A Study on Proposing Evaluation Criteria for the Development Potential of High-Quality Logistics Human Resources in the Southeastern Region of Vietnam

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Abstract: This study aims to propose a set of criteria for assessing the potential for developing high-quality logistics human resources in the Southeast region of Vietnam - an area that holds a strategic position in the country's supply chains and logistics services. The proposed framework aligns with the Government's orientation toward green and sustainable development in the near future. The criteria were identified through a systematic review of reputable scientific publications, an analysis of the current state of the logistics system and consultations with leading experts in the field. To achieve the research objectives, the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) is employed as the primary analytical method. The results reveal that four criteria stand out by contributing more than 15% in terms of relative importance, significantly outweighing the remaining factors. Based on this ranking, targeted solutions for developing high-quality logistics human resources are proposed, with their implementation prioritized accordingly. Furthermore, in the context of deepening global integration and increasing labor market uncertainty, the findings of this study provide a valuable scientific basis for enterprises to evaluate and strategically guide their human resource development efforts.

Keywords: Fuzzy AHP, Green and Sustainable Development, High-Quality Human Resources, Logistics Workforce

1 Introduction

The logistics industry is playing an increasingly vital role in promoting trade, optimizing supply chains, and enhancing national competitiveness amid digital transformation and global integration. According to the Vietnam Logistics Business Association (VLA), the logistics service sector in Vietnam has recorded an annual growth rate of approximately 14% to 16% in recent years, with a market size of USD 40 - 42 billion [1]. It is recognized as one of the fastest-growing and most stable service industries in the country. Within this context, the Southeast region featuring key logistics hubs such as Ho Chi Minh City, Ba Ria - Vung Tau and Dong Nai is emerging as a strategic transit node within the national logistics network.

However, the rapid expansion of the industry has brought about several challenges, most notably the shortage of high-quality human resources. The Vietnam Logistics Report 2024 highlights that only around 5 - 7% of the workforce in this sector have received formal training in logistics. Furthermore, approximately 65% of logistics enterprises report difficulties in recruiting personnel with appropriate skillsets, and merely 6.7% express satisfaction with the professional qualifications of their current employees [1]. These statistics underscore a significant gap between the supply and demand of skilled labor, underscoring the urgent need for strategic approaches to human resource development, training, and evaluation in the logistics sector.

In addition to the quantitative and qualitative deficiencies, logistics human resources in Vietnam face structural challenges due to the weak integration among enterprises, educational institutions, and local authorities. The current training infrastructure remains fragmented, lacks practical orientation, and falls short of aligning with market needs. Meanwhile, most international models for evaluating and developing logistics human resources are tailored to the conditions of developed economies, where training systems, human resource policies, and enterprise capabilities are more standardized. Specific contextual factors in Vietnam such as the role of local governments in linking vocational education to labor market needs, or the degree of inter-regional cooperation in workforce development are often overlooked in existing studies.

Notably, the Future of Jobs Report 2023 by the World Economic Forum (WEF) identifies logistics as one of the sectors experiencing the fastest shifts in skill requirements over the next five years, especially in terms of technology proficiency, critical thinking, and adaptability [2]. This further highlights the pressing need to develop a robust set of criteria for assessing the potential for high-quality human resource development in logistics. Such criteria will serve to guide training, recruitment, and workforce development strategies aligned with the ongoing trends of supply chain industrialization and digitalization.

Against this backdrop, the present study proposes a comprehensive set of evaluation criteria for assessing the development potential of high-quality logistics human resources in Vietnam's Southeast region. These criteria are derived from an extensive review of international literature, contextual analysis of Vietnam's logistics practices, and expert consultations. The proposed framework aims to serve as a scientific foundation for policymaking and strategic planning in human resource development, ultimately contributing to the enhancement of the logistics sector's competitiveness in the years ahead.

2 Theoretical Background

Enhancing the quality of human resources is a critical prerequisite for logistics enterprises to effectively adapt to the increasingly competitive global landscape and the demands of digital transformation. Numerous international studies have identified key factors that significantly influence human resource development capacity within organizations, particularly in environments that require continuous innovation and technological adaptation.

