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A PROPOSED FRAMEWORK TO OPTIMIZE WAREHOUSE SITE SELECTION FOR A 3PL SERVICE PROVIDER IN A RELOCATION PHASE

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ABSTRACT

In the dynamic global logistics landscape, third-party logistics (3PL) providers are pivotal, especially in regions like Ghana where economic activities rely heavily on efficient supply chains. This study addressed a notable void in the available research by focusing on tailored guidelines for warehouse site selection during relocation phases, a crucial yet understudied aspect for 3PL providers using Centrepoint Supply Chain Solutions Ltd. Drawing on a mixed-methods approach, the study investigated strategies for warehouse relocation, factors influencing site decisions, and their interrelationship. Findings revealed diverse relocation strategies, critical factors influencing warehouse site selection, and the relationship that exists between them. Employing the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS), the study identified the ideal warehouse site for a 3PL during relocation that aligns with their selected relocation strategy. By filling this knowledge gap and offering a tailored decision-making framework, this research enhances operational efficiency and strategic decision-making for 3PL providers, fostering sustainable growth in dynamic environments like Accra, Ghana

Keywords: Optimize, Relocation phase, Third Party (3PL) Logistics, Warehouse

1.0 INTRODUCTION

In today's rapidly evolving global marketplace, characterized by dynamic economic conditions and ever-increasing consumer demands, the role of third-party logistics (3PL) providers has become increasingly vital. Marasco's (2008) comprehensive literature review underscores the significant attention given to logistics outsourcing, commonly referred to as 3PL, by scholars worldwide. These 3PL entities serve as pivotal intermediaries, facilitating the seamless movement of products and services across intricate supply chains. In the context of Ghana's logistics landscape, the importance of 3PL providers cannot be overstated. These entities are vital components in optimizing supply chain operations, ensuring the timely delivery of goods to both domestic and international markets as emphasized by (Dzogbewu, 2010). Helm (2023) highlights the strategic significance of selecting warehouse sites to support the seamless functioning of logistics operations, particularly during relocation phases. Despite the growing importance of 3PL services in Ghana and beyond, there remains a notable gap in the literature concerning tailored guidelines for warehouse site decision for 3PL providers in a relocation phase.

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This literature gap poses significant challenges for 3PL providers operating in Ghana and other emerging economies. Blessing (2023) underscores the importance of clear strategies and methodologies to guide warehouse relocation decisions, and without such guidance, 3PLs may struggle to identify optimal warehouse sites that complement their company's objectives and current clients' needs. Therefore, addressing this gap in the literature is imperative for enhancing the operational capabilities and competitiveness of 3PL providers, not just in Ghana but also on the global stage.

To provide clarity, a 3PL, is a company that offers outsourced logistics services to businesses, managing various aspects of the supply chain, including warehousing, transportation, and distribution. These entities play a crucial role in ensuring the efficient movement of goods and services, particularly during periods of disruption or growth (Marasco, 2008). Additionally, they facilitate international trade by providing expertise in navigating complex customs regulations, managing cross-border shipments, and optimizing global supply chain networks (Skender, Host, & Nuhanović, 2016).

The strategic importance of 3PL providers extends beyond the local context, with implications for global trade and economic development. As businesses increasingly rely on outsourced logistics services to navigate complex supply chain dynamics, the role of 3PL providers in facilitating international trade and fostering global economic integration cannot be overlooked. Therefore, bridging the absence in the body of knowledge concerning tailored guidelines specific to 3PL providers having to select an ideal warehouse site when relocating is necessary not only to improve the operational efficiency of logistics operations but also for driving broader economic growth and competitiveness on a global scale.

The lack of tailored guidelines for warehouse site selection in a relocation phase poses a significant challenge for 3PL providers. Without clear strategies and methodologies to guide the decision-making process, 3PLs struggle to identify optimal warehouse sites that complement their business objectives and current clients' needs. Not only does this void in the knowledge hinder the efficiency and effectiveness of 3PL operations, but also undermines their ability to deliver value to clients in an increasingly competitive market. This study therefore seeks to optimize warehouse site selection for a 3PL service provider in a relocation phase.

The purpose of this paper is to identify strategies available for warehouse relocation, ascertain the key factors influencing warehouse site decision and optimize warehouse site selection for 3PLs during a relocation phase through a recommended framework (Fuzzy TOPSIS).

2.0 METHODOLOGY

The methodology employed aims to comprehensively explore warehouse site selection strategies for third-party logistics (3PL) providers using mixed methods consisting of qualitative and quantitative procedures. This study's research design makes use of both exploratory and experimental approaches to comprehensively address the objectives set forth, with a specific focus on Centrepoint Supply Chain Solutions Ltd in Accra, Ghana. In tandem with the qualitative exploration, a quantitative method was employed under the experimental approach. In the context of warehouse site selection for 3PL providers, the characteristics and features of experimental research, as discussed by Zubair (2022), underscore the importance of active manipulation of independent variables, control over relevant variables, and systematic observation of outcomes. This aligns closely with the objectives outlined, wherein the aim is to optimize warehouse site selection strategies. By employing experimental design, the study can effectively manipulate relocation strategies (independent variables) and observe their impact on site selection criteria (dependent variables) under controlled conditions. This approach ensures precision, control, and systematic analysis, essential for drawing specific conclusions regarding the effectiveness of different strategies (Zubair, 2022).

