Towards Effective Management of Cold Chain: A DEMATEL Approach

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Abstract: Information and infrastructure management is critical component in management of cold chain. Management of cold chain thrives to preserve the integrity of cold chain from the point of production and processing, to storage at the consuming household or restaurant. This paper identifies the barriers for effective management of cold chain and evaluate the inter-relationship among them. The findings suggest that unavailability of proper infrastructure is highly impacting whereas the lack of regulatory framework and commitment of top management are relatively influencing the effective management of cold chain. Government needs to upgrade the redundant infrastructure & develop robust network and impose regulatory framework to mitigate the uncertainties associated with cold chain operations. Mitigation of barriers may have implications on food security and conservation of environment resources. This work may be used policy makers of government or industries to understand the interrelationship of barriers and their influence on cold chain management.

Keywords: Cold Chain; Cold Chain Management; Barriers; Temperature Controlled Logistics, Perishable Products

1. Introduction
Perishable products such as food, flowers, pharmaceuticals, and chemicals, needs temperature-controlled logistics, to mitigate the chemical reactions in them. To ensure the safety and quality of perishable products industries are increasingly relying on the cold chain. The cold chain refers to “the transportation of temperature sensitive products along a supply chain through thermal and refrigerated packaging methods and the logistical planning to protect the integrity of these shipments” [1]. A typical cold chain infrastructure generally consists of ‘pre-cooling facilities’, ‘cold storages’, ‘refrigerated carriers’, ‘packaging’, ‘warehouse’, ‘traceability system’ and retailer & consumers, under the aegis of information management systems [2]. An efficient management of the cold chain is the key to prevent unnecessary losses and maintaining the bottom line. Due to increasing focus of developing economies towards export of agricultural products, temperature-controlled logistics is getting more vital. To keep food free from bacterial, microbial, and fungal contamination for extended period of time, for commercial as well as health reasons, the role of cold chain is becoming imperative [3]. However, developing countries, are facing diverse problems such as deficient infrastructural facilities, including lack of regulatory framework, deficient infrastructural facilities, out-of-date technologies, and shortage of competent work force in developing a robust cold chain logistics. Effective management of cold chain needs a thorough understanding of chemical and biological processes linked with perishability in addition to physical means (such as dedicated warehousing, loading/unloading facilities, and refrigeration units non-destructive examination, vacuum pre-cooling technology, automatic identification, global positioning system (GPS) transportation vehicle automatic temperature control system, and electronic data interchange) to insure appropriate temperature conditions along the supply chain. Therefore, there is a need to identify the barriers that are critical in developing and managing comprehensive cold chain.

1.1 Research Objectives
The following are the primary aims of the research undertaken and communicated through this paper:

I. To identify the barriers for effective management of cold chain.
II. To evaluate the identified barriers in order to understand their interrelationships in effective management of cold chain.

It is important for the policy makers and executive involved in business of cold chain to understand characteristics and interrelationship of barriers that influence the cold chain management.

2. Major Barriers for effective management of cold chain

The understanding of the barriers for effective management of cold chain may help management, as well as policymakers, to develop an effective strategy. Barriers for effective management of cold chain are identified through systematic literature review and later verified with expert’s opinion shown in Table 1.

| S.No | Barriers                          | References     |
|------|----------------------------------|----------------|
| B1   | Lack of top management support   | [4], [5]       |
| B2   | Higher number of intermediaries  | [6]            |
| B3   | Improper collaboration           | [7, 15]        |
| B4   | High cost for installation and operation | [2, 8] |
| B5   | Lack of proper infrastructure    | [9, 13]        |
| B6   | Lack of government regulation/ standard | [10, 11] |
| B7   | Lack of capacity building        | [12, 14]       |
| B8   | Lack of effective traceability   | [11]           |

3. Research Methodology

The aim of this work is to evaluate the barriers for effective management of cold chain through causal relationship. The major barrier is identified through literature review and experts input. The causal relationship among these barriers are is evaluated through a DEMATEL approach.

