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İLKAY ERARSLAN
HASAN BOZTOPRAK
KENAN ORÇANLI

Determining the significance levels of individual and organizational factors influencing logistics capabilities in the healthcare sector using the Pythagorean Fuzzy AHP Method: Türkiye example

Abstract

Research background and purpose: The present study evaluates the significance levels of individual and organizational factors influencing logistics capabilities in the healthcare sector, particularly within private hospitals in Istanbul, utilizing the Pythagorean Fuzzy Analytic Hierarchy Process (AHP). The research addresses the gap in detailed prioritization of individual and organizational factors influencing logistics capabilities, crucial in healthcare logistics, especially during crises like the COVID-19 pandemic.

Design/methodology/approach: A multi-stage approach was employed. First, a literature review identified key logistics capabilities, which were then refined by an expert group. Subsequently, a second expert group from private hospital procurement departments in Istanbul assessed the finalized capabilities. Expert opinions were linguistically expressed and converted into Pythagorean fuzzy numbers for AHP analysis. Finally, a sensitivity analysis was conducted by varying the main criteria weights by ±10%, ±20%, and ±30% across 24 scenarios to test the robustness of the resulting priorities.

Findings: The study revealed that "Ethics and Social Responsibility" holds the highest significance, followed by "Human Resources and Relations", "Strategic Thinking and Management", and "Scientific Foundations and Technical Knowledge". Specifically, "Social Responsibility", "Conflict Management", "Risk Management", and "Information Systems" were identified as critical sub-items. The sensitivity analysis confirmed that these results – particularly the primacy of "Ethics and Social Responsibility" – remained robust to ±30% variations in the main criteria weights. This research uniquely applies Pythagorean Fuzzy AHP to prioritize individual and organizational factors influencing logistics capabilities within the Turkish private healthcare sector, offering a nuanced understanding of their significance.

Value added and limitations: The study's focus on private hospitals in Istanbul limits generalizability. Future research could expand the geographical scope and include public hospitals. The findings highlight the necessity for integrating ethical considerations and robust human resource management into healthcare logistics. The results provide a framework for healthcare institutions to evaluate and enhance their logistics capabilities, informing training programs and operational strategies. By emphasizing social responsibility and ethical practices, this research underscores the significance of equitable healthcare resource distribution and sustainable logistics, contributing to improved public health outcomes.

Keywords: *Logistics Management, Healthcare Management; Pythagorean Fuzzy AHP, Organizational Behavior*

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İlkay Erarslan ✉
Department of Management Information Systems, Istanbul Beykent University, Turkey; email: ilkaye@beykent.edu.tr; ORCID: 0000-0002-1550-3693

Hasan Boztoprak
Deparment of Logistics Management, Istanbul Beykent University, Turkey
ORCID: 0000-0002-7560-367X

Kenan Orçanli
Department of Software Development, Istanbul Beykent University, Turkey
ORCID: 0000-0001-5716-4004

1. Introduction

Logistics management has recently become a strategic priority in the healthcare sector (Ageron et al., 2018). The COVID-19 pandemic further demonstrated the critical role of logistics in ensuring effective healthcare delivery and continuity of services (Dossou et al., 2021). Timely access to adequate resources is essential for maintaining healthcare quality and operational sustainability (Taşkın & Akçadağ, 2020). Due to the urgent and continuous nature of healthcare services, both human and organizational resources must remain constantly prepared for supply chain operations (Manavgat & Demirci, 2021). Logistics activities directly influence the efficiency, effectiveness, and quality of healthcare services, while well-organized logistics systems provide significant financial and clinical advantages (Zhang et al., 2018; Velasco et al., 2018).

Despite its importance, awareness of logistics management remains limited, particularly in emerging economies where infrastructure deficiencies, resource scarcity, and managerial inadequacies reduce efficiency (Ralston et al., 2013; Kritchanchai et al., 2018). Therefore, logistics capabilities have become essential strategic assets that enhance organizational performance and sustainable competitive advantage when effectively integrated with technological and dynamic organizational competencies (Polat, 2021; Lynch et al., 2000).

While capability is viewed holistically in the resource-based view (Barney, 1991), individual actors within organizations are shaped by social and cultural contexts (Meyer & Jepperson, 2000). Thus, capability has both individual and organizational dimensions (Hsu & Sabherwal, 2011; Wang & Zeng, 2017). Logistics activities require integrating both aspects (Mandal, 2017). In the literature the logistics capabilities are broadly categorized as demand, supply, and information management capabilities (Lyu et al., 2019). Gligor & Holcomb (2012) identified supply and demand-oriented capabilities, along with integration, measurement, and information exchange capabilities. Closs et al. (1997) categorized logistics capabilities into positioning, integration, agility, and measurement. Positioning relates to strategy, integration to connectivity, agility to flexibility, and measurement to assessment.

Logistics capabilities enhance service quality, enabling organizations to focus on internal dynamics and integrate competencies (Ralston et al., 2013). Logistics capabilities like delivery speed, reliability, and responsiveness positively affect firm performance and offer a competitive edge (Morash et al., 1996; Sandberg & Abrahamsson, 2011). They enhance organizational agility, crucial for healthcare organizations during crises (Mutebi et al., 2024).

Despite extensive literature, specific studies on the detailed content and prioritization of the determinants of healthcare logistics capabilities are lacking. Literature often fails to define these capabilities and their critical aspects. Given healthcare logistics' importance in crises and its central role in society, identifying and evaluating the specific individual and organizational factors that drive these capabilities is essential, yet remains a significant research gap internationally. Supply chain planning and healthcare operations management are critical due to high uncertainty (Manavgat & Demirci, 2021; Mackintosh & Armstrong, 2020). To address this gap, this study seeks to answer the following research questions:

RQ1: What are the most critical individual and organizational factors influencing logistics capabilities in the healthcare sector?
RQ2: How do healthcare strategic experts evaluate, integrate, and balance normative determinants (such as ethics and social responsibility) against technical and operational execution capabilities when dealing with cognitive subjectivity and fuzzy decision environments?
RQ3: What practical insights can hospital executives derive from the prioritized ranking of these logistics capability factors to improve overall healthcare supply chain efficiency?

The present paper evaluates and determines the individual and organizational factors influencing logistics capabilities in the healthcare sector using Pythagorean Fuzzy AHP. Expert opinions were collected from procurement professionals in Istanbul's private hospitals. A literature review informed a preliminary table, refined by an expert group. The final table was assessed by another expert group, ensuring robust evaluation through theoretical and practical insights. Linguistic expert opinions were converted into Pythagorean fuzzy numbers for analysis.

The primary objective of this study is threefold: theoretically, it aims to contribute to knowledge and address the literature gap by establishing a clear boundaries for the individual and organizational determinants of healthcare logistics capabilities; methodologically, it presents the application of Pythagorean Fuzzy AHP to effectively model the inherent uncertainty in healthcare operations management (Manavgat & Demirci, 2021; Mackintosh & Armstrong, 2020); and practically, it provides actionable guidance for healthcare institutions to evaluate and improve their logistics capabilities, while offering valuable insights for education and training applications in this domain.

2. Literature review

The healthcare sector requires simultaneous delivery of diverse and urgent services, necessitating continuous readiness in personnel, equipment, and materials (Bekmezci & Orçanlı, 2019). Healthcare logistics covers all activities from initial medical procedures to final service delivery, contributing to operational efficiency and patient safety through timely material provision (Yiğit, 2016). Dobrzańska et al. (2013) emphasized that healthcare logistics includes medication management, laboratory logistics, medical product distribution, sterile product handling, information management, and hazardous waste disposal, alongside secondary and administrative support processes. Effective coordination of these activities is essential for maintaining service quality and operational continuity. Healthcare organizations also integrate logistics with information systems, marketing, human resources, financial management, and medical support services (Kandemir et al., 2013).

