

A Framework for 3PL Service Provider Appraisement using Fuzzy AHP





Presented by : Nitin Kumar Sahu Ph.D Scholar



Department of Mechanical Engineering National Institute of Technology, Rourkela-769008

Outlines

REUSE S RECYCLE

- Introduction
- ✓ Size & return percentage on Reverse Logistic
- Why Reverse Logistics take place
- Scope and activities
- Methodology Adopted
- Results and Discussions
- Conclusions
- References

Definitions

REUSE SI RECYCLE

✓ Logistics (Forward)

"Process of planning, implementing and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements"

- Council of Logistics, 1988

✓ Reverse Logistics

"Process of planning, implementing and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal"

- Rogers and Tibben-Lembke

WHY REVERSE LOGISTICS TAKE PLACE.....

- \checkmark Products that have failed, but can be repaired or reused.
- \checkmark Products that are obsolete but still have value.
- $\checkmark \quad Unsold products from retailers.$
- \checkmark Recalled products.
- \checkmark Parts repaired in the field that still have value.
- ✓ Items that have secondary usage, i.e. items that have another usage after they have exhausted their original use.
- ✓ Waste that must be accounted for and disposed of or used for energy production.
- \checkmark Containers that must be returned to their origin





- Helping The Customer
- Warehouse Operations
- Refund, Restock, Refurbish, Refilling
- Recycling and waste disposal
- Product recall
- Remanufacturing



Reverse Logistics Activities

✓ Handling of returned merchandise

- Damage
- Seasonal inventory
- Resell via outlet
- Salvage of outdated products
- Stock-balancing returns
- ✓ Recycling and reuse
 - Material reuse
 - Remanufacturing / refurbishing

 $\checkmark Hazardous\ materials\ disposition$





PRODUCT LIFE CYCLE

Supply Chain

AfterMarket Supply Chain

FORWARD LOGISTICS

New Product	Material	Manufacturing &
Development	Management	Distribution
 Design Development Technology Roadmaps ASIC Development Mechanical Design PCB Layout Prototyping New Product Introduction 	 Vendor Relations Planning Procurement Inventory Planning Component Fabrication 	 PCB Assembly Box Assembly Volume Manufacturing Integration Integration Configuration Final Testing Distribution to Customer Customer Fulfilment Transportation

REVERSE LOGISTICS

ASSOCIATION®

REVERSE LOGISTICS

AfterMarket Customer Service

- Customer Service (HelpDesk)
- Depot Repair

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- Service Logistics
 - Field Service
 - Transportation Warehousing
 - Spare Parts Management
 - RMA Management
 - Replacement Management
- End-of-Life Manufacturing
- Fulfilment Service
- IT Process Management
- Recycling
- Refurbishment / Screening
- Warranty Management
- "B" Channel Management
- Asset Management
- Environmental Resources
- Sustainability



"Reverse logistics costs in the United States are estimated to be approximately <u>4% of total</u> <u>U.S. logistics costs</u>"

- ROGERS, D., Reverse Logistics Challenges, 2002
- Roughly \$47 billions in 2006

"It is estimated that reverse logistics costs account for almost <u>1% of the total United States</u> gross domestic product"

-MOORE, R., Reverse logistics: The least used differentiator, 2006.
- Roughly \$132 billions in 2006

"The Center for Logistics Management at the University of Nevada conservatively estimates that <u>6% of all goods may be returned</u>, but concedes that the true number may be closer to 8%"

- MOORE, R., Reverse logistics: The least used differentiator, 2006.

Return Percentages



Industry	Percent
Magazine Publishing	50 %
Book Publishers	20-30 %
Book Distributors	10-20 %
Greeting Cards	20-30 %
Catalogue Retailers	18-35 %
Electronic Distributors	10-12 %
Computers Manufactures	10-20 %
CD ROMs	18-25 %
Printers	4-8 %
Mail Order Computer Manufactures	2-5 %
Mass Merchandisers	4-15 %
Auto Industry (Parts)	4-6 %
Consumer Electronics	4-5 %
House Hold Chemicals	2-3 %

Forward vs. Reverse Logistics

Differences Between Forward and Reverse Logistics

Forward Logistics

Forecasting relatively Straightforward

One to many distribution points

Product quality uniform

Product Packaging uniform

Destination / routing clear

Disposition options clear

Pricing relatively uniform

Importance of speed recognized

Forward distribution costs easily visible

Inventory management consistent

Product life cycle manageable

Negotiation between parties straightforward

Marketing methods well known

Visibility of process more transparent

Reverse Logistics

Forecasting more difficult

Many to one distribution points

Product quality not uniform

Product packaging often damaged Destination / routing unclear

Disposition not clear

Pricing dependent on many factors

Speed often not considered a priority

Reverse costs less directly visible

Inventory management not consistent

Product lifecycle issues more complex

Negotiations complicated by several factors

Marketing complicated by several factors

Visibility of process less transparent



PROPOSED EVALUATION MODEL: CASE STUDY

The reverse logistics performance evaluation index platform adapted in this paper has been shown in *Table 1*.

The 2-level hierarchical model consists of various indices: Attributes and Sub Attributes. Cost of Service, Reputation of the 3PL, Long-term Relationships, Finance, Service level, Infrastructure, Third party logistics services, Reverse logistics function, Organizational role, User satisfaction and IT Applications have been considered as the 1st level indices (called Attributes) followed by 2nd level indices which encompass a number of reverse logistics Sub Attributes.

An approach based on Fuzzy Analytic hierarchy process (FAHP) with Triangular Fuzzy Numbers Set (TFNS) has been used to evaluate an overall performance index. This method has been found fruitful for solving the group decision-making problem under uncertain environment due to vagueness, inconsistency and incompleteness associated with decision-makers' subjective evaluation. The proposed evaluation index platform has been explored by the reverse supply chain of an Indian automobile part manufacturing company at eastern part of India.

Proposed Supplier Appraisement Platform: Procedural

Hierarchy and Case Study

Step 1: The value of fuzzy synthetic extent with respect to the object is defined as:

A committee of Three decision-makers express their subjective preferences (priority importance) in linguistic terms (*Tables 2*).