In the context of global green transition and digitalization, the ability to adapt to green logistics and sustainable development has emerged as a strategic competency in building high-quality logistics human resources. Recent research confirms that green human capital plays a pivotal role in advancing environmentally responsible logistics practices, thereby enhancing firms' social performance, financial outcomes, and overall competitiveness [3]. The integration of Green Human Resource Management (GHRM) with Sustainable Green Logistics (SGLOG) is considered essential for developing an effective environmental management system. Within this system, employees' knowledge, skills, and attitudes act as critical mediating variables [4]. Additionally, absorptive capacity defined as the ability to acquire, assimilate, transform, and exploit environmental information has been recognized as a foundational driver of green innovation and improved environmental performance in logistics [5]. Building on this foundation, the development of logistics capabilities rooted in green resources including technological assets, professional knowledge, strategic partnerships and organizational structure contributes to the formation of a unique environmental competency framework. This framework offers a sustainable competitive advantage for logistics service providers [6]. Attracting and retaining talent also constitutes a strategic imperative for maintaining workforce stability and long-term sustainability. Al-Dalahmeh established a direct relationship between talent management and organizational performance [7], while Hazra et al. demonstrated that effective retention policies enhance both employee productivity and engagement [9]. Employee training and development represent another cornerstone of human resource advancement. Attar affirmed that strategically designed training programs significantly improve adaptability and work performance [11]. Lowe et al. emphasized the importance of aligning training strategies with broader supply chain operations [12], while Caratozzolo et al. focused on future skills forecasting to prepare a high-quality, future-ready workforce [14]. Performance management and career development are equally critical in sustaining employee motivation and fostering long-term growth. Micacchi et al. highlighted the importance of a transparent and equitable performance evaluation system [15]. Uddin and Das proposed the adoption of gamification to enhance workplace engagement and efficiency [16], while Elrayah and Semlali introduced the concept of sustainable rewards as a long-term motivational tool for talented employees [18]. In the dynamic and volatile logistics environment, flexibility and adaptability are essential competencies. Tretiakov et al. proposed empowerment strategies and flexible working arrangements to enhance employees' responsiveness [21]. Similarly, Wang et al. emphasized the role of emotional intelligence in facilitating effective career adaptation [24]. Technological competency and digital transformation readiness have become indispensable criteria in modern human resource evaluation models. Reis et al. identified that an employee's ability to adopt technology is influenced by organizational factors, IT proficiency and personal traits [25]. Kane further emphasized that technological proactiveness enhances performance [26], while Gekara et al. underlined the importance of digital awareness and upskilling needs among logistics workers [27]. Leadership commitment represents a foundational element in shaping workforce development. Mannan stressed the strategic role of leadership in fostering a learning-oriented organizational culture [31]. Al Jubouri reinforced this by illustrating how transformational leadership can promote employee learning and adaptability through targeted HR strategies and internal learning policies [33]. In the context of globalization, the ability to operate in multicultural and internationalized work environments has become a crucial indicator of high-quality human resources. Harris et al. proposed the Collaborative Online International Learning (COIL) model to strengthen employees' global competencies [35]. Studies by Liu et al. [36] and Orsini and Magnier-Watanabe further affirmed that effective cross-cultural collaboration is essential for success in international supply chains [37].

However, a common limitation of many current research models lies in their development within the context of advanced economies, where infrastructure, technological maturity, and stakeholder connectivity are relatively well established. In contrast, the logistics sector in Vietnam, particularly in the Southeast region exhibits several distinct characteristics, such as the dominance of small and medium-sized enterprises (SMEs), uneven levels of digital transformation and a fragmented vocational training system. Most notably, the collaboration among training institutions, enterprises, and research organizations in the development of logistics human resources remains weak and lacks effective coordination mechanisms.

In light of this practical context, the present study has developed a set of criteria to evaluate the potential for high-quality logistics human resource development, drawing on two complementary sources. First, eight criteria are adapted and selected from reputable international studies, representing core competencies such as training, technology, leadership, performance, adaptability, and global integration. These criteria have been modified to align with the specific conditions of the research setting. Second, an additional criterion was introduced based on expert interviews namely, the linkage ecosystem among educational institutions, enterprises, and research bodies. This component reflects a critical and context-specific challenge in Vietnam's logistics sector that has not been adequately addressed in prior literature.

The integration of international theoretical foundations with localized practical insights not only strengthens the systematic and scientific rigor of the research model but also enhances its relevance and applicability in the Vietnamese context, where the logistics industry is undergoing a significant transformation in workforce quality. The resulting set of nine criteria, presented in Table 1, forms the basis for the evaluation conducted in the subsequent sections of this study.