Moreover, Zubair (2022) highlights that experimental research is particularly appropriate when there's a need to understand cause-and-effect relationships precisely. This justification further supports the use of experimental design, as the objective is to determine the causal relationship between relocation strategies and warehouse site selection criteria for 3PL providers. Through experimental manipulation and controlled observation, the study can ascertain the direct impact of various strategies on site selection outcomes, thus fulfilling the research objective of optimizing warehouse site selection for 3PL providers in Accra, Ghana (Zubair, 2022).

In crafting the sampling strategy for this study, a purposive approach has been meticulously chosen to ensure the selection of participants who possess specific knowledge, experience, or characteristics pertinent to the research topic. This deliberate selection process allowed for targeting of individuals directly involved in warehouse site selection and relocation decisions within Centrepoint Supply Chain Solutions Ltd. The rationale behind this strategy lies in its ability to align closely with the research objectives, thereby ensuring that the collected data effectively addresses the study's focus. The projected sample size of six employees, which includes CP workers, strikes a balance between gathering enough information for a thorough study, efficiently allocating resources, and guaranteeing that each respondent gave their authorization to participate.

the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS) was used to evaluate alternative based on the level of importance assigned to the set of criteria by the respondents under the relocation strategy selected by the 3PL (Gradual Transition Without Dual Fulfillment). This structured approach allowed for the evaluation and ranking of potential warehouse sites based on predefined criteria and their relative level of importance, aligning with the research objective of validating the reliability of Fuzzy TOPSIS in evaluating warehouse site.

The Fuzzy TOPSIS analysis involved several steps, including defining evaluation criteria, evaluation of criteria by decision makers using the linguistic scale, translation of linguistic ratings to fuzzy triangular numbers, aggregation of fuzzy weights, computation of the weighted normalized decision matrix, computation of Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS), computation of Si+ and Si-, computation of closeness coefficient, and the ranking of alternatives. This quantitative analysis complements the qualitative findings, providing a systematic method for evaluating and comparing potential warehouse sites objectively.

Overall, the data analysis phase will integrate qualitative and quantitative findings to address the research objectives comprehensively, yielding insights into warehouse relocation strategies and their relationship with factors that influence warehouse site decision making; and the validation of the Fuzzy TOPSIS model for warehouse site decision in a relocation phase.

3.0 RESULTS

3.1 Participants

Six employees were purposively sampled for the study using questionnaires. The respondents comprised 6 individuals, majority in terms of gender was male (66.67%) while the female were minority (33.33%), with ages ranging from 18 to 60 years with majority of the respondents falling within the age range of 20-30 (50%), representing a younger cohort within the workforce. This group may bring fresh perspectives and technological savvy, reflecting the evolving landscape of the logistics industry. Participants had varying experience, ranging from 1 to 9 years (M = 4.8). Participation was voluntary, and no incentives were provided.

3.2 Available Relocation Strategies

Three strategies were reviewed through available literature. They include: Gradual transition strategy, Gradual transition strategy with dual fulfillment and Full and immediate transition strategy.

Firstly, the gradual transition strategy, as proposed by Tan, Wahab, and Sundarakani (2023), involves the gradual relocation of warehouse operations to a new site over an extended period. This approach aims to minimize disruptions and ensure a smooth transition. This strategy prioritizes transferring slow-moving inventory before fast-moving items.

In contrast to the gradual transition strategy, the second strategy, gradual transition strategy with dual fulfillment was recommended by Petersen & Aase (2016); Winograd (2021) and Blessing (2023) is a variant of the Gradual Transition discussed by Tan, Wahab, and Sundarakani (2023). It focuses on operating in both the old and new warehouses concurrently. This approach necessitates robust inventory management systems to ensure seamless fulfillment operations, as advocated by Blessing (2023).

The third strategy which is the full and immediate transition strategy, akin to Winograd's (2021) "rip the bandaid" method was recommended by Winograd (2021), Petersen & Aase (2016), and Tan, Wahab, and Sundarakani (2023). It involves the complete relocation of operations to the new site at once. Unlike the gradual or simultaneous approaches, operations in both warehouses cease entirely during the transition. The focus shifts to moving all inventories from the old warehouse to the new one before the new system can begin fulfillment.

