A Hybrid MCDM approach using entropy and CODAS to select vaccines cold chain logistics suppliers

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Abstract:

The COVID-19 pandemic is causing unprecedented human and economic costs in all countries and societies across the world. The COVID-19 vaccines are temperature-sensitive and face various risks for controlling temperature because of store and transport temperatures of vaccines are less than zero degree Celsius or more less. It is required to maintain the COVID-19 vaccines in a temperature-controlled area like refrigerated stores and refrigerated trucks for storing and transportation to ensure their quality. In this regard, it is of great significance to evaluate and select drug cold chain logistics suppliers from different perspectives to ensure the quality of vaccines and reduce the risks of transportation and storage. To select the best alternative from a multiple criteria decision making (MCDM) problem a Hybrid multi-criteria decision-making strategy proposed with entropy weight method (EWM) and combinative distance-based assessment (CODAS) approaches are proposed for storage and transportation of COVID-19 vaccines in India. This Entropy–CODAS multiple criteria decision-making based Hybrid approach can be used for alternative selection in real-world applications .

Keywords: Cold Supply Chain, Entropy, MCDM and CODAS

INTRODUCTION

Cold Supply Chain Management:

Cold Supply Chain Management: A cold distribution network, also known as a thermally-isolated distribution chain, is indeed an operations and supply service that delivers a series of ideal conditions for products to maintain temperature inside range from origin to the point of consuming. Food is often transported via a refrigerated supply chain. It is a process since it entails a series of operations to prepare, store, and transport items across the cold supply chain. Failing to maintain cold chain items cold renders them worthless, resulting in product waste. Both the transporter and the buyer lose revenue when cold items spoil. Thermally-isolated items are kept within appropriate temperatures and maintain the intended states from start to end with an effective cold storage facility. Ice cream must be kept cold to extend its shelf life. If temperature exceeds beyond thread, the item will lose its solid state and be rendered worthless. With the increasing global movement of essential commodities, it becomes more important to take into account the supply chain as a whole, including not only food and agriculture processing, and moreover wrapping, carrying, storing, and transmission, and perhaps even the technologies used to track the entire system. These procedures lead to more complicated distribution network and highlight the key importance of transport operations in managing the cold supply chain effective as well as efficient from origin to destination. In a various internal and external source, the management of a cold supply chain needs to be out there. For example, as product categories generally provided via cold supply chain, as well as a comprehension of usage in IT applications and the physics of heating transfer and therapy. The management of cold supply chain Full views of cold supply chains are needed by practitioners.

The Cold Supply Chain (CSC) is a method of acquiring raw resources and end consumers via temperature separated activities. A sustainable provider of the cold chain includes sustainable practices throughout its operating cycle. This ensures that the products, particularly in a poor country, are kept from ending up in landfills. Identifying the driving forces for the sustainable provider of the cold chain. Due to the specificity of the immunizations that will have to be maintained at a cold temperature for quality, The COVID-19 vaccinations confront several dangers while shipping and storage. Solving an issue with multiple decision-making criteria (MCDM). COVID-19 cold inventory management ensures safely and effectively dissemination and has been a key component in guaranteeing the efficacy and quality of immunizations.

The Pharmaceuticals Cold Chain's imports is about US$400 billion in 2003, of which around 10 percent or $41 billion was biopharmaceutical [2]. Pharmaceutical pharma's sold in 2003 over the world. From 1999 to 2003 the average annual growth in compounds in the biomedical industry was 21%, substantially greater than in traditional healthcare market at 11%, respectively. As the heat resistance of monoclonal antibodies [3], the cold chain has grown into an essential part of the entire medical arena. The growing focus on investments and management in the market for cortical biopharmaceuticals is due to many variables, including the capacity of a biopharmaceutical to meet an unmet demand, premium prices compared with other medications and low generic erosion [2]. Whilst the sector's projections are different, research company AS Insights is reported to agree that by the end of the 10th, the biopharmaceutical market is expected to reach $100 bn.