Step 2: Since $\tilde{M_1} = \langle n_1, u_1 \rangle$ and $\tilde{M_2} = \langle n_2, u_2 \rangle$ are two triangular fuzzy

numbers, the degree of possibility $M_1 \ge M_2$ defined as:

$$V\left(\tilde{M}_{1} \geq \tilde{M}_{2}\right) = \sup_{x \geq y} \min \left(\mathcal{M}_{M_{1}} \otimes \mathcal{M}_{M_{2}} \otimes \mathcal{M}_{M_{2}} \right)$$
$$V\left(\tilde{M}_{2} \geq \tilde{M}_{1}\right) = hgt\left(\tilde{M}_{1} \cap \tilde{M}_{2}\right) = \mu_{M_{2}} \otimes \mathcal{M}_{M_{2}}$$

$$= \begin{cases} 1, & \text{if } m_2 \ge m_1, \\ 0, & \text{if } l_1 \ge u_2, \\ \hline l_1 - u_2 & \text{otherwise}, \end{cases}$$
(2)

Step 3: The degree possibility for a convex fuzzy number to be greater than

k convex fuzzy M_i (=1,2,...., k numbers can be defined by;

$$V \mathbf{M} \ge M_1, M_2, \dots, M_k$$

$$= V M \ge M_1$$
 and $M \ge M_2$ andand $M \ge M_k$

 $= \min V \quad M \ge M_i \quad i = 1, 2, ..., k.$ (3)

Step 4: Assume that $d \bigotimes_{i} = \min V \bigotimes_{i} S_{k}$ for $k = 1, 2, ..., n; k \neq i$ Then, the weight vector is given by

Where; $X_i = \langle 1, 2, ..., n \rangle$ are *n* elements

Step 5: Via normalization, the normalized weight vectors are:

Where; W is a non-fuzzy number that gives the priority weights of one criterion over another.

The normalized weight vectors are calculated as:

$$NW_i = \frac{W_i}{\sum W_i}$$

Consistency of pair-wise comparison matrix (Saaty, 1980, Alonso and Lamata, 2006, Ramik, and Korviny, 2010):

In classical AHP we consider an $n \times n$ pair-wise comparison matrix A with positive elements such that

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}$$
(7)

This matrix is *reciprocal*, if $a_{ij} = \frac{1}{a_{ji}}$ for each $1 \le i$, $j \le n$ We say that A is consistent if

for each $1 \le i, j, k \le n$

If for some i, j, k Equation (15) does not hold, than A is said to be *inconsistent*. In analytic hierarchy process (AHP), it is assumed that $\frac{1}{9} \le a_{ij} \le 9$ for all $1 \le i$, $j \le n$ Saaty, 1991. The inconsistency of A is measured by the consistency index CI_n as

Where λ_{\max} is the principle eigen value of A. It holds $CI_n \ge 0$

In practical decision situations inconsistency is "acceptable" if CR < 0.1

Saaty defined the consistency ratio $(CR)^{-1}$ as :

Where RI is the average value of CI for random matrices using the (Saaty, 1980,) given scale.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table 1: 3PL supplier evaluation criterions

	Attributes	Sub-attributes	Attributes	Sub-attributes
		Freight Price		Inventory replenishment
		Terms of Payment	Third party	Warehouse management
		Extra Costs	logistics	Shipment consolidation
	Cost of Service	IT capability	services	Carrier selection
	Cost of Service	Size and quality of fixed assets		Direct transportation services
		Delivery performance		Collection
		Employee satisfaction level		Packing
		Flexibility in operations and delivery	Reverse	Storage
		Market share	logistics	Sorting
	Reputation of	Geographic spread and access to retailers	function	Transitional processing
Evaluation	the 3PL	Market knowledge		Delivery
and		Experience in similar products		Reclaim
Selection of		Information sharing		Recycle
3 PL		Willingness to use logistics manpower	Organizational	Remanufacture
provider	Long-term	Trust and fairness	role	Re use
1	Relationships	Benefit and risk sharing		Disposal
	1	Quality of management		Effective communication
		Compatibility	User	Service improvement
		Cost of relationship	satisfaction	Cost saving
	Finance			Overall working relations
		Financial stability		Warehouse management
		Reliability and timeliness		Order management
	Service level	Quality of service		Supply chain planning
		Flexibility and responsiveness	IT Applications	Shipment and tracking
	Infrastructure			
		Logistics manpower		Freight payment

Table 2: Fuzzy Importance scale with Triangular Fuzzy Number for Criteria and Sub-Criteria

Verbal judgment	Triangular Fuzzy number	Triangular Fuzzy number (fraction form)	Reverse Triangular Fuzzy	Reverse Triangular Fuzzy number
		(number	(fraction form)
Just equal (JE)	(1, 1, 1)	(1.00, 1.00, 1.00)	(1, 1, 1)	(1.00, 1.00, 1.00)
Equally important (EI)	(1/2, 1, 3/2)	(0.50, 1.00, 1.50)	(2/3, 1, 2)	(0.67, 1.00, 2.00)
Weakly important (WI)	(1, 3/2, 2)	(1.00, 1.50, 2.00)	(1/2, 2/3, 1)	(0.50, 0.67, 1.00)
Strongly more important (SMI)	(3/2, 2, 5/2)	(1.50, 2.00, 2.50)	(2/5, 1/2, 2/3)	(0.40, 0.50, 0.67)
Very strongly more important (VSMI)	(2, 5/2, 3)	(2.00, 2.50, 3.00)	(1/3, 2/5, 1/2)	(0.33, 0.40, 0.50)
Absolutely more important (AMI)	(5/2, 3, 7/2)	(2.50, 3.00, 3.50)	(2/7, 1/3, 2/5)	(0.29, 0.33, 0.40)