Table 1: The available relocation strategies suggested by different authors

Authors	Relocation strategies in common	Brief description of relocation strategies
Winograd (2021) Petersen & Aase (2016)	Full and Immediate Transition Strategy (Rip the Bandaid)	Quick transition within 30 days by mass transfer of inventory/Managers assess feasibility of DC shutdown during relocation considering customer service, notice, and post-relocation operations/High-risk

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Tan, Wahab & Sundarakani (2023)	OR Decision on DC Shutdown/Big Bang Approach	strategy transferring all inventory over a weekend.
Winograd (2021) Blessing (2023) Petersen & Aase (2016)	Gradual Transition Strategy with Dual Fulfillment OR Decision on Simultaneous Operation of DCs	Splitting inventory between two locations and gradually fulfilling orders from both sites/Operating both DCs concurrently if shutdown isn't feasible, with risks and strategies to manage them
Tan, Wahab & Sundarakani (2023)	Gradual Transfer Approach by Region/Gradual Transfer Approach by Product Category OR Gradual Transition without Dual Fulfillment	Transferring inventory gradually by category over weeks/Transferring forecasted volume by region gradually over time/Transferring inventory gradually while fulfilling from the old warehouse only

3.3 Factors Influencing Warehouse Site Selection

Existing literature has enumerated some factors that influence warehouse site selection. Among them are Proximity to Transportation Networks (Škerlič & Muha, 2013), Labor Availability and Skill Level (Jantachalobon, 2023; Nouri, 2014/2015), Regulatory Compliance (Singh et al., 2018; Düzgün, 2020), Infrastructure (Nouri, 2014/2015; Düzgün, 2020).

Table 2: Factors influencing warehouse site selection suggested by different authors

Factors	Authors
Proximity to Transportation Networks	Škerlič & Muha, 2013
Labor Availability and Skill Level	Jantachalobon, 2023; Nouri, 2014/2015
Regulatory Compliance	Singh et al., 2018; Düzgün 2020
Infrastructure	Nouri, 2014/2015; Düzgün 2020

Relationship between Relocation Strategies and the Criteria for Warehouse Site Selection. The survey conducted to explore the relationship between relocation strategies and factors influencing warehouse site decisions for third-party logistics (3PL) service providers yielded insightful findings. Analysis of questionnaire responses revealed a notable correlation between the chosen relocation strategies and the perceived importance of various criteria in warehouse site decision-making.

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Respondents demonstrated inconsistency in rating the importance of criteria across different relocation scenarios. For instance, under the gradual transition strategy without dual fulfillment, respondents prioritized criteria such as regulatory compliance and lease flexibility. In contrast, under the full and immediate transition strategy, factors like utility infrastructure, warehouse capacity and scalability, and security measures received greater emphasis.

To define the selection criteria, the operations manager at CP was asked to suggest criteria that could be used to evaluate different site alternatives. These criteria were further compared to criteria identified in other papers addressing warehouse site decision. The comparison revealed that the criteria selected were recurrent across paper or at least appeared under a similar theme in their respect. These were then validated to be applicable for the study and are taken into account during site selection and they include the following:

- Proximity to Transportation network (C1): The geographic position of the warehouse site in relation to major transportation infrastructure such as highways, railways, ports, and airports. Proximity to these networks ensures efficient transportation of goods and facilitates logistical operations. 3PLs are always on the look for sites close to transportation networks for reduced lead times and cost effectiveness.
- Warehouse Capacity and Scalability (C2): The available space within the warehouse to store inventory and conduct operations. Scalability refers to the ability of the warehouse to accommodate future growth and expansion needs without significant disruption to operations. 3PLs are always on the look for sites with enough space to accommodate current and projected demand for warehouse space.
- Security Measures (C3): The measures in place to protect the warehouse, its contents, and personnel from theft, vandalism, or unauthorized access. This includes security systems such as surveillance cameras, access control systems, perimeter fencing, and security personnel. 3PLs have a responsibility to protect their clients' property. Hence, they value more secured sites.
- Lease Flexibility (C4): The degree to which the terms of the warehouse lease can be adjusted to meet the needs of the tenant. This may include flexibility in rates, payment terms, lease duration, termination options, and the ability to modify space requirements as needed. A landlord that offers more flexible lease terms often is less of a burden to tenants. Hence, a favorable option.
- Accessibility to Skilled Labor (C5): The availability of a skilled workforce in the vicinity of the warehouse site. This includes individuals with expertise in warehouse operations, logistics, inventory management, and other relevant skills necessary to efficiently run the warehouse. A location clustered with skilled labour is often the attractive option.
- Utility Infrastructure (C6): The availability and reliability of essential utilities such as electricity, water, gas, telecommunications, and internet connectivity at the warehouse site. Adequate utility infrastructure is essential to support day-to-day operations without interruption. A location with more of utility infrastructure is often what experts are on the lookout for.
- Regulatory Compliance (C7): Adherence to local, state, and for federal regulations governing warehouse operations, building codes, zoning ordinances, environmental regulations, and safety standards is essential to avoid legal issues and ensure operational compliance. A less strict jurisdiction is often a more attractive option.

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- Economic Indicators (C8): Economic factors such as local economic conditions, business environment, and cost of living can impact the feasibility and profitability of warehouse operations in a particular area. A less economically stressed or unstable location is often attractive.

Table 3: The linguistic Scale and Fuzzy numbers for evaluation of criteria

Linguistic rating	Triangular Fuzzy numbers (Lower bound, Mid bound, Upper bound)
Extremely Low (EL)	(0, 0, 0.1)
Very Low (VL)	(0, 0.1, 0.3)
Low (L)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
High (H)	(0.5, 0.7, 0.9)
Very High (VH)	(0.7, 0.9, 1)
Extremely High (EH)	(0.9, 1, 1)

3.4 Evaluation of Warehouse Sites under Gradual Transition Strategy

Step 1: Evaluation of Criteria by Decision Makers

Once the criteria are established, they undergo evaluation in the context of the selected relocation strategy, using a linguistic scale. Table 3 above illustrates the linguistic scale representing the weight or importance of the criteria and their respective triangular fuzzy numbers. Alternative sites, for this study, were identified by the company's staff and they chose to keep this information private. So, the alternatives are represented by: A1, A2, A3, A4, and A5. The linguistic rating assigned by the decision makers (respondents) to each criterion are detailed in Table 4.