A quality management system (QMS) and risk management procedure are required to stay up with worldwide regulatory standards and tendencies [18]. Included but not confined to: organization, roles and responsibilities, processes, qualified resources, implementation strategy, conformance, regulate on changes, distribution of the right products in time, performance measures, continual improvements and client satisfaction monitoring. The following factors may apply to the QMS.

Process for risk management: A continual risk assessment procedure complements the QMS for effective distribution procedures. Physicochemical stability [5, 7, 9], ecosystem (thermal mapping, refrigeration, and temperatures and humidity tracking are all examples of temperature and relative humidity monitoring.), method of transportation [4, 17](ground, air, sea), consignment location (domestic, export), package (primary and secondary), and people are among the factors to be evaluated (training, communicating, documenting, recognizing, resolving, and rectifying adverse occurrences, and modification management are all part of the standard modus operandi.).

Literature Review:

The significance of the supplier selection process rests in assisting companies in achieving the highest level of regulated thermal and financial boost [1]. In general, the supplier selection process is divided into many stages. The procedure begins with the identification of needs and specifications. The criteria are then developed. Managers or decision makers then choose a group of capable providers. Eventually, the analysis and finalization are completed [2]. Self-sustaining selection process attempts to identify and evaluate suitable suppliers who outperform the rest of the supply chain in terms of financial, environmental, and thermal aspects [2,3,4]. As a result, the development of supply chain management should be primarily driven by the monitoring and development of professional developers [5]. COVID-19 vaccination: supply and logistics guidance by world health organization [6] gives some guidelines towards supply and logistics. the requirements for supply chain, stages in transportation and the description about the vaccines like Approval status, efficacy, safety, dose and dose regimen, duration between doses, stability, shelf life, cold chain requirements, packed volume, etc. The data helps to find the range of temperature in the storage plants, transportation trucks and also data helps to know the stability days of the vaccines at 2 degrees Celsius to 8 degrees Celsius which helps for fixing the transportation duration from source and destination. Stability of drug testing done in [7][8] International conference and stability program on drugs helps for predicting storing, transportation days. C Huayou used the entropy weight method in forecasting to determine the weights of the criteria. This research helps me to analyze the entropy method and the features inside the entropy method. S Ouyang, ZW Liu, Q Li, YL Shi improves the efficiency of the entropy weight method by modification of the process and they use the entropy method in power quality evaluation this help to determine the drawbacks in previous entropy method. It also helps the process evaluation in entropy method and also its characteristics. We use the entropy method in [9, 10] journals to find the criteria weights. Drug cold chain logistics refers to a supply chain network that ensures the quality of chilled pharmaceuticals. In a recent research on cold chain logistics of medication, Sinha et al. [11] examined the cold chain and logistics management about an immunization program using the GOI monitoring framework. The results showed that effective cold chain management and vaccination reverse logistics may increase the caliber of a vaccination campaign. Chatterjee and Pandey [12] investigated the pharmaceutical cold chain from the perspective of risk evaluation, assessing t The provider of the flow and recommending risk-aversion strategies.

Ghorabaee et al., [13] created a novel technique to tackle multi-criteria decision-making situations in 2016; this technique is dubbed CODAS, and contains a lot of features not included in previous MCDM approaches. For example, in [14] the CODAS approach was compared to various current MCDM approaches. According to their findings, the CODAS technique was effective for dealing with MCDM issues. The Euclidean and Taxicab distances from the negative-ideal point are used to assess an alternative's current effectiveness in this technique. The Euclidean distance is the fundamental assessment metric in the CODAS. When two options' Euclidean distances are extremely close, the Taxicab distance is employed to compare them. A baseline parameter determines how near Euclidean distances are to one other. The Euclidean and Taxicab distances, respectively, are measurements of norm and norm aversion spaces. As a result, the CODAS technique evaluates the options in a -norm apathy space first. An -norm disinterest occurs when the possibilities are not comparable inside this area. Each pair of options should be investigated in order to complete this procedure. The CODAS approach is described in depth in this paper, along with a numerical example. A comparative comprehensive review is also undertaken to assess the method's accuracy and sustainability.