2.1. Theoretical framework of logistics capabilities

The theoretical framework of this study is structured upon the conceptual boundary between final operational outcomes and their underlying organizational antecedents. In healthcare supply chain literature, focus often centers heavily on downstream performance metrics such as delivery speed, flexibility, or accuracy. This research, however, shifts the analytical lens upward to investigate the multidimensional determinants – specifically individual qualifications and organizational attributes – that shape the logistics capabilities. Rather than treating logistics capability as an isolated technical process, the model developed here integrates cognitive, strategic, relational, and normative elements into a cohesive framework. By evaluating how these human and systemic factors are prioritized under uncertainty, the study provides a comprehensive conceptual baseline that clarifies how internal dynamics structurally constitute the capacity for operational resilience before any physical logistics activity takes place.

Logistics capabilities that healthcare organizations should have, are not static operational routines; rather, they represent an organization's adaptive capacity to reconfigure resources under highly volatile conditions (Tiwari et al., 2024; Dovbischuk, 2022). Therefore, the crucial role of dynamic aspects of logictics capabilities emphaised in the dynamic capabilities literature (Ma & Kang, 2025; Özcan et al., 2024; Tukamuhabwa et al., 2023; Chen et al., 2019). Because of this dynamic aspect, organizational resilience has become a key factor, particularly in the development of logistical capabilities within healthcare organizations (Mishra et al., 2026; Ma & Kang, 2025; De Luca et al., 2025; Carbonara et al., 2024; Yılmaz et al., 2023). Therefore, analyzing the underlying individual and organizational factors – rather than just final operational outcomes – is crucial for fostering healthcare supply chain resilience during large-scale crises and systemic disruptions (Pratono & Maharani, 2024).

Due to sectoral uncertainty, sustainable supply chain management practices and proactive crisis management strategies are increasingly important (Wogwu & Hamilton, 2018). Literature identifies various logistics capability dimensions, including information, management, support, recovery, and improvement capabilities (Zhang et al., 2021). Within healthcare operations, these dimensions are heavily influenced by individual competencies that act as enablers of real-time supply chain agility (Patel & Sambasivan, 2022; Harland et al., 2021; Mandal, 2018). In this regard, studies emphasize the significance of human competencies such as work experience, analytical thinking, communication, teamwork, foreign language proficiency, computer literacy, and logistics information technologies in enhancing logistics performance and resilience (Keleş & Genç, 2022; Polat, 2021; Ersoy, 2021; Akar & Çakır, 2016).

2.2. An integrated framework of individual and organizational logistics capabilities in the healthcare sector

Logistics capabilities refer to organizational skills and experiences that facilitate coordination and efficient resource utilization (Bakan et al., 2020). Efficient logistics management improves healthcare quality while reducing costs through supply chain management practices, thereby strengthening financial and economic performance (Mackintosh & Armstrong, 2020; Hayes & Pisano, 1994). Due to this role, we took a different approach in this study to examine the topic in greater depth. We developed an integrated classification of the determinants influencing logistics capabilities based on Polat (2021) and the relevant literature. Since manpower is critical for operational support, integrating human roles and competencies into logistics management is essential for understanding how dynamic capabilities are structurally formed and sustained (Modgil et al., 2025; Tran et al., 2025; Harland et al., 2021; Acar & Yurdakul, 2013). Although logistics has been widely studied, a comprehensive prioritization of the knowledge, skills, and attitudes required for healthcare logistics professionals to mitigate unexpected disruptions and ensure operational continuity remains limited.

The study classifies these underlying determinants into four dimensions: scientific foundations and technical knowledge, strategic thinking and management, human resources and relationships, and ethics and social responsibility. As logistics has evolved from military practice into a multidisciplinary field, both technical expertise and strategic insight have become increasingly important for managing risk in volatile environments (Klaus & Müller, 2012; Milenkov et al., 2020). Logistics capabilities and their antecedent factors contribute significantly to operational efficiency and competitive advantage, requiring strategic managerial competencies rooted in dynamic capability development (Mutebi et al., 2024; Tukamuhabwa et al., 2023; Junaid et al., 2023; Zehir & Öztürk, 2019; Olavarrieta & Ellinger, 1997). Human resources also play a critical role in managing information and knowledge flows within logistics systems, serving as the cornerstone for organizational adaptability during public health emergencies (Čižiūnienė et al., 2025; Evangelista et al., 2023; Lu & Feng, 2021; Lu & Chen, 2021; Ding et al., 2015).

Scientific and technical knowledge includes logistics systems, operational research, quality management, and logistics information systems, all of which improve integration, efficiency, and coordination (Shang, 2009; Yang et al., 2021; Somuyiwa & Adewoye, 2010). These technical factors directly determine the velocity and accuracy of resource allocation when networks are strained and they are critical components of an organization's capability to absorb supply chain shocks and prevent material shortages (Padovano & Ivanov, 2025; Akram et al., 2024; Rajesh, 2017). Strategic thinking encompasses decision-making, risk management, and agility, which are essential for resilience and supplier performance (Tracey, 2006; Tukamuhabwa et al., 2023). Human resources and relationship capabilities involve teamwork, leadership, communication, and conflict management (Gammelgaard & Larson, 2001; Özcan, 2023). Finally, ethics, sustainability, and social responsibility are increasingly recognized as fundamental logistics capabilities and institutional determinants that guide equitable resource distribution across healthcare networks (Carter & Jennings, 2002; García-Dastugue & Eroglu, 2019).

3. Characteristics of the research process

3.1. Item analysis, scale validation and content evaluation

This study employs a comprehensive scale development and validation process, to structurally map and prioritize individual and organizational determinants influencing healthcare logistics capabilities. Content validity indicates how effectively the measurement tool represents the targeted subject, and a comprehensive screening process is necessary to achieve structural conformity (Bakan et al., 2020; Bekmezci & Orçanlı, 2019). The initial item pool was extracted from established healthcare and industry logistics literature (Polat, 2021; Kandemir et al., 2013). To perform strict item pruning and verification, Content Validity Ratios (CVR) were calculated based on Lawshe's standard quantification method. In this approach, specialized experts rate each proposed logistical determinant as 'essential', 'useful but not essential', or 'not necessary'. The CVR values are structurally calculated for each dimension using the classical Lawshe formulation. Any determinant falling below the established statistical threshold was systematically excluded from the operational matrix, ensuring high construct and structural validity before progressing to advanced multi-criteria optimization (Table 1).

Table 1. **Lowest content validity ratios**

Number of Experts	5	10	15	20	25	30	35	40
Minimum CVR	0.99	0.62	0.49	0.42	0.37	0.33	0.31	0.29

Source: Alpar 2012, p. 415

CVI values for the scale are calculated by averaging the CVI values of the remaining items in the pool and are expected to be greater than 0.67. If the scale is multidimensional, CVI should be calculated separately for each dimension (Alpar, 2012).

3.2. Methodological justification: selecting Pythagorean Fuzzy AHP

Evaluating individual competencies and structural organizational attributes within healthcare networks introduces critical human subjectivity, cognitive biases, and epistemic vagueness. Traditional multi-criteria decision-making (MCDM) tools, such as the classical Analytic Hierarchy Process (AHP), rely on crisp, exact numbers that cannot capture the hesitation, ambiguity, or partial ignorance of human decision-makers. While classical fuzzy sets introduce membership functions (Zadeh, 1965), and Intuitionistic Fuzzy Sets (IFS) (Atanassov, 1986) integrate non-membership values, IFS models enforce a rigid linear boundary condition requiring that the sum of membership (μ) and non-membership (v) degrees cannot exceed 1 ($\mu + v \leq 1$).

In highly volatile healthcare operations, experts frequently experience intense cognitive conflicts, causing collective assessments to violate this linear boundary. To mitigate this limitation, this study uniquely implements the Pythagorean Fuzzy AHP method. Formulated upon the extension proposed by Yager (2014) and further operationalized by Yager and Abbasov (2015), Pythagorean fuzzy numbers permit the sum of membership and non-membership degrees to exceed 1, provided that the sum of their squared values satisfies the boundary condition: $\mu^2 + v^2 \leq 1$. This mathematical framework provides a significantly wider, non-linear orthogonal space to model expert hesitancy. For instance, if an expert believes a qualification is highly relevant ($\mu = 0.8$) yet acknowledges severe systemic barriers ($v = 0.4$), this state is mathematically invalid under IFS ($0.8 + 0.4 = 1.2 > 1$) but fully modeled under Pythagorean sum-of-squares logic ($0.8^2 + 0.4^2 = 0.64 + 0.16 = 0.80 \leq 1$). Consequently, this method offers superior flexibility, real-time agility representation, and mathematical accuracy over other MCDM variants in complex health operations (Yucesan & Kahraman, 2019; Yucesan & Gul, 2020).

