

Modeling Barriers of Green Cold Chain Management in India

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ABSTRACT

In this twenty-first century, our country is still incurring significant post-harvest losses. Most of the cold storage facilities are based on conventional energy intensive process with outdated technologies. Improper storage and cold treatment infrastructure reduces the life and deteriorates the quality of perishable products. Supply chain practitioners adopted the green cold chain management practices to overcome numerous challenges associated with developing the cold chain network. Literature review reported that green cold chain management is underdeveloping phase in India, but these practices have gained huge popularity in the western world. The purpose of the paper is to identify necessary barriers, determine hierarchical and contextual relationships between variables influencing green cold chain practices in India. Here researcher used interpretive structural methodology that uses systematic application of some elementary notions of graph theory approach and Boolean algebra to construct directed graph. Further the dependence and driving power of variables are categorised using MICMAC analysis. The formulation of strategy considers barriers of green cold chain management, i.e.: (1) High capital costs of renewable projects, (2) Outdated technology, (3) Poor cold chain network, (4) Lack of skilled manpower, (5) Poor cold storage Infrastructure, (6) Cold chain sterilisation with chemicals, (7) Lack of reverse logistics, (8) Lack of information system infrastructure, (9) Lack of government support, and (10) Non-recyclable packaging. The findings suggest that cold chain infrastructure and government support are key drivers of green cold chain practices.

Keywords: Green Cold Chain Management, Agriculture, Supply chain, Barriers, models, ISM, MICMAC

INTRODUCTION

According to the World Bank's 2014 Logistics Performance Indicator, India is ranked 54th and is behind countries like Japan, United States, Germany, and China. Logistics costs account for around 6-10 percent of average retail prices in India as against the global average of 4-5 percent. Therefore, there is a clear scope to improve margins by 3-5 percent by improving the efficiency of the supply chain and logistics processes. Developing an integrated supply chain, including cold chain can save up to INR 300 billion annually and at the same time reduce the wastage of perishable agricultural produce (ONICRA Report, 2014). In India agriculture sector is one of the key contributors in national GDP and contributed 17% in the year 2013-14. Therefore agriculture is a critical sector and an important driver of growth for rest of the economy. Proper storage and transport is crucial for this sector since cooling of majority of agriculture produce is done before it is transported to sorting centers and final refrigeration. But it is worth noting that the price of vegetables, fruits, milks, eggs, meat, and fish has been rising faster in spite of the fact that India is the second highest producer of fruits and vegetables. This is led by inadequate supply chain and logistics infrastructure and management. Also

power crisis and the rising energy costs is also a burning issue in front of many companies. This has forced to re-think and development of alternative energy efficiency technologies. In cold storage chain, the entire refrigeration system is among the most energy-intensive areas, but also offers opportunity for short and long term saving. It also provides an opportunity for enhancement of sustainable development and cold chain management (Mulobe & Huan, 2012). Therefore everybody is looking forward to switch over to renewable source of energy. This will give India a low carbon future with availability of better quality of food products at an economic price.

To evaluate research developments and directions of future research in green cold chain practices of agricultural produce in India, we ask the following research questions:

1. What are the barriers in building and implementing a green cold chain in India?
2. What is the interrelationship between barriers of green cold chain in context to India?
3. Define future research in the area of green cold chain of agricultural produce in India?

This paper is structured into four additional sections. The next section presents the literature review which

helps to identify the barriers. The third section introduces ISM methodology and MICMAC analysis; the results are presented in section four. Finally the conclusions, managerial implications, limitations, and directions of future research are presented.

LITERATURE REVIEW

The concept of “Green Cold Chain” is observed as current topic for managerial principle. The cold chain infrastructure consists of pre-cooling facilities, refrigerated storage, refrigerated transport, packaging, and information management systems. Here researcher made an attempt to understand, what work has been carried out in the past in the direction of “Green Cold Chain”. In order to understand the evolution of GCC, review was performed on latest papers published in reputed journals from EBSCO database.

The literature review is limited to only include: scientific research from the last 10 years; Cold Chain; Green Cold Chain. Moreover each reviewed paper need to match the filtering criteria such as: the research study must be written in English and published in peer reviewed journals between 2005 and 2015 and manuscripts with non-managerial focus were excluded from the review process.

To address the three research questions, a thorough review of papers was performed. Only seminal papers and selected work are considered in the present study.