METHODOLY

In this study multi-criteria decision-making strategy for finding weights of the first phase. various sustainability factors were analyzed and selected most effective factors. The next stage of this research focuses on the identification of cold chain providers in India, there are 44 cold supplier are identified in those select top five Logistic Saviors based on operating efficiency, Sales, technology level and satisfaction, refrigerated trucks, storage plants, Among the logistics leaders select that are preparing for “vaccines supply mission” for this purpose We utilize the EWM-CODAS MCDM-based Hybrid methodology to examine five logistics executives using five different criteria. According to the findings, the storage and transportation of Covid -19 Vaccine in India are the most commercially, ecologically, and ecologically inclusive providers.

Methodology

The following steps are followed for effective Hybrid approach for Selection of Logistic Savior’s for storage and transport of Covid -19 Vaccine

Step-1: Framing the relevant criteria for Logistic Savior’s selection

Step-2: Finding the criteria’s weights by entropy weight method (EWM)

Step-5: Performing the combinative distance-based assessment (CODAS) approach to determine the rank for Logistics Savior’s.

The following processer are applied for Selection of Logistic Saviors

(Flow chart)

Brief on Various Techniques Used

Entropy Weight Method

For assessing value dispersion, the entropy weight method (EWM) is a prominent decision-making weighing approach. The larger the dispersion, the bigger the breadth of difference, and the more knowledge that may be recovered. In the meanwhile, the score should be given more weight, and vice versa.

The measurement process includes m indicators and n samples and the value measures of the ith indicator are recorded as xij in the jth sample..

Step 1: The p_{ij} stands for the standardized value of the ith index in the jth sample, and its calculating technique is as follows:

$$P_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \tag{1}$$

Step 2: The entropy value Ei in the EWM is given as the

$$E_i = \frac{\Sigma_{j=1}^{n} P_{ij} \cdot ln\, P_{ij}}{ln\, n} \tag{2}$$

Step3: In the actual evaluation using the EWM, is $\Sigma_{j=1}^{n} P_{ij} \cdot ln\, P_{ij}$ For the sake of computation, it is usually set when $P_{ij} = 0$.

Ei's entropy value range is (0, 1). The bigger the Ei, the greater the differentiation degree of index i and the more information that may be extracted. As a result, the index should be given more weight. As a result, the weight computation mechanism in the EWM is

$$w_i = \frac{1-E_i}{\sum_{i=1}^{m}(1-E_i)} \tag{3}$$

COMBINATIVE DISTANCE-BASED ASSESSMENT (CODAS) METHOD

The CODAS (Combinative Distance-based Assessment) approach is used to solve MCDM problems. This technique employs the Euclidean distance as the major measure and the Taxicab distance as the secondary measure to estimate the attractiveness of an option, and both distances are calculated using the negative ideal point. In the CODAS approach, the option with longer distances is preferable. CODAS and contrast it with several current MCDM approaches. These evaluations reveal that the suggested strategy is efficient and produces consistent results.

Combinative Distance-based Assessment: The attractiveness of alternatives is judged using two metrics in this technique. The main and essential metric is the Euclidean distance of alternatives and the negative ideal. This kind of distance requires an area of indifference of l 2 for criterion. The secondary measurement is the taxi distance connected by the l 1-standard indifference space. It is obvious that the option that is further away from the negative-ideal solution is preferable. In this process, the Taxicab distance is used as an additional metric. if two alternatives are dissimilar based on the current Euclidean distance. Although the CODAS prefers the l 2 -norm indifference space, two other types of indifference spaces might be evaluated in its procedure. Assume we have n choices and m criteria. The following are the steps of the suggested method:

Step 1: Create the decision-making matrix (X), as illustrated below:

$$X = [x_{ij}]_{nxm} = \begin{bmatrix} x_{11} & x_{12} \cdots & x_{1m} \\ x_{21} & x_{21} \cdots & x_{21} \\ \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} \cdots & x_{nm} \end{bmatrix} \tag{8}$$

Where x_{ij} ($x_{ij} \geq 0$) represents the performance value of the ith alternative according to the jth criteria ($i \in \{1,2, \dots, n\}$ and $j \in \{1,2, \dots, m\}$).