Table 1. Proposed evaluation criteria for the development potential of high-quality logistics human resources in southeastern Vietnam

Code	Criterion	Source
C1	Green and sustainable logistics capabilities	[3]; [4]; [5]; [6]

C2	Training - Enterprise - Academic ecosystem	Expert Panel
C3	Talent attraction and retention	[7]; [8]; [9]; [10]
C4	Training and staff development	[11]; [12]; [13]; [14]
C5	Mechanisms for performance enhancement and career development	[15]; [16]; [17]; [18]; [19]; [20]
C6	Flexibility and adaptability	[21]; [22]; [23];[24]
C7	Technological capability and digital transformation	[25]; [26]; [27]; [28]; [29]; [30]
C8	Leadership and managerial commitment	[31]; [32]; [33]; [34]
C9	Multicultural and international work environment	[35]; [36]; [37]; [38]; [39]

Source: Proposed by the authors

3 Research Methodology

To develop a comprehensive set of criteria for assessing the potential of high-quality logistics human resource development in the Southeast region of Vietnam, this study adopted an integrated three-step approach, combining a theoretical literature review, practical analysis and expert consultation.

3.1 Literature review and contextual analysis

First, the research team conducted a systematic review of international academic and empirical studies in the fields of logistics, human resource management, vocational education, digital transformation and organizational development. The criteria selected from this review were those most frequently cited in validated assessment models and strongly associated with organizational capabilities, strategic human resource development, innovation capacity and global integration within modern logistics environments. In addition, high-reliability industry reports such as the Vietnam Logistics Report 2024 and the Future of Jobs Report 2023 were examined to capture updated skill requirements in the context of digital transformation and labor market volatility [1] [2].

3.2 Expert consultation and criteria refinement

Drawing from these theoretical and practical sources, a preliminary set of eight criteria was developed and subsequently refined through semi-structured interviews with 20 experts in logistics, human resource management and vocational training. These experts were selected using purposive sampling based on three key criteria: (i) a minimum of five years of professional experience; (ii) current roles in middle or senior management at enterprises, training institutions or governmental bodies; and (iii) in-depth knowledge of the human resource landscape in Vietnam's logistics sector. The expert panel included representatives from logistics firms (3PL, transportation, warehousing, seaports), lecturers from specialized training institutions, officials from state management agencies in the Southeast region, and delegates from the Vietnam Logistics Business Association (VLA).

The interviews focused on evaluating the relevance, clarity, and measurability of each proposed criterion in the Vietnamese logistics context. Notably, one important context-specific factor absent in international frameworks was identified during the consultation: the “Training - Enterprise - Academic ecosystem”. This criterion reflects the degree of coordination among these three actors in developing and implementing workforce training programs that are responsive to actual labor market demands. By synthesizing the findings from these three methodological steps, the study finalized a set of nine criteria. Among these, eight were adapted from international theoretical models to fit the Vietnamese logistics environment and one was newly introduced based on expert insight to ensure contextual relevance and enhance practical applicability.

3.3 Quantitative prioritization using Fuzzy AHP

Following the qualitative development of the criteria, the study applied a quantitative assessment to determine the relative importance of each factor. The Fuzzy Analytic Hierarchy Process (Fuzzy AHP) was employed as an extended version of the classic AHP method developed by Saaty [40]. As a widely used Multi-Criteria Decision-Making (MCDM) technique, Fuzzy AHP enables the prioritization of decision attributes by incorporating human judgment expressed in fuzzy numbers. A fuzzy pairwise comparison matrix was constructed to capture expert evaluations, using triangular fuzzy numbers (TFNs) to represent the linguistic scales. The weights of criteria were computed from the fuzzy comparison matrices using established defuzzification techniques, including the logarithmic least squares method, fuzzy extent analysis, fuzzy row sums, fuzzy column inverses and both geometric and arithmetic means [41]. This integrated methodology ensured both academic rigor and practical relevance, producing a context-sensitive framework for evaluating logistics workforce development potential in the Southeastern region of Vietnam.

Fuzzy set theory

Zadeh introduced Fuzzy Set Theory to describe uncertainty and imprecision in the parameters of decision-making processes [42]. A fuzzy set $\widetilde{M}$ is defined by a membership function $\mu\widetilde{M}(X)$, as shown in Equation (1). A Triangular Fuzzy Number (TFN) $\widetilde{M}$ is typically represented by a triplet of values (a;b;c), where: a is the lower bound, b is the most likely (modal) value and c is the upper bound, as illustrated in Fig. 1.

