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Optimizing Logistics and Transportation Locations in the China–Pakistan Economic Corridor: A Strategic Risk Assessment

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Abstract: Logistics centers (LCs) have become a critical component of supply chain networks, playing an essential role in the development and implementation of logistics and supply chain management strategies. Recognizing the importance of LCs, Pakistan and China have initiated an extensive plan to establish and expand an LC system as part of the China–Pakistan Economic Corridor (CPEC) initiative. However, the implementation of this plan has faced challenges due to the inadequate prioritization of factors used to identify LCs. This research proposes a structured framework for selecting LC locations, employing a combination of fuzzy logic and the technique for order of preference by similarity to the ideal solution (TOPSIS). These widely used methods address various challenges encountered in location selection. The findings highlight crucial logistics hubs in China and Pakistan, emphasizing factors such as port accessibility, freight demand, and transportation costs. The prioritization of criteria for LC selection is determined through the evaluation of variables and alternatives. The proposed framework enhances decision-making based on multiple criteria by addressing uncertainty and subjective assessments.

Keywords: logistics centers; supply chains; fuzzy Delphi (FD) method; TOPSIS

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1. Introduction

The strategic location of logistics centers (LCs) is crucial for ensuring the efficacy of supply chain activities in the ever-changing world of international commerce. Viewed from the perspective of logisticians navigating the complicated web of factors influencing the decision-making process, it explores the problematic realm of logistics center localization. In order for businesses to achieve their objectives of cost-effectiveness, sustainability, and agility, the strategic location of logistics facilities becomes crucial [1,2].

An extensive infrastructure and economic development network is intended to link China and Pakistan's strategically located regions as part of the China–Pakistan Economic Corridor (CPEC), a major economic project. The corridor transverses several Pakistani areas and connects the deep-water port of Gwadar with the western Chinese city of Kashgar [3]. Because it impacts the choice of hubs and ports in Pakistan, the CPEC's geolocation is crucial. The hub of the CPEC is Gwadar, which is situated in the province of Baluchistan in the southwest. Because of its advantageous position on the Arabian Sea, it is an essential port for trade and business, giving China a quicker and safer path for its imports and exports. Another port in Balochistan, Ormara, is crucial to the CPEC because it offers a different path for trade and improves communication throughout the area [4]. Karachi, Pakistan's main metropolis and commercial center, handles a sizable amount of the nation's trade and is a key port for the CPEC. Its well-developed infrastructure and proximity to the Arabian Sea make it a crucial node within the corridor. Balochistan port town, Pasni, contributes to the adequate flow of commodities and services by strengthening the CPEC's maritime connectivity [5].

The hubs of Gilgit, Peshawar, Karachi, and Quetta are positioned efficiently along the CPEC route in addition to the ports. These hubs are crucial locations for the movement and distribution of goods and for the growth of economic and industrial zones. As a vital hub for the movement of products into and out of the corridor, Tianjin, a significant port city in northeastern China, plays a pivotal role in the Chinese side of the CPEC [6,7]. Situated in the Xinjiang area of China, Kashgar serves as a crucial hub for the China–Pakistan Economic Corridor (CPEC), linking the corridor to the broader web of Chinese trade routes and infrastructure. For the corridor to operate effectively and efficiently, there must be a relationship between the CPEC's geolocation and the ports and hubs chosen in China and Pakistan [8]. It promotes regional integration and economic growth while guaranteeing smooth connectivity and trade between the two nations [9].

LC selection in the CPEC is different from other scenarios. CPEC's strategic location, transport logistics, and international cooperation with China and Pakistan make geopolitical factors more critical [10]. Location strategy must consider transportation hubs, weather patterns, and the intricate geopolitical landscape, including diplomatic interactions, political stability, and international agreements. Infrastructure has become increasingly essential for domestic and cross-border networks [11,12]. The market proximity is necessary to understand Chinese and Pakistani consumers and economic conditions. Regulations span national borders, requiring careful compliance with local, international, and trade agreements. Sustainability must align with the global commitment to green supply chains and emphasize sustainable corporate practices in CPEC's cross-national context [13].

Locating LC involves predicting and adjusting to dynamic changes in market demands, consumer behavior, and geopolitical issues, which may affect selected locations' long-term viability and effectiveness. This research, which focuses on the CPEC, uses an FD TOPSIS approach to determine the best sites for LC in China and Pakistan. To simplify the process of selecting a site and improve efficiency and strategic placement in the changing logistics environment of the CPEC region, the research incorporates fuzzy logic and decision-making tools from the logisticians' perspective.

2. Literature Review

Any organization must carefully consider its options when choosing a logistics location because it directly impacts the effectiveness and affordability of its supply chain operations. The literature considers several factors and decision support techniques to help readers make well-informed decisions. The decision support approach is useful for determining the best site in logistics. Employing this approach allows businesses to make well-informed decisions by considering several variables, including labor availability, supplier and consumer proximity, and transportation costs. The decision support technique aids in assessing several location possibilities and selecting the optimal one that complements the business's overall logistics strategy [14].

Furthermore, choosing a location for logistics operations research highlights the need to adopt decision support tools that consider qualitative and quantitative considerations [15]. The decision support method offers a systematic approach to logistics location selection, resulting in more effective and economical supply chain management.