3.3. Expert panel architecture and selection criteria

To ensure high scientific replicability, empirical transparency, and strict adherence to data verification standards, data collection was executed through two separate, specialized expert panels. The selection follows strict purposive sampling criteria, ensuring participants possessed localized operational authority and deep technical expertise within Istanbul's private healthcare networks.

Expert Panel 1 (Content Validation - 8 Experts): Composed of 8 senior healthcare management and logistics professionals. Inclusion criteria demanded a minimum of 10 years of direct managerial experience in healthcare operations and a post-graduate degree in Health Administration or Supply Chain Management. This panel conducted the qualitative evaluation and content validation during February 2026 via iterative Delphi rounds to refine the initial operational attributes based on Polat (2021) and relevant literature, verifying CVR parameters.

Expert Panel 2 (Pairwise Comparisons - 10 Experts): Formed by 10 active decision-makers directly managing procurement, distribution, and material routing infrastructure across private hospital groups in Istanbul. These experts filled out standardized linguistic pairwise matrix surveys during March 2026 via structured, in-person semi-structured interviews. To maximize replicability, their detailed institutional status, professional positioning, and rigorous expertise levels were evaluated using Single-Valued Neutrosophic Sets (SVNS) to establish individualized mathematical weights, as documented in the subsequent analytical steps (Table 6) (Kara et al., 2024).

3.4. Profile of sampled healthcare institutions

The empirical context centers on private hospital operations in Istanbul, a critical metropolitan healthcare hub characterized by high patient velocity and intricate logistical networks. To preserve institutional anonymity while fulfilling full data replicability requirements, the institutional profiles are contextualized in Table 2.

Table 2. **Institutional profiles**

Hospital ID / Cluster	Location Zone (Istanbul)	Bed Capacity Range	Logistical Specialization / Infrastructure
H1, H2, H3 (Large Scale)	European Side (Central Business District)	250 - 400 beds	Multi-campus central procurement, automated unit-dose pharmaceutical dispensing, active cold-chain management.

H4, H5, H6 (Medium-Large)	Anatolian Side (High-Density Residential Hubs)	150 - 250 beds	Decentralized medical inventory routing, specialized intensive care support supply chains, VMI networks.
H7, H8, H9, H10 (Medium Scale)	Periphery / Growing Urban Corridors	100 - 150 beds	Just-In-Time (JIT) medical supplies sourcing, localized emergency material staging, agile safety stock.

Source: own study

3.5. Condensed mathematical framework of Pythagorean Fuzzy AHP

The structural execution of the Pythagorean Fuzzy AHP process bypasses extensive classical fuzzy iterations by mapping linguistic preferences directly into interval-valued numbers and resolving structural inconsistencies through a synchronized mathematical progression.

Step 1: Expertise Modeling via SVNS. The initial step characterizes the decision-makers' weights using Single-Valued Neutrosophic Sets (SVNS) (Kara et al., 2024) to quantify their subjective professional backgrounds. Through Equations (1) and (2), each expert's linguistic expertise level is transformed into distinct truth (T), indeterminacy (I), and falsity (F) components. The linguistic variables and their corresponding SVNS values used in this transformation are presented in Table 3. Once the decision-makers' weights were established, their pairwise evaluations of the criteria were expressed using the interval-valued Pythagorean fuzzy linguistic scale given in Table 4.

$$w_k = \frac{3+\widetilde{T_k}-2*\widetilde{I_k}-\widetilde{F_k}}{\sum_{k=1}^{l} 3+\widetilde{T_k}-2*\widetilde{I_k}-\widetilde{F_k}} \quad (1)$$

$$\sum_{k=1}^{l} w_k = 1 \quad (2)$$

Table 3. **Linguistic variables for expertise**

Linguistic Variable)	**SVNS Numbers**		
	$\widetilde{T_k}$	$\widetilde{I_k}$	$\widetilde{F_k}$
Expert	0.90	0.10	0.10
Proficient	0.80	0.25	0.20

Competent	0.60	0.35	0.40
Advanced Beginner	0.40	0.55	0.55
Novice	0.20	0.75	0.80

Source: own study

Table 4. **Evaluation scale**

Linguistic Variables	**Pythagorean Fuzzy Numbers**			
	The lower value of the membership degree	**The upper value of the membership degree**	**The lower value of the non-membership degree**	**The upper value of the non-membership degree**
	(μ_L)	(μ_U)	(v_L)	(v_U)
Certainly, Low Importance (CLI)	0	0	0.9	1
Very Low Importance (VLI)	0.1	0.2	0.8	0.9
Low Importance (LI)	0.2	0.35	0.65	0.8
Below Average Importance (BAI)	0.35	0.45	0.55	0.65
Average Importance (AI)	0.45	0.55	0.45	0.55
Above Average Importance (AAI)	0.55	0.65	0.35	0.45
High Importance (HI)	0.65	0.8	0.2	0.35
Very High Importance (VHI)	0.8	0.9	0.1	0.2
Certainly, High Importance (CHI)	0.9	1	0	0
Exactly Equal (EE)	0.1965	0.1965	0.1965	0.1965

Source: own study

Step 2: Matrix Construction and Disparity Modeling. Pairwise evaluations are converted into Pythagorean numbers to form comparison matrices. A difference matrix $D=(d_{ik})_{mxm}$ measures the gap between the squared membership and non-membership boundaries using equations (3) and (4).

$$d_{ikl}=\mu_{ikl}^2 - v_{iku}^2 \tag{3}$$

$$d_{iku}=\mu_{iku}^2 - v_{ikl}^2 \tag{4}$$

Step 3: Multiplier and Significance Optimization. The disparity boundaries are mapped into a structured multiplier matrix $S = (s_{ik})_{mxm}$ through equations (5) and (6), while the aggregate core determination degree (τ_{ik}) for each attribute is isolated via equation (7).

$$s_{ikl}=\sqrt{1000^{d_{ikl}}} \tag{5}$$

$$s_{iku}=\sqrt{1000^{d_{iku}}} \tag{6}$$

$$\tau_{ik}=1 - (\mu_{ikl}^2) - (v_{iku}^2 - v_{ikl}^2) \tag{7}$$

Step 4: Operational Weight Derivation. Unnormalized intermediate weights ($t_{ık}$) are synthesized via equation (8), combining the structural multiplier data with the extracted determination degrees. Final normalized capability weights (w_i) are then structurally computed across all system layers using equation (9).

$$\tau_{ik}t_{ik}=(\frac{s_{ikl}+ s_{iku}}{2})^* \tau_{ik} \tag{8}$$

$$w_i=\frac{\sum_{k=1}^{m} t_{ik}}{\sum_{i=1}^{m}\sum_{k=1}^{m} t_{ik}} \tag{9}$$

4. Results

4.1. Application and research model

This study evaluates the factors influencing healthcare logistics employee qualifications, derived from a literature review, using expert opinions and item analysis. The significance of these underlying factors (Table 4) is analyzed via interval-valued Pythagorean fuzzy

AHP. A flowchart (Figure 1) details the process, ensuring objective evaluation and systematic significance determination of healthcare logistics personnel qualifications.

