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# Determination Method for Index Weights of Logistics Information Systems in a Mass Customization Environment

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**Abstract:** To address the challenge of representing key index weights of logistics information systems in a mass customization environment using multi-granularity mixed semantic phrases, a method for determining index weights based on complex semantic information is proposed. First, an integrated method processes the multi-granularity mixed semantic variables to obtain initial index weights. Second, the probability of uncertain semantic information is calculated to determine the correction coefficient for key indicators of logistics information systems. Finally, the initial index weights and correction coefficients are synthesized to derive the final index weights. The effectiveness and feasibility of the proposed method are demonstrated using the selection of a logistics information system for a computer company as a case study.

**Keywords:** Mass customization; Logistics information system; Language information; Key indexes

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## 1. Introduction

With the advent of economic globalization, enterprise production modes have gradually transitioned from mass production to Mass Customization (MC). MC integrates the improvement of customer-perceived value with cost reduction and has increasingly become the mainstream operational model for enterprises in the 21st century [1]. The implementation of MC is a systematic endeavor involving the integration and optimization of product design, production processes, and collaboration among production enterprises and their upstream and downstream partners. Given the critical role of logistics information in the MC model, enhancing traditional Logistics Information Systems (LIS) is imperative [2].

The primary objective of LIS design in the MC model is to meet the customized requirements of customers. However, due to constraints in enterprise resources, time, and energy, it is impractical to give equal attention to all required items in the design process. The importance of different needs must be assessed and prioritized. During LIS improvement and selection, customer demands must be refined into the system's key indices. Determining the weight of these indices is a crucial step, as a scientific and reasonable weight determination directly contributes to effective LIS design.

Existing methods for determining index weights have certain limitations. The Delphi method is highly subjective and often introduces significant errors when integrating customer demand and enterprise information. The Analytic Hierarchy Process (AHP) and Fuzzy Analytic Hierarchy Process (FAHP) require evaluators to compare indicators and draw accurate conclusions, imposing high demands on evaluation members [3]. The entropy method partially evaluates fuzzy information but necessitates extensive data collection, which is often challenging [4]. Most approaches rely on the subjective judgment of experts, which is insufficient due to the inherent complexity and uncertainty of the objective world.

In practice, evaluators often provide qualitative semantic evaluation information when determining indicator weights. For instance, in evaluating LIS security, semantic expressions such as "important," "general," or "not important" are frequently used. Variations in knowledge levels and work experiences among evaluators lead to differing levels of familiarity with LIS [5]. Some evaluators may directly assign a definite semantic variable from the semantic scale, while others might assign an interval to indicate uncertain semantic variables. Therefore, studying LIS index weights expressed in complex semantic forms within an MC environment holds significant theoretical and practical value.

To determine LIS index weights effectively and fully utilize enterprise and market information, enterprises can select systems that better meet customer needs, thereby gaining a competitive advantage in the market. Strategically, production enterprises analyze market development trends to formulate comprehensive plans, while operationally, the implementation plans are carried out at the executive level. In determining indicator weights, it is essential to integrate the perspectives and interests of strategic enterprise leaders, operational executives, and end customers. This study aims to analyze and address these challenges.

## 2. Logistics information system evaluation methods

The determination of LIS index weights in a MC environment involves a group evaluation process, which requires the participation of multiple heterogeneous personnel to ensure the rationality of the results. Due to the complexity and uncertainty inherent in LIS selection under the MC environment, evaluators often find it challenging to accurately quantify weight information. Instead, evaluations are typically expressed in the form of semantic variables. Given that evaluators from diverse fields have varying degrees of familiarity with LIS, their assessments are conducted using different semantic scales.

$$S^3=\{S^3_{-2}=\text{very unimportant}, S^3_{-2/3}=\text{unimportant}, S^3_0=\text{ordinary}, S^3_{2/3}=\text{important}, S^3_2=\text{very important}\}$$

$$S^4=\{S^4_{-3}=\text{very unimportant}, S^4_{-4/3}=\text{unimportant}, S^4_{-1/3}=\text{relatively unimportant}, S^4_0=\text{ordinary}, S^4_{1/3}=\text{relatively important}, S^4_{4/3}=\text{important}, S^4_3=\text{very important}\}$$

$$S^5=\{S^5_{-4}=\text{extremely unimportant}, S^5_{-2}=\text{very unimportant}, S^5_{-1}=\text{unimportant}, S^5_{-0.4}=\text{relatively unimportant}, S^5_0=\text{ordinary}, S^5_{0.4}=\text{relatively important}, S^5_1=\text{important}, S^5_2=\text{very important}, S^5_4=\text{extremely important}\}$$

**Step 1:** Enterprise and customer representatives from the strategic level of the enterprise are selected to form an evaluation team. The project leader explains the project requirements to the evaluation members. Through a comprehensive survey, the team collects historical enterprise data and market information, analyzing and organizing the key indicators of LIS in the MC mode. Members then evaluate these indicators using an integrated approach to determine their relative importance, based on semantic information decisions.