2.1. Methods for Decision Support

Decision support techniques are crucial to solving the intricate allocation problems that arise while choosing a logistics location. The analytic hierarchy process (AHP) technique has been extensively utilized in the literature to rank the criteria for logistics location selection [16]. AHP helps in the selection process by enabling decision-makers to methodically evaluate and rank various location possibilities according to various criteria. The study established an international crew transfer facility located in Taiwan using the FD–AHP–TOPSIS technique [17]. The researchers used a methodology that integrated the FD approach, the analytical hierarchy process (AHP), and the technique for order preference by similarity to ideal solution (TOPSIS). The findings offered a systematic methodology for assessing and selecting the best site for an international crew transfer facility located in Taiwan. Personal evaluations in the fuzzy analysis and possible differences in stakeholder perspectives are examples of limitations. To determine the placement of logistical centers, they utilized the AHP and the fuzzy comprehensive evaluation method in their analysis [18]. The researchers offered possible improvements in the efficiency and effectiveness of central location selection and provided a methodical approach to logistics decision-making. However, the particular context and variables considered during the evaluation may have constraints. The Gulf Cooperation Council (GCC) nations' logistics performance within international supply chains was examined in previous research [19]. The researchers used an extensive approach, perhaps combining quantitative and qualitative methodologies, to evaluate the GCC countries' logistical efficiency. The findings shed light on the differences in performance between GCC nations and their involvement in international supply chains. However, data accessibility issues and the changing characteristics of logistics factors could present challenges. A mixed-integer linear programming (MILP) model was utilized in the article to solve the logistics village location and capacity planning problem [20]. Capacity planning and logistics village site selection should be optimized to increase sustainability. The method used formulates and resolved the problem using MILP modeling. The findings offered information about effective capacity allocation and logistics network design techniques. Streamlining assumptions that might affect the model's applicability in the real world is one of its potential disadvantages.

The study focused on risk assessment in the CPEC's supply chain networks. The authors concentrated on the complex dynamics of the business partnership. They examined the possible supply chain hazards and provided insights into the difficulties faced in the context of the CPEC. They assisted in comprehending and controlling hazards in the intricate CPEC network. The research investigated sustainable modeling using reverse logistics techniques in CPEC [21]. The authors used fuzzy multi-criteria decision-making (MCDM) to evaluate environmental and economic problems. They offered valuable perspectives for improving sustainability measures in the logistics sector, focusing on the complex dynamics of the CPEC. The article examined associated risks in the CPEC's road transportation networks [22]. The authors offered a complete analysis of these hazards and highlighted their all-encompassing characteristics. They provided insightful information that could be used to identify better and manage the risks connected to CPEC construction projects. The authors analyzed the CPEC's technical specifications and the policy implications for electric vehicles used in Pakistan [23]. They offered insights into technological issues and policy recommendations for a sustainable and effective electric transportation system. They examined whether Pakistan's transportation system could be integrated with electric vehicles. The study examined whether China's crude oil purchases through the CPEC were an optimal solution [24]. They assessed different criteria and identified the best import possibilities using fuzzy TOPSIS and cost–benefit analysis. They offered valuable perspectives on optimizing the economy and efficiency of China's transportation of crude oil via the corridor. The study focused on integrating green supply chain management techniques into the CPEC's construction supply chain [25]. The authors investigated how implementing environmentally friendly practices affects supply chain management. They investigated methods to improve the CPEC construction supply chain's environmental performance.

2.2. Selection Criteria for Logistics Locations

The literature has outlined several factors that are thought to be essential for selecting the ideal logistics location. The cost-related, infrastructure-related, and demand-related criteria can be broadly divided into three groups.

2.2.1. Accessibility to Markets

When choosing a logistics location, accessibility to customer markets is essential. To enable more effective delivery to final customers, businesses frequently look for locations that minimize lead times and transportation costs [26].

2.2.2. Transportation Infrastructure

The availability of robust transportation infrastructure, including highways, railways, ports, and airports, is crucial for efficient logistical operations. Research indicates that transportation connections play a major role in determining the viability of a logistics location [27].

2.2.3. Worker Availability and Skill

Another important factor is the availability of skilled labor. When choosing logistics locations, businesses consider both the cost of labor and the availability of labor with the necessary skills [28].

2.2.4. Financial Aspects

The cost of land and real estate, utilities, taxes, and total operational expenses are all important considerations when choosing a location. One of the main goals businesses have when selecting a logistics location is to minimize operating costs [29].

2.2.5. Proximity to Suppliers

This is a crucial factor, especially for manufacturing and distribution firms, regarding the suppliers' locations and supply chains. This shortens lead times and lowers the cost of incoming transportation for locating raw materials and components [30].

The literature highlights the significance of applying decision support techniques like AHP and MCDM to handle the intricate allocation problems of logistics location selection. Several techniques highlighted by the authors are displayed in Table 1.

Table 1. Summary of numerous investigations and their importance.

Year of Publication	Authors	Objective	Applied Method	Reference
2024	Kaiser, Jan et al.	Reduce transportation costs	Network Optimization Cost–Benefit	[31]
2023	Thakur, Mamta et al.	Applications of artificial intelligence and machine learning in supply chain management	Comprehensive Review	[32]
2021	Johnson, Dylan, and Emmanouil Chaniotakis.	Optimize last-mile delivery	Simulation, Optimization Models	[33]
2021	Aslani, Babak, Meysam Rabiee, and Madjid Tavana.	To develop a decision-making framework for logistics location selection	Multi-Criteria Decision-Making (MCDM)	[34]
2020	Bag, Surajit et al.	Enhance supply chain visibility	Data Analytics, RFID	[35]
2012	Benjaafar, Saif, Yanzhi Li, and Mark Daskin	To analyze the impact of sustainability on logistics location selection	Lifecycle Assessment (LCA)	[36]
2004	Ghiani, Gianpaolo, Gilbert Laporte, and Roberto Musmanno	To evaluate the role of transportation costs in logistics location selection	Geographic Information Systems (GIS)	[37]

For selecting a logistics location, it is also essential to consider several aspects, such as those connected to cost, infrastructure, demand, and environmental sustainability. The research determined the danger of landslides along the CPEC [38]. The authors evaluated the risks connected to landslides in the area and offered insightful recommendations for lowering the probability of disasters. The results enhanced the understanding of geological risks within the framework of the economic corridor. The author focused on freight trucks operating along the CPEC's altitude-dependent gaseous emissions [39]. They investigated the effects of truck emissions on the environment at various elevations. They provided essential insights into the variations in gaseous pollutants emitted by freight trucks. The study investigated the risk and vulnerability of the CPEC to natural hazards [40]. They evaluated the possible natural disasters that could affect the CPEC's socioeconomic and physical elements. They intended to provide insightful information on effective resilience and risk management strategies in the important economic corridor.