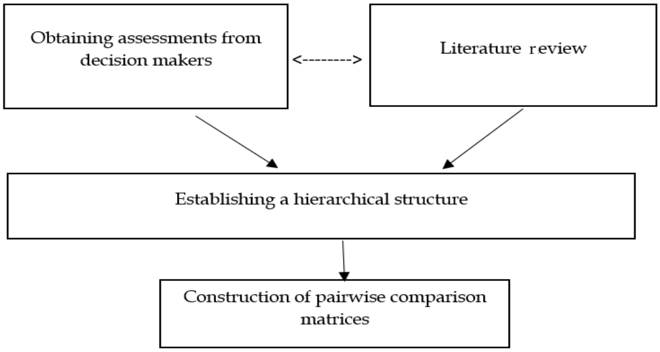

Figure 1. **Research model**

Source: own study

4.2. Item analysis

A literature review identified healthcare logistics employee qualifications, forming an initial framework. Eight experts evaluated this framework, categorizing qualifications as "Necessary," "Necessary but Insufficient," or "Unnecessary." No qualifications were deemed unnecessary, but refinements were suggested. Experts recommended adding teamwork, conflict management, decision-making techniques, agility skills, and green logistics practices. These were deemed crucial for healthcare logistics success. The framework was revised to incorporate these, resulting in the final qualification framework presented in Table 5.

Table 5. **Determinants of logistics capabilities in the healthcare sector**

Scientific Foundations and Technical Knowledge	Strategic Thinking and Management	Human Resources and Relationships	Ethics and Social Responsibility
Logistics Systems	Strategic Management	Teamwork	Professional Ethics
Operational Research	Decision Making	Leadership	Sustainability
Quality Management	Risk Management	Communication	Social Responsibility
Information Systems	Agility	Conflict Management	

Source: own study

4.3. Determining the weights of decision makers in healthcare logistics

In the decision-making process for evaluating determinants of logistics capabilities in the healthcare sector, the expertise levels of decision-makers play a critical role. To accurately assess their influence, Single-Valued Neutrosophic Sets (SVNS) were utilized, allowing for a more precise representation of uncertainty, indeterminacy, and non-membership in expertise evaluation.

Table 6 presents the positions, expertise levels, and corresponding SVNS values for the 10 decision-makers, which were then transformed into numerical weights using the given formula. Table 6 displays the pay values and calculated weights (w_{ik}) for each decision-maker.

Table 6. **Professional status, expertise levels and weights of decision makers (svns-based evaluation)**

Decision Maker	Profession/Position	Expertise Level	$\widetilde{T}_k$	$\widetilde{I}_k$	$\widetilde{F}_k$	Pay	w_k
D1	Supply Chain Director	Expert	0.90	0.10	0.10	3.60	0.1519
D2	Logistics Manager	Expert	0.90	0.10	0.10	3.10	0.1308
D3	Operations Manager	Proficient	0.80	0.25	0.20	2.50	0.1055
D4	Transportation Coordinator	Proficient	0.80	0.25	0.20	1.75	0.0738
D5	Procurement Officer	Competent	0.60	0.35	0.40	0.90	0.0380
D6	Warehouse Supervisor	Competent	0.60	0.35	0.40	3.60	0.1519
D7	Supply Chain Analyst	Advanced Beginner	0.40	0.55	0.55	3.10	0.1308
D8	Logistics Specialist	Advanced Beginner	0.40	0.55	0.55	2.50	0.1055
D9	Warehouse Manager	Novice	0.20	0.75	0.80	1.75	0.0738
D10	Logistics Intern	Novice	0.20	0.75	0.80	0.90	0.0380

Source: own study

The results of this study show that decision-makers with higher expertise levels have a greater impact on healthcare logistics evaluations. For example, Logistics Managers and Operations Managers have the highest weights, indicating their significant contribution to the decision-making process. Additionally, decision-makers at the Proficient level, such as Purchasing and Inventory Control Specialists, hold substantial influence, whereas decision-makers with lower expertise levels, particularly those at the Novice and Advanced Beginner levels, contribute less to the decision-making process. The sum of all calculated weights equaling 1 ensures that the importance of the decision-makers is represented in a balanced and accurate manner.

4.4. Determining the weights of decision makers in healthcare logistics

Step 1**:** Ten equal-importance expert evaluations were converted to interval-valued Pythagorean fuzzy numbers using Table 4. These were aggregated via weighted arithmetic mean, yielding pairwise comparison matrices (Table 7). This ensures objective expert opinion analysis and consistent integration, establishing a robust foundation for logistics decision-making through diverse perspectives.

Table 7.1. **Pairwise comparison matrix of the main factors influencing logistics capabilities**

	Scientific Foundations and Technical Knowledge				Strategic Thinking and Management				Human Resources and Relationships				Ethics and Social Responsibility			
Scientific Foundations and Technical Knowledge	0.20	0.20	0.20	0.20	0.64	0.76	0.24	0.36	0.61	0.74	0.26	0.39	0.62	0.73	0.27	0.38
Strategic Thinking and Management	0.24	0.36	0.64	0.76	0.20	0.20	0.20	0.20	0.61	0.74	0.26	0.39	0.59	0.73	0.27	0.41
Human Resources and Relationships	0.26	0.39	0.61	0.74	0.26	0.39	0.61	0.74	0.20	0.20	0.20	0.20	0.61	0.71	0.29	0.39
Ethics and Social Responsibility	0.27	0.38	0.62	0.73	0.27	0.41	0.59	0.73	0.29	0.39	0.61	0.71	0.20	0.20	0.20	0.20

Source: own study

Table 7.2. **Pairwise comparison matrix of the sub-factors: scientific foundations and technical knowledge**

	Logistics Systems				Operational Research				Quality Management				Information Systems			
Logistics Systems	0.20	0.20	0.20	0.20	0.67	0.76	0.12	0.19	0.63	0.73	0.27	0.35	0.64	0.74	0.14	0.22
Operational Research	0.12	0.19	0.67	0.76	0.20	0.20	0.20	0.20	0.57	0.69	0.31	0.43	0.59	0.70	0.18	0.29
Quality Management	0.27	0.35	0.63	0.73	0.31	0.43	0.57	0.69	0.20	0.20	0.20	0.20	0.58	0.67	0.21	0.28
Information Systems	0.14	0.22	0.64	0.74	0.18	0.29	0.59	0.70	0.21	0.28	0.58	0.67	0.20	0.20	0.20	0.20

Source: own study

Table 7.3. **Pairwise comparison matrix of the sub-factors: strategic thinking and management**

	Strategic Management				Decision Making				Risk Management				Agility			
Strategic Management	0.20	0.20	0.20	0.20	0.49	0.60	0.40	0.51	0.79	0.90	0.10	0.19	0.61	0.71	0.29	0.37
Decision Making	0.40	0.51	0.49	0.60	0.20	0.20	0.20	0.20	0.76	0.88	0.12	0.22	0.74	0.85	0.15	0.22
Risk Management	0.10	0.19	0.79	0.90	0.12	0.22	0.76	0.88	0.20	0.20	0.20	0.20	0.58	0.69	0.31	0.40
Agility	0.31	0.41	0.59	0.69	0.17	0.26	0.72	0.83	0.33	0.44	0.56	0.67	0.20	0.20	0.20	0.20

Source: own study

Table 7.4. **Pairwise comparison matrix of the sub-factors: human resources and relationships**

	Teamwork				Leadership				Communication				Conflict Management			
Teamwork	0.20	0.20	0.20	0.20	0.45	0.55	0.45	0.55	0.63	0.74	0.26	0.37	0.74	0.82	0.06	0.08
Leadership	0.45	0.55	0.45	0.55	0.20	0.20	0.20	0.20	0.69	0.81	0.19	0.29	0.83	0.94	0.06	0.11
Communication	0.26	0.37	0.63	0.74	0.19	0.29	0.69	0.81	0.20	0.20	0.20	0.20	0.65	0.73	0.15	0.19
Conflict Management	0.06	0.08	0.74	0.82	0.06	0.11	0.83	0.94	0.15	0.19	0.65	0.73	0.20	0.20	0.20	0.20

Source: own study

Table 7.5. **Pairwise comparison matrix of the sub-factors: ethics and social responsibility**

	Professional Ethics				Sustainability				Social Responsibility			
Professional Ethics	0.20	0.20	0.20	0.20	0.57	0.67	0.21	0.27	0.60	0.69	0.19	0.26
Sustainability	0.21	0.27	0.57	0.67	0.20	0.20	0.20	0.20	0.73	0.86	0.14	0.25
Social Responsibility	0.19	0.26	0.60	0.69	0.14	0.25	0.73	0.86	0.20	0.20	0.20	0.20

Source: own study

Following the construction of the pairwise comparison matrices, the analysis proceeded through two sequential computational steps. First, the differences between the membership and non-membership functions were obtained using Equations (3)–(4), producing the difference matrices that verify the accuracy of the interval-valued Pythagorean fuzzy numbers. These differences were then used to derive the multiplier matrices (S) through Equations (5)–(6), which express the relative strength of each feature against the others. Next, the determination degrees were computed via Equation (7), quantifying how strongly positive or negative each feature is and thereby clarifying its relative strengths and weaknesses. Finally, the pre-normalization weights were calculated with Equation (8) by multiplying the average elements of the multiplier matrices by the corresponding determination degrees, establishing the initial feature weights that form the basis for the final importance-weight determination. The full matrices generated at each of these steps are provided in Appendix A (Tables A.1–A.4).