Table 4: Evaluation of each criterion by decision makers

	CEO	Operations Manager	Warehouse Lead	Logistics Head	Customer Service Lead	Shop Floor Supervisor
C1	EH	VH	EH	H	H	M
C2	VH	H	VH	H	VH	H
C3	VH	H	H	H	VH	VH
C4	VH	VH	VH	H	H	EH
C5	H	VH	VH	M	EH	M
C6	VH	VH	VH	H	EH	EH
C7	EH	VH	VH	H	H	VH

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C8	EH	H	EH	H	VH	VH

Step 2: Translate Linguistic Ratings to Fuzzy Triangular Numbers

The linguistic terms representing the level of importance of the criteria are quantified into their corresponding triangular fuzzy numbers, which will serve as weights in the Fuzzy TOPSIS algorithm. The fuzzified criteria are presented in Table 5 below. The criteria in the green cells represent criteria for which higher magnitudes are favorable and those in red cells are criteria for which lower magnitudes are favorable. For example, a site closer to a transport network is favorable and a less strict jurisdiction is favorable. Separating them allows for accurate computation.

Table 5: Fuzzy weights/numbers of each criterion

	CEO			Operations Manager			Warehouse Lead			Logistics Head			Customer Service Lead			Shop Floor Supervisor		
C1	0.9	1	1	0.7	0.9	1	0.9	1	1	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7
C2	0.7	0.9	1	0.5	0.7	0.9	0.7	0.9	1	0.5	0.7	0.9	0.7	0.9	1	0.5	0.7	0.9
C3	0.7	0.9	1	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.7	0.9	1	0.7	0.9	1
C4	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1	0.5	0.7	0.9	0.5	0.7	0.9	0.9	1	1
C5	0.5	0.7	0.9	0.7	0.9	1	0.7	0.9	1	0.3	0.5	0.7	0.9	1	1	0.3	0.5	0.7
C6	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1	0.5	0.7	0.9	0.9	1	1	0.9	1	1
C7	0.9	1	1	0.7	0.9	1	0.7	0.9	1	0.5	0.7	0.9	0.5	0.7	0.9	0.7	0.9	1
C8	0.9	1	1	0.5	0.7	0.9	0.9	1	1	0.5	0.7	0.9	0.7	0.9	1	0.7	0.9	1

Step 3: Aggregate Fuzzy Weights

To generate aggregate fuzzy triangular numbers for each criterion, we average the fuzzy weights contributed by the decision-makers. This pivotal step ensures a cohesive representation of the fuzzy weights attributed to individual criteria and reduces potential bias from one decision maker.

For instance, let's examine the criterion "Proximity to Transport Network." Decision-makers offered linguistic ratings represented by fuzzy triangular numbers such as "Lower Bound" (L), "Mid Bound" (M), and "Upper Bound" (U). By computing the average membership value for each linguistic rating by all decision-makers, we derive the aggregated fuzzy triangular numbers.

This process entails calculating the mean membership value for every linguistic rate based on the input from all decision-makers. Suppose three decision-makers rate the criterion's importance using the linguistic scale which is then translated into fuzzy triangular number or weights given by membership values for lower, mid, and upper bounds. In that case, the average membership value for this set of fuzzy numbers is computed by finding the average of all lower bound values, all mid bound values, and all upper bound values. This results in a set of aggregated membership values representing the fuzzy triangular numbers for the criterion.

Following this method for all criteria enables the creation of aggregated fuzzy triangular numbers, which serve as comprehensive representations of the unbiased fuzzy weights associated with each criterion. These aggregated numbers are then utilized within the Fuzzy TOPSIS algorithm to facilitate effective decision-making in site selection.

In summary, the process of generating aggregated fuzzy triangular numbers entails consolidating the ratings provided by decision-makers to each criterion. This approach ensures the creation of a unified and representative set of fuzzy weights, thereby enhancing the efficacy of subsequent decision-making processes. Below is an example of how this calculation can be performed for C1 and rating by CEO (DCM 1), Operations Manager (DCM 2), and Warehouse Lead (DCM 3).

Table 6: Sample Fuzzy weights/Triangular Fuzzy Numbers for the Criterion, Proximity to Transport Network (C1)

	Lower (L-FW)	MID (M-FW)	Upper (U-FW)
Decision-maker 1	0.9	1	1
Decision-maker 2	0.7	0.9	0.1
Decision-maker 3	0.9	1	1

Computation of Average Fuzzy weight of the criterion, proximity to transport network:

Sum of lower membership values across all DCMs divided by number of DCMs: (0.9 + 0.7 + 0.9)/3 = 0.83

Sum of mid membership values across all DCMs divided by number of DCMs: (1 + 0.9 + 1)/3 = 0.96

Sum of upper membership values across all DCMs divided by number of DCMs: (1+ 0.1 + 1) / 3 = 0.70

So, the aggregated fuzzy triangular numbers for the criterion "proximity to transport network" if only three DCMs participated in the decision making process would be: (0.83, 0.96, 0.70).

