International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

# Selection of Best Cold Chain Supplier Using Fuzzy-AHP and TOPSIS Method for Temperature Controlled Logistics (TCL) during COVID-19 Pandemic Era

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**Abstract:** ***Temperature control logistics (TCL) involves temperature control operations from raw material procurement to end users. Adequate cattle chain infrastructure is essential to maintain the vaccine intact since preparation by the administration. at the end of the chain The primary care provider must have the proper knowledge of cold chain operation. The "cold chain" is maintained and maintained as a network of refrigerators, cold rooms, freezers and refrigerated boxes. To ensure that vaccines are kept at the appropriate temperature during the purchase of vaccines and suppliers, transportation, storage and distribution from the factory to the management, the quality of the vaccines Evaluation and selection of cold medicine suppliers from various angles to insure and reduce the risks of transportation and storage is critical, weak, multidimensional problem solving (MCDM) for optimal order selection). TOPSIS is a logistics provider for the storage and transport of COVID-19 vaccines in India. MCDM-based hybrid approach. TOPSIS can implement choice in global deployments.***

**Keywords:** cold chain supplier, fuzzy AHP, TOPSIS, Temperature Controlled Logistics

## 1. Introduction

**Cold supply chain (CSC)**

The cold supply chain (CCS) includes temperature control activities from the purchase of raw materials to the end customer. Processes and controls the flow and storage of waste products Equal services and data to meet the needs of customers globally from production, distribution and use from one or more sources. "Successful cold chain management enhances efficiency and saves costs. Both data tracking and temperature monitoring are key aspects of cold chain management."

Since globalization reduces the distance between different parts of the world differently, the physical isolation of the same region is an important fact. Load more damage on more physically isolated, more complex transport work Some items may be damaged by the effects Improper temperature changes can damage other products In particular, their quality deteriorates over time due to food (products), chemical reactions This rate is greatly reduced with low temperatures It takes time and coordination to run things efficiently And every delay has a negative effect Especially if this product is wasted This ensures that objects are not destroyed or compromised in the process. Businesses in the pharmaceutical, medical and food industries are more dependent on the cold chain.

The cold chain includes the transport of temperature-sensitive products between the supply chain and the supply chain through the cold packaging system. And a logistical plan to maintain the integrity of this material There are many ways to ship cold chain products With refrigerated trucks and trams Refrigerated containers, refrigerated containers and air cargo

Therefore, cold chain science, technology and processes It is a science because it requires understanding and understanding of the chemical and biologic sales processes involved in business qualifications. It is a technology because it depends on the physical method to ensure the highest temperature conditions on the supply chain. This is a process because the preparation, storage, transportation and inspection of temperature sensitive products need to be done in batches. The main components of the cold chain are: Bring food-like items at the highest temperatures for the refrigeration system processing, storage and transportation.

Refrigerated storage allows you to store items for a specified period of time. Intermediate for processing and distribution rather than goods to distant markets And near the market for distribution

Cold Transportation: There are trucks to operate the goods while maintaining the integrity of the goods as well as maintaining the constant temperature and humidity.

Processing and processing and refrigeration distribution facilities facilitate monitoring of the processing and health status of the material. Together and separate loads for

distribution (beans, boxes, pallets), From the point of view of economic development, the cold chain system has allowed many developing countries to participate in the global market for waste products. As a producer or consumer, income growth is associated with an improved trend in the use of fruits, vegetables, fish and meat products. The increase in income is associated with food changes Demand for this specialty has grown significantly as a result of fresh fruit, vegetables and corporate corruption related to meat and fish. Customers with a wide range of purchasing power, especially large quantities of fresh produce, develop an enthusiasm for healthy food. Therefore, producers and retailers react to a variety of foreign fresh fruits

**Cold storage in India**

The cold storage is a place where you can easily maintain a certain temperature, with the help of which you can store a variety of food items. There are many places where you can find cold storage for safe and over-use. Some of these places are as follows: Cold storages should be observed in shopping malls where safe seafood is stored. It can get cold rooms in different places a large number of vegetables are collected and stored using cold storage so that you can keep fresh vegetables longer. Cold storages are also used in pharmacies and elsewhere You will be able to collect various pills It can be stored in cold temperatures with cold storage

**Benefits of cold storage in India:**

The first and foremost benefit of cold storage construction companies in India is that you can use the cold room in many ways. With so many you can take advantage of a variety of applications with the help of cold storage construction companies.