The studies employed a systematic framework for evaluating possible locations to improve decision-making and planning efficiency for logistics in the Thrace region. The input parameter and assumption sensitivity can be limited in the study. Sustainability considerations were researched before deciding on a location for a logistics center [41]. The authors suggested improving decision-making using an ordered weighted average (OWA) operator and a similarity based TOPSIS technique. The outcomes provided insightful information for logistics center location optimization and demonstrated that the strategy considers sustainability concerns. Criteria and regional applicability may restrict the research's scope.

3. Methodology

3.1. Data Acquisition

The logistics center locations were chosen by utilizing the Delphi technique, which was informed by the conclusions derived from a comprehensive literature analysis and data obtained from interviews conducted with subject matter experts [42]. A total of six logisticians, including CEOs and presidents with over a decade of professional experience, were selected to participate in the interview process. These individuals were chosen from major logistics service organizations. The interviews were conducted through face-to-face and telephone interactions to eliminate unnecessary factors and include omitted variables, while emails were distributed to obtain input on 14 significant elements. The second survey was designed to evaluate the comparative significance of the criteria and the suggested sites for LC. The second round of questionnaires was administered to a group of 18 individuals who possess extensive expertise in management positions within logistics service organizations. These experts have at least seven years of experience in the field. Notably, six participants participated in the initial survey round.

3.2. FD Method

The FD method is a technique that integrates the Delphi procedure with the fuzzy procedure [43]. The implementation of a repeated group response methodology for consecutive questionnaires resulted in a decrease in the overall number of responses. The previously mentioned method has been employed to achieve the state of anonymity, repetition, regulated feedback, and statistical collective reaction [44]. The Delphi method necessitates the inclusion of a panel consisting of a minimum of five and a maximum of nine experts to attain a rational evaluation [45].

The methodology has been employed to address the challenge of multi-attribute decision-making by utilizing linguistic expressions to represent variables on a continuous scale of grades. A membership function that can define a fuzzy set can assign a membership grade between zero and one. In the fuzzy field, it is usual to refer to classical dual sets as crisp sets. Equation (1) presents a fuzzy number with a triangular shape characterized by three parameters and a membership function.

$$B(\chi) = \begin{cases} 0, \ \chi < b_1 \\ \frac{\chi - b_1}{b_2 - b_3}, \ b_1 \leq \chi \leq b_2 \\ \frac{b_3 - \chi}{b_3 - b_2}, \ b_2 \leq \chi \leq b_3 \\ 0, \ \chi > b_3 \end{cases} \tag{1}$$

The calculation of the j^{th} fuzzy function n is determined using:

$$\overline{B} = \left(b_1^{(j)}, b_2^{(j)}, b_3^{(j)}\right), j = 1, 2, \ldots, n \tag{2}$$

Moreover, the process of fuzzification is quantified as follows:

$$\overline{B} = B_{ave} \frac{\overline{B_1} + \overline{B_2 + \ldots + \overline{B_n}}}{n} = \frac{\left(\sum_{j=1}^{n} b_1^{(j)}, \sum_{j=1}^{n} b_2^{(j)}, \sum_{j=1}^{n} b_3^{(j)}\right)}{n} = (b_1, b_2, b_3) \tag{3}$$

The fuzzy technique was employed to represent the linguistic variables in words or phrases. Linguistic terminology can be utilized to denote a fuzzy set. A Likert scale with seven points ("Very Low (VL), Low (L), Medium Low (ML), Medium (M), Medium High (MH), High (H), Very High (VH)") was employed to assign scores to each indicator, ranging from a value of 7 for highly high to a value of 1 for very low, as depicted in Table 2.

Table 2. Linguistic variables for each criterion's significance value.

Fuzzy Score	Linguistic Scale
(0.0, 0.0, 0.1)	VL
(0.0, 0.1, 0.3)	L
(0.1, 0.3, 0.5)	ML
(0.3, 0.5, 0.7)	M
(0.5, 0.7, 0.9)	MH
(0.7, 0.9, 1.0)	H
(0.9, 1.0, 1.0)	VH

Defuzzification serves as the conclusive stage in converting all results into physical values, wherein the center of gravity is typically employed.

$$z^* = b_3 - \sqrt[2]{\frac{(b_2 - b_3)(b_1 - b_3)}{2}} \tag{4}$$

The G-factor, denoted as z^*, is determined by measuring the gravity center.

3.3. Fuzzy-TOPSIS Method

The selected alternative demonstrates the most significant deviation from the "unfavorable ideal option" and the nearest resemblance to the "favorable ideal option" [46]. The optimal selection is distinguished by incorporating the most favorable criteria, while the suboptimal choice is formed by amalgamating the least desirable performances. To address the inherent imprecision and subjectivity associated with experts' judgments, the use of fuzzy TOPSIS is employed. This approach involves expressing evaluations in linguistic words and transforming them into fuzzy terms [47]. The fuzzy-TOPSIS approach entails the following procedural stages:

Stage 1. *The linguistic values* $\widetilde{w}_{ji}, j = 1, 2, \ldots m; i = 1, 2, \ldots n$ *should be established for the options in relation to the criteria [48]. To omit the "normalization stage, the fuzzy linguistic rating"* $\widetilde{w}_{ji}$ *is defined using a range of "normalized triangular fuzzy integers spanning"between 0 and 10 as* *displayed in Table 3 ("Very Poor (VP), Poor (P), Medium Poor (MP), Medium (M), Medium Good (MG), Good (G), Very Good (VG)") [49].*

Table 3. Linguistic variables affecting each alternative's preference.