This process was applied to each criterion to obtain their respective aggregated fuzzy triangular numbers taking into consideration all decision makers' input. The results are seen in Table 7 below.

Table 7: Aggregated Fuzzy weights/Triangular Fuzzy Numbers for the Criteria

	L-FW	M-FW	U-FW
ACCESS TO TRANSPORT NETWORK	0.63	0.80	0.92
WH CAPACITY & SCALABILITY	0.60	0.80	0.95

SECURITY MEASURES	0.60	0.80	0.95
LEASE FLEXIBLITY	0.67	0.85	0.97
ACCESSIBILTY TO SKILLED LABOR	0.57	0.75	0.88
UTILITY INFRASTRUCTURE	0.73	0.90	0.98
REGULATIONS	0.67	0.85	0.97
COST OF LIVING	0.70	0.87	0.97

Step 4: Weighted Normalized Decision Matrix

To construct a weighted normalized decision matrix, we multiply each entry in the normalized data matrix, representing the rating of each alternative against each criterion, by the lower, medium, and upper aggregated weights or fuzzy numbers. This process results in a fuzzy weighted normalized decision matrix that contains three fuzzified values (lower, medium, and upper) for each alternative against each criterion, indicating the weighted scores. However we need to normalize the data set first.

Step 4.1 Normalize Data set

Firstly; we need to normalize the data set containing the scores of each alternative under each criterion. To normalize the matrix containing the raw dataset, we'll apply the same normalization process to each cell in the matrix. Here's how to do it step by step:

Step 4.1.1 Calculate the Euclidean Norm for Each Column

For each column in the raw dataset, calculate the Euclidean norm, which is the square root of the sum of the squares of all values in that column.

For example, for the "Access to Transport Network" column, calculate the Euclidean norm using the formula:

$$\text{Euclidean Norm} = \sqrt{(x_1^2) + (x_2^2) + \ldots + (x_n^2)}$$

Where $x_1, x_2, \ldots, x_n$ are the values in that column.

Step 4.1.2 Normalize Each Cell

For each cell in the matrix, divide the original value in that cell by the Euclidean norm of the corresponding column. Repeat this process for all cells in the matrix.

Here's the formula to normalize each cell (i,j) in the matrix, where Xij represents the original value and Euclidean Normj represents the Euclidean norm of the column j:

$$\text{Normalized Value}_{ij} = \frac{X_{ij}}{\text{Euclidean Norm}_j}$$

Now, let's use this formula to calculate the normalized value for A1 in the "Access to Transport Network (C1)" column.

Original Value ij (value for A1 in the "C1" column) = 5

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values in the C1 column = 5, 5, 4, 3, 4

Then, we plug these values into the formula:

$$\text{Normalized Value}_{ij} = \frac{5}{\sqrt{(5^2)+(5^2)+(4^2)+(3^2)+(4^2)}}$$

Calculate the denominator:

$$\text{Denominator} = \sqrt{(5^2)+(5^2)+(4^2)+(3^2)+(4^2)} = \sqrt{91}$$

Now, calculate the normalized value:

$$\text{Normalized Value}_{ij} = \frac{5}{\sqrt{91}}$$

These steps are repeated for each cell in the data set matrix to obtain the normalized matrix in Table below. This normalization process ensures that each entry is scaled by the overall magnitude of its column, allowing for fair comparison across different columns.

Table 8: Data Set of Scores for Each Alternative against each Criterion

	DATA SET							
	POSITIVE CRITERIA					NEGATIVE CRITERIA		
	C1	C2	C3	C4	C5	C6	C7	C8
A1	5	5	4	3	5	4	2	3
A2	5	4	3	4	4	5	3	4
A3	4	4	4	3	5	4	2	3
A4	3	5	4	4	4	4	3	2
A5	4	3	3	2	4	3	3	3

Table 9: Normalized Data Set of Scores for Each Alternative Against Each Criterion

	NORMALIZED DATA							
	C1	C2	C3	C4	C5	C6	C7	C8
A1	0.5241	0.5241	0.4924	0.4082	0.5051	0.4417	0.3381	0.4376
A2	0.5241	0.4193	0.3693	0.5443	0.4041	0.5522	0.5071	0.5835
A3	0.4193	0.4193	0.4924	0.4082	0.5051	0.4417	0.3381	0.4376
A4	0.3145	0.5241	0.4924	0.5443	0.4041	0.4417	0.5071	0.2917
A5	0.4193	0.3145	0.3693	0.2722	0.4041	0.3313	0.5071	0.4376

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Now we can find the weighted normalized decision matrix. To prepare the weighted normalized decision matrix, we begin with the normalized data matrix, which outlines the ratings of each alternative against specific criteria. Each entry in this matrix represents the degree to which an alternative satisfies a particular criterion. Next, we introduce the aggregated weights or fuzzy numbers obtained earlier, which reflect the importance of each criterion and encompass the lower, medium, and upper bounds.