Step 2: Make a decision matrix that is normalized. The following is how we normalize performance values using linear normalization:

$$n_{ij} = \begin{cases} \dfrac{x_{ij}}{\max x_{ij}} & if\ j \in N_b \\ \dfrac{\min x_{ij}}{x_{ij}} & if\ j \in N_c \end{cases} \quad (9)$$

Where N_b and N_c reflect the benefit and cost criterion sets, respectively.

Step 3: Make a weighted, normalized decision matrix. The following are the weighted normalized performance values:

$$r_{ij} = w_j n_{ij} \quad (10)$$

Where wj ($0 < w_j < 1$) signifies the importance of the *j*th criteria, and $\sum_{j=1}^{m} w_j = 1$

Step 4: As a result, the negative-ideal solution (point) is as follows:

$$ns = \left[ns_j\right]_{1xm} \quad (11)$$

$$ns_j = \min r_{ij} \quad (12)$$

Step 5: Calculate the Euclidean and Taxicab distances between the options and the negative-ideal solution, as indicated below:

$$\text{Ei} = \sqrt{\sum_{j=1}^{m}\left(\left(r_{ij} - ns_j\right)^2\right)} \quad (13)$$

$$\text{Ti} = \sum_{j=1}^{m}\left|r_{ij} - ns_j\right| \quad (14)$$

Step 6: Construct the relative assessment matrix, shown as follows:

$$Ra = [h_{ik}]_{n\times n} \quad (15)$$

$$h_{ik} = (E_i - E_k) + (\Psi(E_i - E_k) \times (T_i - T_k)), \quad (16)$$

Where $k \in \{1,2, \dots, n\}$ and ψ denotes a threshold function for recognizing the equality of two alternatives' Euclidean distances, and is written as follows:

$$\Psi(x) = \begin{cases} 1, & if\ |x| \geq \tau \\ 0, & if\ |x| < \tau \end{cases} \quad (17)$$

In this function, τ is the threshold parameter that the decisionmaker can set. It is recommended that you set this option to a value between 0.01 and 0.05. When the difference between two options' Euclidean distances is smaller than, the Taxicab distance is used to compare them. or the computations in this study, we use $\tau = 0.02$.

Step 7: Calculate the evaluation score for each option, as follows:

$$H_i = \sum_{k=1}^{n} h_{ik} \quad (18)$$

Step 8: Rank the choices in decreasing order of evaluation score (Hi). The option with the highest I is the best option among the others.

CASE STUDY

Entropy weight method considers criteria's for measure value dispersion. Criteria for selecting Logistic Saviors are determined based on the experience of managers and decision makers. In this present work proposes a set of practical success factors for Logistic Saviors. 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 Operating Efficiency (OE), Sales, Technology and Level of Satisfaction (T&LS), Refrigerated Trucks, Storage Plants.

	Operating Efficiency (percentage)	Sales(Q1) (crores)	Technology and Level of satisfaction (percentage)	Refrigerated trucks (num)	Storage Plants (num)
LS1	84	64.11	77	300	75
LS2	79	89.3	80	170	55
LS3	80	122.01	83	230	60
LS4	83	98.56	75	195	80
LS5	76	69.25	84	200	66
Column sum	**402**	**443.23**	**399**	**1095**	**336**

Table 1. Data Table

	C1	C2	C3	C4	C5
LS1	0.208955	0.144643	0.192982	0.273973	0.223214
LS2	0.196517	0.201476	0.200501	0.155251	0.16369
LS3	0.199005	0.275275	0.20802	0.210046	0.178571
LS4	0.206468	0.222368	0.18797	0.178082	0.238095
LS5	0.189055	0.156239	0.210526	0.182648	0.196429