Table 3: Fuzzy Pairwise Comparison matrix at Criteria level

Cri teri ons	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C9	C ₁₀	C ₁₁
C ₁	(1,1,1)	(1/3,2/5,1/2)	(2/3,1,2)	(1/2,2/3,1)	(2/5,1/2,2/3)	(1/3,2/5,1/2)	(1/2,2/3,1)	(2/5,1/2,2/3)	(1/3,2/5,1/2)	(2/3,1,2)	(2/5,1/2,2/3)
C ₂	(2,5/2,3)	(1,1,1)	(3/2,2,5/2)	(1/2,1,3/2)	(5/2,3,7/2)	(3/2,2,5/2)	(1/2,1,3/2)	(2,5/2,3)	(3/2,2,5/2)	(1/2,1,3/2)	(2,5/2,3)
C ₃	(1/2,1,3/2)	(2/5,1/2,2/3)	(1,1,1)	(3/2,2,5/2)	(3/2,2,5/2)	(1/3,2/5,1/2)	(1,3/2,2)	(3/2,2,5/2)	(1,3/2,2)	(1/3,2/5,1/2)	(3/2,2,5/2)
C ₄	(1,3/2,2)	(2/3,1,2)	(2/5,1/2,2/3)	(1,1,1)	(5/2,3,7/2)	(1/2,2/3,1)	(2,5/2,3)	(2/3,1,2)	(1/2,2/3,1)	(5/2,3,7/2)	(2/3,1,2)
C ₅	(3/2,2,5/2)	(2/7,1/3,2/5)	(2/5,1/2,2/3)	(2/7,1/3,2/5)	(1,1,1)	(1/2,2/3,1)	(2/3,1,2)	(1/2,2/3,1)	(2,5/2,3)	(2/3,1,2)	(2,5/2,3)
C ₆	(2,5/2,3)	(2/5,1/2,2/3)	(2,5/2,3)	(1,3/2,2)	(1,3/2,2)	(1,1,1)	(2/3,1,2)	(5/2,3,7/2)	(2/3,1,2)	(2/5,1/2,2/3)	(5/2,3,7/2)
C ₇	(1,3/2,2)	(2/3,1,2)	(1/2,2/3,1)	(1/3,2/5,1/2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)	(2/7,1/3,2/5)	(2/3,1,2)	(2/7,1/3,2/5)
C ₈	(3/2,2,5/2)	(1/3,2/5,1/2)	(2/5,1/2,2/3)	(1/2,1,3/2)	(1,3/2,2)	(2/7,1/3,2/5)	(1/2,1,3/2)	(1,1,1)	(1/3,2/5,1/2)	(1/2,2/3,1)	(1/2,1,3/2)
C ₉	(2,5/2,3)	(2/5,1/2,2/3)	(1/2,2/3,1)	(1,3/2,2)	(1/3,2/5,1/2)	(1/2,1,3/2)	(5/2,3,7/2)	(2,5/2,3)	(1,1,1)	(2,5/2,3)	(2/5,1/2,2/3)
C ₁₀	1/2,1,3/2)	(2/3,1,2)	(2,5/2,3)	(2/7,1/3,2/5)	(1/2,1,3/2)	(3/2,2,5/2)	(1/2,1,3/2)	(1,3/2,2)	(1/3,2/5,1/2)	(1,1,1)	(1/3,2/5,1/2)
C ₁₁	(3/2,2,5/2)	1/3,2/5,1/2)	(3/2,2,5/2)	(1/2,1,3/2)	(1/3,2/5,1/2)	(2/7,1/3,2/5)	5/2,3,7/2)	(2/3,1,2)	(3/2,2,5/2)	(2,5/2,3)	(1,1,1)

By applying Equation (1), the value of fuzzy synthetic extent with respect to the goal were calculated:

 S_1 (Cost of Service) = (0.028, 0.047, 0.092)

 S_3 (Long-term Relationships) = (0.053, 0.095, 0.159)

 S_5 (Service level) = (0.049, 0.083, 0.148)

 S_8 (Reverse logistics function) = (0.034, 0.065, 0.114)

 S_{10} (User satisfaction) = (0.043, 0.080, 0.143)

 S_7 (Third party logistics services) = (0.032, 0.061, 0.125)

 S_2 (Reputation of the 3PL) = (0.078, 0.136, 0.223)

 S_4 (Finance) = (0.062, 0.105, 0.189)

 S_6 (Infrastructure) = (0.071, 0.119, 0.204)

 S_9 (Organizational role) = (0.063, 0.106, 0.173)

 S_{11} (IT Applications) = (0.061, 0.104, 0.174)

These synthetic values were compared by using Equation (2), and the same is given in Table 15.

With the help of equations (3), (4) and (5), the minimum degree of possibility of superiority of each criterion over another is obtained. This further decides the weight vectors of the criteria. Therefore, the weight vector is given as:

W' = (0.136, 1.000, 0.663, 0.783, 0.571, 0.884, 0.387, 0.339, 0.765, 0.542, 0.749)

The normalized value of this vector decides the priority weights of each criterion over another. The normalized weight vectors are calculated using the Equation (6) and the same is given in Table 16.

Table 4: Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C1)

Sub- criteria	C ₁₁	C ₁₂	C ₁₃	C ₁₄	C ₁₅	C ₁₆	C ₁₇	C ₁₈
C ₁₁	(1,1,1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(2/5, 1/2, 2/3)
C ₁₂	(1, 3/2, 2)	(1,1,1)	(5/2, 3, 7/2)	(2, 5/2, 3)	(1, 3/2, 2)	(5/2, 3, 7/2)	(2, 5/2, 3)	(1, 3/2, 2)
C ₁₃	(3/2, 2, 5/2)	(2/7, 1/3, 2/5)	(1,1,1)	(2/3, 1, 2)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(2/3, 1, 2)	(3/2, 2, 5/2)
C ₁₄	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(1,1,1)	(2/7, 1/3, 2/5)	(1/2, 2/3, 1)	(2/7, 1/3, 2/5)	(1/2, 2/3, 1)
C ₁₅	(5/2, 3, 7/2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(5/2, 3, 7/2)	(1,1,1)	(1/2, 1, 3/2)	(1/2, 2/3, 1)	(1/2, 1, 3/2)
C ₁₆	(3/2, 2, 5/2)	(2/7, 1/3, 2/5)	(2/7, 1/3, 2/5)	(1, 3/2, 2)	(2/3, 1, 2)	(1,1,1)	(1, 3/2, 2)	(5/2, 3, 7/2)
C ₁₇	(2, 5/2, 3)	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(5/2, 3, 7/2)	(1, 3/2, 2)	(1/2, 2/3, 1)	(1,1,1)	(2, 5/2, 3)
C ₁₈	(3/2, 2, 5/2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1, 3/2, 2)	(2/3, 1, 2)	(2/7, 1/3, 2/5)	(1/3, 2/5, 1/2)	(1,1,1)

Table 5: Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C2)

Sub-criteria	C ₂₁	C ₂₂	C ₂₃	C ₂₄
C ₂₁ (1,1,1)		(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(2/5, 1/2, 2/3)
C ₂₂	(3/2, 2, 5/2)	(1,1,1)	(1, 3/2, 2)	(1/2, 1, 3/2)
C ₂₃	C ₂₃ (2, 5/2, 3)		(1,1,1)	(1, 3/2, 2)
C ₂₄	(3/2, 2, 5/2)	(2/3, 1, 2)	(1/2, 2/3, 1)	(1,1,1)