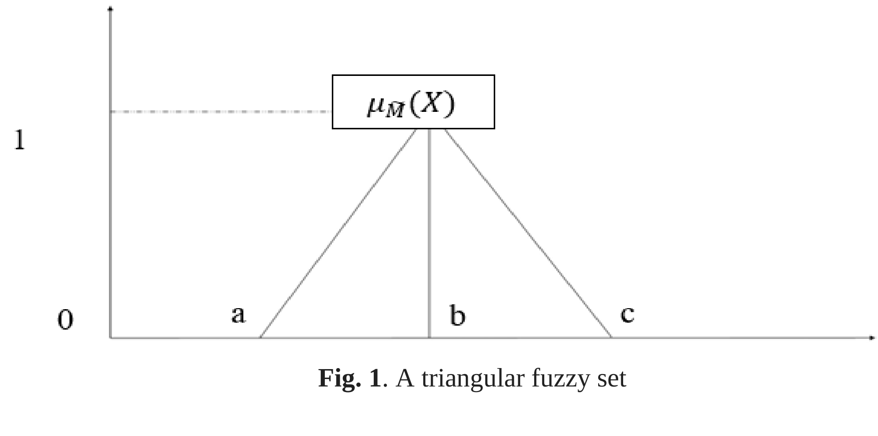

Fig. 1. A triangular fuzzy set

Several useful arithmetic operations on Triangular Fuzzy Numbers (TFNs), including addition, multiplication, scalar multiplication, and reciprocal operations, are presented in Equations (2) to (5). Let $\widetilde{M_1} = (a_1, b_1, c_1)$ and $\widetilde{M_2} = (a_2, b_2, c_2)$ be two TFNs. The operations are defined as follows:

$$\mu_{\widetilde{M}}(X) = \begin{cases} \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{x-c}{b-c} & b \leq x \leq c \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

$$\widetilde{M_1} + \widetilde{M_2} = (a_1 + a_2, b_1 + b_2, c_1 + c_1) \tag{2}$$

$$\widetilde{M_1} - \widetilde{M_2} = (a_1 - a_2, b_1 - b_2, c_1 - c_1) \tag{3}$$

$$k \times \widetilde{M_1} \times \widetilde{M_2} = (ka_1, kb_1, kc_1), \text{where } k > 0 \tag{4}$$

$$\widetilde{M_1}^{-1} = (\frac{1}{c_1}, \frac{1}{b_1}, \frac{1}{a_1}) \tag{5}$$

Step 1: Constructing the hierarchical structure of objectives

The first step in applying the Fuzzy AHP method is to clearly define the main objective of the evaluation. Once the goal is established, the related domains and contributing factors that affect the achievement of this objective are identified. This process is carried out based on a combination of theoretical foundations and expert opinions.

Step 2: Evaluation and comparison by decision-makers

Table 2 presents the linguistic scale used for pairwise comparisons among the evaluation criteria and critical success factors (CSFs). These linguistic terms assist decision-makers in expressing the relative importance of each factor. Based on these judgments, a pairwise comparison matrix is constructed using Equation (6), where d_{ijk} represents the assessment of decision-maker k when comparing criterion iii with criterion j. To aggregate individual judgments into a group consensus, Equation (7) is used to calculate the fuzzy average of all decision-makers' inputs. The resulting aggregated fuzzy comparison matrix is then formulated according to Equation (8), ensuring that the collective preferences are reflected in the analysis.

$$D_k = \begin{bmatrix} \tilde{d}_{11k} & \dots & \tilde{d}_{1nk} \\ \dots & \tilde{d}_{ijk} & \dots \\ \tilde{d}_{n1k} & \dots & \tilde{d}_{nnk} \end{bmatrix} \; k = 1, \dots, K; i = 1, \dots, n; j = 1, \dots, n \tag{6}$$

$$\tilde{d}_{ij} = \frac{\sum_{k=1}^{K} \tilde{d}_{ijk}}{K} = 1/\tilde{d}_{ji} \quad \forall i, j \tag{7}$$

$$D = \begin{bmatrix} \tilde{d}_{11} & \tilde{d}_{1n} \\ \dots & \dots \\ \tilde{d}_{n1} & \tilde{d}_{nn} \end{bmatrix} \quad (8)$$

Table 2. Linguistic variables and corresponding triangular fuzzy numbers

Linguistic Term	Meaning	TFN
Equal importance	Both elements contribute equally	(1; 1; 1)
Weak importance	Slightly favor one over another	(1; 2; 3)
Moderate importance	Moderate preference	(2; 3; 4)
Moderate plus importance	Moderate to strong preference	(3; 4; 5)
Strong importance	Strongly favor one over another	(4; 5; 6)
Strong plus importance	Strong to very strong preference	(5; 6; 7)
Very strong importance	Very strongly preferred	(6; 7; 8)
Very, very strong importance	Extremely preferred	(7; 8; 9)
Absolute importance	Decisively more important	(9; 9; 9)