The next goal of Cold Storage Construction Company is to talk to your cold storage manufacturer in India. You can create custom sizes. You can change the general settings of your cold room construction company

You can build a cool room for yourself it depends on the type of business you are in addition, we can say that there is no limit to the size of a cold room, you can increase the size and storage of a cold room. There are a lot of people who want to build a room-sized cold room they will be able to do it easily. These cold room builders don't just provide you with a cold system. But you can also use improved backup and access capabilities with this cool room With the entry of cold room manufacturers in India you will be able to save a lot of money. With storage options you will be able to keep food fresh

**Cold chain work**

Moving the distribution along the supply chain without encountering interruptions or temperature abnormalities requires the establishment of a comprehensive logistics process to maintain the distribution integrity. This process includes a number of steps, from preparation for sending to verifying the integrity of the sending:Transportation preparation It is important to first assess the properties when moving sensitive products. Temperature control and shipping packaging are important issues It should already be at the desired temperature Generally cold, cold chain devices are designed to maintain a stable temperature. But did not bring transport at this temperature Therefore, it will not work properly until it is shipped and conditioned An important exception is cabbage, which is shipped at about 13 degrees Celsius, where it is possible to use a cold store to cool the shipment. Other considerations include transportation destinations and weather conditions in that area, for example, whether or not the transport is too cold or too hot. Using cold storage with your own power supply unit will eliminate such worries Unit loading containing temperature sensitive materials should also be made. Refrigerated containers, for example, should be cleaned to eliminate the risk of bacterial contamination and to bring specific conditions, such as temperature and humidity, to the weavers. Another problem is climate control It maintains the right level of oxygen and carbon dioxide, helping to control maturity. This control can be applied to both conveyors (refrigerators), but usually wraps the product in the polythene bag. It controls the expansion of gas during transportation

Model selection has many important factors that affect the speed of a transmission Distance between source and final destination (which usually includes a set of intermediate locations), size and transport weight. The required external temperature weather and the pericability of any restrictive products at any time affect all available transportation options. Short distances can be maintained with vans or trucks Long-haul travel may require aircraft or container ships, in which case the price / loss ratio becomes a factor in choosing a mode.

Customization method border transportation if customization measures are very important. Because cold chain products are more sensitive to time and require more scrutiny than traditional shipments (such as products, C drugs, and logical sales samples), the difficulty of this task varies across the country. (Or financial groups) and the Gateway due to various policies and delays Frequent problems with sanitation that require smoking Customs problems have been recognized as an important factor in building a reliable international refrigeration chain.

**The "Last Mile"**, The final step is the actual distribution to the destination Logistically, most important things are indicated in the preparation of the final final distribution, which includes not only the destination, but also the destination. But from the time of distribution, important work and storage space is available Trucks and vans, which are the main mode of transportation at this stage, need to meet the requirements for transportation in a cold chain. Due to the distribution of a large number of products for the cold chain, dieting is done, especially in urban areas. So, they have trouble getting around and parking In addition, the end must be transferred to the cold storage, as there may be non-compliance. And damage to broken items such as products

Integrity and quality assurance after the distribution should be recorded and reported to the temperature recorder or the abnormal temperature should be known. This is the stage of the logistics process that is trusted and responsible. Creates If there is any liability for the shipment. There is If there is a problem or error affecting the symptoms, the symptoms should be tried and corrective action should be taken. This is

especially true for high-value cold chain products The standard size of containers is between 50,000 and 100,000, while refrigerator containers can cost up to 1 million cases. The cost of the goods will reach US $ 50 million.

Used Technology: The first and foremost thing when choosing the best cold room builder in India is to look at the technology used for refrigeration purposes. Be sure to choose a cool room maker that gives you cooling technology. With the help of the above technical options You will be able to enjoy the best cold effects You can save a lot of energy efficiently So it will reduce your electricity bill for you

Good Features Features: You will find many cold room manufacturers in India who build cold rooms without temperature control. Therefore, you should only use a cold room at a certain temperature

Price: The next factor you should consider when choosing one of the best cold room manufacturers in India is the price value at which you can get the best option. When dealing with cold room builders make sure you don't run out of budget and just keep the final price.