3.1 DEMATEL Method

The DEMATEL technique is adopted as a solution methodology in this article. DEMATEL is a comprehensive method to provide the causal relationship among the complex factors through graphs. Some other system-based tool such as ISM and TISM are used for the develop the relationship among factor/barriers [14, 5, 11]. However, these system-based tool (ISM/TISM) is having some limitation [11, 16]. These methods are more subjective in nature and inefficient to quantify the relationships. Therefore, we adopt the DEMATEL approach for the analysing the complex causal relationship among the barrier for effective management of cold chain. The DEMATEL method is summarised step by step as follows:

Step 1: The scale may be designated four levels (i.e., 0, 1, 2, 3, 4) to construct direct influence matrix (See Table 2). Each expert was asked to evaluate the direct influence between each two-factor combination through a score 0, 1, 2, 3, 4. The notation of $x_{ij}$ represents that the factor $i$ influence the factor $j$. The diagonal element (i.e., $i=j$) of the direct inflectional matrix is zero. A non-negative n×n matrix is obtained for each expert as $X^k = [x_{ij}^k]$ where $k$ is the no of experts $1 \leq k \leq H$. Thereafter obtain $X^1$, $X^2$, $X^3$, $X^H$ from $H$ experts.

| Table 2: Scale and their interpretation |
|----------------------------------------|
| Scale | 0 | 1 | 2 | 3 | 4 | Interpretation |
|-------|---|---|---|---|---|----------------|
| No influence | Very Low influence | Medium influence | High influence | Very high influence |

Step 2: Establish an overall direct-relation matrix from $H$ respondents, the average matrix $A = [a_{ij}]$ can be obtained from the equation:

$$a_{ij} = \frac{\sum_{k=1}^{H} x_{ij}^k}{H}$$ (1)
Step 3: Obtain normalized initial direct-relation matrix, \( D \) using Equation (2) & (3).
\[
D = A.S \tag{2}
\]
Where \( S = \frac{1}{\max_{i\leq n} \sum_{j=1}^{n} a_{ij}} \) \tag{3}

Each element in matrix \( D \) falls between zero and one.

Step 4: Calculate Total relation matrix “\( T \)” using Equation (4)
\[
T = D.(I-D)^{-1} \tag{4}
\]

Step 5: Determine the causal parameters through Equations. (4) and (5):
\[
R_i = \sum_{j=1}^{n} t_{ij} \quad V_j \tag{5}
\]
\[
c_i = \sum_{j=1}^{n} t_{ij} \quad V_i \tag{6}
\]
Where \( R_i \) indicate the sum of rows and \( C_i \) represent the sum of columns.

Step 6: Develop a causal and effect diagram using the dataset consisting of prominence (\( P_i \)) and net effect(\( E_i \)) using expressions (6) and (7):
\[
P_i = R_i + C_j \mid i=j \tag{7}
\]
\[
E_i = R_i - C_j \mid i=j \tag{8}
\]
The difference \((R_i - C_i)\) shows the net effect that factor \( i \) contributes to the system. Moreover, if \((R_i - C_i)\) is positive, factor \( i \) is a net cause, while factor \( i \) is a net receiver or result if \((R_i - C_i)\) is negative.

4. Results

The barriers for effective management of cold chain are identified through literature review. These barriers are discussed with a five members expert’s group to obtaining the deeper insight of these barriers and finalised eight barriers (See Table 1). After finalising the barriers, the experts were asked to evaluate the direct influence among the barriers for effective management of cold chain on the scale of 0-4 (See Table 2). The evaluation is taken in form overall direct relation matrix is obtained through expert input and shown in table 3 using equation 1.

| Table 3: Overall Direct-Relationship Matrix (\( Z \)) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Barriers**    | **B1**          | **B2**          | **B3**          | **B4**          | **B5**          | **B6**          | **B7**          | **B8**          |
| **B1**          | 0               | 1.8             | 2               | 1               | 2               | 2               | 0               | 3               |
| **B2**          | 0               | 0               | 3.8             | 1               | 0               | 0.8             | 3               | 2               |
| **B3**          | 1               | 2               | 0               | 2               | 0               | 0               | 2               | 3               |
| **B4**          | 2               | 1               | 2               | 0               | 2               | 0               | 2.2             | 3               |
| **B5**          | 2               | 2               | 1               | 3               | 0               | 1               | 2               | 3               |
| **B6**          | 2               | 0               | 1               | 1               | 3               | 0               | 1               | 0               |
| **B7**          | 0               | 2               | 2.2             | 1.8             | 2               | 0               | 0               | 2               |
| **B8**          | 1               | 0               | 0               | 1               | 2               | 1               | 0               | 0               |

Further, the Normalized direct-relation matrix (\( N \)) is developed using Equation (2) and (3). Thereafter, this matrix is transformed into Total-Relation Matrix (\( T \)) using Equation (4).