By multiplying each entry in the normalized data matrix by the corresponding lower, medium, and upper aggregated weights of their respective criterion, we derive three fuzzified values for each alternative/criterion pair. These values represent the weighted scores, accounting for both the relative importance of the criteria and the performance of alternatives across them. Upon completion of this computation for all criteria, we obtain a fuzzy weighted normalized decision matrix. This matrix provides a nuanced perspective, offering insight into the weighted evaluation of each alternative across all criteria while considering the inherent uncertainty in the decision-making process. In essence, the fuzzy weighted normalized decision matrix serves as a valuable tool for comprehensive analysis, guiding decision-makers by providing a structured assessment of alternatives that integrates both subjective judgments and objective criteria.

Example of the calculation

Table 10: Sample Normalized Data Matrix

	C1	C2
A1	0.5241	0.5241
A2	0.5241	0.4193

Aggregated Fuzzy Numbers for Criterion C1 = Lower Bound: 0.63, Mid Bound: 0.80, and Upper Bound: 0.92

To calculate the fuzzy weighted normalized decision matrix values for Criterion C1 against Alternative A1:

Lower Bound: 0.63 × 0.5241= 0.33196
Mid Bound: 0.80 × 0.5241= 0.41931
Upper Bound: 0.92 × 0.5241= 0.48046

Computation for Alternative A2 against Criterion C2:

Aggregated Fuzzy Numbers for Criterion C2: Lower Bound: 0.60, Mid Bound: 0.80, and Upper Bound: 0.95

Lower Bound: 0.60 × 0.4193= 0.25159
Medium Bound: 0.80 × 0.4193= 0.33545
Upper Bound: 0.95 × 0.4193= 0.39835

The same computation is performed for the other Alternative-Criterion pairs: A2-C1 and A1-C2. The results is compiled into the fuzzy weighted normalized decision matrix.

Table 11: Sample of Fuzzy weighted normalized decision matrix

	C1			C2		
	Lower Bound	Mid Bound	Upper Bound	Lower Bound	Mid Bound	Upper Bound
A1	0.33196	0.41931	0.48046	0.31449	0.41931	0.49794
A2	0.33196	0.41931	0.48046	0.25159	0.33545	0.39835

This process showcases the computation of the weighted normalized decision matrix for the criteria, C1 and C2 using the provided normalized matrix and aggregated fuzzy numbers. Similar calculations were performed for other criteria to complete the Fuzzy weighted normalized decision matrix. Table 12 showcases the final Fuzzy weighted normalized decision matrix after performing computations for every pair of Alternative-Criterion.

Table 12 Final Fuzzy weighted normalized decision matrix

		A1	A2	A3	A4	A5
Weighted Normalized Decision Matrix	C1	0.33196	0.33196	0.26557	0.19917	0.26557
		0.41931	0.41931	0.33545	0.25159	0.33545
		0.48046	0.48046	0.38437	0.28828	0.38437
	C2	0.31449	0.25159	0.25159	0.31449	0.18869
		0.41931	0.33545	0.33545	0.41931	0.25159
		0.49794	0.39835	0.39835	0.49794	0.29876
	C3	0.29542	0.22156	0.29542	0.29542	0.22156
		0.39389	0.29542	0.39389	0.39389	0.29542
		0.46775	0.35081	0.46775	0.46775	0.35081
	C4	0.27217	0.36289	0.27217	0.36289	0.18144
		0.34701	0.46268	0.34701	0.46268	0.23134
		0.39464	0.52619	0.39464	0.52619	0.26309
	C5	0.28621	0.22897	0.28621	0.22897	0.22897
		0.37881	0.30305	0.37881	0.30305	0.30305
		0.44615	0.35692	0.44615	0.35692	0.35692
	C6	0.32393	0.40492	0.32393	0.32393	0.24295
		0.39755	0.49694	0.39755	0.39755	0.29817
		0.43436	0.54296	0.43436	0.43436	0.32577
	C7	0.22537	0.33806	0.22537	0.33806	0.33806
		0.28735	0.43103	0.28735	0.43103	0.43103
		0.32679	0.49019	0.32679	0.49019	0.49019
	C8	0.30632	0.40842	0.30632	0.20421	0.30632
		0.37925	0.50567	0.37925	0.25283	0.37925
		0.42301	0.56401	0.42301	0.28201	0.42301

Step 5: Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS).

After computing the fuzzy weighted normalized decision matrix, the next step is to calculate the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS).