Table 6: Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C3)

Sub- criteria	C ₃₁	C ₃₂	C ₃₃	C ₃₄	C ₃₅	C ₃₆	C ₃₇
C ₃₁	(1,1,1)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(2/3, 1, 2)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(5/2, 3, 7/2)
C ₃₂	(2/5, 1/2, 2/3)	(1,1,1)	(1, 1, 1)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(1, 1, 1)	(1/2, 1, 3/2)
C ₃₃	(2/7, 1/3, 2/5)	(1, 1, 1)	(1,1,1)	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)
C ₃₄	(1/2, 1, 3/2)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(1,1,1)	(2/3, 1, 2)	(1/2, 1, 3/2)	(2, 5/2, 3)
C ₃₅	(2/5, 1/2, 2/3)	(2/3, 1, 2)	(2, 5/2, 3)	(1/2, 1, 3/2)	(1,1,1)	(2/3, 1, 2)	(2/7, 1/3, 2/5)
C ₃₆	(2/3, 1, 2)	(1, 1, 1)	(3/2, 2, 5/2)	(2/3, 1, 2)	(1/2, 1, 3/2)	(1,1,1)	(1, 3/2, 2)
C ₃₇	(2/7, 1/3, 2/5)	(2/3, 1, 2)	(2, 5/2, 3)	(1/3, 2/5, 1/2)	(5/2, 3, 7/2)	(1/2, 2/3, 1)	(1,1,1)

Table 7: Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C4)

Sub-criteria	C ₄₁	C ₄₂
C ₄₁	(1,1,1)	(1/3, 2/5, 1/2)
C ₄₂	(2, 5/2, 3)	(1,1,1)

 Table 8: Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C5)

Sub-criteria	C ₅₁	C ₅₂	C ₅₃
C ₅₁	(1,1,1)	(2, 5/2, 3)	(2, 5/2, 3)
C ₅₂	(1/3, 2/5, 1/2)	(1,1,1)	(2/3, 1, 2)
C ₅₃	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(1,1,1)

 Table 9: Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C6)

Sub-criteria	C ₆₁	C ₆₂
C ₆₁	(1,1,1)	(2/5, 1/2, 2/3)
C ₆₂	(3/2, 2, 5/2)	(1,1,1)

 Table 10: Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C7)

Sub-criteria	C ₇₁	C ₇₂	C ₇₃	C ₇₄	C ₇₅
C ₇₁	(1,1,1)	(1/2, 1, 3/2)	(2, 5/2, 3)	(1/2, 1, 3/2)	(2, 5/2, 3)
C ₇₂	(2/3, 1, 2)	(1,1,1)	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(1/3, 2/5, 1/2)
C ₇₃	(1/3, 2/5, 1/2)	(2, 5/2, 3)	(1,1,1)	(3/2, 2, 5/2)	(1, 1, 1)
C ₇₄	(2/3, 1, 2)	(2/3, 1, 2)	(2/5, 1/2, 2/3)	(1,1,1)	(1/3, 2/5, 1/2)
C ₇₅	(1/3, 2/5, 1/2)	(2, 5/2, 3)	(1, 1, 1)	(2, 5/2, 3)	
Table 11: Fu	zzy Pair-wise	Compariso	n matrix at S	ub-criteria	level for (C8)

Sub-criteria	C ₈₁	C ₈₂	C ₈₃	C ₈₄	C ₈₅	C ₈₆
C ₈₁	(1,1,1)	(1, 3/2, 2)	(1/2, 2/3, 1)	(5/2, 3, 7/2)	(1, 1, 1)	(1/2, 2/3, 1)
C ₈₂	(1/2, 2/3, 1)	(1,1,1)	(1/2, 1, 3/2)	(2, 5/2, 3)	(1/2, 1, 3/2)	(1, 1, 1)
C ₈₃	(1, 3/2, 2)	(2/3, 1, 2)	(1,1,1)	(5/2, 3, 7/2)	(1/2, 2/3, 1)	(5/2, 3, 7/2)
C ₈₄	(2/7, 1/3, 2/5)	(1/3, 2/5, 1/2)	(2/7, 1/3, 2/5)	(1,1,1)	(2, 5/2, 3)	(3/2, 2, 5/2)
C ₈₅	(1, 1, 1)	(2/3, 1, 2)	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(1,1,1)	(1, 1, 1)
Car	$(1 \ 3/2 \ 2)$	(1 1 1)	(2/7 1/3 2/5)	$(2/5 \ 1/2 \ 2/3)$	$(1 \ 1 \ 1)$	(1 1 1)

Table 12: Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C9)

Sub-criteria	C ₉₁	C ₉₂	C ₉₃	C ₉₄	C ₉₅
C ₉₁	(1,1,1)	(3/2, 2, 5/2)	(2/3, 1, 2)	(3/2, 2, 5/2)	(2/3, 1, 2)
C ₉₂	(2/5, 1/2, 2/3)	(1,1,1)	(2/3, 1, 2)	(1/2, 2/3, 1)	(5/2, 3, 7/2)
C ₉₃	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(1,1,1)	(2/3, 1, 2)	(2/5, 1/2, 2/3)
C ₉₄	(2/5, 1/2, 2/3)	(1, 3/2, 2)	(1/2, 1, 3/2)	(1,1,1)	(3/2, 2, 5/2)
C ₉₅	(1/2, 1, 3/2)	(2/7, 1/3, 2/5)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)	(1,1,1)

Table 13: Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C10)

Sub-criteria	C ₁₀₁	C ₁₀₂	C ₁₀₃	C ₁₀₄
C ₁₀₁	(1,1,1)	(5/2, 3, 7/2)	(1/2, 2/3, 1)	(1/2, 2/3, 1)
C ₁₀₂	(2/7, 1/3, 2/5)	(1,1,1)	(2/3, 1, 2)	(2, 5/2, 3)
C ₁₀₃	(1, 3/2, 2)	(1/2, 1, 3/2)	(1,1,1)	(1/2, 1, 3/2)
C ₁₀₄	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(2/3, 1, 2)	(1,1,1)

Table 14: Fuzzy Pair-wise Comparison matrix at Sub-criteria level for (C11)