Source: [43]

Step 3: Consistency check of the comparison matrix

Saaty introduced the Consistency Ratio (CR) to assess the degree of consistency in the pairwise comparison judgments provided by decision-makers in the Analytic Hierarchy Process (AHP) [40]. Similarly, the consistency of the comparison matrix in the Fuzzy AHP method can be estimated based on the approach proposed by Kwong & Bai [44]. First, the average Triangular Fuzzy Numbers (TFNs) are defuzzified into crisp numbers using Equation (9), resulting in a crisp comparison matrix denoted as matrix A. Next, the priority vector or principal eigenvector W, which represents the normalized relative weights of the criteria, is derived from matrix A using Equation (10). The values in W are computed as the row averages of the column-normalized version of matrix A. Subsequently, matrix X, representing the weighted sum of criteria, is calculated using Equation (11). The maximum eigenvalue λ_{max} is then computed from the equation AW=λW, as stated in Saaty [45] and expressed in Equation (12).

From these results, the Consistency Index (CI) and Consistency Ratio (CR) are calculated using Equations (13) and (14), respectively. The Random Consistency Index (RI), which depends on the size nnn of the comparison matrix, is obtained from Table 3. To ensure consistency in expert judgments, the CR value must be less than 0.1. If CR exceeds 0.1, the Fuzzy AHP process must be halted and returned to Step 2 for the revision of pairwise comparisons [40].

$$M_i = \frac{a + 4b + c}{6} \text{ for any triangular fuzzy number } \widetilde{M} \quad (9)$$

$$w_i = \frac{\sum_{j=1}^{n} \frac{a_{ij}}{\sum_{x=1}^{n} a_{xi}}}{n} \quad (10)$$

$$X = AW \quad (11)$$

$$\lambda_{max} = \frac{\sum_{x=1}^{n} \frac{x_i}{w_i}}{n} \quad (12)$$

$$CI = \frac{\lambda_{max} - 1}{n - 1} \quad (13)$$

$$CR = \frac{CI}{RI(n)} \quad (14)$$

Table 3. Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.51

Source: [40]

Step 4: Determining the fuzzy geometric mean matrix for the criteria

In this step, the fuzzy geometric mean matrix for all criteria is determined using Equation (15). This matrix is constructed by calculating the geometric mean of the fuzzy pairwise comparisons provided by the decision-makers. Subsequently, the fuzzy weights for each criterion are computed using Equation (16). These weights are expressed in terms of triangular fuzzy numbers $(lw_i; mw_i; nw_i)$, where: lw_i is the lower bound of the fuzzy weight, mw_i is the most likely value (modal value) and nw_i is the upper bound. These values define the range and shape of the fuzzy weight for each criterion, reflecting the degree of uncertainty and variability in expert judgments.

$$\tilde{r}_i = \sqrt[n]{\prod_{j=1}^{n} \tilde{d}_{ij}} \quad i = 1, \dots, n \quad (15)$$

$$w_i = \frac{r_i}{\sum_{i=1}^{n} r_i} = (lw_i, mw_i, nw_i) \quad (16)$$

Step 5: Defuzzification of triangular fuzzy logic and weight normalization

In this step, the defuzzification of the triangular fuzzy numbers is performed, following a similar approach to that described in Equation (9), in order to convert fuzzy weights into crisp values. The defuzzified value of each fuzzy weight is calculated using Equation (17). This transformation allows the representation of the relative importance of each criterion in a clear, deterministic form, facilitating subsequent analysis. Once the crisp weights are obtained, they are normalized using Equation (18) to ensure that the sum of all weights equals one. This normalization step enables consistent comparison and interpretation of the relative significance of each criterion within the decision hierarchy.

$$M_i = \frac{lw_i + 4mw_i + nw_i}{6} \quad (17)$$

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad (18)$$

Step 6: Finalizing the weights and ranking the criteria

In the final step, the criteria are ranked in descending order based on their normalized crisp weights obtained from the previous step. This ranking reflects the relative importance of each criterion in achieving the overall objective of the decision-making process. The resulting priority order provides the basis for interpreting the decision-makers' preferences and supports strategic planning, policy formulation, or resource allocation aligned with the most critical factors identified through the Fuzzy AHP analysis.