## 2. Literature Review

Multi-criteria decision-making (MCDM) is one of the most active areas of interdepartmental research in management science and functional research [1], multi-attribute design (MADM) and multi-objective design-making (MODM). MCDM, MADM are usually associated with isol separate variables and a limited number of evaluation options. MODM is to identify the best of the infinite options under a set of constraints. Each standard of the MODM is associated with a goal, but each MADM is associated with a different feature set. Of course, in recent years MADM and MCDM have been used to indicate the same problem. The word MCDM is used to refer to a decision problem with multiple features In short, the internal b features of MCDM are attractive and useful in practice. Some of the features described by Belton and Stuart [20] are as follows: It acts as a center of discussion and (4) demonstrates a process that makes rational, rational, and clear decisions. Researchers have proposed a number of MCDM methods and ques- tions over the past decade Most importantly are the Weight Scale Model (WSM), Weight Product Model (WPM), Weight Total Product Assessment (WASPAS), Hierarchical Analytical Process (AHP) [11], and ELECtre (Elimination). Et ChoixTraduisant la REalité), Priority Technology Possibilities with Ideal Solutions (TOPSIS) [21] PROMETHEE, Complex Ratio Assessment (COPRAS), Approved Assessment Methods for VIKOR. (VIseKriterijumska Optimizacija I KompromisnoResenje) Optimization by multimura (multiple purpose) ratio analysis and full multiplication model. Ratio Assessment (ARAS) and Remote Solution-Based WSM (EDAS) Assessment are probably the most common methods. Based on WPM umption [4] it determines the same appropriate option as WSM. This method uses the multiplication of the weight ratio (efficiency) instead of the amount of weight ratio that makes up the deer. In WSM, the WASPAS method is based on a combination of the WSM and WPM methods and has both advantages. MCDM problems of many real worlds The AHP proposed by Sati (Sati, 1981) depends on the choice or weight of the AHP. Criteria and importance of selection in terms of their sequence structure [11]

There are three levels in the structure of the AHP system The first level represents the purpose of the problem The second level meets the standard And provides a third option This method has two similarities, so it takes a long time when we have a lot of measurements and / or options. The original ELECTER method was named "ELECTER I" And the evolution continues with ELECTER II, ELECTER III, ELECTER IV, ELECTER IS and ELECTER TRI. The ELECTER method consists of two main stages: the creation and exploitation of one or more high-level relationships. Like other MCDM methods, the ELECTER method does not consider neutral standards from each other. [8] The disadvantage of the ELECTER method is that it represents a parameter of inconsistency and compliance criteria. Decide on any justification For the values selected for these parameters, the TOPSIS method was developed as a value-based compensation method. This method tries to prioritize the options based on the ideal solution and the distance from the minimum point. . The method is based on the comparison of options, each criteria takes into account the deviation of those options, and the criteria uses preliminary work to determine this variable, the positive and negative currents of the alternatives. An effective MCDM method, based on both reports, determines the best options: profit margins, performance summaries, and total value criteria [13] [14] [15] [16] The VIKOR method was developed by addressing the criteria against the decision-making process. Dictatorial ruler And comparative (standard with different units) options are evaluated against all established values. And in this way the best ideological solution is the best The logic of this method is similar to the TOPSIS method [21], which consists of three parts: the reporting system, the benchmark, and the full multiplication model. This method is effective and applies to a wide range of MCDM problems and extends to a variety of environments such as weak and gray environments [17]. The ARAS method for office microclimate estimation is an effective MCDM method. This method has been expanded and used in many cases in the recent past The EDAS method is the new MCDM method proposed by KeshvajGhorabai, Javadkas, Olfat and Turkis (2015). Multi-Scale Inventory ABC Classification Multi-scale shows that the EDAS method is effective in solving multiple decision-making problems. [22]

**Brief on Various Methods and Techniques Used**

Analytic Hierarchy Process (AHP) is a decision support method that aims to solve problems by separating solution problems, grouping them, and then arranging them in a hierarchical structure. In order to obtain priority standards in this method, use and specific Comparison of standards corresponding to measurement scales. The main input of the AHP method is the perception of experts or experts, so there are subjective factors when deciding on restoration. The method also considers the validity of data with inconsistency limits. [10] Uncertainty and uncertainty will affect the accuracy of the data and the results obtained. On this basis, another theory has been developed, namely the fuzzy analytic hierarchy process. The fuzzy analytic hierarchy

process is a method of analysis and analysis. Based on fuzzy logic The hierarchical process of theoretical development (AHP). The usage of fuzzy analytic hierarchy process is similar to that of analytic hierarchy process. The scale is based on the diffusion triangle of priority access.

In this section, the F-AHP method was developed. Te procedure used in the proposed method is described as follows

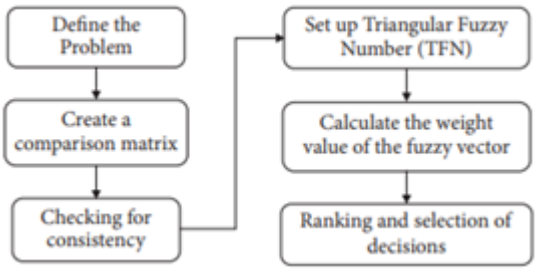



**Figure 1:** Block diagram has six steps of F-AHP phase process

**Fuzzy AHP**

Fuzzy analytic hierarchy process (f-AHP) fuzzy analytic hierarchy process (f-AHP) embeds the fuzzy theory to basic Analytic Hierarchy Process (AHP), which was developed by Saaty [18] .

