown in Table2.

Table 2 Conversion of fuzzy functions.

Performance	Specific gravity	Ambiguity function
	Text evaluation	
So serious (SS)	So low (SL)	(0.0, 0.1, 0.25)
Serious (S)	Low (L)	(0.15, 0.3, 0.45)
Normal (N)	Medium (M)	(0.35, 0.5, 0.65)
Good(G)	High (H)	(0.55, 0.7, 0.85)
So good (SG)	So high (H)	(0.75, 0.9, 1.0)

In this article, the evaluation of the performance of indicators and the proportion of indicators are evaluated using the same fuzzy function. Therefore, when the proportion of an indicator is evaluated as “low”, it means that its fuzzy function has a minimum value of 0.15 and a maximum value of 0.45. This relationship can be represented by Figure 2.

After being transformed by fuzzy functions, the proportion of indicators can be calculated through the basic operations of triangular fuzzy functions.

2.3 Evaluation of Supply Chain Agility Level

The proportion of indicators in the form of fuzzy numbers can be obtained through fuzzy analytic hierarchy process. Then, the agility level of the existing supply chain can be evaluated by introducing the Fuzzy Agility Index (FAI). The fuzzy agility index is the fusion of previous information, which combines the fuzzy evaluation and fuzzy weighting of all indicators. Through the collection of information and data, we have obtained evaluations of indicators from various experts. In order to simplify the calculation, we choose to calculate based on the average of all data.

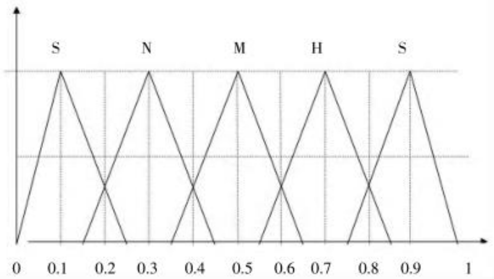

Figure 2 Triangular fuzzy function of case.

For example, we have m experts participating in our information data collection work, which is $E_t, t = 1, \cdots, m$. We have n indicators to measure the agility of the supply chain, which is $K_j, j = 1, \cdots, n$.

R is the fuzzy evaluation of indicator K by expert Et. The average fuzzy evaluation R and the average fuzzy weight W can be calculated using the following Eq. (1) and (2):

$$R_j = (a_j, b_j, c_j) = (R_{j1} + R_{j2} + \cdots + R_{jm}) / m \quad \text{(Eq.1)}$$

$$W_j = (x_j, y_j, z_j) = (W_{j1} + W_{j2} + \cdots + W_{jm}) / m \quad \text{(Eq.2)}$$

The fuzzy agility index represents the overall evaluation of supply chain agility. The higher the fuzzy agility index, the higher the level of supply chain agility. The fuzzy agility index can be calculated by weighting the average of the data, and Eq. (3) is as follows:

$$FAI = \frac{\sum_{j=1}^{n} W_j \times R_j}{\sum_{j=1}^{n} W_j} \quad \text{(Eq.3)}$$

The agility level of the supply chain can be determined by calculating the fuzzy agility index. The measurement of agility level is calculated by the distance between the fuzzy agility index and the fuzzy function expressed in the written evaluation. For example, when the fuzzy agility index is closer to the fuzzy function expressed as "high" in text, it indicates that the agility level of the supply chain is rated as high.

2.4 Analyzing the Weaknesses of Supply Chain Agility

Evaluating supply chain agility is not just about evaluating the level of the supply chain, but more importantly, identifying the weaknesses of the supply chain in these areas. By analyzing weaknesses, we can optimize the supply chain and formulate correct future development strategies. To identify its weaknesses, Lin et al. (2006) proposed a measurement parameter. This parameter is the fuzzy importance index. This index can be defined through Eq. (4). The conversion of proportion can reduce the negative impact of excessive proportion in evaluation.

$$FMII_i = R_i \times [(1.0, 1.0, 1.0) - W_i] \quad \text{(Eq.4)}$$

Since this index exists in the form of fuzzy numbers, we cannot directly sort them. So we need to perform a series of calculations and transformations on fuzzy numbers. This transformation is also known as deblurring, which means transforming fuzzy numbers into ordinary numerical forms.