FPIS and FNIS, represented by A+ and A-, respectively, are determined based on the benefit (positive) criteria and the cost (negative) criteria. A+ values denote the maximum value of each positive criterion and the minimum value of each negative criterion, while A- values represent

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the minimum value of each benefit criterion and the maximum value of each cost criterion. The formula for A+ and A- calculation is as follows, and Table 13 illustrates the resulting A+ and A- values.

$$\tilde{A}_j^+ = \begin{cases} \text{Max}\,\tilde{N}_{ij} | j \in B \\ \text{Min}\,\tilde{N}_{ij} | j \in C \end{cases} \quad where\ i = 1, \dots, m$$

$$\tilde{A}_j^- = \begin{cases} \text{Min}\,\tilde{N}_{ij} | j \in B \\ \text{Max}\,\tilde{N}_{ij} | j \in C \end{cases} \quad where\ i = 1, \dots, m$$

Table 13: A+ and A- values

A+	A-
0.33196	0.19917
0.41931	0.25159
0.48046	0.28828
0.31449	0.18869
0.41931	0.25159
0.49794	0.29876
0.29542	0.22156
0.39389	0.29542
0.46775	0.35081
0.36289	0.18144
0.46268	0.23134
0.52619	0.26309
0.28621	0.22897
0.37881	0.30305
0.44615	0.35692
0.40492	0.24295
0.49694	0.29817
0.54296	0.32577
0.22537	0.33806
0.28735	0.43103
0.32679	0.49019
0.20421	0.40842
0.25283	0.50567
0.28201	0.56401

Step 6: Compute Si+ and Si-

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Having calculated A+ and A-, the next step is to compute the Euclidean distance of each alternative from FPIS and FNIS, denoted as Si+ and Si-, respectively. However, before determining Si+ and Si-, we need to find d, the distance between each alternative-criterion pair from the corresponding ideal solution of the criterion under scrutiny. The formula for finding d, applicable only to triangular fuzzy numbers, is as follows:

$$d(\tilde{A},\tilde{B}) = \sqrt{\frac{1}{3}[(a_l - b_l)^2 + (a_m - b_m)^2 + (a_u - b_u)^2]}$$

The process for calculating d for each alternative-criterion pair is as follows:

We subtract each A+ value from its corresponding membership (l,m,u) value under specific alternative-criterion pairs for the criterion under scrutiny. Then, we square each set of subtractions made for each membership value of a specific alternative-criterion pair, sum the resulting figures, divide the outcome by 3, and finally, find the square root of the resulting figure. The same process is followed for A- values.

The resulting Tables will be two matrices containing a value for each alternative-criterion pair, representing the distance of each alternative-criterion pair from the Fuzzy Ideal Solutions (positive ideal solution for calculations made with A+ values and negative ideal solution for calculations made with A- values) under each criterion.

Below is a practical example of how d is calculated:

Let's consider an alternative A1 and Criterion C1 and their triangular fuzzy numbers (l, m, u) values.

(L, M, U) for A1-C1= (0.33196, 0.41931, 0.48046)

For their corresponding A+ and A- values:

A+= (0.33196, 0.41931, 0.48046)

A−= (0.19917, 0.25159, 0.28828)

Using the formula, we calculate d as follows:

For A1-C1 pair using A+ values:

$$d_{A+} = \sqrt{\frac{((0.33196-0.33196)^2)+((0.41931-0.41931)^2)+((0.48046-0.48046)^2)}{3}}$$

$$d_{A+} = \sqrt{\frac{0^2+0^2+0^2}{3}}$$

$$d_{A+} = \sqrt{0}$$

$$d_{A+} = 0$$

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For A1-C1 pair using A- values:

$$d_{A-} = \sqrt{\frac{((0.33196-0.19917)^2)+((0.41931-0.25159)^2)+((0.48046-0.28828)^2)}{3}}$$
$$d_{A-} = \sqrt{\frac{(0.13279)^2+(0.16772)^2+(0.19218)^2}{3}}$$
$$d_{A-} = \sqrt{\frac{0.01763+0.02813+0.03694}{3}}$$
$$d_{A-} = \sqrt{\frac{0.08270}{3}}$$
$$d_{A-} = \sqrt{0.02757}$$
$$d_{A-} = 0.166030532$$

Tables 14 and 15 respectively display the resulting matrices when computation for all alternative-criterion pairs was done using A+ and A- values, with FPIS representing computation with A+ values and FNIS representing computation with A- values.

Table 14: d Values for each alternative-criterion pair using A+ values

	FNPS				
	A1	A2	A3	A4	A5
C1	0.00000	0.00000	0.08302	0.16603	0.08302
C2	0.00000	0.08348	0.08348	0.00000	0.16696
C3	0.00000	0.09802	0.00000	0.00000	0.09802
C4	0.11389	0.00000	0.11389	0.00000	0.22779
C5	0.00000	0.07523	0.00000	0.07523	0.07523
C6	0.09700	0.00000	0.09700	0.09700	0.19400
C7	0.00000	0.14147	0.00000	0.14147	0.14147
C8	0.12422	0.24843	0.12422	0.00000	0.12422

Table 15: d Values for each alternative-criterion pair using A- values

FNIS				
A1	A2	A3	A4	A5
0.16603	0.16603	0.08302	0.00000	0.08302

0.16696	0.08348	0.08348	0.16696	0.00000
0.09802	0.00000	0.09802	0.09802	0.00000
0.11389	0.22779	0.11389	0.22779	0.00000
0.07523	0.00000	0.07523	0.00000	0.00000
0.09700	0.19400	0.09700	0.09700	0.00000
0.14147	0.00000	0.14147	0.00000	0.00000
0.12422	0.00000	0.12422	0.24843	0.12422