Sub-criteria	C ₁₁₁	C ₁₁₂	C ₁₁₃	C ₁₁₄	C ₁₁₅
C ₁₁₁	(1,1,1)	(1, 1, 1)	(1, 3/2, 2)	(2/5, 1/2, 2/3)	(5/2, 3, 7/2)
C ₁₁₂	(1, 1, 1)	(1,1,1)	(2/7, 1/3, 2/5)	(1, 1, 1)	(3/2, 2, 5/2)
C ₁₁₃	(1/2, 2/3, 1)	(5/2, 3, 7/2)	(1,1,1)	(1/2, 1, 3/2)	(3/2, 2, 5/2)
C ₁₁₄	(3/2, 2, 5/2)	(1, 1, 1)	(2/3, 1, 2)	(1,1,1)	(2/3, 1, 2)
C ₁₁₅	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)	(1/2, 1, 3/2)	(1,1,1)

Table 15: The degree of possibility of main criteria

V(S1>S2)	0.136	V(\$2>\$1)	1.000	V(S3>S1)	1.000	V(S4>S1)	1.000	V(S5>S1)	1.000	V(S11>S1)	1.000
V(S1>S3)	0.446	V(S2>S3)	1.000	V(S3>S2)	0.663	V(S4>S2)	0.783	V(S5>S2)	0.571	V(S11>S2)	0.749
V(S1>S4)	0.336	V(S2>S4)	1.000	V(S3>S4)	0.905	V(S4>S3)	1.000	V(S5>S3)	0.889	V(S11>S3)	1.000
V(S1>S5)	0.540	V(S2>S5)	1.000	V(S3>S5)	1.000	V(S4>S5)	1.000	V(S5>S4)	0.796	V(S11>S4)	0.988
V(S1>S6)	0.223	V(S2>S6)	1.000	V(S3>S6)	0.782	V(S4>S6)	0.892	V(S5>S6)	0.680	V(S11>S5)	1.000
V(S1>S7)	0.804	V(S2>S7)	1.000	V(S3>S7)	1.000	V(S4>S7)	1.000	V(S5>S7)	1.000	V(S11>S6)	0.868
V(S1>S8)	0.758	V(S2>S8)	1.000	V(S3>S8)	1.000	V(S4>S8)	1.000	V(S5>S8)	1.000	V(S11>S7)	1.000
V(S1>S9)	0.322	V(S2>S9)	1.000	V(S3>S9)	0.891	V(S4>S9)	1.000	V(S5>S9)	0.782	V(S11>S8)	1.000
V(S1>S10)	0.589	V(S2>S10)	1.000	V(S3>S10)	1.000	V(S4>S10)	1.000	V(S5>S10)	1.000	V(S11>S9)	0.975
V(S1>S11)	0.352	V(S2>S11)	1.000	V(S3>S11)	0.917	V(S4>S11)	1.000	V(S5>S11)	0.808	V(S11>S10)	1.000
V(S6>S1)	1.000	V(S7>S1)	1.000	V(S8>S1)	1.000	V(S9>S1)	1.000	V(S10>S1)	1.000		
V(S6>S2)	0.884	V(S7>S2)	0.387	V(S8>S2)	0.339	V(S9>S2)	0.765	V(S10>S2)	0.542		
V(S6>S3)	1.000	V(S7>S3)	0.682	V(S8>S3)	0.672	V(S9>S3)	1.000	V(S10>S3)	0.863		
V(S6>S4)	1.000	V(S7>S4)	0.589	V(S8>S4)	0.565	V(S9>S4)	1.000	V(S10>S4)	0.768		
V(S6>S5)	1.000	V(S7>S5)	0.778	V(S8>S5)	0.784	V(S9>S5)	1.000	V(S10>S5)	0.975		
V(S6>S7)	1.000	V(S7>S6)	0.482	V(S8>S6)	0.443	V(S9>S6)	0.889	V(S10>S6)	0.651		
V(S6>S8)	1.000	V(S7>S8)	0.960	V(S8>S7)	1.000	V(S9>S7)	1.000	V(S10>S7)	1.000		
V(S6>S9)	1.000	V(S7>S9)	0.576	V(S8>S9)	0.550	V(S9>S8)	1.000	V(S10>S8)	1.000		
V(S6>S10)	1.000	V(S7>S10)	0.810	V(S8>S10)	0.821	V(S9>S10)	1.000	V(S10>S9)	0.754		
V(\$6>\$11)	1.000	V(\$7>\$11)	0.602	V(S8>S11)	0.580	V(\$9>\$11)	1.000	V(S10>S11)	0.781		

By following the same procedure, the pair-wise comparison matrix for sub criteria is constructed

with the help of expert team and the same is shown in *Table 4–14*, and the priority weights of

sub-criteria were calculated as given in Table 17.

The global composite priority weights given in *Table 18* were calculated by multiplying the

priority weights of sub-criteria with those of their corresponding main criteria in the next higher

level of the hierarchy, indicating the ranking order of sub attribute / criteria. This indicates that

Logistics manpower (0.129618) is the most important sub criteria in selecting a 3PL provider,

followed by various other sub criteria.

Table 16: The normalized priority weight vectors of the main criteria

Main Criterions	Priority Weight
Cost of Service	0.0199
Reputation of the 3PL	0.1466
Long-term Relationships	0.0973
Finance	0.1148
Service level	0.0837
Infrastructure	0.1296
Third party logistics services (3PLS)	0.0568
Reverse logistics function (RLFs)	0.0498
Organizational role (OR)	0.1122
User satisfaction (US)	0.0795
IT Applications (IT)	0.1098