Status of Cold Chain Management in India

The national cold chain summit 2015 reports that Indian cold chain industry is expected to grow at a CAGR of 28% over the next four years and reach a market size of USD 13 Billion in 2017. This sector presents a great opportunity for foreign companies to explore and invest.

The Indian cold chain sector is highly fragmented with more than 3500 companies in the whole value system. Organised players contribute only 8% to 10% of the cold chain industry market as on today. North India together has 47 percent of cold stores whereas; Eastern region occupies 33 percent of cold stores.

As per National Centre for Cold chain Development (NCCD) report 2015, the country has created 31.82 MT of cold storage space. This evaluates into a current gap of 3.27 MT in cold storage space.

The cold chain logistics is at a nascent stage in developing countries like China and India (Xin et al., 2013). In India the bottlenecks in food processing sector are non-availability of critical infrastructure facilities such as cold chain, packing and quality testing centers (Rathore, 2013). There are numerous challenges of cold storage and recently the weak links of fruits and vegetables cold chain has been identified by (Negi & Anand, 2015 a,b). NCCD 2015 report presented the major components that need to be developed for effective integration of the cold chain sector, are static infrastructure, mobile infrastructure, standards and protocols, and skilled resources.

Verbic (2006) examined the parameters of preservation of perishable goods in cold chain logistics using econometric estimation technique. There is tremendous scope of improvement of cold chain logistics in developing countries. Xu et al. (2014), showed that comprehensive risk prediction of cold chain logistics can be calculated using improved neural network algorithm.

Green Agricultural Products supply chain (GAPSC) has been defined as the concept of “green health and environmental protection” throughout the agricultural products supply chain. The dimensions of GAPSC are green design, green material, green production, green manufacturing, green logistics, green marketing and green recycling (Zhao et al., 2013).

Table 1: Cold Chain Infrastructure Gap

Type of Infrastructure	Infrastructure Requirement	Infrastructure Created	All India Gap
Pack House	70,080 nos.	249 nos.	69,831 nos.
Cold Storage (Bulk)	341,64,411 MT	318,23,700 MT	32,76,962 MT
Cold Storage (Hub)	9,36,251 MT		
Reefer Vehicles	61,826 nos.	9,000 nos.	52,826 nos.
Ripening Chamber	9,131 nos.	812 nos.	8,319 nos.

Source: NCCD report 2015

Bag and Anand (2015) reported that outdated technology is one of the reasons for failure of sustainable supply chain network in food processing industry which is directly linked with green cold chain management in India.

Renewable sources of energy may be used to supply power to the cold chain infrastructure. Sinha and Tripathi (2014) have done an interesting study in the area integrating renewable energy to cold chain. They have highlighted the need for integrating renewable energy in this sector. 25-30% losses are occurring in the post harvest stage due to lack of proper storage and transit facility. It is happening due to unreliable grid power supply and which necessitated the need for self sustained, environment friendly renewable source of energy to avoid the losses. Bag, Dubey, and Mondal (2015) suggested that currently untapped energy from waste has a potential of generating 439 MW of power from 32,890 TPD of combustible waste. Policy makers and technologists may think of developing waste to energy plants in key areas and supply the energy through state grids to these cold chain storages.

The renewable technological options for cold storage facilities are storage photovoltaic power pack, solar photovoltaic system+ diesel gen-set hybrid, solar photovoltaic system+ phase change material, vapour absorption machines using solar thermal energy, biomass gasifier and solar/biomass cogeneration. These projects can be rewarding and significant monetary savings. But the high capital costs involved in setting up the facility are a major disincentive. Installation cost is also higher because of the cost of importing the equipment and bringing installation engineers from overseas (Joshi et al., 2009).

Mulobe and Huan (2012) conducted a study and presented a combination of three efficient technologies for cold rooms.

Freiboth *et al.* (2013) highlighted some of the possible problem areas in the cold chain, from the cold store to the port, by analysing historic temperature data from different fruit export supply chains of apples, pears and grapes. In addition, a trial shipment of apples was used to investigate temperature variation between different pallets in the same container. This research has added value by identifying the need to improve operational procedures in the cold chain.

Cold chain management is a more complicated barrier for exporters (Sandrey et al., 2008).

Aung and Chang (2014) presented comprehensive information about traceability with regards to safety and

quality in the food supply chain. Good traceability systems will help to minimise the production and distribution of unsafe or poor quality products, thereby minimizing the potential for bad publicity, liability, and recalls.