4 Research Result

Following consultations with 20 experienced experts in the fields of logistics and supply chain management, the research team compiled and synthesized expert evaluations to construct a fuzzy pairwise comparison matrix among the identified criteria. Experts were asked to compare the relative importance between each pair of criteria using a linguistic fuzzy scale, which was subsequently converted into Triangular Fuzzy Numbers (TFNs). Each expert's judgment was encoded as a triplet (l;m;n), representing the lower, most likely, and upper bounds of the fuzzy number. To ensure representativeness and stability in the input data, the individual fuzzy judgments were aggregated using the arithmetic mean method, applied to each corresponding component of the TFNs across all experts. This approach preserves the fuzzy nature of the data while also capturing the consensus trend among the expert panel. The resulting fuzzy comparison matrix, presented in Table 4, serves as the primary input for the Fuzzy AHP analysis. It provides the basis for calculating fuzzy weights, defuzzification, and normalization in the subsequent steps of the model.

Table 4. Fuzzy pairwise comparison matrix of evaluation criteria

Code	**C1**	**C2**	**C3**
C1	(1;1;1)	(0.22;0.29;0.41)	(1.47;2.43;3.4)
C2	(2.7;3.7;4.7)	(1;1;1)	(4.4;5.35;6.3)
C3	(0.34;0.53;0.97)	(0.17;0.21;0.27)	(1;1;1)
C4	(4.65;5.65;6.65)	(2.15;3.15;4.15)	(5.7;6.7;7.7)
C5	(0.29;0.41;0.75)	(0.15;0.18;0.22)	(0.36;0.56;1.05)
C6	(0.19;0.23;0.3)	(0.17;0.21;0.26)	(0.32;0.46;0.88)
C7	(3;4;5)	(0.75;1.19;1.8)	(3.8;4.8;5.8)
C8	(2.3;3.3;4.3)	(0.4;0.59;1.05)	(3.4;4.4;5.4)

C9	(1.45;2.13;2.85)	(0.28;0.4;0.72)	(3.05;4.05;5.05)

Table 4. Fuzzy pairwise comparison matrix of evaluation criteria (cont)

Code	C4	C5	C6
C1	(0.16;0.19;0.23)	(1.9;2.9;3.9)	(3.7;4.7;5.7)
C2	(0.25;0.33;0.51)	(5.55;6.55;7.55)	(4.15;5.15;6.15)
C3	(0.14;0.17;0.21)	(1.07;2.03;3)	(1.25;2.25;3.25)
C4	(1;1;1)	(6.15;7.05;7.95)	(8.05;8.45;8.85)
C5	(0.14;0.15;0.18)	(1;1;1)	(1.32;2.27;3.23)
C6	(0.12;0.12;0.13)	(0.4;0.58;1.01)	(1;1;1)
C7	(0.35;0.5;0.9)	(5;5.95;6.9)	(5.55;6.5;7.45)
C8	(0.43;0.62;1.07)	(6.05;7.05;8.05)	(5.1;6.1;7.1)
C9	(0.24;0.32;0.48)	(5.3;6.2;7.1)	(5.75;6.7;7.65)

Table 4. Fuzzy pairwise comparison matrix of evaluation criteria (cont)

Code	C7	C8	C9
C1	(0.2;0.25;0.34)	(0.24;0.31;0.46)	(0.54;0.77;1.14)
C2	(0.86;1.5;2.23)	(1.07;1.98;2.9)	(1.95;2.95;3.95)
C3	(0.18;0.22;0.28)	(0.2;0.24;0.32)	(0.2;0.25;0.33)
C4	(1.2;2.15;3.1)	(1.07;1.93;2.8)	(2.35;3.35;4.35)
C5	(0.16;0.18;0.23)	(0.13;0.15;0.17)	(0.15;0.17;0.21)
C6	(0.14;0.17;0.2)	(0.15;0.17;0.2)	(0.14;0.16;0.19)
C7	(1;1;1)	(0.85;1.6;2.45)	(1.85;2.8;3.75)
C8	(0.53;0.95;1.58)	(1;1;1)	(2.37;3.33;4.3)
C9	(0.32;0.44;0.78)	(0.28;0.41;0.66)	(1;1;1)

Next, the research team proceeded to compute the aggregated fuzzy values for each criterion based on the previously constructed fuzzy pairwise comparison matrix. The fuzzy weight for each criterion was calculated by multiplying the criterion's aggregated fuzzy value with the inverse of the total fuzzy sum across all criteria. This procedure enables the representation of relative priorities among the criteria while accounting for the inherent uncertainty in expert evaluations. After obtaining the fuzzy weights in the form of triangular fuzzy numbers (l;m;n), the values were defuzzified using Equation (17) to convert them into crisp scores. These crisp values were then normalized using

Equation (18) to yield the final normalized weights, which clearly reflect the importance ranking among the criteria in a form that is more interpretable and actionable for decision-makers. Table 5 below presents the results of this process, including aggregated fuzzy values for each criterion, fuzzy weight vectors, defuzzified values and final normalized weights.