Firstly, we need to establish a set of maximum and minimum values, as shown in Eq. (5):

$$U_{\max(x)} = \begin{cases} x, 0 \le x \le 1 \\ 0, otherwise \end{cases}$$
$$U_{\min(x)} = \begin{cases} 1 - x, 0 \le x \le 1 \\ 0, otherwise \end{cases} \quad \text{(Eq.5)}$$

By using the deblurring formula, the fuzzy importance index can be digitized. Eq. (6) is as follows:

$$U_R(FMII)=\sup\left[U_{FMII}(x)\cap U_{\max}(x)\right]$$
$$U_L(FMII)=\sup\left[U_{FMII}(x)\cap U_{\min}(x)\right] \quad \text{(Eq.6)}$$
$$U_T(FMII)=\left[U_R(FMII)+1-U_L(FMII)\right]/2$$

Here we assume that the FMII of triangular fuzzy numbers is (a, b, c). After merging and calculation, the following simplified Eq. (7) can be obtained:

$$U_R(FMII)=\sup\left[U_{FMII}(x)\cap U_{\max}(x)\right]=\frac{c}{1-b+c}$$
$$U_L(FMII)=\sup\left[U_{FMII}(x)\cap U_{\min}(x)\right]=\frac{1-a}{1-a+b} \quad \text{(Eq.7)}$$

By simplifying Eq.(7), the required values can be calculated more quickly and conveniently.

3. Case Analysis

3.1 Select Evaluation Criteria and Establish a Hierarchical Structure

For different industries and even enterprises, different indicators are needed to evaluate the supply chain. Although many indicators may seem similar, the key points are not entirely the same. For selecting indicators, research recommends the expert opinion method, which involves collecting opinions from experienced experts to select measurement indicators.

Here, three main indicators proposed by Henke und Lasch (2012) were used, which are the ability to obtain information, flexibility, and speed of conversion. However, these three indicators do not include the important indicator of partnership. In this case, we have added partnership as a supplement to the above three indicators and incorporated it into the indicator system.

In order to use the Analytic Hierarchy Process, we transformed the indicators into a hierarchical structure, as shown in Figure 3. This structure consists of three layers. The first layer is the target layer, which is the agility of the supply chain. The second layer consists of four main indicators. The third layer consists of sub indicators related to the main indicator.

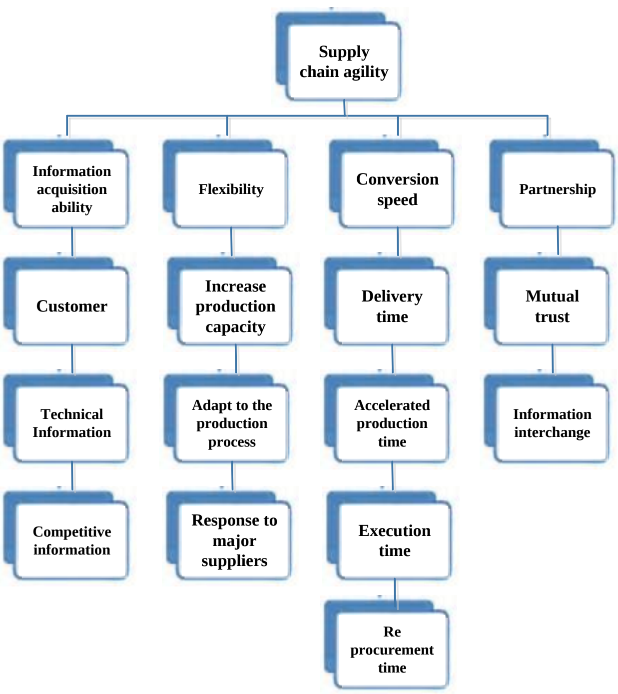

Figure 3 Hierarchical structure of supply chain agility evaluation indicators.

3.2 Data Collection and Establishment of Comparison Matrix

After establishing the hierarchical structure, it is necessary to collect data and establish a comparison matrix. Experts need to apply their professional knowledge and rich experience to fill out the comparison matrix. The elements in the comparison matrix must be indicators within the same level. In the comparison matrix, indicators will be compared pairwise on a scale of 1 to 9. For the convenience of subsequent calculations and descriptions, all indicators in Table 3 are replaced with abbreviations.

Table 3 Abbreviations of indicators.

Abbreviation	Indicators	Abbreviation	index
K_1	Ability to obtain information	K_3	Conversion speed
K_{11}	Customer Information	K_{31}	Delivery time
K_{12}	Technical Information	K_{32}	Accelerated production time
K_{13}	Competitive information	K_{33}	Execution time
K_2	Flexibility	K_{34}	Re-procurement time
K_{21}	Increase production capacity	K_4	Partnership
K_{22}	Adapt to the production process	K_{41}	Mutual trust in cooperation
K_{23}	Response to major suppliers	K_{42}	Information interchange

By processing the data, we can obtain the following comparison matrix. The data in the matrix represents the evaluation of the importance relationship between various indicators by experts, as shown in Tables 4 to 8.