After finding d, we then calculate Si+ and Si-. This is achieved by summing all fuzzy distances for each alternative against all criteria. This process converts the fuzzy distances to a crisp number, representing the distance of each alternative from the overall FPIS and FNIS for Si+ and Si- values, respectively. The formulas for finding Si+ and Si- are found below. Table 16 and 17 below demonstrates the resulting values of Si+ and Si- respectively.

$$S_i^+ = \sum_{j=1}^{n} d\left(\tilde{N}_{ij}, \tilde{A}_j^+\right) \quad i = 1, \dots, m; j = 1, \dots, n$$

$$S_i^- = \sum_{j=1}^{n} d\left(\tilde{N}_{ij}, \tilde{A}_j^-\right) \quad i = 1, \dots, m; j = 1, \dots, n$$

Table 16: Si+ values

SI+	0.33511
	0.64663
	0.50161
	0.47973
	1.1107

Table 17: Si- values

SI-	0.98282
	0.6713
	0.81633
	0.8382
	0.20723

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Step 7: Compute Closeness Coefficient

The subsequent step is to calculate the closeness coefficient (Cci) of each alternative, representing the distance of each alternative from the singular ideal solution (both positive and negative). The formula and process are as follows:

Cci = (Si-)/((Si+)+(Si-))

So, for each cell under Si-, we will divide it by the sum of its corresponding Si+ value and the Si- value in the Si- cell we selected earlier.

Table 18 below shows the resulting Cci value for each alternative

Table 18: Cci value for each alternative

	Cci
A1	0.745730119
A2	0.509358776
A3	0.619399608
A4	0.635997483
A5	0.157239321

Step 8: Ranking of Alternatives

The final step involves ranking the Cci values in descending order, where the alternative with the highest Cci value is the alternative closest to both the positive and negative ideal solution.

Table 19: Ranking of alternative

	Rank
A1	1
A2	4
A3	3
A4	2
A5	5

4.0 DISCUSSIONS

This segment of this study discusses the findings and insights regarding warehouse site selection for third-party logistics (3PL) service providers in a relocation phase. It is divided into two sections, focusing respectively on the relationship between relocation strategies and factors influencing warehouse site decisions, and the evaluation of potential warehouse sites using Fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS).

Relationship between Relocation Strategies and Factors Influencing Warehouse Site Decisions

The findings of this study reveal a significant relationship between the identified relocation strategies and the factors influencing warehouse site decisions for third-party logistics (3PL) service providers. Through the survey conducted using a questionnaire, it was observed that respondents demonstrated inconsistency in rating the importance of criteria across different relocation scenarios. This inconsistency implies that the selected relocation strategies indeed influence the perceived importance of each criterion for warehouse site decision-making.

The varying importance assigned to criteria across different relocation strategies suggests that different strategies necessitate different priorities in warehouse site selection. For instance, under the gradual transition strategy without dual fulfillment, respondents prioritized criteria such as regulatory compliance and lease flexibility, while under the full and immediate strategy they gave more weight to factors like utility infrastructure, warehouse capacity and scalability, and security measures. This variability underscores the need for 3PLs to tailor their warehouse site selection criteria according to the specific strategy being employed during relocation.

Evaluation of Potential Warehouse Sites Using Fuzzy TOPSIS

The application of Fuzzy TOPSIS in this study proved instrumental in evaluating potential warehouse sites for 3PL service providers during a relocation phase. Fuzzy TOPSIS, renowned for its ability to handle uncertainty and imprecision in decision-making, emerged as a vital mathematical model for selecting the best warehouse site under different relocation strategies.

After examining the alternative ranked first or closest to the positive and negative ideal solution (A1), I found out that indeed it aligned with the characteristics of the gradual transition without dual fulfillment. A1 scored relatively high scores under the positive criteria with high weights like utility infrastructure, warehouse capacity and security measures and also scoring relatively low scores under the negative criteria. This alignment validates the reliability of Fuzzy TOPSIS in solving warehouse site decision during relocation.

Moreover, the findings from the literature review support the efficacy of Fuzzy TOPSIS in warehouse location selection. Various studies have highlighted its strengths in integrating multiple criteria effectively and accommodating expert opinions to enhance the decision-making process. Additionally, the comparative analysis conducted by Jayant, Giri, and Ojha (2015) demonstrated the reliability and efficacy of TOPSIS in comparison to alternative evaluation models, reaffirming its suitability for warehouse site selection.

Despite its notable strengths, it is essential to acknowledge the limitations of Fuzzy TOPSIS, as pointed out by Erkayman et al. (2011) and others. The subjective nature of linguistic variables and fuzzy evaluation matrices may introduce bias into the decision-making process. Moreover, the implementation complexity, particularly in hybrid models, may pose challenges in practical application, necessitating expertise and computational resources.

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In conclusion, the utilization of Fuzzy TOPSIS for evaluating potential warehouse sites in a relocation phase offers a robust framework for decision-making, considering the nuanced relationship between identified strategies and factors influencing warehouse site selection. By leveraging the strengths of Fuzzy TOPSIS while addressing its limitations, 3PL service providers can enhance efficiency and customer service through informed warehouse site selection decisions tailored to the specific requirements of each relocation strategy.

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