Table 17: The normalized priority weight vectors of the Sub criterions

Sub criterions	Priority Weight	Sub criterions	Priority Weight
Freight Price	0.00000	Inventory replenishment (3PLS1)	0.28637
Terms of Payment	0.26376	Warehouse management (3PLS2)	0.09665
Extra Costs	0.19055	Shipment consolidation (3PLS3)	0.23681
IT capability	0.00000	Carrier selection (3PLS4)	0.12032
Size and quality of fixed assets	0.14885	Direct transportation services (3PLS5)	0.25985
Delivery performance	0.14846	Collection (RLF1)	0.21104
Employee satisfaction level	0.18761	Packing (RLF2)	0.18356
Flexibility in operations and delivery	0.06078	Storage (RLF3)	0.31072
Market share	0.01013	Sorting (RLF4)	0.13778
Geographic spread and access to retailers	0.34335	Transitional processing (RLF5)	0.11487
Market knowledge	0.35392	Delivery (RLF6)	0.04202
Experience in similar products	0.29260	Reclaim (OR1)	0.24589
Information sharing	0.26796	Recycle (OR2)	0.21925
Willingness to use logistics manpower	0.11385	Remanufacture (OR3)	0.16253
Trust and fairness	0.00257	Re use (OR4)	0.21172
Benefit and risk sharing	0.14177	Disposal (OR5)	0.16062
Quality of management	0.13627	Effective communication (US1)	0.28899
Compatibility	0.16918	Service improvement (US2)	0.26171
Cost of relationship	0.16840	Cost saving (US3)	0.24193
Logistics costs	0.00000	Overall working relations (US4)	0.20737
Financial stability	1.00000	Warehouse management (IT1)	0.27488
Reliability and timeliness	0.50000	Order management (IT2)	0.15537
Quality of service	0.00000	Supply chain planning (IT3)	0.31088
Flexibility and responsiveness	0.50000	Shipment and tracking (IT4)	0.23854
IT/IS capability	0.00000	Freight payment (IT5)	0.02032
Logistics manpower	1.00000		

Table 18: Overall ranking of sub criteria forEvaluation and Selection of 3PL provider



Goal	Attributes (Level 1)	Priority Weight (Level 1)	Sub-attributes (Level 2)	Priority Weight (Level 2)	Overall Priority Weight	Ranking
Goal			C ₁₁	0.00000	0.000000	46
		0.0100	C ₁₂	0.26376	0.005251	36
			C ₁₃	0.19055	0.003794	37
	(\mathbf{C})		C ₁₄	0.00000	0.000000	46
	(C_1)	0.0199	C ₁₅	0.14885	0.002963	39
Evaluation and Selection of 3 PL provider			C ₁₆	0.14846	0.002956	40
			C ₁₇	0.18761	0.003735	38
			C ₁₈	0.06078	0.001210	44
			C ₂₁	0.01013	0.001485	43
	(\mathbf{C})	0.1466	C ₂₂	0.34335	0.050349	4
	(C_2)		C ₂₃	0.35392	0.051901	3
			C ₂₄	0.29260	0.042908	5
			C ₃₁	0.26796	0.026070	11
	(C ₃)	0.0973	C ₃₂	0.11385	0.011076	29
			C ₃₃	0.00257	0.000251	45
			C ₃₄	0.14177	0.013793	26
			C ₃₅	0.13627	0.013258	28
			C ₃₆	0.16918	0.016459	21
			C ₃₇	0.16840	0.016384	22
	$(\mathbf{C}_{\mathbf{r}})$	0 1148	C ₄₁	0.00000	0.000000	46
	(04)	0.1110	C ₄₂	1.00000	0.114818	2
			C ₅₁	0.50000	0.041854	6
	(C ₅)	0.0837	C ₅₂	0.00000	0.000000	46
			C ₅₃	0.50000	0.041854	6
	(\mathbf{C})	0 1296	C ₆₁	0.00000	0.000000	46
	(~_6)	0.1270	C ₆₂	1.00000	0.129618	1

Goal	Attributes (Level 1)	Priority Weight (Level 1)	Sub-attributes (Level 2)	Priority Weight (Level 2)	Overall Priority Weight	Ranking	
			C ₇₁	0.28637	0.016269	23	
			C ₇₂	0.09665	0.005491	35	
	(C ₇)	0.0568	C ₇₃	0.23681	0.013453	27	
			C ₇₄	0.12032	0.006835	33	
	$ \begin{array}{ c c c c c c } \hline \mbox{Attributes} & \mbox{Priority Weight} & \mbox{(Level 1)} & \mbox{(Level 2)} & \mbox{Priority Weight} & \mbox{(Level 2)} & \mbox{WW} \\ \hline \mbox{(Level 1)} & \mbox{(Level 1)} & \mbox{(Level 2)} & \mbox{WW} \\ \hline \mbox{(Level 1)} & \mbox{(Level 1)} & \mbox{(Level 2)} & \mbox{WW} \\ \hline \mbox{(Level 1)} & \mbox{(Level 1)} & \mbox{(Level 2)} & \mbox{WW} \\ \hline \mbox{(C_7)} & \mbox{0.0568} & \mbox{C_{71}} & \mbox{0.09665} & \mbox{0.00} \\ \hline \mbox{C_{72}} & \mbox{0.09665} & \mbox{0.00} \\ \hline \mbox{C_{74}} & \mbox{0.12032} & \mbox{0.00} \\ \hline \mbox{C_{75}} & \mbox{0.23681} & \mbox{0.00} \\ \hline \mbox{C_{75}} & \mbox{0.25985} & \mbox{0.00} \\ \hline \mbox{C_{75}} & \mbox{0.25985} & \mbox{0.00} \\ \hline \mbox{C_{82}} & \mbox{0.18356} & \mbox{0.00} \\ \hline \mbox{C_{83}} & \mbox{0.31072} & \mbox{0.00} \\ \hline \mbox{C_{84}} & \mbox{0.31072} & \mbox{0.00} \\ \hline \mbox{C_{85}} & \mbox{0.11487} & \mbox{0.00} \\ \hline \mbox{C_{86}} & \mbox{0.04202} & \mbox{0.00} \\ \hline \mbox{C_{92}} & \mbox{0.24589} & \mbox{0.00} \\ \hline \mbox{C_{92}} & \mbox{0.16253} & \mbox{0.00} \\ \hline \mbox{C_{95}} & \mbox{0.16062} & \mbox{0.00} \\ \hline \mbox{C_{95}} & \mbox{0.16062} & \mbox{0.00} \\ \hline \mbox{C_{101}} & \mbox{0.28899} & \mbox{0.0} \\ \hline \mbox{C_{102}} & \mbox{0.26171} & \mbox{0.0} \\ \hline \mbox{C_{102}} & \mbox{0.26171} & \mbox{0.0} \\ \hline \mbox{0.0} \end{tabular}$	0.014762	25				
			C ₈₁	0.21104	0.010506	30	
(C ₈)	(C ₈)	0.0498	C ₈₂	0.18356	0.009138	31	
			C ₈₃	0.31072	0.015468	24	
			C ₈₄	0.13778	0.006859	32	
			C ₈₅	0.11487	0.005719	34	
			C ₈₆	0.04202	0.002092	42	
Evaluation and			C ₉₁	0.24589	0.027579	9	
Selection			C ₉₂	0.21925	0.024591	12	
of 3 PL provider	$(\mathbf{C}_{\mathbf{r}})$	0.1122	C ₉₃	0.16253	0.018229	17	
	(09)		C ₉₄	0.21172	0.023747	13	
			C ₉₅	0.16062	0.018015	18	
			C ₁₀₁	0.28899	0.022961	14	
	$(\mathbf{C}_{\mathbf{i}})$	0.0705	C ₁₀₂	0.26171	0.020794	15	
	(C_{10})	0.0793	C ₁₀₃	0.24193	0.019222	16	
			C ₁₀₄	0.20737	0.016476	20	
			C ₁₁₁	0.27488	0.030184	8	
			C ₁₁₂	0.15537	0.017061	19	
	(C ₁₁)	0.1098	C ₁₁₃	0.31088	0.034137	7	
			C ₁₁₄	0.23854	0.026193	10	
			C ₁₁₅	0.02032	0.002232	41	