Table 4 Comparison matrix of supply chain agility.

	K_1	K_2	K_3	K_4
K_1	1	1/3	1/5	2
K_2	3	1	1/3	3
K_3	5	3	1	3
K_4	1/2	1/3	1/3	1

Table 5 Comparison matrix for information acquisition.

	K_{11}	K_{12}	K_{13}
K_{11}	1	3	5
K_{12}	1/3	1	3
K_{13}	1/5	1/3	1

Table 6 Comparison matrix of flexibility.

	K_{21}	K_{22}	K_{23}
K_{21}	1	3	7
K_{22}	1/3	1	5
K_{23}	1/7	1/5	1

Table 7 Comparison matrix of conversion speed.

	K_{31}	K_{32}	K_{33}	K_{34}
K_{31}	1	5	4	2
K_{32}	1/5	1	1/2	1/5
K_{33}	1/4	2	1	1/5
K_{34}	1/2	5	5	1

Table 8 Comparison matrix of partnership relationships.

	K_{41}	K_{42}
K_{41}	1	1
K_{42}	1	1

After obtaining the comparison matrix, we can use the Analytic Hierarchy Process to calculate the proportion between each indicator. By using the calculation formula in the previous section, we can obtain the proportions between various indicators as shown in Table 9. And sort them according to their proportion to supply chain agility.

Table 9 Weights and sorting of indicators.

Index	The proportion of main indicators		The proportion of SCA	Sort
K_1				
K_{11}	0.121	0.637	0.077	4
K_{12}		0.258	0.031	10
K_{13}		0.105	0.013	12
K_2				
K_{21}	0.263	0.649	0.171	3
K_{22}		0.279	0.073	5
K_{23}		0.072	0.019	11
K_3				
K_{31}	0.519	0.472	0.245	1
K_{32}		0.071	0.037	9
K_{33}		0.105	0.055	6
K_{34}		0.352	0.183	2
K_4				
K_{41}	0.097	0.5	0.049	7
K_{42}		0.5	0.049	7

The next step is to verify the consistency of the comparison matrix, and the consistency index of the matrix can be obtained through the formula. By looking up the matrix order, the random consistency index can be obtained, and the consistency rate can be calculated. If the consistency rate is greater than 0.1, the calculation of the comparison matrix will not be accepted. After calculation, as shown in Table 10, it can be seen that all consistency rates are less than 0.1, which proves that the consistency of the data is acceptable and also represents that the negative impact caused by subjectivity in the data processing is within an acceptable range.

Table 10 Consistency of detection comparison matrix.

Matrix	λ_{max}	CI	RI	CR	<0.1
Sva	4.226	0.075	0.9	0.083	√
K_1	3.039	0.019	0.58	0.033	√
K_2	3.065	0.032	0.58	0.055	√
K_3	4.128	0.043	0.9	0.048	√
K_4	2	0	0	0	√

3.3 Application of Simulated Analytic Hierarchy Process

In this step, we need to convert the existing ordinary comparison matrix into a fuzzy comparison matrix, in order to further eliminate the uncertainty caused by subjectivity. For example, in the matrix, the number elements in row K1 and column K2 are 0.071, and its evaluation is known to be very low through textual description evaluation. However, through the conversion table between fuzzy numbers and textual description, the corresponding low evaluation is the fuzzy number SN (0.0, 0.1, 0.25). Transform the ordinary comparison matrix into a fuzzy comparison matrix using this method.

According to the calculation rules of fuzzy numbers, we can calculate the proportion of each indicator to the agility of the supply chain. For example, for $K_{11}:(0.00,0.1,0.25)\times(0.55,0.7,0.85)=(0.00,0.07,0.21)$.