Fuzzy Score	Linguistic Scale
(0, 0, 1)	VPMG
(0, 1, 3)	P
(1, 3, 5)	MP
(3, 5, 7)	M
(5, 7, 9)	MG
(7, 9, 10)	G
(9, 10, 10)	VG

Stage 2. *The "weighted normalized fuzzy decision" matrix can be calculated using:*

$$\tilde{v} = \left[\tilde{v}_{ji}\right]_{m*i'} j = 1, 2, \ldots m; i = 1, 2, \ldots n \tag{5}$$

$$\tilde{v}_{ji} = \tilde{w}_{ji} * x_i \tag{6}$$

The measurement of x_i is conducted through the utilization of data obtained from expert surveys.

Stage 3. *The favorable-ideal (B^*) and unfavorable-ideal (B^-) possibilities can be evaluated using:*

$$B^* = \left\{v_1^*, \ldots\ldots\ldots\ldots, v_j^*\right\} = \left\{\left(\max_i v_j, j \in \omega_a\right), \left(\min_i v_i, j \in \omega_d\right)\right\} \tag{7}$$

$$B^- = \left\{v_1^-, \ldots\ldots\ldots\ldots, v_j^-\right\} = \left\{\left(\max_i v_j, j \in \omega_a\right), \left(\min_i v_i, j \in \omega_d\right)\right\} \tag{8}$$

The sets of benefit criteria are denoted as ω_a, whereas the sets of cost criteria are denoted as ω_d.

Stage 4. *Determine how far the choice is between the best possible outcome and the worst possible one.*

$$C_j^* = \sum_{i=1}^n c\left(\tilde{V}_i, \tilde{V}_j\right), j = 1, 2, ..m \tag{9}$$

$$C_j^- = \sum_{i=1}^n c\left(\tilde{V}_i, \tilde{V}_j\right), j = 1, 2, ..n \tag{10}$$

$$c\left(\tilde{b}, \tilde{a}\right) = \sqrt{\left(\frac{1}{3}\right)\left[(b_1 - a_1)^2 + (b_2 - a_2)^2 + (b_3 - a_3)^2\right]} \tag{11}$$

where b and a represent two triangular fuzzy integers denoted as $(b_{1,}\ b_{2,}\ b_{3,})$ and $(a_{1,}\ a_{2,}\ a_{3,})$, respectively.

Stage 5. *Determine the degree of proximity of each alternative to the optimal choice. The proximity between alternative B8 and B9 can be described as follows:*

$$ED_j = \frac{C_j^-}{c_j^* + C_j^-}, j = 1, 2, \ldots n \tag{12}$$

3.4. FD-TOPSIS Approach

The FD technique combines the benefits of "fuzzy and the Delphi method". The results obtained using the Delphi technique exhibited objectivity in instances in which a limited sample size was employed. As a result, the utilization of the hybrid method resulted in a reduction of time and money necessary to attain acceptance while maintaining the integrity of the outcomes. Moreover, the TOPSIS method is utilized to resolve "multi-criteria decision-making problems" due to its efficacy in determining significance among several choices and its computational simplicity. Therefore, the fuzzy TOPSIS technique has been developed to enhance alternative performances' comprehensive and logical evaluation. This is done by taking into consideration uncertain and ambiguous judgments, as well as linguistic assessments.

The FD–TOPSIS architecture methodology is presented in Figure 1. The methodology involves formulating criteria derived from the existing literature and expert evaluations using the Delphi technique. The application of the FD method determines the criteria weights. Finally, the suggested altered locations for the LC are ranked using the fuzzy TOPSIS approach.

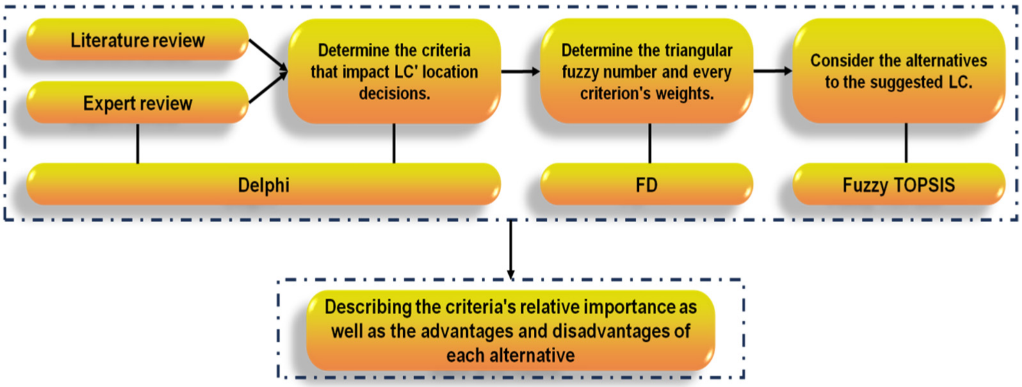

Figure 1. FD–TOPSIS methodology.

4. Results

4.1. Logistics Performance

The logistics sector in Pakistan and China is in the early stages of growth. Determining the best location for LC in Pakistan is a multifaceted process that is dependent on several key factors. The Gwadar Port Area in Baluchistan stands out as an important logistics hub due to its proximity to the Gwadar Port, coastal highway access, and ongoing infrastructure development. Similarly, Balochistan's Ormara Port benefits from its strategic coastal location and connectivity to major cities, ensuring seamless maritime trade operations. Port Qasim in Karachi gains importance as an economic hub due to its proximity to Karachi and well-developed transportation infrastructure. The strategic coastal location of the Port of Pasni, as well as the associated logistics infrastructure, contributes to its role in facilitating trade (Table 4). Beyond ports, logistics hubs in Gilgit, Peshawar, Quetta, and Karachi are strategically located to take advantage of geographical importance, proximity to neighboring countries, and well-established transportation networks (Table 5).

Table 4. Ports and their significance.