Table 19: Pairwise comparison judgment matrix for Nine-point rating scale

Sub criteria	Outstan ding	Excell ent	Very Good	Above Average	Aver age	Below Average	Fair	Poor	Very Poor	Relative vector	Idealized vector
Out- standing	1	2	3	4	5	6	7	8	9	0.3245	1.0000
Ex- cellent	1/2	1	2	3	4	5	6	7	8	0.1822	0.5616
Very Good	1/3	1/2	1	2	3	4	5	6	7	0.1653	0.5095
Above Average	1/4	1/3	1/2	1	2	3	4	5	6	0.1142	0.3519
Average	1/5	1/4	1/3	1/2	1	2	3	4	5	0.0782	0.2411
Below Average	1/6	1/5	1/4	1/3	1/2	1	2	3	4	0.0536	0.1652
Fair	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	0.0370	0.1141
Poor	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	0.0260	0.0802
Very Poor	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	0.0189	0.0581

The **Consistency Index** for a matrix is calculated from *Equation (9)*, as and, since for this matrix, the is **0.03499**.

Using Equation (10), Consistency Ratio, 0.03499/1.45=0.02413. According to Saaty argues, In practical decision situations inconsistency is "acceptable" if CR > 0.1

Table 20: Overall scores of 3PL providers

	Local	Global	3PI	(A)	3PI	L (B)	3PI	- (C)	3PL	. (D)
Criteria / Sub-criteria	Weight (LW)	Weight (GW)	Rating scores	X GW	Rating scores	X GW	Rating scores	X GW	Rating scores	X GW
Cost of Service (C ₁)	0.01991									
Freight Price	0.00000	0.000000	0.5095	0.00000	0.3519	0.00000	0.1652	0.00000	0.3519	0.00000
Terms of Payment	0.26376	0.005251	0.5616	0.00295	1.0000	0.00525	0.5095	0.00268	0.5095	0.00268
Extra Costs	0.19055	0.003794	0.1141	0.00043	0.5095	0.00193	0.5616	0.00213	0.1652	0.00063
IT capability	0.00000	0.000000	1.0000	0.00000	0.1141	0.00000	0.3519	0.00000	0.1141	0.00000
Size and quality of fixed assets	0.14885	0.002963	0.1141	0.00034	0.5095	0.00151	0.2411	0.00071	0.5095	0.00151
Delivery performance	0.14846	0.002956	0.3519	0.00104	0.1141	0.00034	0.1652	0.00049	0.5616	0.00166
Employee satisfaction level	0.18761	0.003735	0.2411	0.00090	0.3519	0.00131	0.5095	0.00190	0.1141	0.00043
Flexibility in operations and delivery	0.06078	0.001210	0.5095	0.00062	0.1652	0.00020	0.1652	0.00020	0.5095	0.00062
Reputation of the 3PL (C ₂)	0.14664									
Market share	0.01013	0.001485	0.1652	0.00025	0.5095	0.00076	0.5616	0.00083	0.1652	0.00025
Geographic spread and access to retailers	0.34335	0.050349	0.1652	0.00832	0.5616	0.02828	0.1652	0.00832	0.3519	0.01772
Market knowledge	0.35392	0.051901	0.5616	0.02915	0.1141	0.00592	0.5095	0.02644	0.1141	0.00592
Experience in similar products	0.29260	0.042908	0.1141	0.00490	0.2411	0.01035	0.1652	0.00709	0.5095	0.02186

	Local	Global	3PI	L (A)	3PI	L (B)	3PI	L (C)	3PI	. (D)
Criteria / Sub-criteria	Weight	Weight	Rating	X GW	Rating	X GW	Rating	XGW	Rating	X GW
	(LW)	(GW)	scores		scores		scores		scores	
Long-term Relationships (C ₃)	0.09729									
Information sharing	0.26796	0.026070	0.1652	0.00431	0.5095	0.01328	0.3519	0.00917	0.1141	0.00297
Willingness to use logistics manpower	0.11385	0.011076	0.5095	0.00564	0.1141	0.00126	0.2411	0.00267	0.2411	0.00267
Trust and fairness	0.00257	0.000251	0.1652	0.00004	0.1652	0.00004	0.5095	0.00013	0.5095	0.00013
Benefit and risk sharing	0.14177	0.013793	0.3519	0.00485	0.5616	0.00775	0.5616	0.00775	0.5616	0.00775
Quality of management	0.13627	0.013258	0.5616	0.00745	0.1652	0.00219	0.1652	0.00219	0.1652	0.00219
Compatibility	0.16918	0.016459	0.2411	0.00397	0.3519	0.00579	0.1141	0.00188	0.1141	0.00188
Cost of relationship	0.16840	0.016384	0.5095	0.00835	0.2411	0.00395	0.5095	0.00835	0.5095	0.00835
Finance (C ₄)	0.11482									
Logistics costs	0.00000	0.000000	0.1141	0.00000	0.5095	0.00000	0.1141	0.00000	0.3519	0.00000
Financial stability	1.00000	0.114818	0.3519	0.04040	0.5616	0.06448	0.2411	0.02769	0.2411	0.02769
Service level (C ₅)	0.08371									
Reliability and timeliness	0.50000	0.041854	0.5095	0.02133	0.3519	0.01473	0.3519	0.01473	0.5616	0.02350
Quality of service	0.00000	0.000000	1.0000	0.00000	0.1141	0.00000	0.5616	0.00000	0.1141	0.00000
Flexibility and responsiveness	0.50000	0.041854	0.5616	0.02350	0.5095	0.02133	0.1141	0.00478	0.5095	0.02133