Step 4: In step fourth, feature importance weights were calculated, considering the relative importance of all features. Equation (9) determined each feature's weight, serving as a basis for overall performance and prioritization. These calculations enable objective, balanced evaluation. Importance weights present feature performance comparatively, aiding selection. Results (Table 8) clearly display final weights and rankings, enhancing decision-making robustness and consistency.

Table 8. **Local and global importance weights of the main and sub-criteria influencing logistics capabilities**

Main criterion	Sub-criterion	Local weight	Global weight	Rank
Scientific Foundations and Technical Knowledge (weight = 0.10)	Logistics Systems	0.08	0.0080	15
	Operational Research	0.24	0.0240	12
	Quality Management	0.26	0.0260	11
	Information Systems	0.42	0.0420	8

Strategic Thinking and Management (weight = 0.22)	Strategic Management	0.09	0.0198	14
	Decision Making	0.10	0.0220	13
	Risk Management	0.43	0.0946	**4**
	Agility	0.38	0.0836	6
Human Resources and Relationships (weight = 0.30)	Teamwork	0.09	0.0270	9
	Leadership	0.09	0.0270	10
	Communication	0.28	0.0840	5
	Conflict Management	0.55	0.1650	**2**
Ethics and Social Responsibility (weight = 0.38)	Professional Ethics	0.13	0.0494	7
	Sustainability	0.28	0.1064	**3**
	Social Responsibility	0.60	0.2280	**1**

Source: own study

4.5. Sensitivity Analysis findings

To test the robustness of the criteria weights obtained in this study, the weights of the four main criteria (Scientific Foundations and Technical Knowledge, Strategic Thinking and Management, Human Resources and Relationships, and Ethics and Social Responsibility) were individually increased and decreased by 10%, 20%, and 30%, while the remaining criteria were proportionally rescaled to preserve a total weight of 1. This procedure generated 24 distinct scenarios (4 criteria × 6 change ratios), and the resulting effects on both the main criteria weights and the global weights and rankings of the 16 sub-criteria were examined.

The tornado diagram presented in Figure 2 illustrates the ±30% change range of the main criteria weights. The Ethics and Social Responsibility criterion (0.38), which has both the highest base weight and the widest change range (approximately 0.27–0.49), emerges as the most influential criterion on the overall results. It is followed by Human Resources and Relationships (0.30) and Strategic Thinking and Management (0.22), whereas Scientific Foundations and Technical Knowledge (0.10), having the lowest base weight and the narrowest change range, exerts a limited influence on the overall model outcomes.

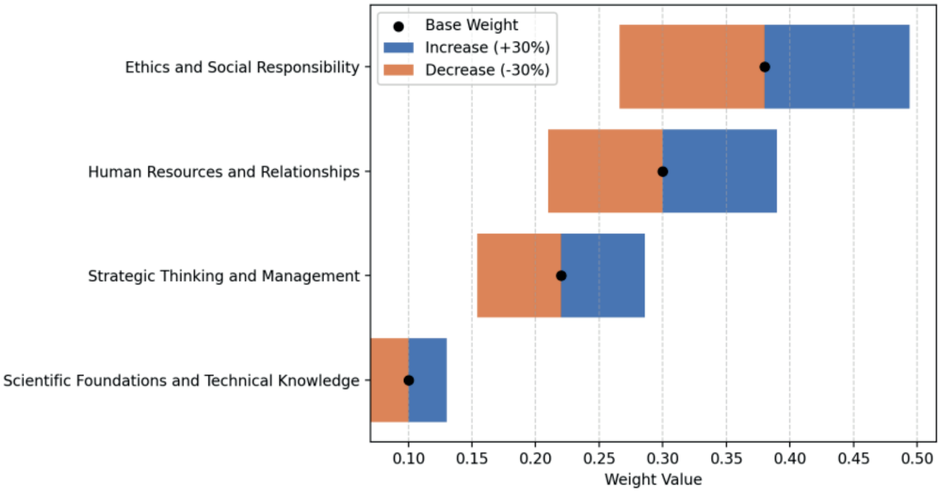

Figure 2. **Tornado diagram of the main criteria weights across the ±30% change range**

Source: own study

Figure 3 shows how the weights of the remaining three criteria are rescaled when the weight of any single main criterion is altered. Notably, when the weight of Ethics and Social Responsibility is decreased by 30% (bottom-right panel), the weight of Human Resources and Relationships rises from 0.30 to approximately 0.43, becoming the highest-weighted criterion. This indicates that the reduced weight of the Ethics criterion is predominantly redistributed to the Human Resources criterion. Similarly, when the weight of Human Resources and Relationships is increased (bottom-left panel), a potential position swap with the Ethics criterion emerges.

The upper chart in Figure 4 displays the global weights of the 16 sub-criteria in the base case, ranked in descending order. Social Responsibility (0.2280) holds the highest global weight, followed by Conflict Management (0.1650), Sustainability (0.1064), and Risk Management (0.0946), whereas Logistics Systems (0.0080) has the lowest global weight.

The four panels in the lower part of Figure 4 illustrate how the ranking of the 16 sub-criteria changes when the main criteria weights are varied by ±30%. The results demonstrate that the top four sub-criteria – Social Responsibility, Conflict Management, Sustainability, and Risk Management – remain highly robust to changes in the main criteria weights, retaining their positions within the top four ranks across almost all scenarios. However, in scenarios where the weight of Ethics and Social Responsibility is reduced (bottom-right panel), a position swap between Social Responsibility (rank 1) and Conflict Management (rank 2) can occur. Likewise, when the weight of Strategic Thinking and Management is increased (top-right panel), minor fluctuations are observed in the ranking of Risk Management and Agility. Lower-ranked sub-criteria (ranks 9–15) exhibit more frequent rank changes in response to weight variations; however, these fluctuations do not affect the overall interpretation of the results.

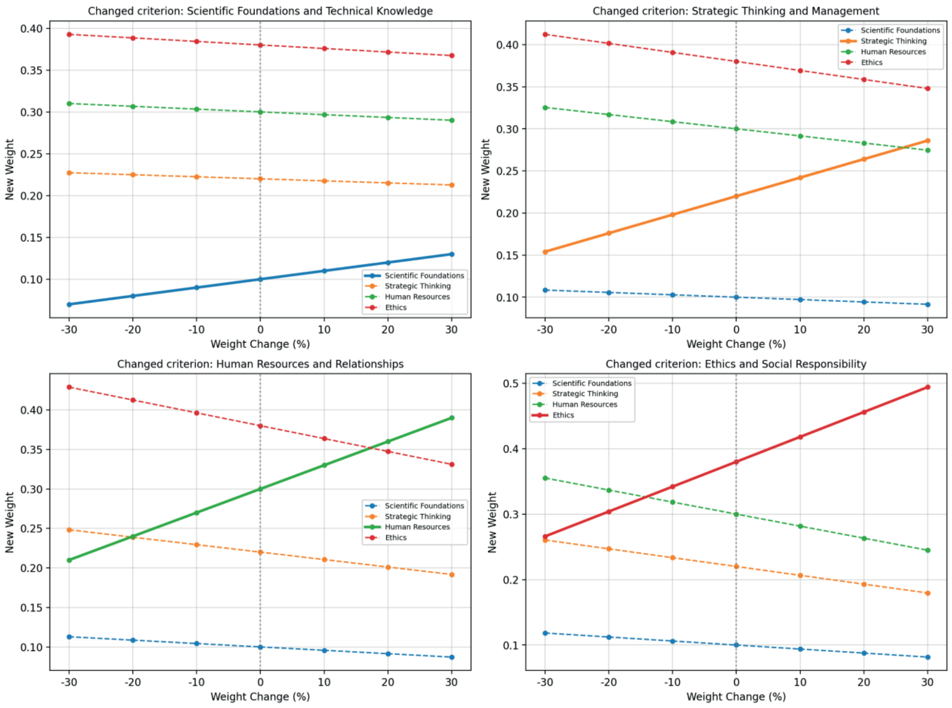

Figure 3. **Rescaling of the other main criteria when one criterion's weight changes**