Table 2. Standardization table

	C1	C2	C3	C4	C5
LS1	-0.32715	-0.27967	-0.31749	-0.35472	-0.334737
LS2	-0.31973	-0.32278	-0.32219	-0.28919	-0.296243
LS3	-0.32128	-0.3551	-0.32662	-0.32776	-0.307637
LS4	-0.32573	-0.33431	-0.31419	-0.30728	-0.341687
LS5	-0.31491	-0.29004	-0.32803	-0.31054	-0.319679
Column sum	-1.6088	-1.5819	-1.60851	-1.58949	-1.599983
E_{ij}	**0.999603**	**0.982888**	**0.999425**	**0.987605**	**0.994126**

Table 3. Entropy value Table

$1-E_{ij}$	0.000397	0.017112	0.000575	0.012395	0.005874

Sum	0.036353

W_i	**0.01**	**0.47**	**0.01**	**0.34**	**0.16**

Table 4. Entropy Weight Table

Step 1: Construct the decision-making matrix

This issue has five solutions, and the related data are shown in Table.

Weightage	0.01	0.47	0.01	0.34	0.16
	Operating efficiency (%)	Sales Qtr1 (crores)	Technology level and Satisfaction (%)	Refrigerated storage plants	Refrigerated trucks.
LS1	84	64.11	77	200	300
LS2	79	89.3	80	100	200
LS3	80	122.01	83	187	250
LS4	83	98.56	75	120	190
LS5	73	69.25	84	100	200

Table 5. The decision-making matrix

Step 2: Calculate the standardized matrix of decision.

As indicated in the Table. the standard decision matrix is created

Weightage	0.01	0.47	0.01	0.34	0.16
	Operating efficiency (%)	Sales Qtr1 (crores)	Technology level and Satisfaction (%)	Refrigerated storage plants	Refrigerated trucks.
LS1	1.00	0.52	0.91	1.00	0.93
LS2	0.94	0.73	0.95	0.56	0.68
LS3	0.95	1.00	0.98	0.76	0.75
LS4	0.98	0.80	0.89	0.65	1.00
LS5	0.90	0.56	1.00	0.66	0.82

Table 6. The normalized decision matrix

Step 3: Calculate the weighted normalized decision matrix.

The weighted normalized performance values may be determined using the weights of criteria specified in Table 1.

Weightage	0.01	0.47	0.01	0.34	0.16
	Operating efficiency (%)	Sales Qtr1 (crores)	Technology level and Satisfaction (%)	Refrigerated storage plants	Refrigerated trucks.
LS1	0.010	0.247	0.014	0.340	0.151
LS2	0.010	0.344	0.015	0.193	0.111
LS3	0.010	0.470	0.015	0.261	0.121
LS4	0.010	0.380	0.014	0.221	0.161
LS5	0.009	0.267	0.015	0.227	0.133

Table 7. The weighted normalized decision matrix

Step 4: Determine the negative-ideal solution (point)

The negative-ideal solution is determined.

Weightage	**0.01**	**0.47**	**0.01**	**0.34**	**0.16**
	Operating efficiency (%)	Sales Qtr1 (crores)	Technology level and Satisfaction (%)	Refrigerated storage plants	Refrigerated trucks.
LS1	0.010	0.247	0.014	0.340	0.151
LS2	0.010	0.344	0.015	0.193	0.111
LS3	0.010	0.470	0.015	0.261	0.121
LS4	0.010	0.380	0.014	0.221	0.161
LS5	0.009	0.267	0.015	0.227	0.133
Negative ideal solution	0.009	0.247	0.014	0.193	0.111

Table 8. The weighted normalized decision matrix and the negative-ideal solution

Step 5: Compute distances from negative ideal solution between Euclidean and Taxicab

The distances of alternatives to the negative ideal solution are also calculated in Euclidean and Taxicab according to the values obtained. Table 5 presents the results