**Step 1:** Decision maker compares the criteria or alternatives via linguistic terms shown in Table.

| S. No | Saaty Scale Definition | Fuzzy Triangular Scale |
|---|---|---|
| 1 | Equally Important (Eq. Imp) | (1, 1, 1) |
| 2 | The intermittent Values | (1, 2, 3) |
| 3 | Weekly Important | (2, 3, 4) |
| 4 | The intermittent Values | (3, 4, 5) |
| 5 | Fairly Important (F. Imp) | (4, 5, 6) |
| 6 | The intermittent Values | (5, 6, 7) |
| 7 | Strongly Important (S. Imp) | (6, 7, 8) |
| 8 | The intermittent Values | (7, 8, 9) |
| 9 | Absolutely Important (A. Imp) | (9, 9, 9) |

Linguistic Terms and the corresponding triangular fuzzy numbers

According to the corresponding triangular fuzzy numbers of these linguistic terms, for example if the decision maker state “Criterion 1 (C1) is weakly important than Criterion 2 (C2)”, then it takes the fuzzy triangular scale as (6, 7, 8). On the contrary, in the pair wise contribution matrix of the criteria comparison of C2 to C1 will take the fuzzy triangular scale as (1/8, 1/7, 1/6). The pair wise contribution matrix is shown in Eq.(1). Where $\tilde{d}^{k}_{ij}$ indicates the $k^{th}$ decision maker’s preference of $i^{th}$ criterion over $j^{th}$ criterion, via fuzzy triangular numbers .

$$\tilde{A}^{K} = \begin{bmatrix} \tilde{d}^{k}_{11} & \tilde{d}^{k}_{12} \dots & \tilde{d}^{k}_{1n} \\ \tilde{d}^{k}_{21} & \tilde{d}^{k}_{2n} \dots & \tilde{d}^{k}_{2n} \\ \tilde{d}^{k}_{n1} & \tilde{d}^{k}_{n2} \dots & \tilde{d}^{k}_{nn} \end{bmatrix} \quad (1)$$

**Step-2:** If there is more than one decision maker. Preferences of each decision maker ($\tilde{d}^{k}_{ij}$) are averaged and ($\tilde{d}_{ij}$) is calculate as in the Eq..2).

$$\tilde{d}_{ij} = \frac{\sum_{k=1}^{k} \tilde{d}^{k}_{ij}}{K} \quad (2)$$

**Step-3:** According to averaged preferences, pair wise contribution matrix is updated as show in Eq.(3) .

$$\tilde{A} = \begin{bmatrix} \tilde{d}_{11} & \dots & \tilde{d}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{d}_{n1} & \dots & \tilde{d}_{nn} \end{bmatrix} \quad (3)$$

**Step-4:** the geometric mean of fuzzy comparison values f each criterion is calculated as show in Eq.(4). Here, $\tilde{r}_i$ still represents triangular values .

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{d}_{ij}\right)^{1/n}, \quad i = 1,2,\dots,n \quad (4)$$

**Step-5:** The fuzzy weights of each criterion can be found with Eq.(5) by incorporating next steps .

- Find the vector summation of each$\tilde{r}_i$.Find the (–1) power of summation vector. Replace the fuzzy triangular number. To make it in an increasing order .
- To find the fuzzy weight of criterion i ($\tilde{w}_i$), multiply each $\tilde{r}_i$ with this reverse vector .

$$\tilde{w}_i = \tilde{r}_i \times (\tilde{r}_1 \times \tilde{r}_2 \times \dots\dots\dots \times \tilde{r}_n) - 1 = (lwi, mwi, uwi) \quad (5)$$

**Step 6:** Since $\tilde{w}_i$ are still fuzzy triangular numbers, they need to de-fuzzified by centre of area method proposed by Chou and Chang [50] via applying the Eq.(6) .

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \quad (6)$$

Mi is non fuzzy number. But it needs to be normalized by following Eq.(4.7)

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad (7)$$

**TOPSIS method**

TOPSIS method Preference by Similarity to Ideal Solution (TOPSIS) is a multi-measures choice examination strategy, which was initially evolved by Ching-Lai Hwang and Yoon in 1981 with additional advancements by Yoon in 1987[8], and Hwang, Lai and Liu in 1993[9] Multi-standards dynamic. From an overall perspective, it is the goal of individual to make "determined" choice in a place of different determination. In logical terms, it is the expectation to foster insightful and mathematical strategies that consider numerous options with various measures. TOPSIS is one of the mathematical techniques for the multi-models dynamic. This is a comprehensively relevant strategy with a straightforward numerical model. Moreover, depending on PC support, it is truly appropriate pragmatic strategy. The technique is applied over the most recent thirty years (on the historical backdrop of TOPSIS see [5], [6]), and there are numerous papers on its applications ( [7], [8], [9]).