Table 5. Fuzzy, defuzzified and normalized weights of evaluation criteria

Code	Fuzzy synthetic extent	Fuzzy weight vector	Defuzzified weight	Normalized weight
C1	(0.6;0.78;1.02)	(0.04;0.06;0.11)	0.061	0.058
C2	(1.71;2.32;2.97)	(0.1;0.18;0.3)	0.181	0.172
C3	(0.35;0.47;0.63)	(0.02;0.04;0.07)	0.037	0.035
C4	(2.74;3.59;4.36)	(0.16;0.27;0.44)	0.277	0.264
C5	(0.27;0.34;0.45)	(0.02;0.03;0.05)	0.027	0.025
C6	(0.22;0.27;0.34)	(0.02;0.02;0.04)	0.021	0.020
C7	(1.72;2.32;3.05)	(0.1;0.18;0.31)	0.182	0.174
C8	(1.55;2.08;2.79)	(0.09;0.16;0.28)	0.164	0.156
C9	(0.98;1.26;1.73)	(0.06;0.1;0.18)	0.101	0.096
Inverse	(0.06;0.08;0.1)		1.050	1.000

Upon completing all computational steps including aggregation of fuzzy judgments, calculation of fuzzy weights, defuzzification and normalization the final weights representing the relative priorities of each criterion were determined. Before presenting the results, the consistency of the fuzzy pairwise comparison matrix was assessed. The Consistency Ratio (CR) was found to be 0.094, which is below the acceptable threshold of 0.10 as recommended by Saaty [40]. This confirms that the expert evaluations exhibit a satisfactory level of consistency, ensuring the validity of input data and the reliability of the analysis. This result further supports the robustness of the evaluation process and provides a strong quantitative foundation for ranking the criteria according to their relative importance in developing high-quality logistics human resources. Table 6 presents the final defuzzified and normalized weights, along with the rankings of the criteria based on their significance in the model.

Table 6. Final weights and rankings of criteria

Code	Criteria	Normalized weight	Rank
C4	Training and staff development	0.264	1
C7	Technological capability and digital transformation	0.174	2

C2	Training - Enterprise - Academic ecosystem	0.172	3
C8	Leadership and managerial commitment	0.156	4
C9	Multicultural and international work environment	0.096	5
C1	Green and sustainable logistics capabilities	0.058	6
C3	Talent attraction and retention	0.035	7
C5	Mechanisms for performance enhancement and career development	0.025	8
C6	Flexibility and adaptability	0.020	9

5 Conclusion

5.1 Discussion

The analysis using the Fuzzy AHP model reveals a distinct differentiation in the relative importance of the criteria used to evaluate the potential for high-quality logistics human resource development in the Southeast region of Vietnam. Specifically, four criteria exceed the 15% significance threshold: C4 - Training and Staff Development (26.4%), C7 - Technological Capability and Digital Transformation (17.4%), C2 - Training - Enterprise - Academic Ecosystem (17.2%), and C8 - Leadership and Managerial Commitment (15.6%). These criteria not only rank highest in terms of weighted importance but also represent core competencies fundamental to the sustainable growth of the logistics workforce amid accelerating digitalization and deepening global integration.

Among them, Training and Staff Development emerged as the most critical factor, underscoring the urgent need to enhance workforce quality through structured training programs, hands-on skills development, and adaptability to dynamic work environments. This priority is particularly salient given Vietnam's transition toward a modern and environmentally sustainable logistics sector.

The second-ranked factor, Technological Capability and Digital Transformation, plays a vital role in preparing human resources capable of leveraging advanced technologies such as automation, big data, and artificial intelligence. These capabilities serve as a foundation for logistics firms to optimize operational efficiency and strengthen international competitiveness.

The third factor, Training - Enterprise - Academic Ecosystem was identified as a key enabler of labor-market alignment. This tri-sectoral collaboration model helps bridge the gap between educational outputs and industry demands, while facilitating the timely integration of emerging skills into training curricula.

Fourth, Leadership and Managerial Commitment was recognized for its strategic significance in guiding and sustaining internal talent development. This commitment may be demonstrated through robust career advancement policies, investment in in-house training, and the promotion of a continuous learning culture within organizations.

In contrast, the remaining criterias Multicultural Work Environment (9.6%), Green and Sustainable Logistics Capabilities (5.8%), and Talent Attraction and Retention (3.5%) although supportive, were not perceived as top priorities in the current developmental phase. This suggests that regional enterprises are focusing on core, immediate-impact capabilities related to training, technology, and organizational readiness, rather than long-term sustainability or cultural integration.