3.4 Evaluating Supply Chain Agility

In section 3.3, we obtained the fuzzy weight of the indicators through the fuzzy analytic hierarchy process. To evaluate the agility of the supply chain, we also need to evaluate the performance of various indicators. Based on existing data and expert expertise and experience, a qualitative textual evaluation of the performance of indicators will be conducted. Here we adopt the opinions of 5 experts and convert them into fuzzy numbers through a conversion table. And obtain the average evaluation in fuzzy numerical form through calculation, as shown in Table 11. For example, R11 is the average evaluation of K_{11}.

$$R_{11} = [(0.47,0.62,0.77)\times(0.00,0.07,0.21)+(0.63,0.78,0.91)\times(0.00,0.03,0.11)+(0.31,0.46,0.61)$$
$$\times(0.00,0.01,0.06)]/[(0.00,0.07,0.21)+(0.00,0.03,0.11)+(0.00,0.01,0.06)]\cong(0.00,0.65,0.78)$$

Obtain the results of the other three main indicators through calculation:

$$R_2 \cong (0.51,0.62,0.75), R_3 \cong (0.46,0.57,0.70), R_4 \cong (0.00,0.70,0.84)$$

Obtained through calculation: $FAI \cong (0.47,0.61,0.75)$

Table 11 Average evaluation of sub indicators.

Sub indicators	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average evaluation (R)
K_{11}	L	G	G	L	G	（0.47， 0.62， 0.77)
K_{12}	SG	G	SG	G	G	（0.63，0.78，0.91）
K_{13}	L	L	S	L	L	（0.31，0.46，0.61）
K_{21}	G	G	G	G	G	（0.55，0.7，0.85）
K_{22}	S	G	L	L	L	（0.35，0.5，0.65）
K_{23}	L	L	L	S	L	（0.31，0.46，0.61）
K_{31}	G	L	G	G	G	（0.51，0.66，0.81）
K_{32}	G	G	L	SG	L	（0.51，0.66，0.80）
K_{33}	SS	S	SS	S	L	（0.13，0.26，0.41）
K_{34}	G	L	L	L	S	（0.35，0.5，0.65）
K_{41}	G	L	L	G	L	（0.47，0.62，0.77）
K_{42}	SG	SG	G	G	G	（0.63，0.78，0.91）

After calculating the fuzzy agility index (FAI), the agility level of the supply chain can be evaluated. The fuzzy agility index is obtained in the form of triangular fuzzy numbers, so it needs to be further transformed into textual expressions. As shown in Figure 4, the fuzzy agility index is between “medium” and “high”. The question is, what level should the supply chain in the case belong to? This requires determining by measuring the distance between the index and the fuzzy function of the other two textual variables.

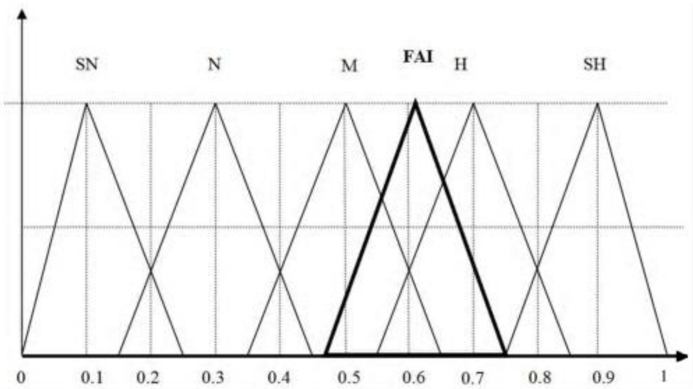

Figure 4 Text expression of fuzzy agility index.

The formula can be used to calculate the fuzzy agility index and the distance between adjacent textual expressions:

$$d\left(FAI,M\right)=\sqrt[2]{\frac{1}{3}\left[\left(0.47-0.35\right)^{2}+\left(0.61-0.5\right)^{2}+\left(0.75-0.65\right)^{2}\right]}\cong 0.11$$

$$d\left(FAI,H\right)=\sqrt[2]{\frac{1}{3}\left[\left(0.47-0.55\right)^{2}+\left(0.61-0.7\right)^{2}+\left(0.75-0.85\right)^{2}\right]}\cong 0.09$$

The calculation results indicate that the fuzzy agility index is closer to”high”, indicating that the supply chain agility level of the case is at a higher level.

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3.5 Analyzing the Weaknesses of Supply Chain Agility

We evaluated the supply chain agility of the case using the fuzzy analytic hierarchy process. However, evaluating supply chain agility is not only about identifying issues, but also about preparing for future optimization and development. Through calculation, we know that the agility level of the supply chain is high. However, it can be seen from the results that the agility of the supply chain is not far from being at a moderate level, only slightly leaning towards a higher level, and it is easy to decline to a moderate level. To prevent a decline and improve, we need to identify which indicators are constraining the development of supply chain agility, which is the direction we need to optimize and strengthen. By calculating the fuzzy importance index of all sub indicators, all sub indicators can be ranked according to it. The specific data is shown in Table 12.