**The process of TOPSIS method is carried out as follows:**

**Step 1**

Create an evaluation matrix consisting of m alternatives and n criteria, with the intersection of each alternative and criteria given as $x_{ij}$, therefore have a matrix $(x_{ij})_{mxn}$

**Step 2**

The matrix $(x_{ij})_{mxn}$ is then normalised to form the matrix $R = (r_{ij})_{mxn}$ using the normalisation method

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}} \quad i = 1,2,\dots\dots.m, \; j = 1,2,3\dots\dots\dots,n \quad (8)$$

**Step 3**
Calculate the weighted normalised decision matrix

$$t_{ij} = r_{ij} \cdot w_j,\ i= 1,2,3,\ldots\ldots,m,\quad j= 1,2,\ldots\ldots,n \qquad (9)$$

*where* $w_j = w_j / \sum_{k=1}^{n} w_k$ , $j = 1,2,\ldots\ldots,n$ *so that* $\sum_{k=1}^{n} w_k = 1$ *and* $w_j$ *is the original weight given to the indicator* $v_j$, $j=1,2,\ldots\ldots,n$.

**Step 4**
Determine the worst alternative ($V^-$) and the best alternative($V^+$) :

$V^- = \{(\max(t_{ij} \mid i= 1,2,\ldots\ldots,m) \mid j\in J_-),\ (\min(t_{ij} \mid i= 1,2,\ldots\ldots,m) \mid j\in J_+)\} \equiv \{t_{wj} \mid i= 1,2,\ldots\ldots,n\}$,

(10)

$V^+ = \{(\min(t_{ij} \mid i= 1,2,\ldots\ldots,m) \mid j\in J_-),\ (\max(t_{ij} \mid i= 1,2,\ldots\ldots,m) \mid j\in J_+)\} \equiv \{t_{bj} \mid i= 1,2,\ldots\ldots,n\}$,

(11)

where
$J_+ = \{ j = 1,2,\ldots\ldots,n \mid j \}$ associated with the criteria having a positive impact, and
$J_- = \{ j = 1,2,\ldots\ldots,n \mid j \}$ associated with the criteria having a negative impact .

**Step 5**
Calculate the $L^2$-distance between the target alternative *i* and the worst condition $A_b$

$$d_{iw} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{wj})^2},\ i=1,2,\ldots\ldots,m. \qquad (12)$$

and the distance between the alternative *i* and the best condition $A_b$

$$d_{ib} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{bj})^2},\ i=1,2,\ldots\ldots,m \qquad (13)$$

where$d_{iw}$ and $d_{ib}$ are $L^2$-norm distances from the target alternative *i* to the worst and best conditions, respectively .

**Step 6**
Calculate the Performance Score:

$S_{iw} = d_{iw}/(d_{iw} + d_{ib}),\ 0 \le S_{iw} \le 1,\ i =1,2,\ldots\ldots,m,$ (14)

$S_{iw}=1$ if and only if the alternative solution has the best condition; and
$S_{iw}=0$ if and only if the alternative solution has the worst condition .

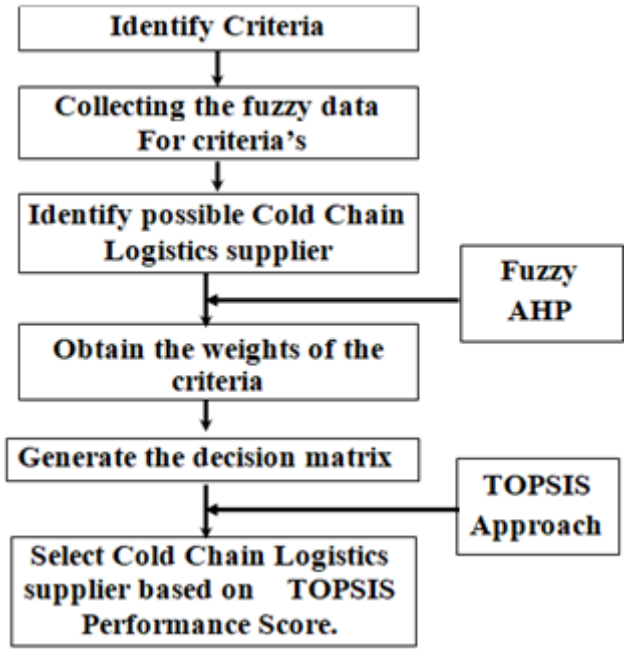
**Step 7**
Rank the alternatives according to $S_{iw}$( i = 1,2,……,m) .