Sustainability practices and dynamic capabilities in the supply chain are used among others to enhance traceability and tracking and to fulfill customer demands (Beske et al., 2014).

Most essentially cold chain management should not neglect the packaging aspects. Packaging protects the products from microbiological and sensory deterioration. Merwe et al. (2013) recommends all product developers and manufacturers in the cold chain must take into account consumers' experiences, requirements and needs of the packaging standard.

From the literature review the following gaps emerged:

- ◆ Cold chain is at a nascent stage in developing country like India. There is dearth of studies on green cold chain management.
- ◆ Although studies are available on identifying barriers in the cold chain. But there is lack of studies which presented the contextual interrelationship between the barriers.

RESEARCH DESIGN

ISM based Model

The appropriate methodology for addressing the research question is ISM based modeling approach. ISM can transform complex links into a transparent model. Nowadays this technique has gained popularity due to multiple benefits. ISM has been used in various areas of supply chain management. The ISM steps followed in the present study has been adopted based on the guidelines by Attri et al., (2013).

Findings of Barriers from Literature Review

Literature review was conducted to identify the leading barriers. Next a questionnaire was presented to the five experts from the food industry and asked them to analyse the listed barriers, eliminate the repeat barriers and rearrange the list. In this process the initial list of 17 barriers was narrowed down to 10 and further used in the ISM modeling and presented in Table 2.

Table 2: List of Ten Barriers Refined Through Experts' Opinion

SI No	Barriers	Source
1	High Capital costs of renewable projects	Painuly (2001); Beck & Martinot, (2004); Mirza,(2009)
2	Outdated Technology	Beamon (1999); Handfield et al., (2005).
3	Poor Cold chain network	Vermeulen et al., (2006); Plambeck,(2012)
4	Lack of Skilled manpower	Rao, (2007). ; Muduli et al., (2013); Luthra et al., (2014)
5	Poor Cold storage Infrastructure	Herlambang et al., (2006); Narrod et al., (2007); Okello et al., (2007)
6	Cold Chain sterilisation with chemicals	Kirezieva et al., (2013); Reeb et al., (2014)
7	Lack of Reverse logistics	Rogers(2001); Zhu et al., (2008)
8	Lack of Information system infrastructure	Jharkharia & Shankar (2005); Fawcett et al.(2008); Mudgal et al., (2010)
9	Lack of Government support	Mathiyazhagan et al., (2013); Govindan et al., (2014)
10	Non-Recyclable packaging	Hervani et al., (2005); Walker et al., (2008)

DATA ANALYSIS AND DISCUSSIONS

In this section the steps of ISM modeling have been presented. The first step is building the structural self interaction matrix where judgments of experts were used to understand the links between the ten barriers. Further the SSIM is converted to reachability matrix which is basically a binary matrix consisting of "1" and "0". Then transitivity principle is checked and level partitioning is done. The final step is developing the diagraph which basically gives us an understanding of the relationships between the identified barriers.

	10	9	8	7	6	5	4	3	2	1
1	O	A	O	V	V	V	O	O	V	
2	V	A	V	V	V	O	O	O		
3	O	A	A	V	O	A	O			
4	V	A	O	O	O	O				
5	V	A	V	V	V					
6	O	A	O	O						
7	V	A	A							
8	V	A								
9	V									
10										

Developing the Structural Self Interaction Matrix (SSIM)

For developing SSIM in Table 3, the below symbols have been used to denote the direction of relationships between variables (i and j):

- V : i lead to j but j does not lead to i
- A : i do not lead to j but j lead to i
- X : i lead to j and j lead to i
- O : i and j are unrelated to each other

Table 3: Structural Self-Interaction Matrix

Develop Reachability Matrix

The SSIM has been converted into a binary matrix i.e., the reachability matrix (Table 4) by substituting V, A and O by 1 and 0. The substitution of '1' and '0' is done as below:

- I. If the (i, j) entry in the SSIM is V, then the (i,j) entry in the reachability matrix becomes '1' and (j,i) entry becomes '0'
- II. If the (i, j) entry in the SSIM is A, then the (i,j) entry in the reachability matrix becomes '0' and (j,i) entry becomes '1'
- III. If the (i, j) entry in the SSIM is X, then the (i,j) entry in the reachability matrix becomes '1' and (j,i) entry also becomes '1'
- IV. If the (i, j) entry in the SSIM is O, then the (i,j) entry in the reachability matrix becomes '0' and (j,i)

entry also becomes '0'