Source: own study

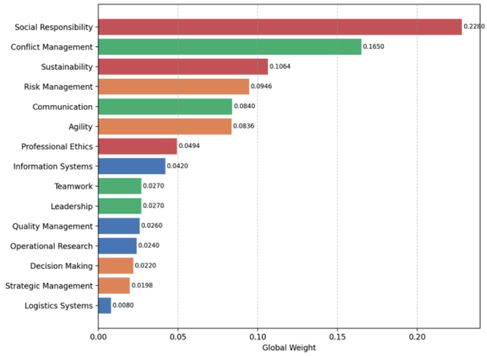

Figure 4a. **Global weights of the 16 sub-criteria in the base case**

Legend: Blue-scientic/technical; orange-startegic; green – HR; red - ethics

Source: own study

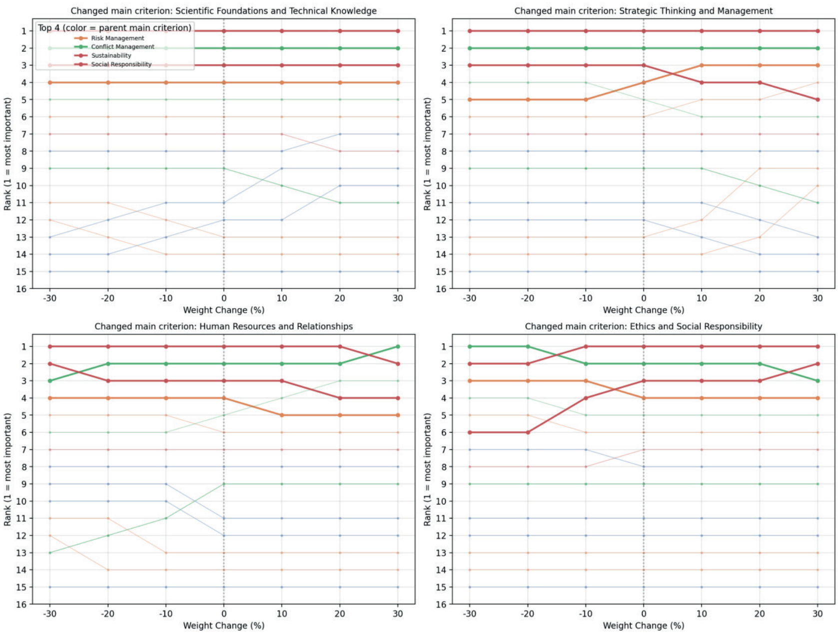

Figure 4B. **The sensitivity of their rankings to ±30% changes in the main criteria weights**

Legend: Blue-scientic/technical; orange-startegic; green – HR; red - ethics

Source: own study

The radar chart in Figure 5 provides a comparative visualization of the base weights of the four main criteria. Ethics and Social Responsibility and Human Resources and Relationships occupy a noticeably larger area compared to the other two criteria, while Scientific Foundations and Technical Knowledge forms the smallest vertex of the diagram.

Overall, the sensitivity analysis results indicate that the study's central finding – that Ethics and Social Responsibility is the most important criterion – remains generally robust to weight variations of up to ±30% in the main criteria. Nonetheless, a substantial reduction in the weight of the Ethics criterion could allow Human Resources and Relationships to take precedence. This finding suggests that the model's outputs remain stable under reasonable weight perturbations, while underscoring the critical importance of the accuracy of the expert judgments used to determine the weight of the highest-ranked criterion (Ethics and Social Responsibility) for the overall model results.

Figure 5. **Radar chart of the main criteria weights (base case)**

Source: own study

5. Discussion

The present study analyzed individual and organizational factors affecting logistics capabilities in healthcare using Pythagorean Fuzzy AHP. Ethics and Social Responsibility (0.38) had the highest weighting, indicating a priority for social benefit and ethical responsibility. Patient privacy, equitable resource distribution, and environmental sustainability were deemed critical, with the pandemic amplifying these concerns. Additionally, Ethics and Social Responsibility are considered values not because they ignore the importance of daily delivery accuracy, but because they are recognized as an indispensable structural pillar of long-term supply chain resilience. Indeed, the ethical dilemmas faced in the procurement of scarce medications or vital intensive care equipment, along with the growing regulatory and societal pressures regarding green logistics and corporate sustainability, have completely dominated the agendas of top executives. Recent literature (Abaku & Odimarha, 2024; Bentahar et al., 2023; Zaman et al., 2022; Duque-Uribe et al., 2019) supporting this finding emphasizes the importance of ethics and social responsibility for logistics operations in healthcare organizations. It appears that a similar trend is also evident in the national literature (Tutar, 2024; Balcı et al., 2022; Eren & Tuzkaya, 2021).

Human Resources and Relationships (0.30) was second highest, highlighting the decisive role of human factors and organizational relations. Trained personnel, team harmony, and effective communication were key to successful logistics. Teamwork, multidisciplinary approaches, and employee motivation are vital for productivity. Indeed, studies in literature (Rashid & Rasheed, 2026; Evangelista et al., 2023; Mandal, 2018) also emphasize the importance of human resources management for logistics capabilities. In recent studies (Ma & Kang, 2025; Junaid et al., 2023), it can be seen that the scope of research on strategic thinking and management has narrowed to focus on logistics capabilities and is discussed in relation to specific topics such as resilience. Supporting this trend, our study also shows that the factor of strategic thinking and management is less prioritized than the other two factors. So, Strategic Thinking and Management (0.22) is important for long-term planning and resource efficiency. Strategic decisions are crucial for logistics chain sustainability, especially during crises. Scientific Foundations and Technical Knowledge (0.10) received lower weighting, suggesting that while technical knowledge is important, it is insufficient alone. Technological innovations and data-driven decisions play a supporting role, needing integration with other criteria.

In general, ethical and people-oriented factors are prioritized as key determinants of healthcare logistics, while technical knowledge and strategic thinking factors play a supporting role. Effective logistics management in the health sector is shaped by human and social values.

5.1. Findings related to sub-items within the scope of scientific foundations and technical knowledge

Analysis of Scientific Foundations and Technical Knowledge sub-items showed that Information Systems (0.42) had the highest importance in health logistics, highlighting the critical role of technology and digitalization. Quality Management (0.26) ranked second, emphasizing reliability and standardization in logistics processes. Operations Research (0.24) contributed to analytical decision-making, resource allocation, and efficiency improvement. Systems (0.08), although weighted lower, provided the integrative framework supporting all processes. In general, effective health logistics management requires the integration of technology, quality management, and analytical approaches.

5.2. Findings related to sub-items within the scope of strategic thinking and management

Analysis of Strategic Thinking and Management sub-items showed that Risk Management (0.43) and Agility (0.38) were the most important factors in health logistics, emphasizing resilience, flexibility, and operational continuity under uncertainty. Decision Making (0.10) contributed to timely and accurate operational processes, while Strategic Management (0.09) provided an integrative and guiding framework. The findings indicate that effective healthcare logistics management requires a holistic strategic approach in which risk management and agility are prioritized and supported by decision-making and strategic coordination processes.