## 3. Case Study

The criterion values in linguistic terms or in terms of vagueness are taken into account by Fuzzy AHP. Criteria for selecting Cold Chain Logistics supplier are determined based on the experience of managers and decision makers. The current study suggests a collection of realistic success factors for suppliers in Cold Chain Logistics. To do so, it analyzes storage and transport of Covid -19 Vaccines practices in Logistics industry through interviews with Central vaccine store manager, District hospital or facility technicians, Primary health &center /community health center staff and Sub-health center staff from Logistics with long experience. The practical success factors are found to be Total capacity (pallets)(TC),Reserved space(million doses)(RS), Temperature-controlled warehousing, Delivery Terms, Environmental Competence. A integrate method proposed with fuzzy AHP and TOPSIS method for evaluated five Cold Chain Logistics suppliers. This methodology applicable for to select an ideal supplier.

## 4. Methodology

The following steps are performed.
Step 1. Set supplier selection criteria
Step 2.Collection of fuzzy data for each standard by field studies.
Step 3. Determine the comparison of data and weights / points by the Fuzzy AHP method
Step4. Using the TOPSIS method to calculate the Performance Score
Step 5. Rank the supplier according to TOPSIS Performance Score.




**Fuzzy weights of all the criteria**

| Attribute or Criteria | Capacity | Reserved space | Temper-controlled warehousing | Delivery Terms | Environmental Competence |
|---|---|---|---|---|---|
| Capacity | (1,1,1) | (1,2,3) | (2,3,4) | (1/3,1/2,1) | (4,5,6) |
| Reserved space | (1/3,1/2,1) | (1,1,1) | (1,2,3) | (5,6,7) | (1/6,1/5,1/4) |
| Temper-controlled warehousing | (1/4,1/3,1/2) | (1/3,1/2,1) | (1,1,1) | (3,4,5) | (1,2,3) |
| Delivery Terms | (1,2,3) | (1/7,1/6,1/5) | (1/5,1/4,1/3) | (1,1,1) | (1/4,1/3,1/2) |
| Environmental Competence | (1/6,1/5,1/4) | (4,5,6) | (1/3,1/2,1) | (2,3,4) | (1,1,1) |

$\widetilde{r_i} = \left([\prod_{j=1}^{n} \widetilde{d_{ij}}]\right)^{1/n}$

$= \left[(1*1*2*0.33*4)^{\frac{1}{5}}; (1*2*3*0.5*5)^{1/5}; (1*3*\right.$

*4∗1∗61/5=1.22;1.72;2.35*

**Relative fuzzy values of quality weights**

| | | | |
|---|---|---|---|
| Capacity | 1.22 | 1.72 | 2.35 |
| Reserved space | 0.77 | 1.04 | 1.39 |
| Temper-controlled warehousing | 0.76 | 1.06 | 1.50 |
| Delivery Terms | 0.37 | 0.49 | 0.63 |
| Environmental Competence | 0.85 | 1.08 | 1.43 |
| Total | **3.97** | **5.39** | **7.30** |

**Relative fuzzy values of quality weights**

| | | | |
|---|---|---|---|
| Capacity | 1.22 | 1.72 | 2.35 |
| Reserved space | 0.77 | 1.04 | 1.39 |
| Temper-controlled warehousing | 0.76 | 1.06 | 1.50 |
| Delivery Terms | 0.37 | 0.49 | 0.63 |
| Environmental Competence | 0.85 | 1.08 | 1.43 |
| Total | 3.97 | 5.39 | 7.30 |
| Inverse(1/Col Value) | 0.25 | 0.19 | 0.14 |
| Ascending Order | 0.14 | 0.19 | 0.25 |

$\widetilde{w_1} = [(1.22 * 0.14); (1.72 * 0.19); (2.35 * 0.25);] = [0.17; 0.33; 0.59]$

Hence the relative fuzzy weights of each criterion are given Table ;

**Weights of fuzzy values for criteria**

| | | | |
|---|---|---|---|
| Capacity | 0.17 | 0.33 | 0.59 |
| Reserved space | 0.11 | 0.20 | 0.35 |
| Temper-controlled warehousing | 0.11 | 0.20 | 0.37 |
| Delivery Terms | 0.05 | 0.09 | 0.16 |
| Environmental Competence | 0.12 | 0.21 | 0.36 |

The relative non fuzzy weight of each criterion ($M_i$) is calculated by taking the average of fuzzy numbers for each criterion .

Ex: for price m1 = (0.17+0.33+0.59)/3 = 0.36

- by using non fuzzy $M_i$'s, the normalize weights ($N_i$) of each criterion are calculated and tabulated in Table .

