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Evaluating Logistics Systems in the Context of Mass Customization Based on Goal Expectation

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Abstract: Given the complexity and uncertainty of logistics systems in a mass customization environment, decision-making teams often rely on linguistic phrases rather than quantifiable evaluation indices when selecting an evaluation system. This paper proposes a logistics system evaluation method based on index goal expectation. First, linguistic phrases are processed through an integration method to derive standardized weight vectors. Next, the decision-making team establishes the expected compliance degree for each alternative, which is processed using an axiomatic design to calculate the final evaluation index for each option. The options are then ranked based on these indices to identify the most appropriate logistics system. Applying this method to a company's logistics system selection demonstrates its effectiveness and feasibility.

Keywords: Logistics system; Goal expectation; Axiomatic design

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1. Introduction

With the rapid acceleration of economic globalization, enterprises face continuous changes in their development processes. Consumer demand for diversification and customization has grown significantly. Mass customization, a production model oriented toward customer demands, aims to provide personalized products or services without compromising response time or final cost [1]. To adapt to this shift in production models, enterprises must concentrate on core business activities while outsourcing non-core functions. Achieving rapid responses and value-added services requires enhancing the development of diversified product modules and optimizing logistics systems. Such optimized logistics systems help reduce operational costs, increase profitability, and improve responsiveness.

The implementation of mass customization places higher demands on logistics systems, increasing their complexity and the uncertainty associated with their selection. Identifying effective methods for logistics system selection in such a complex environment is the primary problem this study seeks to address.

In logistics system theory, evaluation plays a crucial role and has consistently been a focus of research. Enterprises must adopt more effective logistics systems to maintain a competitive edge in intense market competition [2]. Current methods for logistics system evaluation include the analytic hierarchy process, genetic algorithms, improved genetic algorithms, and fuzzy mathematics [3]. Some scholars employ combination methods to enhance evaluations, while others explore multi-objective evaluation systems applied to supply chain design processes. For example, decision-making network planning methods have been used to establish optimal equilibrium models through multi-attribute utility function theory, addressing logistics implementation optimization under multiple objectives [4].

However, existing research often fails to provide explicit target expectations for indicators. Although some studies mention target expectations, these methods typically require pre-established utility or probability distribution functions, which are challenging to determine in practical applications [5].

This paper introduces a logistics system evaluation method based on linguistic weight and goal expectation in a mass customization environment. Linguistic weight information is converted into explicit values to fully utilize the linguistic evaluation data. The decision-making team determines the indicator design values for alternative schemes [6]. Compliance degree and information content matrices are then derived based on the expectation types of three indicators. Finally, using the information axiom from axiomatic design, the evaluation indices for alternative schemes are compared.

The proposed method aims to provide an effective evaluation strategy for logistics systems in a mass customization environment, addressing linguistic weight and decision-making target expectations.

2. Logistics system evaluating method

When evaluating the logistics system within the mass customization (MC) environment, under the premise of considering the target expectation, there are typically three possible scenarios regarding the evaluation value of an alternative scheme based on key indicators: (1) the evaluation value does not exceed the established target expectation; (2) the evaluation value falls within the defined target expectation interval; (3) the evaluation value must exceed or meet the established expectations. To obtain clear evaluation results, it is necessary to process the evaluation values of different alternatives. The evaluation values provided by decision-making members for various key indicators are compared with the expected values to determine the degree of alignment with the target expectation. Axiomatic design is defined, and the calculation formulas are provided. In accordance with the principles of axiomatic design, to select a reasonable logistics system under the MC environment, it is essential to convert the evaluation value or interval of key indicators from alternative schemes, as provided by decision-making members, into a degree of compliance with the target expectation. This paper presents calculation formulas for the three distribution types, based on existing research.

Step 1: In the MC environment, the set of decision-making members participating in the logistics system evaluation is denoted as $\boldsymbol{D} = \{D_1, D_2, ..., D_T\}$, the set of key indicators affecting the selection of the logistics system is denoted as $\boldsymbol{G} = \{G_1, G_2, ..., G_M\}$, and the goal expectation for each key indicator, as determined by the decision-making team, is denoted as $\boldsymbol{E} = \{E_1, E_2, ..., E_M\}$.