Location of Ports	Key Factors	Significance
Gwadar	Proximity to Gwadar Port, coastal highway, and infrastructure development	Vital logistics hub, central to CPEC, strategic coastal position
Ormara	Strategic coastal location, connectivity to major cities	Facilitates seamless maritime trade operations
Qasim, Karachi	Proximity to Karachi; well-developed transportation infrastructure	Economic hub, significant for maritime trade operations
Pasni	Strategic coastal position, associated logistics infrastructure	Facilitates trade operations

Table 5. Hubs and their key factors.

Hubs	Location	Key Factors
Gilgit	Pakistan	It is essential for commercial routes, strategically located to connect the north, and improves regional accessibility.
Peshawar	Pakistan	A crucial hub for transportation networks and a critical junction for international trade.
Quetta	Pakistan	A geostrategic center promotes regional economic integration and is essential for border trade.
Karachi	Pakistan	It is an important seaport and trading center essential to global trade and economic growth.

Tianjin emerged as a critical logistics center in China due to its proximity to the capital city of Beijing and its strategic connection to the Tianjin Port, which is a major gateway. Khashgar, which is strategically located at the border and a component of China's Belt and Road Initiative (BRI), is critical in facilitating trade with Central Asian countries (Table 6).

Table 6. Chinese cities and their key factors.

City	Location	Key Factors
Tianjin	China	It is close to Beijing, has a strategic connection to Tianjin Port, and has a crucial role as a logistics center.
Khashgar	China	Strategic border location, part of China's Belt and Road Initiative (BRI), and trade facilitation with Central Asian countries.

The Gwadar Port Area case study in Baluchistan provides a more in-depth examination. Gwadar, located along the Arabian Sea, is an important stop on the China–Pakistan Economic Corridor (CPEC), making it a regional trade hub (Figure 2). Ongoing infrastructure projects, such as road networks and a free trade zone, highlight the country's potential as a logistics powerhouse. Gwadar is approximately 620 km from Karachi, 873 km from Quetta, and approximately 1450 km from Islamabad. These factors highlight how Gwadar's strategic location, infrastructure development, and involvement in regional economic initiatives position it as a key logistics center in Pakistan.

Figure 2. Locations of logistics centers in Pakistan.

Furthermore, the logistics center location decision-making process includes a comprehensive analysis that takes into account economic, regulatory, and environmental considerations for a holistic understanding of each location's viability.

4.2. Evaluation of Variables and Alternatives

Using Equation (2), we calculated the highest possible fuzzy score for each of the factors. The crisp value was derived through the process of defuzzification, which involved applying Equation (3) to the fuzzy scores. The results are displayed in Table 7 and Figures 3 and 4.

Table 7. Highest fuzzy criteria outcomes.

Criteria	Factor	Defuzzification	Fuzzy Score	Rank
1	Seaports	0.79	(0.63, 0.81, 0.93)	4
2	Demand for freight	0.87	(0.74, 0.89, 0.97)	1
3	Proximity to the marketplace, manufacturing region, and customers	0.84	(0.70, 0.86, 0.95)	3
4	Highways	0.68	(0.49, 0.69, 0.85)	5
5	Inland waterways	0.67	(0.49, 0.69, 0.84)	6
6	The expense of acquiring land	0.66	(0.49, 0.67, 0.83)	7
7	Expense of constructing	0.63	(0.45, 0.63, 0.81)	8
8	Railways	0.57	(0.38, 0.58, 0.76)	9
9	Airports	0.56	(0.37, 0.57, 0.75)	10
10	Transportation expenses	0.86	(0.74, 0.88, 0.95)	2

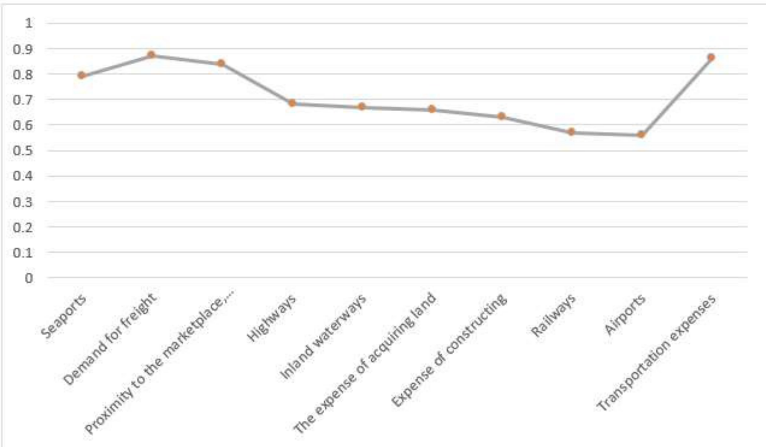

Figure 3. Defuzzification values for factors.

The criteria were ranked according to their fuzzy scores following a thorough analysis of every criterion. With the highest fuzzy score of one, the demand for freight occupies the top position and highlights its essential significance in decision-making. With a fuzzy score of, transportation expenditures come in second place, indicating the importance of taking them into account throughout the decision process. Third place comes from proximity to the customers, production region, and marketplace, recognizing the significance of geographic location and the high fuzzy score of. Seaports are always important for companies that depend on transport by sea, even with their high fuzzy score, which places them fourth among other factors with somewhat higher scores. With a fuzzy score of, highways rank fifth, suggesting that while they are important, they are not as important as other elements. With a fuzzy score of, inland waterways rank sixth and have a similar situation. The cost of purchasing land comes in at number seven, with a fuzzy score of, indicating that while expenses are considered, they are not as important. The construction cost comes in eighth place with a fuzzy score of, indicating that it is relevant but not a high priority. Railways rank ninth with a fuzzy score of, indicating that, while still important, they are not as important as higher-level criteria. Airports rank tenth and last among the factors mentioned, with the lowest fuzzy score of, suggesting their limited impact.

This research highlights the importance of freight demand, transportation expenses, and proximity to the marketplace, manufacturing region, and customers in selecting a logistics center. To enhance freight transportation demand, economic growth policies and free trade zones are implemented. Transportation, land acquisition, and building costs are considered to reduce logistics expenses. LCs with combined logistics facilities and transport hubs prioritize proximity to water and highways for price and adaptability. Expanding geographical areas fosters sustainable development. The decision-making process assigns relatively lower priorities to building and transportation activities' environmental effects, as shown in Figures 5 and 6.