**Normalised values of criteria of supplier**

| Attribute | $M_i$ | ($N_i$ ) |
|---|---|---|
| Capacity | 0.36 | 0.32 |
| Reserved space | 0.22 | 0.19 |
| Temper-controlled warehousing | 0.23 | 0.20 |
| Delivery Terms | 0.10 | 0.09 |
| Environmental Competence | 0.23 | 0.20 |

**TOPSIS Performance Score Calculation:**

**Step 1:** define criteria and alternatives and formulate decision matrix

**Step 2:** normalize matrix

**Step 3:** weighted normalize matrix

**Step 4:** finding positive and negative ideal solutions

**Step 5:** closeness coefficient

**Step 6:** ranking of alternatives

| Weightage | 0.32 | 0.19 | 0.20 | 0.09 | 0.20 |
|---|---|---|---|---|---|
| Attribute or Criteria | Capacity (%) | Reserved space (pallets) | Temperature-controlled warehousing (%) | Delivery Time (days) | Environmental Competence (%) |
| Cold Chain Supplier -1 | 90 | 10,000 | 75 | 7 | 85 |
| Cold Chain Supplier -2 | 92 | 9,000 | 92 | 10 | 80 |
| Cold Chain Supplier -3 | 90 | 10,500 | 82 | 5 | 75 |
| Cold Chain Supplier -4 | 93 | 8000 | 90 | 7 | 70 |
| Cold Chain Supplier -5 | 95 | 9200 | 85 | 9 | 82 |

**Step-1:** Calculate Normalised Matrix

The matrix $\overline{X}_{ij}$ is then normalized to form the matrix

$$\overline{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i-1}^{n} X_{ij}^2}}$$

| *Weightage* | *0.32* | *0.19* | *0.20* | *0.09* | *0.20* |
|---|---|---|---|---|---|
| Attribute or Criteria | Capacity (%) | Reserved space (pallets) | Temperature-controlled warehousing (%) | Delivery Time (days) | Environmental Competence (%) |
| Cold Chain Supplier -1 | 0.44 | 0.48 | 0.39 | 0.41 | 0.48 |
| Cold Chain Supplier -2 | 0.45 | 0.43 | 0.48 | 0.59 | 0.45 |
| Cold Chain Supplier -3 | 0.44 | 0.50 | 0.43 | 0.29 | 0.43 |
| Cold Chain Supplier -4 | 0.45 | 0.38 | 0.47 | 0.41 | 0.40 |
| Cold Chain Supplier -5 | 0.46 | 0.44 | 0.45 | 0.53 | 0.47 |

**Step-2:** Calculate weighted Normalised Matrix

$V\_ij = X\bar{}\_ij \times W\_j$

| *Weightage* | *0.32* | *0.19* | *0.20* | *0.09* | *0.20* |
|---|---|---|---|---|---|
| Attribute or Criteria | Capacity (%) | Reserved space (pallets) | Temperature-controlled warehousing (%) | Delivery Time (days) | Environmental Competence (%) |
| Cold Chain Supplier -1 | 0.1398 | 9.0588 | 0.0789 | 0.0371 | 0.0968 |
| Cold Chain Supplier -2 | 0.1429 | 8.1530 | 0.0968 | 0.0529 | 0.0909 |
| Cold Chain Supplier -3 | 0.1398 | 9.5118 | 0.0863 | 0.0265 | 0.0852 |
| Cold Chain Supplier -4 | 0.1445 | 7.2471 | 0.0947 | 0.0371 | 0.0795 |
| Cold Chain Supplier -5 | 0.1476 | 8.3341 | 0.0895 | 0.0476 | 0.0932 |

**Step-3:** Calculate the ideal best and ideal worst value

| *Weightage* | *0.32* | *0.19* | *0.20* | *0.09* | *0.20* |
|---|---|---|---|---|---|
| Attribute or Criteria | Capacity (%) | Reserved space (pallets) | Temperature-controlled Warehousing (%) | Delivery Time (days) | Environmental Competence (%) |
| Cold Chain Supplier -1 | 0.1398 | 9.0588 | 0.0789 | 0.0371 | 0.0968 |
| Cold Chain Supplier -2 | 0.1429 | 8.1530 | 0.0968 | 0.0529 | 0.0909 |
| Cold Chain Supplier -3 | 0.1398 | 9.5118 | 0.0863 | 0.0265 | 0.0852 |
| Cold Chain Supplier -4 | 0.1445 | 7.2471 | 0.0947 | 0.0371 | 0.0795 |
| Cold Chain Supplier -5 | 0.1476 | 8.3341 | 0.0895 | 0.0476 | 0.0932 |
| Positive Solution(V+) | 0.1476 | 9.5118 | 0.0968 | 0.0265 | 0.0795 |
| Negative Solution(V-) | 0.1398 | 7.2471 | 0.0789 | 0.0529 | 0.0968 |