5.3. Findings related to sub-items within the scope of human resources and relation

Analysis of Human Resources and Relationships reveals varying importance levels for Teamwork, Leadership, Communication, and Conflict Management in health logistics. Weight values highlight key elements in people-oriented processes.

Conflict Management (0.55) is paramount, crucial for operational continuity. High workload and low error tolerance in healthcare necessitate effective conflict management. Experts emphasize its role in enhancing cooperation and efficiency. Communication (0.28) is a cornerstone of effective human relations, vital for information flow, especially among multidisciplinary teams. Its significance extends beyond organizational levels to include suppliers, transport networks, and personnel. Teamwork (0.09) and Leadership (0.09), while lower in weighting, complement healthcare logistics' dynamic nature. Teamwork enhances cooperation, while leadership guides and motivates. Experts note their amplified impact when combined with communication and conflict management.

In general, Conflict Management and Communication are prioritized for effective human resource management. Given healthcare's people-centric nature, their harmonious interaction enhances logistics process efficiency and success.

5.4. Findings related to sub-items within the scope of ethics and social responsibility

The Ethics and Social Responsibility criterion, analyzed for social benefit, environmental sensitivity, and professional standards in health logistics, revealed significant sub-item weightings. Social Responsibility (0.60) emerged as the top priority, emphasizing societal service and fair resource distribution. Experts consider timely medical supply delivery and crisis resource management as key social responsibility practices, reflecting the healthcare sector's people-centric nature. Sustainability (0.28) was the second priority, focusing on environmental, economic, and social balance. Environmentally friendly supply chain management, waste minimization, and long-term sustainability are crucial. Experts highlighted carbon footprint reduction and environmental sensitivity as strategic necessities in healthcare logistics. Professional Ethics (0.13), while lower in weighting, complements professionalism, integrity, and reliability. Patient privacy, ethical procurement, and legal compliance fall within this category, contributing to a reliable health logistics infrastructure.

In general, Social Responsibility and Sustainability are prioritized, with Professional Ethics playing a supporting role. This integrated approach emphasizes logistics management that is sensitive to both people and the environment in the healthcare sector.

5.5. Practical implications and executive action guidelines

To bridge the gap between mathematical modeling and management practices, priority weights must be translated into clear and specific management action items. Table 9 summarizes the key empirical findings as strategic and practical requirements for hospital administrators and supply chain directors.

Table 9. **Practical suggestions**

Core Dimension	Pythagorean Weight	Strategic Meaning for Managers	Recommended Operational / Tactical Actions
Ethics & Social Responsibility	0.38	Ethical sourcing, transparency, and social equity are perceived as foundational pillars for building long-term organizational resilience and brand trust during macro-crises.	Establish formal ethical compliance matrices for suppliers. Implement green procurement and waste-mitigation standards. Build equitable resource allocation protocols for crisis-driven material bottlenecks.
Human Resources & Relations	0.30	Logistical velocity and automated software tools are completely bottlenecked by human non-technical skills, collaboration quality, and team communication efficiency.	Deploy simulation-based crisis exercises for procurement teams. Formulate targeted communication streams across clinical and material control departments. Mandate continuous logistics certs.
Strategic Thinking & Management	0.22	Proactive contingency planning and continuous risk-hedging structures outweigh reactive, short-term cost-cutting maneuvers in volatile supply markets.	Develop multi-tiered safety-stock tracking dashboards. Formalize institutional risk-assessment sheets. Transition from strict JIT sourcing to diversified near-shoring vendor networks.
Scientific & Technical Knowledge	0.10	Digital health capabilities, automated ERP tracking, and data proficiency serve as the primary operational mechanics to execute high-level corporate strategies.	Invest heavily in integrated hospital information systems and cloud-based material control modules. Provide structured data-analytics training to warehouse management staff.

Source: own study

6. Conclusions

The present study successfully prioritized individual and organizational determinants influencing healthcare logistics capabilities by constructing a multi-layered mathematical hierarchy evaluated through the Pythagorean Fuzzy Analytic Hierarchy Process (AHP). By moving away from descriptive overviews, the quantitative framework establishes that normative attributes, specifically Ethics and Social Responsibility, serve as the indispensable structural foundation for long-term operational resilience during macro-crises. A sensitivity analysis spanning 24 scenarios of ±10%, ±20%, and ±30% weight variations confirmed the robustness of this hierarchy, with the primacy of Ethics and Social Responsibility, and the top-ranked sub-criteria overall, remaining stable across nearly all perturbations. While day-to-day logistics performance relies heavily on delivery speed and accuracy, the strategic judgements of sector experts indicate that technical knowledge, information systems, and human non-technical skills remain completely bottlenecked without robust ethical guardrails, risk-hedging mechanisms, and proactive strategic management. Ultimately, the methodology bridges subjective expert cognition with mathematical exactness, offering hospital administrators and supply chain directors a strategic roadmap to prioritize capability-building investments and fortify healthcare distribution networks against systemic shocks.

This study, despite its methodological and conceptual originality, also has various limitations. First, the geographic and institutional scope of this study is limited to private hospital networks operating in Turkey's Istanbul metropolitan area. Public hospital systems, which operate largely under centralized regulatory frameworks, and the critical perspectives of patients receiving healthcare services were not included in the decision model.

Second, the derived priority parameters and hierarchical rankings – particularly the absolute primacy of the areas of Ethics and Social Responsibility and Risk Management – are deeply intertwined with the macroeconomic and operational realities specific to the Turkish healthcare sector. Since private hospitals in Istanbul operate in an extremely competitive commercial environment characterized by severe currency fluctuations, inflationary pressures, and heavy systemic dependence on imported components and medical devices, the expert panel's assessments naturally reflect the objectives of local risk mitigation and brand value preservation. Consequently, these weight distributions may differ in healthcare systems operating within highly stable international environments.

Third, although the fuzzy logic framework minimized personal biases, the sample size of experts included in the binary matrices was relatively small (10 experts); this may have led to the final weights being influenced by specific organizational perspectives.

Finally, this study is based on a cross-sectional design and reflects the consensus of experts during a specific post-crisis period; the prioritized competency weights have not yet been validated by continuous empirical operational performance data or clear numerical measures of hospital workload.

To address these limitations, subsequent investigations should focus on several promising pathways. Future studies ought to execute comprehensive public-private hospital comparative analyses to capture the distinct operational mechanics of different regulatory models. Additionally, researchers are encouraged to adopt longitudinal research designs to track how priority dynamic weights shift across different macroeconomic phases. Finally, conducting cross-country and multi-regional comparative analyses would be invaluable in determining which healthcare logistics capabilities remain universally applicable global realities and which features constitute context-specific national parameters.

Authors' contribution

I.E.: article conception, theoretical content of the article. **H.B.:** theoretical content of the article. **K.O.:** article conception, theoretical content of the article, research methods applied, conducting the research, data collection, analysis and interpretation of results, draft manuscript preparation.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors did not use Generative AI and AI-assisted technologies in the writing process.