Table 12 Fuzzy importance index of supply chain agility.

Sub indicators	Average evaluation (R)	$(1,1,1)-W_{ij}$	FMII	U (FMII)
K_{11}	(0.47， 0.62， 0.77	（0.79，0.93，1.00）	（0.3713，0.5766，0.77）	0.561801
K_{12}	（0.63，0.78，0.91）	（0.89，0.97，1.00）	（0.5607，0.7566，0.91）	0.710817
K_{13}	(0.31， 0.46， 0.61	（0.94，0.99，1.00）	（0.2914，0.4554，0.61）	0.459779
K_{21}	（0.55，0.7，0.85）	（0.62，0.79，0.92）	（0.341，0.533，0.782）	0.536624
K_{22}	（0.35，0.5，0.65）	（0.80，0.91，0.98）	（0.28，0.455，0.637）	0.463076
K_{23}	（0.31，0.46，0.61）	（0.89，0.97，1.00）	（0.2759，0.4462，0.61）	0.452707
K_{31}	（0.51，0.66，0.81）	（0.58，0.75，0.88）	（0.2958，0.495，0.7128）	0.499046
K_{32}	（0.51，0.66，0.80）	（0.84，0.95，1.00）	（0.4284，0.6270，0.8）	0.602561
K_{33}	（0.13，0.26，0.41）	（0.84，0.95，1.00）	（0.1092，0.247，0.41）	0.284811
K_{34}	（0.35，0.5，0.65）	（0.71，0.85，0.95）	（0.2485，0.425，0.6175）	0.43953
K_{41}	（0.47，0.62，0.77）	（0.84，0.95，1.00）	（0.3948，0.589，0.77）	0.572604
K_{42}	（0.63，0.78，0.91）	（0.84，0.95，1.00）	（0.5292，0.741，0.91）	0.694965

The fuzzy importance index represents the contribution of each sub indicator to supply chain agility. In order to measure and distinguish various indicators, 0.45 is used as the measurement standard, which means finding the indicator of $U\left(FMII\right)<0.45$. These indicators are the most urgent directions for improvement.

In the table, we can find two indicators, namely the execution time of K33 and the repurchase time of K34. This indicates that if we want to continue improving the agility of the supply chain, we must focus on improving the main indicator of K3 conversion speed, and reduce execution time and re procurement time as the top priority. This is the direction that needs to be improved in the future, and formulating future strategies based on it will be of greatest help to supply chain agility.

4. Conclusion

Nowadays, agile supply chain plays an increasingly important role in the globalized and ever-changing environment. In order to survive in fierce competition, enterprises need to improve the agility of their supply chain. To improve the agility of the supply chain, enterprises need to first have a clear and accurate evaluation of their own supply chain. Therefore, how to evaluate the agility of the supply chain has become a topic of concern for researchers.

It is easy to evaluate quantitative indicators, but there are too many qualitative evaluation indicators in supply chain agility, which makes evaluating agility more difficult to overcome. Firstly, it is necessary to eliminate the subjective impact on qualitative evaluation. In practical work and research, not only is the performance of indicators qualitatively evaluated, but the relationship between indicators is also mixed with the subjective ideas of many experts and decision-makers. In order to reduce the impact of this problem, a new evaluation method based on fuzzy analytic hierarchy process has been developed, which monitors the consistency of the comparison matrix and reduces the negative impact of subjectivity in decision-making.

Secondly, supply chain management should be implemented with the concept of sustainable development. In the process of evaluating supply chain agility, methods to improve its performance should also be considered. In the method proposed in this article, the weakest link in supply chain agility is analyzed by calculating and ranking relevant parameters. This provides a theoretical basis for both decision-makers and implementers, laying the foundation for the sustainable development and optimization of the supply chain.

Due to the lack of information in actual cases and the confidentiality of relevant data, the case data used in this article is virtual. Although there was no calculation and analysis of the actual data, and no comparison was made between the actual results and the calculated results. However, there is still confidence that this method has practical application value.

Setting aside the theme of this article, not only can this mathematical method be applied to evaluate supply chain agility, but it also has reference value for qualitative decision-making problems with multiple evaluation criteria.

Although the formulas in the article have been simplified, the calculation steps and methods are still somewhat complex, which also increases the difficulty and acceptance of the application of this method. With the development of informatization and the increasing emphasis on supply chain agility, methods for evaluating supply chain agility will be more easily applied.

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