**Step 2:** Evaluators select their preferred semantic granularity according to their individual circumstances. Depending on their familiarity with LIS in the MC environment, different types of semantic variables are used to evaluate the key indicator weights, and an initial evaluation matrix is constructed. According to **Equations (1)** and **(2)**, semantic scales of varying granularities are transformed into a unified semantic scale. To minimize information loss, the most frequently used scale in the evaluation matrix is set as the basic scale during the transformation.

$$f: S_{\alpha}^{\phi} \to S_{\beta}^{\varphi} \quad (1)$$

$$\beta = f(\alpha) = \alpha \frac{\varphi - 1}{\phi - 1} \quad (2)$$

**Step 3:** Using the unified granularity matrix, the evaluation vector of LIS key indicator weights is listed according to **Equations (3)** and **(4)**.

For definite linguistic variables:

$$\begin{cases} x_i^{+} = \max_j \{\xi_{ij}\} \\ y_i^{-} = \min_j \{\xi_{ij}\} \end{cases} \quad (3)$$

For uncertain linguistic variables:

$$\begin{cases} x_i^{+} = \left[x_i^{+^u}, x_i^{+^v}\right] = \left[\max_j \{\xi_{ij}^u\}, \max_j \{\xi_{ij}^v\}\right] \\ y_i^{-} = \left[y_i^{-^u}, y_i^{-^v}\right] = \left[\min_j \{\xi_{ij}^u\}, \min_j \{\xi_{ij}^v\}\right] \end{cases} \quad (4)$$

**Step 4:** The relative proximity of each key indicator is calculated, determining the relative proximity between the weight of each indicator and the positive and negative ideal points according to **Equation (5)**.

$$z_j^{*} = \frac{D_j^{-}}{D_j^{+} + D_j^{-}} \quad (5)$$

**Step 5:** The indicator weights are determined. The greater the relative proximity, the higher the weight of the corresponding indicator. The final weights of LIS key indicators are calculated using **Equation (6)**.

$$\omega_j = \frac{z_j^{*}}{\sum_{j=1}^{M} z_j^{*}} \quad (6)$$

## 3. Examples and analysis of results

To address increasing competition and evolving consumer demands, the company has adopted the MC model as a strategic approach to maintaining and enhancing the competitive advantage of its products. In the MC environment, logistics activities generate a substantial amount of information. All activities within the logistics system rely on information for communication, and resource allocation is also achieved through information.

Logistics information serves as the central hub integrating logistics operations, production, sales, and other enterprise activities under the MC environment, necessitating the development of a more efficient LIS.

**Step 1:** A project leader invited five representatives from the strategic level of the production company and one representative from the customer to form an evaluation team. By collecting comprehensive data, including enterprise information and market development trends, the evaluation team identified and analyzed the key indicators of LIS in the MC mode using questionnaire surveys and on-site observations (see **Table 1**). The relative importance of each evaluator was determined through semantic information voting, resulting in the weight distribution .

**Table 1.** Key indicators of logistics information system in the mass customization environment

| Index | Description |
|---|---|
| System flexibility | The ability of the system to adapt to changes in the enterprise environment and user needs |
| System extensibility | Scalability of system architecture, hardware, and software as business volume or product variety increases |
| System security | The ability to maintain normal operations and ensure safety in the event of interference |
| Response speed | The efficiency of the system in completing information-processing tasks |
| Interface simplicity | The ease with which the operating interface can be learned |
| System construction efficiency | The speed of the information system construction |
| Degree of goal achievement | The extent to which the information system meets the expectations of the enterprise |

**Step 2:** Due to differing levels of familiarity with LIS among evaluators, a matrix of weight information based on semantic indicators provided by the six evaluators was constructed. The linguistic information was then processed consistently using **Equations (1)** and **(2)** to construct a uniform evaluation matrix with the same linguistic scale (see **Table 2**).

**Table 2.** Uniform matrix of linguistic scale granularity

| | $G_1$ | $G_2$ | $G_3$ | $G_4$ | $G_5$ | $G_6$ | $G_7$ |
|---|---|---|---|---|---|---|---|
| RE1 | $S^4_3$ | $S^4_0$ | $S^4_0$ | $S^4_1$ | $S^4_1$ | $S^4_{-1}$ | $S^4_1$ |
| RE2 | $[S^4_{4/3},S^4_3]$ | $[S^4_{-1/3},S^4_0]$ | $[S^4_0,S^4_{1/3}]$ | $[S^4_{1/3},S^4_{4/3}]$ | $[S^4_{4/3},S^4_3]$ | $[S^4_{-4/3},S^4_{-1/3}]$ | $[_{-},S^4_{4/3}]$ |
| RE3 | $S^4_{4/3}$ | $S^4_{1/3}$ | $S^4_0$ | $S^4_{1/3}$ | $S^4_{4/3}$ | $S^4_{-1/3}$ | $S^4_{1/3}$ |
| RE4 | $S^4_{2/3}$ | $S^4_{3/4}$ | $S^4_{3/4}$ | $S^4_{3/4}$ | $S^4_3$ | $S^4_{0.3}$ | $S^4_{-0.3}$ |
| RE5 | $S^4_3$ | $S^4_{-4/3}$ | $S^4_0$ | $S^4_0$ | $S^4_{4/3}$ | $S^4_{1/3}$ | $S^4_0$ |
| RE6 | $[S^4_1,S^4_3]$ | $[S^4_{-3},S^4_{-1}]$ | $[S^4_{-3},S^4_{-1}]$ | $[S^4_1,S^4_3]$ | $[S^4_1,S^4_3]$ | $[S^4_{-1},S^4_0]$ | $[S^4_0,S^4_1]$ |