Step 2: All decision-making members are invited to provide the language-weight preference information for each key indicator. A decision method based on language information is then used to determine the weight of each key indicator, denoted as $\boldsymbol{GIR} = \{gir_1, gir_2, ..., gir_M\}$.

Step 3: If the decision-making team believes that the evaluation value of an alternative scheme for a given key indicator should not exceed the target expectation for that indicator, the evaluation value is converted into the degree of compliance with the target expectation using **Equations (1)** and **(2)**:

If $r_{ij} = r^u_{ij} = r^v_{ij}$,

$$a^1_{ij} = \begin{cases} 0 & r_{ij} > E_j \\ 1 & r_{ij} \le E_j \end{cases} \quad \textbf{(1)}$$

If $r^u_{ij} < r^v_{ij}$,

$$a^1_{ij} = \begin{cases} 0 & r^u_{ij} > E_j \\ (E_j - r^u_{ij})/(r^v_{ij} - r^u_{ij}) & r^u_{ij} < E_j < r^v_{ij} \\ 1 & r^v_{ij} \le E_j \end{cases} \quad \textbf{(2)}$$

If the decision-making team believes that the evaluation value of the alternative scheme for a given key indicator should fall within the target expectation interval, the evaluation value is converted into the degree of conformity with the target expectation using **Equations (3)** and **(4)**:

If $r_{ij} = r^u_{ij} = r^v_{ij}$,

$$a^2_{ij} = \begin{cases} 0 & r_{ij} \notin [E^u_j, E^v_j] \\ 1 & r_{ij} \in [E^u_j, E^v_j] \end{cases} \quad \textbf{(3)}$$

If $r^u_{ij} < r^v_{ij}$

$$a^2_{ij} = \begin{cases} 0 & r^u_{ij} > E^v_j \text{或} r^v_{ij} < E^u_j \\ (E^v_j - E^u_j)/(r^v_{ij} - r^u_{ij}) & r^u_{ij} \le E^u_j < E^v_j \le r^v_{ij} \\ (E^v_j - r^u_{ij})/(r^v_{ij} - r^u_{ij}) & E^u_j \le r^u_{ij} < E^v_j \le r^v_{ij} \\ (r^v_{ij} - E^u_j)/(r^v_{ij} - r^u_{ij}) & r^u_{ij} \le E^u_j < r^v_{ij} \le E^v_j \\ 1 & E^u_j \le r^u_{ij} < r^v_{ij} \le E^v_j \end{cases} \quad \textbf{(4)}$$

If the decision-making team believes that the evaluation value of the alternative scheme on a key indicator should exceed or meet the target expectation for that indicator, the evaluation value is converted into the degree of compliance with the target expectation using **Equations (5)** and **(6)**:

If $r_{ij} = r^u_{ij} = r^v_{ij}$,

$$a^3_{ij} = \begin{cases} 0 & r_{ij} < E_j \\ 1 & r_{ij} \ge E_j \end{cases} \quad \textbf{(5)}$$

If $r^u_{ij} < r^v_{ij}$

$$a^3_{ij} = \begin{cases} 0 & r^v_{ij} < E_j \\ (r^v_{ij} - E_j)/(r^v_{ij} - r^u_{ij}) & r^u_{ij} < E_j < r^v_{ij} \\ 1 & r^u_{ij} \le E_j \end{cases} \quad \textbf{(6)}$$

Step 4: Based on the above key indicators, the information matrix for each alternative scheme can be constructed by evaluating the desired conformity degree matrix of the goal determined through the transformation formula. The equation for calculating the amount of information on the key indicators of the alternative scheme provided by the design enterprise is given by **Equation (7)**:

$$b_{ij} = ln\left(1/a_{ij}\right) \quad \textbf{(7)}$$

Step 5: Based on the weight information of each key indicator, as determined by the decision-making team through language phrases, the information matrix of each alternative scheme can be aggregated to obtain the final evaluation index for each alternative scheme. The calculation formula is shown as **Equation (8)**:

$$B_i = \sum_{j=1}^{M} \omega_j b_{ij} \quad \textbf{(8)}$$

According to the basic principle of the information axiom, the alternative scheme with a smaller final evaluation index is more in line with the target expectations. Based on this, the final evaluation index for each alternative can be ranked to identify the most rational logistics system.