In matrix \( T \), the summation of rows and column are represented by \( R \) and \( C \) respectively using equation (5) and (6) (Please see table 4). \( R_i \) represents the total effect of barrier \( i \) to the other barrier, and \( C_i \) represents net influence received by \( j \) barrier from other barriers. After the determination of \( R \) and \( C \) for every row and column, the prominence (\( P_i \)) and net effect (\( E_i \)) is calculated using equation (7) and (8). The net cause/effect of each barrier are decided through “\( E_i \) (i.e. R-C)”. If \( E_i \) is positive, then the barrier is considered to produce the net cause and if negative then the barrier is the net effect. These cause and effect are shown in Table 4.

| Table 4: Cause and Effect of barriers |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Barriers**    | **R**           | **C**           | **R+C**         | **R-C**         | **Cause/Effect** |
| **B1**          | 2.860626        | 1.95317         | 4.813795        | 0.907456        | Cause           |
| **B2**          | 2.481888        | 2.277517        | 4.759405        | 0.204372        | Cause           |
| **B3**          | 2.362093        | 2.853708        | 5.2158          | -0.49161        | Effect          |
| **B4**          | 2.979116        | 2.768657        | 5.747773        | 0.210459        | Cause           |
| **B5**          | 3.395697        | 2.631742        | 6.027439        | 0.763955        | Cause           |
| **B6**          | 2.268626        | 0.808977        | 3.077603        | 1.45965         | Cause           |
| **B7**          | 2.511215        | 2.914986        | 5.426201        | -0.40377        | Effect          |
| **B8**          | 1.421412        | 4.071917        | 5.493328        | -2.65051        | Effect          |
The R+C and R-C are plotted in figure 1, which shows the causal relationship among the barriers for effective management of cold chain. These results are discussed with the experts for further insights.

5. Discussion
The cold chain management is very challenging in the developing countries due to the several barriers. The result shows that the most important barrier is the “lack of proper infrastructure”. Based on the “R+C” values, the importance order of the barriers is B5 > B4 > B8 > B7 > B3 > B2 > B1 > B6. These identified barriers are categorised into “influential group” and “influenced group” based on the sign of the “R-C” values. Five barriers belong to the “influential group” and three from the “influenced group”.

5.1 Influential barriers
The most influential barrier is the “lack of government regulation/standard” among all the identified barriers. Due to the lack of standard and government regulation, the cold chain partners are not able to effectively manage the cold chain practices. The Government would need to support the industries by proving some relaxation in taxes and infrastructure subsidies in their initiatives. The second most influencing barrier is the “Lack of top management support”. The top management takes initiatives through collaboration with other cold chain partners in capacity building by providing training to the workforce. However, the top management is facing challenges from the other factors such as lack of proper infrastructure (poor highways, lack of cold storage, transportation vehicle automatic temperature control) and a higher number of intermediaries. Next influential barrier is the “lack of proper infrastructure”. Due to the poor infrastructure, the cold chain integrity is challenged several times. In the developing countries, the poor highway condition causes the unnecessary delay in the logistics and lack of cold storage causes the wastages of a large amount of vegetables and fruits. The fourth important barrier is the “High cost of installation and operations”. The installation cost of the cold chain infrastructure is very high. This factor affects the industry people to maintain the cold chain integrity. The producer (such as farmers) does not afford the higher operating cost of the cold chain. The government would need to provide cold chain facilities to the farmers. The next influential barrier is the “higher number of intermediaries”. In the developing countries, a large number of middlemen, which increases the unnecessary hurdles to maintain the cold chain integrity. In India, some initiative is taken by the government to reduce the unnecessary delay through “National Agriculture Market (NAM)”, “Kisan Mandi” which connect the framers to the market.

5.2 Influenced barriers
The barriers which are influenced by other barriers belong to the influenced barrier. The increasing order of the influenced barrier is the B7>B3>B8. The highest influenced barrier is the “lack of effective traceability”. Effective traceability is influenced by government regulation, top management support and collaboration among cold chain partners. The second most influenced barrier is “improper collaboration”. To effectively manage the cold chain collaboration is an important element. Last influenced barrier is the “lack of capacity building”. Due to the uneducated farmers and semi-skilled workers, the cold chain faces many challenges.
6. Implications
This research work will be beneficial for industry professionals in developing strategies for mitigating these barriers for effective cold chain management in the developing countries. This work assists the decision makers to have a holistic insight into the inter-relationships among the various barriers instead of looking separately. These barriers are further analysed for the root cause analysis. This study also helps the government to develop the policies to prevent the wastage of perishable products.

7. Conclusion
The barriers to the effective management of cold are identified through the literature review and validated through the expert opinion. After finalizing the barriers, the interrelationship among the barrier is evaluated using the DEMATEL approach. These barriers are categorised into two groups namely “influenced” and “influential” group. The result is discussed with the expert and useful insight is provided in the discussion section. Finally, the implication of this study is provided.

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