	Local	Global	3PI	L (A)	3PI	L (B)	3PI	L (C)	3PI	. (D)
Criteria / Sub-criteria	Weight	Weight	Rating		Rating		Rating		Rating	
	(LW)	(GW)	scores	XGW	scores	XGW	scores	XGW	scores	XGW
Infrastructure (C ₆)	0.12962									
IT/IS capability	0.00000	0.000000	0.1652	0.00000	0.1141	0.00000	0.5095	0.00000	0.1141	0.00000
Logistics manpower	1.00000	0.129618	0.5095	0.06604	0.5616	0.07279	0.1652	0.02142	0.1652	0.02142
Third party logistics services (C7)	0.05681									
Inventory replenishment	0.28637	0.016269	0.1141	0.00186	1.0000	0.01627	0.1141	0.00186	0.5616	0.00914
Warehouse management	0.09665	0.005491	0.5616	0.00308	0.1652	0.00091	0.5095	0.00280	0.2411	0.00132
Shipment consolidation	0.23681	0.013453	0.1141	0.00154	0.1141	0.00154	0.1652	0.00222	0.5095	0.00685
Carrier selection	0.12032	0.006835	0.5616	0.00384	0.3519	0.00241	1.0000	0.00684	0.1141	0.00078
Direct transportation services	0.25985	0.014762	0.3519	0.00519	0.5095	0.00752	0.5095	0.00752	1.0000	0.01476
Reverse logistics function (C ₈)	0.04978									
Collection	0.21104	0.010506	0.2411	0.00253	0.1141	0.00120	0.2411	0.00253	0.1652	0.00174
Packing	0.18356	0.009138	0.1652	0.00151	0.5616	0.00513	0.1141	0.00104	0.5095	0.00466
Storage	0.31072	0.015468	0.5095	0.00788	0.1141	0.00177	0.5616	0.00869	0.5616	0.00869
Sorting	0.13778	0.006859	1.0000	0.00686	0.1652	0.00113	0.1652	0.00113	0.1141	0.00078
Transitional processing	0.11487	0.005719	0.1652	0.00094	0.5095	0.00291	0.1652	0.00094	0.3519	0.00201
Delivery	0.04202	0.002092	0.1141	0.00024	0.1652	0.00035	0.5095	0.00107	0.1141	0.00024

	Local	Global	3PL	, (A)	3PL	. (B)	3PL	, (C)	3PL	, (D)
Criteria / Sub-criteria	Weight	Weight	Rating	Valu	Rating	VOW	Rating	VOW	Rating	N CIU
	(LW)	(GW)	scores	XGW	scores	XGW	scores	XGW	scores	XGW
Organizational role (C ₉)	0.11216									
Reclaim	0.24589	0.027579	0.5095	0.01405	1.0000	0.02758	0.1141	0.00315	0.2411	0.00665
Recycle	0.21925	0.024591	0.5616	0.01381	0.1652	0.00406	0.2411	0.00593	0.5616	0.01381
Remanufacture	0.16253	0.018229	0.1141	0.00208	0.1652	0.00301	0.5616	0.01024	0.5095	0.00929
Re use	0.21172	0.023747	0.3519	0.00836	0.3519	0.00836	0.1141	0.00271	0.1652	0.00392
Disposal	0.16062	0.018015	0.2411	0.00434	0.5095	0.00918	1.0000	0.01801	1.0000	0.01801
User satisfaction (C ₁₀)	0.07945									
Effective communication	0.28899	0.022961	0.3519	0.00808	0.1652	0.00379	0.5095	0.01170	0.1141	0.00262
Service improvement	0.26171	0.020794	0.5616	0.01168	0.5616	0.01168	0.1652	0.00344	0.5095	0.01060
Cost saving	0.24193	0.019222	0.5095	0.00979	0.2411	0.00463	0.5616	0.01079	0.3519	0.00676
Overall working relations	0.20737	0.016476	1.0000	0.01648	0.1652	0.00272	0.2411	0.00397	0.2411	0.00397
IT Applications (C ₁₁)	0.10981									
Warehouse management (IT1)	0.27488	0.030184	0.1652	0.00499	0.5095	0.01538	0.3519	0.01062	0.5616	0.01695
Order management (IT2)	0.15537	0.017061	0.5616	0.00958	0.2411	0.00411	0.5095	0.00869	0.1652	0.00282
Supply chain planning (IT3)	0.31088	0.034137	0.5095	0.01739	0.5616	0.01917	0.1652	0.00564	1.0000	0.03414
Shipment and tracking (IT4)	0.23854	0.026193	0.2411	0.00632	0.3519	0.00922	0.5616	0.01471	0.5095	0.01335
Freight payment (IT5)	0.02032	0.002232	0.5616	0.00125	0.5095	0.00114	0.3519	0.00079	0.2411	0.00054
Overall scores			20.2628		18.6429		18.0853		18.6634	
Renormalized scores			0.26783		0.24642		0.23905		0.24669	

After renormalizing the overall scores in **Table 20**, S_1 was determined to be the most

suitable alternative amongst all four Third party logistics Service Provider because it had the

highest overall score (0.26783) among the four alternatives. Hence, Alternative sorting is as

following

 $S_1 > S_4 > S_2 > S_3$

It means that S_1 is the best Third party logistics Service Provider.

CONCLUSION

Aforesaid work delivers a structured, methodological framework for multi-criteria decision support model in evaluating and selecting the best 3PL provider as selecting appropriate and desirable 3PL providers has become a critical strategic decision. The proposed methodology is easy to implement and quite reliable for ranking the alternatives. Applicability of the proposed approach has been shown in an automobile company for the selection of the third party logistic provider. The technique can also be applied effectively to help any managerial decisionmaking. The findings provide valuable insights for logistics practitioners, academicians and educators, as well as policy makers and also integrates selection criteria and sub-criteria under the global supply chain environment. For further research, other multi-criteria evaluation methods that have been recently proposed in a fuzzy environment like fuzzy TOPSIS or fuzzy outranking methods can be used and the obtained results can be compared with the ones found in this paper.



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