3. Examples and analysis of results

A well-known domestic computer company specializes in notebook computers. In response to the challenges posed by economic globalization and the continuous changes in consumer demand, the company decided to explore the implementation of the mass customization (MC) model, aiming to fully integrate MC as a key strategy for gaining a competitive advantage. The company's decision-making team places significant importance on improving the logistics system, with the goal of enhancing the system's information processing capacity, shortening the time required for products to reach the final customer, avoiding increases in logistics costs, and further expanding the logistics system's service scope.

Step 1: Based on the collected market and enterprise data, six decision-making members identified key indicators that significantly impact the logistics system in the MC environment. These indicators included the cargo throughput, capital turnover rate, total inventory hours, response time, daily processing order volume, and logistics costs for the improved system. Through detailed market research, the decision-making team engaged with the company's market development, production, technology, and customer service departments. After repeated discussions, they established target expectations for each key indicator (**Table 1**).

Table 1. Key indicators and their target expectations

Index	Goal expectation
Cargo throughput	Over 1.5 million units
Capital turnover rate	More than 18 times
Total inventory hours	Two to six days
Response time	Less than 8 days
Daily processing order volume	More than 180 orders
Logistics cost of improved system	Less than 2% of order price

Step 2: Using decision theory based on language information, the normalized index weight vector was determined as ***GIR*** = (0.11, 0.14, 0.21, 0.31, 0.14, 0.09).

Step 3: **Equations (1)** to **(6)** were applied to determine the degree to which different alternatives met the expected values for various key indicators (**Table 2**).

Table 2. Evaluation matrix of the degree of expected conformity of alternative objectives

	G_1	G_2	G_3	G_4	G_5	G_6
S1	0.46	1.00	0.76	1.00	1.00	1.00
S2	1.00	1.00	0.77	1.00	1.00	1.00
S3	0.38	1.00	0.73	1.00	1.00	1.00
S4	0.63	1.00	0.83	1.00	1.00	1.00
S5	0.00	0.00	1.00	1.00	1.00	1.00
S6	0.47	0.00	0.74	1.00	0.00	1.00
S7	1.00	1.00	0.76	1.00	1.00	1.00

Step 4: Using **Equation (7)**, the information amount for each alternative based on various key indicators was calculated (**Table 3**).

Table 3. Information amount of alternatives

Alternative	G_1	G_2	G_3	G_4	G_5	G_6
S1	0.37	0.00	0.12	0.00	0.00	0.00
S2	0.00	0.00	0.11	0.00	0.00	0.00
S3	0.42	0.00	0.14	0.00	0.00	0.00
S4	0.20	0.00	0.08	0.00	0.00	0.00
S5	∞	∞	0.00	0.00	0.00	0.00
S6	0.47	∞	0.13	0.00	∞	0.00
S7	0.00	0.00	0.12	0.00	0.00	0.00

Step 5: Based on **Equation (8)**, the final evaluation index for each alternative was determined: B_1 = 0.0659, B_2 = 0.0231, B_3 = 0.0756, B_4 = 0.0388, and B_7 = 0.0252. The prioritization of the final evaluation index is as follows: $B_3 \succ B_1 \succ B_4 \succ B_7 \succ B_2$. According to the axiomatic design principle, the alternative S_2 with the smallest final evaluation index is the optimal scheme.

4. Conclusions

To effectively address the challenges of product diversification and changing demand, manufacturers must balance consumer needs with cost benefits. Customers seek personalized solutions at lower costs, which requires production enterprises to both enhance product research and development and select the appropriate logistics system. In the mass customization (MC) environment, logistics system planners must design systems that meet both enterprise requirements and, ultimately, customer needs, taking into account the target expectations for key indicators. For the three types of goal expectations, the evaluation matrix is first constructed based on the design values of the alternative schemes proposed by the planner. This matrix is then transformed into a matrix that reflects the degree of compliance with the goal expectations. Furthermore, the information matrix for the alternative schemes is established according to the information axiom of axiomatic design, and the final evaluation index for each scheme is calculated to determine the optimal solution.

Disclosure statement

The authors declare no conflict of interest.

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