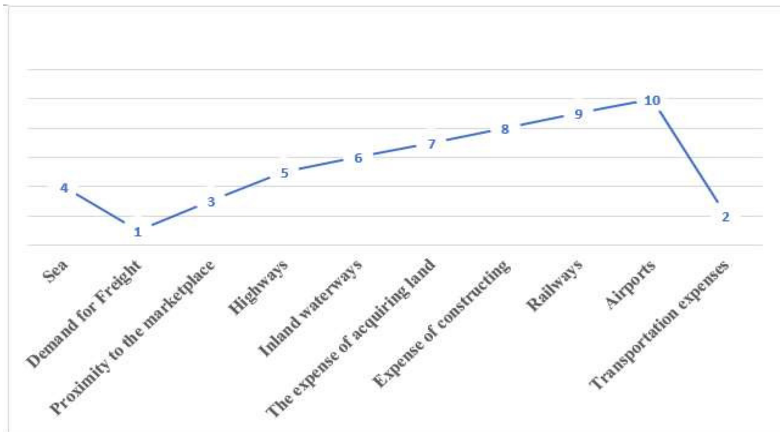

Figure 4. Factors and their ranks.

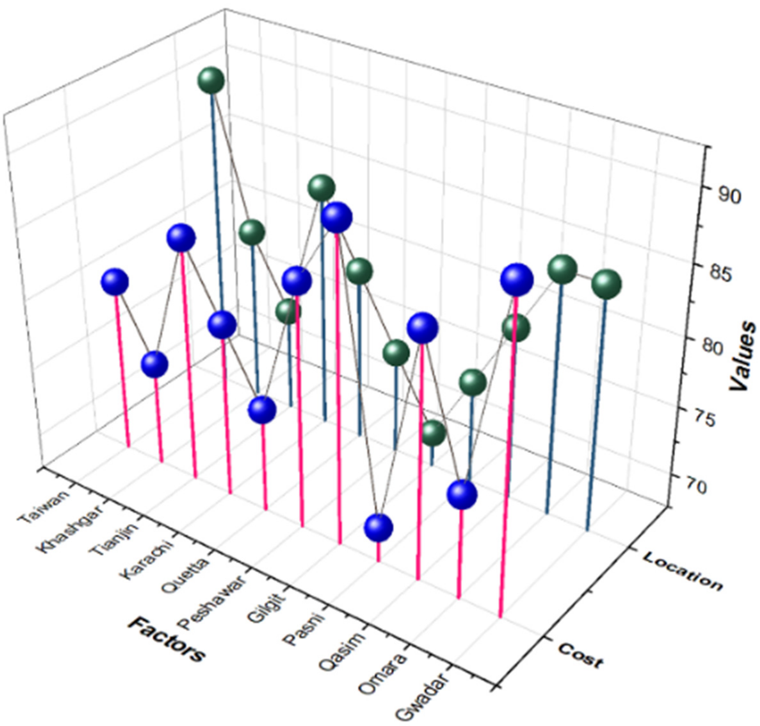

Figure 5. Cost and location values.

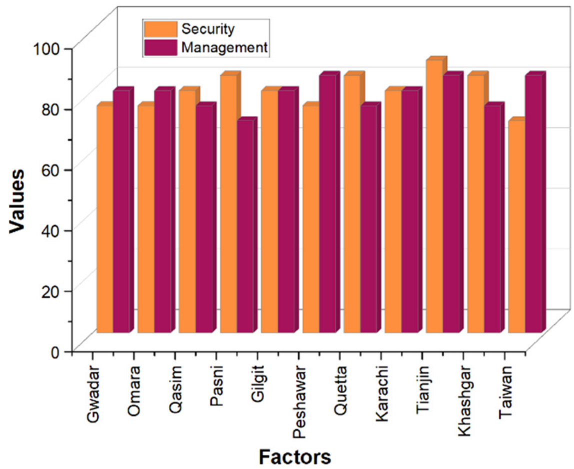

Figure 6. Security and management values.

The 10 determinants chosen for evaluating alternatives were linguistic variables that underwent a transformation process, resulting in fuzzy ratings. A "weight-normalized fuzzy decision matrix," which was assessed by multiplying the ratings with the fuzzy weights, was calculated using Equation (6), and the positive ideal (A^*) and negative ideal (A^-) options under each factor were determined using Equations (7) and (8), as presented in Table 8 (Gwadar (GW), Ormara (OR), Qasim (QA), Pasni (PA), Gilgit (GI), Peshawar (PE), Quetta (QU), Karachi (KA), Tianjin (TI), and Khashgar (KH)). We compared CPEC to Taiwan in terms of cost, location, security, and management in Table 9. And logisticians assessed the options based on the hubs and ports shown in Table 10.

Table 8. Global scores according to location.