These findings provide a clear empirical foundation for stakeholders including policy-makers, vocational institutions, and logistics enterprises to formulate targeted action plans for workforce development. Furthermore, amid the increasing volatility of the logistics labor market, the study contributes to the formulation of a flexible and adaptive human resource development strategy, one that is responsive to the dual pressures of globalization and technological disruption.

5.2 Implications and proposed solutions

The study identified four criteria that made a particularly significant contribution to the development of high-quality logistics human resources in the Southeast region of Vietnam. These include: (1) Training and Staff Development, (2) Technological Capability and Digital Transformation, (3) Training - Enterprise - Academic Ecosystem, and (4) Leadership and Managerial Commitment. These serve as a foundational basis for proposing prioritized and feasible solutions that align with the current context of regional integration and digital transformation.

First, emphasis should be placed on improving the quality of training and human resource development by designing specialized training programs that integrate practical knowledge and soft skills. Updating curricula to reflect the actual needs of enterprises will help bridge the gap between educational institutions and the labor market.

Second, it is essential to enhance technological capacity and digital transformation within the logistics workforce. This includes promoting digital literacy, providing specialized training on emerging technologies such as artificial intelligence (AI), the Internet of Things (IoT), and big data, and fostering a digital mindset among employees to meet the demands of modern logistics and smart supply chains.

Third, the development of a collaborative Training - Enterprise - Academic Ecosystem is a strategic solution. This involves establishing long-term partnership models in which enterprises participate in curriculum design, provide scholarships, organize internships, and take part in evaluating learning outcomes to ensure alignment with labor market demands.

Fourth, promoting the role of leadership and management is vital for sustainable workforce development. Enterprises should formulate long-term human resource development strategies, foster lifelong learning opportunities, and create a workplace culture that supports learning and employee engagement.

Beyond identifying these priority criteria, the study underscores the critical role of various stakeholders in operationalizing solutions for logistics workforce development. In particular, the Vietnam Logistics Business Association (VLA) plays an intermediary role in coordination not only promoting the development of a national logistics competency framework but also bridging enterprises with appropriate training programs to ensure alignment between practical demands and training capacity. At the same time, governmental agencies should formulate policies that support region-specific human resource development and integrate workforce development objectives into local logistics sector planning. Developing appropriate financial mechanisms to incentivize investment in human resource development by businesses and training institutions is also crucial. From the perspective of logistics enterprises, a more proactive role is needed in identifying future skill demands and participating directly in training efforts—from curriculum co-creation to providing practical learning environments to improve workforce quality and readiness. Meanwhile, universities, research institutes, and vocational training centers must innovate their curricula toward practical application, flexibility, and rapid responsiveness to technological trends and labor market fluctuations. Close collaboration among these stakeholders will not only enhance the competitiveness of the logistics workforce in the Southeast region but also lay a sustainable foundation for Vietnam's logistics industry to achieve deeper global integration and pursue a greener, more resilient future.

5.3 Limitations and future research directions

Despite producing meaningful practical results, this study has several notable limitations. First, the scope of the expert survey was relatively narrow, with a limited number of participants primarily concentrated in the Southeast region of Vietnam. As a result, the findings may not fully capture the diversity of regional characteristics, enterprise scales, or business types across the broader Vietnamese logistics industry.

Second, while the Fuzzy AHP method applied in this study is well-suited for determining the relative priority of evaluation criteria, it does not account for potential interdependencies or reciprocal influences among the criteria within the system. Furthermore, although expert input was processed using fuzzy logic and subjected to consistency checks, the resulting data may still be influenced by subjective factors such as individual experience, professional perceptions, and organizational contexts of the respondents.

To address these limitations, future research should consider expanding the scope of the survey to include experts from various geographic regions and a broader spectrum of logistics enterprises. This would enhance the representativeness and generalizability of the findings. Additionally, to explore the interrelationships among criteria in greater depth, the Fuzzy AHP approach could be integrated with other system analysis techniques such as DEMATEL, ANP or ISM. These methods would facilitate the development of causal structures and support the construction of more robust, practice-oriented decision-making models in human resource management.

Moreover, the weights derived from this study could be applied in various practical contexts, including the development of competency assessment frameworks, the establishment of key performance indicators (KPIs), or the design of specialized training programs. Such applications would contribute to enhancing the quality of logistics human resources in a sustainable manner, while supporting their adaptability to the evolving demands of innovation and digital transformation in the logistics sector.

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