**Step-4:** Calculate the Euclidean distance from the ideal best

$$S_i^+ = \left[\sum_{j=1}^{m}\left(V_{ij} - V_j^+\right)^2\right]^{0.5}$$

$$S_i^- = \left[\sum_{j=1}^{m}\left(V_{ij} - V_j^-\right)^2\right]^{0.5}$$

| **Weightage** | **0.32** | **0.19** | **0.20** | **0.09** | **0.20** | **Si+** | **Si-** |
|---|---|---|---|---|---|---|---|
| Attribute or Criteria | Capacity (%) | Reserved space (pallets) | Temperature-controlled warehousing(%) | Delivery Time (days) | Environmental Competence (%) | | |
| Cold Chain Supplier -1 | 0.1398 | 9.0588 | 0.0789 | 0.0371 | 0.0968 | 0.453811136 | 1.811836562 |
| Cold Chain Supplier -2 | 0.1429 | 8.1530 | 0.0968 | 0.0529 | 0.0909 | 1.359138514 | 0.906084172 |
| Cold Chain Supplier -3 | 0.1398 | 9.5118 | 0.0863 | 0.0265 | 0.0852 | 0.014224729 | 2.264904814 |
| Cold Chain Supplier -4 | 0.1445 | 7.2471 | 0.0947 | 0.0371 | 0.0795 | 2.264736501 | 0.028646025 |
| Cold Chain Supplier -5 | 0.1476 | 8.3341 | 0.0895 | 0.0476 | 0.0932 | 1.177940563 | 1.087158029 |
| Positive Solution(V+) | 0.1476 | 9.5118 | 0.0968 | 0.0265 | 0.0795 | 0.453811136 | 1.811836562 |
| Negative Solution(V-) | 0.1398 | 7.2471 | 0.0789 | 0.0529 | 0.0968 | | |

**Step-5:** Calculate TOPSIS Performance Score

$$P_i = \frac{S_i^+}{S_i^+ + S_i^-}$$

| **Weightage** | **0.32** | **0.19** | **0.20** | **0.09** | **0.20** | **Si+** | **Si-** | **Pi** |
|---|---|---|---|---|---|---|---|---|
| Attribute or Criteria | Capacity (%) | Reserved space (pallets) | Temperature-controlled warehousing (%) | Delivery Time (days) | Environmental Competence (%) | | | |
| Cold Chain Supplier -1 | 0.1398 | 9.0588 | 0.0789 | 0.0371 | 0.0968 | 0.453811136 | 1.811836562 | **0.200301** |
| Cold Chain Supplier -2 | 0.1429 | 8.1530 | 0.0968 | 0.0529 | 0.0909 | 1.359138514 | 0.906084172 | **0.600002** |
| Cold Chain Supplier -3 | 0.1398 | 9.5118 | 0.0863 | 0.0265 | 0.0852 | 0.014224729 | 2.264904814 | **0.006241** |
| Cold Chain Supplier -4 | 0.1445 | 7.2471 | 0.0947 | 0.0371 | 0.0795 | 2.264736501 | 0.028646025 | **0.987509** |
| Cold Chain Supplier -5 | 0.1476 | 8.3341 | 0.0895 | 0.0476 | 0.0932 | 1.177940563 | 1.087158029 | **0.520039** |
| Positive Solution(V+) | 0.1476 | 9.5118 | 0.0968 | 0.0265 | 0.0795 | 0.453811136 | 1.811836562 | **0.200301** |
| Negative Solution(V-) | 0.1398 | 7.2471 | 0.0789 | 0.0529 | 0.0968 | | | |

## 5. Conclusion

Many researchers and scholars have mentioned the advantages of cold supply chain management for effective and efficiencies of storage and distribution of vaccine. A temperature controlled supply chain, cold chain extends from material suppliers all the way to consumers, compromises of planning and implementation of processes and instruments. Creating a close and long term relation between the supplier and purchaser is one of the key elements of cold supply chain creation success to obtain competitive advantage. Therefore, the issue of cold chain supplier selection is the most important issue in effectively implementing supply chain. in this study initial select the five suppliers out of many by Delphi method later evaluated them by using fuzzy AHP and TOPSIS method with criteria of Price, Relative Density, Purity and Boiling Range The supplier who receives the best ranking will be selected to perform with highest TOPSIS Performance Score .

| | TOPSIS Performance Score | Rank |
|---|---|---|
| Cold Chain Supplier -1 | 0.200301 | 4 |
| Cold Chain Supplier -2 | 0.600002 | 2 |
| Cold Chain Supplier -3 | 0.006241 | 5 |
| Cold Chain Supplier -4 | 0.987509 | 1 |
| Cold Chain Supplier -5 | 0.520039 | 3 |

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