Weightage	**0.01**	**0.47**	**0.01**	**0.34**	**0.16**	**E_i**	**T_i**
LS1	0.010	0.247	0.014	0.340	0.151	0.15317	0.18
LS2	0.010	0.344	0.015	0.193	0.111	0.09719	0.09
LS3	0.010	0.470	0.015	0.261	0.121	0.23378	0.30
LS4	0.010	0.380	0.014	0.221	0.161	0.14499	0.21
LS5	0.009	0.267	0.015	0.227	0.133	0.04530	0.07
Negative-ideal solution	0.009	0.247	0.014	0.193	0.111		

Table 9. The Euclidean and Taxicab distances from the negative-ideal solution

Step 6: Construct the relative assessment matrix

Table 3 and Equations allows to determine the relative evaluation matrix (Ra) and evaluation scores (Hi) of alternatives. (16) to (16) (18). The findings are shown in Table 5. Calculations are made with It should be remembered that $\tau = 0.02$.

	LS1	LS2	LS3	LS4	LS5
LS1	0	0.0560	0.0804	0.0081	0.1081
LS2	-0.0559	0	-0.1360	-0.0477	0.0519
LS3	-0.0807	0.1371	0	0.0889	0.1893
LS4	-0.0082	0.0479	-0.0886	0	0.0999
LS5	-0.1076	-0.0519	-0.1876	-0.0994	0

Table 10. The relative assessment matrix

Step 7: Calculate the evaluation score for each possibility.

The relative matrix and evaluation scores in Steps 6 and 7 of the CODAS techniques can be calculated according to the gaps shown in Table 9(with τ = 0.02). Table 10 summarizes the findings. The estimated evaluation values

	LS1	LS2	LS3	LS4	LS5	H_i
LS1	0	0.0560	0.0804	0.0081	0.1081	0.0919
LS2	-0.0559	0	-0.1360	-0.0477	0.0519	-0.1877
LS3	-0.0807	0.1371	0	0.0889	0.1893	0.4962
LS4	-0.0082	0.0479	-0.0886	0	0.0999	0.0510
LS5	-0.1076	-0.0519	-0.1876	-0.0994	0	-0.4465

Table 10. The assessment scores

Step 8: Ranking the options by decreasing evaluation values are

	H_i	Rank
LS1	0.0919	**2**
LS2	-0.1877	**4**
LS3	0.4962	**1**
LS4	0.0510	**3**
LS5	-0.4465	**5**

Conclusion

The cold supply chain (CSC) is a process that comprises thermally-isolated operations beginning with the purchase of raw materials and ending with the end users. This is to prevent things from going to waste, which is especially important in poorer countries. Considering the factors that impact the selection of a cold chain distributor, it is important to handle and distribute COVID-19 vaccinations within temperature-controlled areas such as refrigeration warehouses and refrigeration vehicles to assure their excellent quality. Under this approach, it is important to assess and select medication transportation and logistics providers from a variety of perspectives in order to make sure vaccine quality while reducing transit and storage risks. The existence of several uncontrollable variables in the distribution phase necessitates the creation of an adequate monitoring program. In this study, the selection of cold chain providers in the context of India is carried out., there are 50 cold supplier are identified in those select top five cold chain logistic leaders by Delphi method with essential criteria of Operating efficiency, Sales, Technology level and Satisfaction, refrigerated storage plants, Refrigerated trucks. later evaluated them by using with entropy weight method (EWM) and combinative distance-based assessment (CODAS) MCDM-based Five logistics leaders are analyzed based on five different criteria via hybrid technology. The best-ranked cold chain logistic leaders will be chosen to succeed with the highest CODAS evaluation score. This Entropy–CODAS multiple criteria decision-making based Hybrid approach can be used for alternative selection in real-world applications.

	H_i	Rank
LS1	0.0919	**2**
LS2	-0.1877	**4**
LS3	0.4962	**1**
LS4	0.0510	**3**
LS5	-0.4465	**5**

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