Location		Criteria				
		1	2	3	4	5
Port (Pakistan)	GW	(2.80, 4.9, 4.9)	(1.28, 3.15, 4.9)	(4.20, 4.9, 4.9)	(3.0, 4.9, 4.9)	(1.9, 4.2, 4.9)
	OR	(2.11, 3.80, 4.30)	(2.53, 3.70, 4.20)	(4.43, 4.00, 4.45)	(1.50, 4.10, 4.70)	(3.40, 3.80, 4.10)
	QA	(2.20, 4.10, 4.40)	(1.71, 3.20, 4.10)	(2.44, 3.60, 4.30)	(4.00, 4.50, 4.80)	(3.20, 4.70, 4.90)
	PA	(3.50, 3.90, 4.20)	(2.80, 3.30, 4.00)	(4.10, 3.80, 4.10)	(1.50, 3.90, 4.40)	(3.40, 4.20, 4.50)
Hubs (Pakistan)	GI	(3.20, 4.00, 4.30)	(2.60, 3.50, 4.00)	(3.80, 4.10, 4.40)	(1.90, 3.70, 4.20)	(3.00, 4.30, 4.60)
	PE	(2.90, 3.70, 4.10)	(2.30, 3.90, 4.20)	(3.50, 4.20, 4.60)	(2.00, 3.80, 4.40)	(2.80, 4.00, 4.30)
	QU	(3.10, 3.80, 4.20)	(2.40, 3.70, 4.10)	(3.60, 3.90, 4.30)	(2.10, 4.00, 4.20)	(2.90, 4.10, 4.40)
	KA	(4.50, 4.80, 4.60)	(3.80, 4.10, 4.40)	(5.20, 4.30, 4.80)	(3.90, 4.20, 4.70)	(4.30, 4.60, 4.90)
Port (Pakistan)	TI	(4.20, 4.60, 4.30)	(3.50, 4.20, 4.10)	(4.90, 4.40, 4.70)	(3.60, 4.10, 4.50)	(4.10, 4.30, 4.60)
	KH	(4.80, 4.90, 4.40)	(4.10, 4.50, 4.20)	(5.50, 4.60, 4.90)	(4.20, 4.70, 4.80)	(4.50, 4.80, 4.60)
Location		**Criteria**				
		6	**7**	**8**	**9**	**10**
Port (Pakistan)	GW	(4.60, 3.90, 4.20)	(3.20, 3.10, 4.10)	(2.90, 3.70, 4.40)	(4.10, 4.20, 4.30)	(3.50, 4.80, 4.60)
	OR	(3.80, 4.20, 4.30)	(2.30, 3.90, 4.20)	(3.50, 4.20, 4.60)	(4.20, 4.40, 4.70)	(3.40, 4.60, 4.90)
	QA	(4.10, 3.80, 4.20)	(3.50, 3.20, 4.10)	(3.80, 3.90, 4.30)	(4.20, 4.50, 4.80)	(3.80, 4.70, 4.90)
	PA	(3.90, 3.70, 4.20)	(4.20, 3.30, 4.00)	(4.10, 3.80, 4.10)	(3.70, 3.90, 4.40)	(3.40, 4.20, 4.50)
Hubs (Pakistan)	GI	(4.00, 4.00, 4.30)	(2.90, 3.50, 4.00)	(3.80, 4.10, 4.40)	(4.40, 3.70, 4.20)	(3.00, 4.30, 4.60)
	PE	(4.20, 3.70, 4.10)	(3.20, 3.90, 4.20)	(3.50, 4.20, 4.60)	(3.90, 4.20, 4.70)	(4.50, 4.80, 4.60)
	QU	(4.30, 3.80, 4.20)	(2.40, 3.70, 4.10)	(3.60, 3.90, 4.30)	(3.60, 4.10, 4.50)	(4.10, 4.30, 4.60)
	KA	(4.80, 4.80, 4.60)	(3.80, 4.10, 4.40)	(5.20, 4.30, 4.80)	(4.10, 4.00, 4.20)	(4.30, 4.60, 4.90)
Port (Pakistan)	TI	(4.60, 4.60, 4.30)	(4.10, 4.50, 4.20)	(4.90, 4.40, 4.70)	(4.50, 3.80, 4.40)	(2.90, 4.10, 4.40)
	KH	(4.90, 4.90, 4.40)	(3.50, 4.20, 4.10)	(5.50, 4.60, 4.90)	(4.20, 4.70, 4.80)	(2.80, 4.00, 4.30)

Table 9. Logistics center comparison matrix.

Factors	Cost	Location	Security	Management	Ranks
Gwadar	90	85	75	80	5
Omara	75	85	75	80	8
Qasim	85	80	80	75	2
Pasni	70	75	85	70	10
Gilgit	90	70	80	80	7
Peshawar	85	75	75	85	1
Quetta	75	80	85	75	6
Karachi	80	85	80	80	4
Tianjin	85	75	90	85	3
Khashgar	75	80	85	75	9
Taiwan	80	90	70	85	11

Table 10. Logistician alternative evaluation.

Locations	GW	OR	QA	PA	GI	PE	QU	KA	TI	KH
Positive-ideal (A^*)	15.20	18.50	12.80	14.60	20.00	11.70	16.30	22.10	25.50	23.80
Negative-ideal (A^-)	2.50	3.20	2.00	2.80	3.50	2.30	2.90	3.80	4.20	4.00
Ranking	2	3	1	4	5	6	7	8	9	10
Relative Closeness	0.80	0.70	0.90	0.75	0.65	0.92	0.78	0.60	0.50	0.55

Different locations in the CPEC are compared in Table 9 with respect to important variables like cost, security, and management. A score is assigned to each of these factors for the following locations: Gwadar (GW), Ormara (OR), Qasim (QA), Pasni (PS), Gilgit (GI), Peshwar (PE), Quetta (QU), Karachi (KA), Tianjin (TI), and Kashgar (KH). Better performance in a particular area is indicated by a higher score. For example, Gwadar performs well in terms of price and location, but Tianjin shines in terms of security. Conversely, Taiwan has a distinctive geographic location but a relatively low security rating. To help decision-makers evaluate the viability and appropriateness of CPEC and Taiwan for logistical consideration, the comparison provides a brief summary of the advantages and disadvantages of each location.

Table 9 lists the elements that determine the rankings of different locations. Peshawar received the best score in this category and thus holds the top spot due to its excellent administration. Qasim takes second place because of its well-balanced performance in terms of cost, location, security, and management. Tianjin shines out in third place with excellent management and security ratings. Karachi is in fourth place, demonstrating a strong balance between location, security, affordability, and management considerations. Gwadar ranks fifth despite having a lower security rank because of its competitive score in other areas. In sixth location, Quetta, is not far behind, showing a well-rounded performance in several areas. With strong points for affordability and location but slightly lower marks for security and management, Gilgit takes seventh place. Omara is in eighth place, showing steady performance without standing out in any particular area. Khashgar comes in at position nine, with a very even score across the board but without special characteristics. Pasni ranks tenth, with its overall ranking impacted by weaker security and management rankings. Taiwan's poor rankings in cost, security, and management concerns put it at the bottom of the list.