**Step 3:** Based on the uniform matrix, the weight evaluation vector of key LIS indicators was calculated:

$$\xi_1 = \left\{S^4_3, \left[S^4_{4/3}, S^4_3\right], S^4_{4/3}, S^4_{2/3}, S^4_3, \left[S^4_1, S^4_3\right]\right\};$$

$$\xi_2 = \left\{S^4_0, \left[S^4_{-1/3}, S^4_0\right], S^4_{1/3}, S^4_{3/4}, S^4_{-4/3}, \left[S^4_{-3}, S^4_{-1}\right]\right\};$$

$$\xi_3 = \left\{S^4_0, \left[S^4_0, S^4_{1/3}\right], S^4_0, S^4_{3/4}, S^4_0, \left[S^4_{-3}, S^4_{-1}\right]\right\};$$

$\xi_4 = \{S_1^4, [S_{1/3}^4, S_{4/3}^4], S_{1/3}^4, S_{3/4}^4, S_0^4, [S_1^4, S_3^4]\}$;

$\xi_5 = \{S_1^4, [S_{4/3}^4, S_3^4], S_{4/3}^4, S_3^4, S_{4/3}^4, [S_1^4, S_3^4]\}$;

$\xi_6 = \{S_{-1}^4, [S_{-4/3}^4, S_{-1/3}^4], S_{-1/3}^4, S_{0.3}^4, S_{1/3}^4, [S_{-1}^4, S_0^4]\}$;

$\xi_7 = \{S_1^4, [S_{1/3}^4, S_{4/3}^4], S_{1/3}^4, S_{-0.3}^4, S_0^4, [S_0^4, S_1^4]\}$.

Using **Equations (3)** and **(4)**, the positive and negative ideal points for weight evaluation were determined as follows:

$x^+ = \{S_3^4, [S_{4/3}^4, S_3^4], S_{4/3}^4, S_3^4, S_3^4, [S_1^4, S_3^4]\}$, $y^- = \{S_{-1}^4, [S_{-4/3}^4, S_{-1/3}^4], S_{-1/3}^4, S_{-0.3}^4, S_{-4/3}^4, [S_{-3}^4, S_{-1}^4]\}$

**Step 4:** The relative proximity of the index weight evaluation vector to the positive and negative ideal points was calculated using **Equation (5)**:

$z_1^* = 0.890$, $z_2^* = 0.141$, $z_3^* = 0.185$, $z_4^* = 0.320$, $z_5^* = 0.838$, $z_6^* = 0.235$, $z_7^* = 0.375$

**Step 5:** The weights of each key indicator were determined using Equation (6):

$\omega_1 = 0.298$, $\omega_2 = 0.047$, $\omega_3 = 0.062$, $\omega_4 = 0.107$, $\omega_5 = 0.281$, $\omega_6 = 0.079$, $\omega_7 = 0.126$

The results indicate that system flexibility and response speed are the most important key indicators in the MC environment. To verify the effectiveness of this method, the company applied these weights to the actual design of the LIS and subsequently analyzed feedback from the market and production departments. The findings confirm that the determined weights accurately reflect the characteristics of LIS in the MC environment, effectively supporting the company's strategic goals.

## 4. Conclusions

Mass customization has emerged as the predominant production model of the 21st century, garnering significant attention from both academia and industry. While MC ensures the high efficiency and low cost associated with mass production, it simultaneously aims to meet the individual needs of customers. This dual capability provides enterprises with a novel approach to enhancing competitiveness but also introduces new challenges, particularly in the operation of logistics systems. In the MC environment, the constraints on logistics systems are heightened. Despite these limitations, logistics systems must address personalized requirements with minimal increases in costs, significantly elevating the risk associated with logistics system investment. Consequently, the selection and evaluation of LIS becomes a critical issue for achieving MC.

(1) Determination of key indicators: The key indicators of LIS in the MC environment were identified based on historical enterprise data, the macroeconomic environment, and customer analysis, ensuring a relatively scientific selection process. Evaluation team members were invited to provide semantic information regarding these indicators based on actual conditions. The data were then processed consistently to construct an evaluation matrix. Using the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) methodology, the initial weight vector for the key LIS indicators was obtained.

(2) Validation of methodology: Case analysis results demonstrate that the proposed method for determining key indicator weights is both effective and feasible.

## Disclosure statement

The authors declare no conflict of interest.

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