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Appendix

Table A.1

Difference matrix of the main characteristics of factors influencing logistics capabilities

	Scientific Foundations and Technical Knowledge		Strategic Thinking and Management		Human Resources and Relationships		Ethics and Social Responsibility	
Scientific Foundations and Technical Knowledge	0	0	0.28	0.52	0.22	0.48	0.24	0.46
Strategic Thinking and Management	-0.52	-0.28	0	0	0.22	0.48	0.18	0.46
Human Resources and Relationships	-0.48	-0.22	-0.48	-0.22	0	0	0.22	0.42
Ethics and Social Responsibility	-0.46	-0.24	-0.46	-0.18	-0.42	-0.22	0	0

Source: own study

Difference Matrix of the sub-factors: scientific foundations and technical knowledge

	Logistics Systems		Operational Research		Quality Management		Information Systems	
Logistics Systems	0.00	0.00	0.41	0.56	0.27	0.46	0.36	0.53
Operational Research	-0.56	-0.41	0.00	0.00	0.14	0.38	0.26	0.46

Quality Management	-0.46	-0.27	-0.38	-0.14	0.00	0.00	0.26	0.40
Information Systems	-0.53	-0.36	-0.46	-0.26	-0.40	-0.26	0.00	0.00

Source: own study

Difference matrix of the sub-factors: strategic thinking and management

	Strategic Management		Decision Making		Risk Management		Agility	
Strategic Management	0.00	0.00	-0.02	0.20	0.59	0.80	0.24	0.42
Decision Making	-0.20	0.02	0.00	0.00	0.53	0.76	0.50	0.70
Risk Management	-0.80	-0.59	-0.76	-0.53	0.00	0.00	0.18	0.38
Agility	-0.38	-0.18	-0.66	-0.45	-0.34	-0.12	0.00	0.00

Source: own study

Difference matrix of the sub-factors: human resources and relationships

	Teamwork		Leadership		Communication		Conflict Management	
Teamwork	0.00	0.00	-0.10	0.10	0.26	0.48	0.54	0.67
Leadership	-0.10	0.10	0.00	0.00	0.39	0.62	0.68	0.88
Communication	-0.48	-0.26	-0.62	-0.39	0.00	0.00	0.39	0.51
Conflict Management	-0.67	-0.54	-0.88	-0.68	-0.51	-0.39	0.00	0.00

Source: own study

Difference matrix of the sub-factors: ethics and social responsibility

	Professional Ethics		Sustainability		Social Responsibility	
Professional Ethics	0.00	0.00	0.25	0.40	0.29	0.44
Sustainability	-0.40	-0.25	0.00	0.00	0.47	0.72
Social Responsibility	-0.44	-0.29	-0.72	-0.47	0.00	0.00

Source: own study

Table A.2

Multiplication matrix of the main characteristics of factors influencing logistics capabilities

	Scientific Foundations and Technical Knowledge		Strategic Thinking and Management		Human Resources and Relationships		Ethics and Social Responsibility	
Scientific Foundations and Technical Knowledge	1.00	1.00	2.63	6.03	2.14	5.25	2.29	4.90
Strategic Thinking and Management	0.17	0.38	1.00	1.00	2.14	5.25	1.86	4.90
Human Resources and Relationships	0.19	0.47	0.19	0.47	1.00	1.00	2.14	4.27
Ethics and Social Responsibility	0.20	0.44	0.20	0.54	0.23	0.47	1.00	1.00

Source: own study

Multiplication matrix of the sub-factors: scientific foundations and technical knowledge

	Logistics Systems		Operational Research		Quality Management		Information Systems	
Logistics Systems	1.00	1.00	4.15	6.97	2.58	4.90	3.47	6.18
Operational Research	0.14	0.24	1.00	1.00	1.62	3.72	2.49	4.85
Quality Management	0.20	0.39	0.27	0.62	1.00	1.00	2.43	4.04
Information Systems	0.16	0.29	0.21	0.40	0.25	0.41	1.00	1.00

Source: own study

Multiplication matrix of the sub-factors: strategic thinking and management

	Strategic Management		Decision Making		Risk Management		Agility	
Strategic Management	1.00	1.00	0.93	2.00	7.62	15.85	2.25	4.27
Decision Making	0.50	1.07	1.00	1.00	6.22	13.80	5.61	11.22
Risk Management	0.06	0.13	0.07	0.16	1.00	1.00	1.84	3.72
Agility	0.27	0.54	0.10	0.21	0.31	0.66	1.00	1.00

Source: own study

Multiplication matrix of the sub-factors: human resources and relationships

	Teamwork		Leadership		Communication		Conflict Management	
Teamwork	1.00	1.00	0.71	1.41	2.45	5.25	6.46	10.04
Leadership	0.71	1.41	1.00	1.00	3.87	8.51	10.36	20.89
Communication	0.19	0.41	0.12	0.26	1.00	1.00	3.79	5.81
Conflict Management	0.10	0.15	0.05	0.10	0.17	0.26	1.00	1.00

Source: own study

Multiplication matrix of the sub-factors: ethics and social responsibility

	Professional Ethics		Sustainability		Social Responsibility	
Professional Ethics	1.00	1.00	2.38	4.04	2.74	4.56
Sustainability	0.25	0.42	1.00	1.00	5.08	12.02
Social Responsibility	0.22	0.36	0.08	0.20	1.00	1.00

Source: own study

Table A.3

Determination degrees of the main characteristics of factors influencing logistics capabilities

	Scientific Foundations and Technical Knowledge	Strategic Thinking and Management	Human Resources and Relationships	Ethics and Social Responsibility
Scientific Foundations and Technical Knowledge	0.96	0.52	0.54	0.54
Strategic Thinking and Management	0.77	0.96	0.54	0.56
Human Resources and Relationships	0.76	0.76	0.96	0.56
Ethics and Social Responsibility	0.78	0.74	0.78	0.96

Source: own study

Determination degrees of the sub-factors: scientific foundations and technical knowledge

	Logistics Systems	Operational Research	Quality Management	Information Systems
Logistics Systems	0.96	0.53	0.55	0.56
Operational Research	0.86	0.96	0.59	0.60
Quality Management	0.79	0.75	0.96	0.63
Information Systems	0.84	0.83	0.84	0.96

Source: own study

Determination degrees of the sub-factors: strategic thinking and management

	Strategic Management	Decision Making	Risk Management	Agility
Strategic Management	0.96	0.66	0.35	0.58
Decision Making	0.72	0.96	0.39	0.43
Risk Management	0.80	0.79	0.96	0.60
Agility	0.78	0.80	0.76	0.96

Source: own study

Determination degrees of the sub-factors: human resources and relationships

	Teamwork	Leadership	Communication	Conflict Management
Teamwork	0.96	0.70	0.53	0.45
Leadership	0.70	0.96	0.48	0.30
Communication	0.78	0.78	0.96	0.56
Conflict Management	0.87	0.80	0.87	0.96

Source: own study

Determination degrees of the sub-factors: ethics and social responsibility

	Professional Ethics	Sustainability	Social Responsibility
Professional Ethics	0.96	0.65	0.61
Sustainability	0.83	0.96	0.42
Social Responsibility	0.85	0.77	0.96

Source: own study

Table A.4

Pre-normalization weights of the main characteristics of logistics capabilities

	Scientific Foundations and Technical Knowledge	Strategic Thinking and Management	Human Resources and Relationships	Ethics and Social Responsibility
Scientific Foundations and Technical Knowledge	0.96	2.24	2.01	1.96
Strategic Thinking and Management	0.21	0.96	2.01	1.88
Human Resources and Relationships	0.25	0.25	0.96	1.79
Ethics and Social Responsibility	0.25	0.28	0.28	0.96

Source: own study

Pre-normalization weights of the sub-feature: Scientific foundations and technical knowledge.

	Logistics Systems	Operational Research	Quality Management	Information Systems
Logistics Systems	0.96	2.95	2.07	2.71
Operational Research	0.16	0.96	1.56	2.20
Quality Management	0.23	0.33	0.96	2.04
Information Systems	0.19	0.25	0.28	0.96

Source: own study

Pre-normalization weights of the sub-feature: Strategic thinking and management

	Strategic Management	Decision Making	Risk Management	Agility
Strategic Management	0.96	0.97	4.10	1.87
Decision Making	0.57	0.96	3.89	3.59
Risk Management	0.08	0.09	0.96	1.67
Agility	0.31	0.13	0.37	0.96

Source: own study

Pre-normalization weights of the sub-feature: Human resources and relationships

	Teamwork	Leadership	Communication	Conflict Management
Teamwork	0.96	0.74	2.06	3.72
Leadership	0.74	0.96	2.95	4.73
Communication	0.23	0.15	0.96	2.71
Conflict Management	0.11	0.06	0.19	0.96

Source: own study

Pre-Normalization weights of the sub-feature: Ethics and social responsibility

	Professional Ethics	Sustainability	Social Responsibility
Professional Ethics	0.96	2.08	2.22
Sustainability	0.28	0.96	3.63
Social Responsibility	0.25	0.11	0.96

Source: own study