Figure 5 shows the comparison with a particular emphasis on location and cost, and Figure 6 shows the comparison with a focus on security and management. These geographic depictions provide a comprehensive and clear understanding of the comparative advantages and disadvantages of Taiwan and CPEC in these crucial areas.

Using Equations (7) and (8), the positive ideal (A^*) and negative ideal (A^-) possibilities for each factor were determined. The distances between every alternative and the positive ideal (d_i^*) and negative ideal options (d_i^-) were calculated, as well as the relative proximity of each alternative to the relative closeness (fC_i). There was a ranking constructed for the

10 alternatives based on the fC_i score. The 10 alternatives are Gwadar (GW), Ormara (OR), Qasim (QA), Pasni (PA), Gilgit (GI), Peshawar (PE), Quetta (QU), Karachi (KA), Tianjin (TI), and Khashgar (KH). Table 10 presents an analysis of the 10 locations' strengths and shortcomings, along with strategic recommendations derived from the findings.

Peshawar (PE) is a central transportation hub and a critical intersection for global trade, highlighting its vital role in promoting regional connectivity. Qasim (QA) takes second place, benefiting from its advantageous location close to Karachi and an established transportation network that improves trade facilitation. Gwadar (GW) takes third place, demonstrating its significance as a key port in the area by using its strategic coastline linkages and continuous infrastructural development. In fourth place, Quetta (QU) is a geostrategic hub that supports regional economic integration and is essential to border trade. Pasni (PA) is ranked fifth and is a key hub for trade activity with its advantageous coastline location and related logistical facilities. Ormara (OR), which substantially contributes to regional trade, ranks sixth because of its advantageous seaside location and easy access to major cities. Gilgit (GI) holds the seventh rank, highlighting its strategic northern location, enhanced regional accessibility, and significance in trade routes. Karachi (KA), ranked eighth, is an important seaport and trading hub that makes a major contribution. Khashgar (KH) takes ninth place, emphasizing its advantageous border location, active involvement in China's Belt and Road Initiative (BRI), and ability to facilitate commerce with Central Asian nations. Tianjin's (TI) tenth-place ranking highlights the city's importance because of its proximity to Beijing, advantageous location concerning Tianjin Port, and vital function as a regional logistics hub.

5. Discussion

This study explores the crucial factors influencing LC location decisions in the evolving logistics sectors of Pakistan and China. The analysis highlights key regions, such as the Gwadar Port Area in Baluchistan and Tianjin in China, as pivotal logistics hubs due to strategic locations, connectivity, and ongoing infrastructure development. In Pakistan, the prominence of Gwadar, Ormara, Port Qasim, and other locations stems from their geographical advantage, proximity to major cities, and well-developed transportation networks. The Gwadar Port Area, which is situated along the Arabian Sea, stands out as a crucial node in the CPEC, emphasizing its role as a regional trade hub. Ongoing infrastructure projects, including road networks and free trade zones, further underline Pakistan's potential as a logistics powerhouse. The decision-making process incorporates a comprehensive analysis considering economic, regulatory, and environmental factors. The fuzzy–TOPSIS method is employed, ranking criteria such as freight demand, transportation expenditures, and proximity to customers. The results emphasize the significance of freight demand and transportation costs in LC selection, guiding economic growth policies and infrastructure development. Comparative assessments between CPEC locations and Taiwan offer insights into cost, location, security, and management considerations. Peshawar emerges as a top-performing location, excelling in management, while Port Qasim demonstrates a balanced performance. Tianjin in China holds significance for its excellent management and security ratings. Furthermore, this study evaluates alternatives using a weight-normalized fuzzy decision matrix, considering linguistic variables transformed into fuzzy ratings. The positive ideal and negative ideal options are determined, leading to the ranking of locations based on their proximity to the ideal solutions. Strategic recommendations derived from the findings emphasize the vital roles of key locations. Peshawar is recognized as a central transportation hub promoting regional connectivity, while Gwadar's strategic coastline linkages contribute to its significance. Tianjin's importance in China is underscored by its proximity to Beijing and its role as a regional logistics hub. The discussion elucidates the nuanced dynamics of LC location decisions, shedding light on the multifaceted considerations that contribute to the strategic positioning of logistics hubs in Pakistan and China. The integration of fuzzy–TOPSIS methodology, comparative analyses, and strategic recommendations enriches the understanding of the complexities involved in logistics center location planning.

6. Conclusions

In conclusion, establishing LCs is crucial for efficiently functioning supply chain networks. Careful thought must be given to the complications of defining and rating these centers, particularly in light of developing an inclusive LC system in China and Pakistan. To overcome the difficulties in location selection, this study has presented a decision-making framework that integrates fuzzy logic and TOPSIS. The research has identified important logistics hubs in China and Pakistan. It has produced a ranking list of the top 10 logistics center possibilities by considering factors like port accessibility and transportation costs. Furthermore, a comparison has been drawn between Taiwan and the CPEC, which clarifies location, cost, security, and administration issues. The suggested method improves the process of selecting LCs by doing away with uncertainty and accounting for various factors. This enhances the process and results in more intelligent and effective logistical plans. It is imperative to acknowledge the constraints, such as the absence of experts, potential bias, and extraneous elements that may distort the outcomes. To increase the study's relevance, real-time data integration, complex AI models, and dynamic standards for changing CPEC logistics environments should be considered for continual optimization. It is also critical to remember that the findings mostly relate to developing nations like China and Pakistan. Future studies should be conducted in developed nations with developed transportation infrastructure to replicate the findings.

Further research should investigate incorporating logistics center size as a factor. This study offers insightful information on the choice of logistics hubs and establishes the foundation for additional investigation and improvement in this crucial area of supply chain management.

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