Table 4: Initial Reachability Matrix

	1	2	3	4	5	6	7	8	9	10	Driving power (Y)
1	1	1	0	0	1	1	1	0	0	0	5
2	0	1	0	0	0	1	1	1	0	1	5
3	0	0	1	0	0	0	1	0	0	0	2
4	0	0	0	1	0	0	0	0	0	1	2
5	0	0	1	1	1	1	1	1	0	1	7
6	0	0	0	0	0	1	0	0	0	0	1
7	0	0	0	0	0	0	1	0	0	1	2
8	0	0	1	0	0	0	1	1	0	1	4
9	1	1	1	1	1	1	1	1	1	1	10
10	0	0	0	0	0	0	0	0	0	1	1
Dep power (X)	2	3	4	3	3	5	7	4	1	7	

4	0	0	0	1	0	0	0	0	0	1	2
5	0	0	1	1	1	1	1	1	0	1	7
6	0	0	0	0	0	1	0	0	0	0	1
7	0	0	0	0	0	0	1	0	0	1	2
8	0	0	1	0	0	0	1	1	0	1	4
9	1	1	1	1	1	1	1	1	1	1	10
10	0	0	0	0	0	0	0	0	0	1	1
Dep power (X)	2	3	4	3	3	5	7	4	1	8	

Transitivity Principle

After incorporating the transitivity concept as described above, the final reachability matrix is obtained as shown in Table 5.

Table 5: Final Reachability Matrix

	1	2	3	4	5	6	7	8	9	10	Driving power (Y)
1	1	1	0	0	1	1	1	0	0	0	5
2	0	1	0	0	0	1	1	1	0	1	5
3	0	0	1	0	0	0	1	0	0	1*	3

Level Partitioning

The final reachability matrix obtained in Table 5 is now partitioned into different levels. The results for iterations 1 to 8 are summarised in Table 6.

Diagraph

From the final Reachability Matrix and level partitions, the structural model is generated by means of nodes and lines of edges. If there is a relationship between the barriers j and i, this is shown by an arrow which points from i to j. This is called digraph.

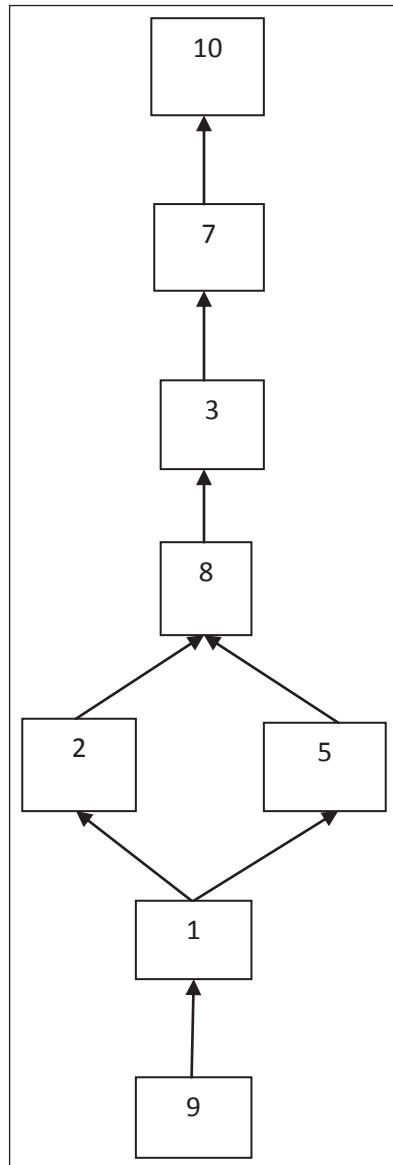
The analysis yields an ISM hierarchy in which the elements are Non-recyclable packaging (the top level), Lack of reverse logistics (second level), Poor Cold chain network (third level), Lack of Information system infrastructure (fourth level), Outdated technology and Poor cold storage Infrastructure (fifth level), High Capital costs of renewable projects (sixth level), and Lack of government support (bottom level).

Table 6: Level Partitioning

Variables	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,2,5,6,7	1,9	1	VI
2	2,6,7,8,10	1,2,9	2	V
3	3,7,10	3,5,8,9	3	III
4	4,10	4,5,9	4	II
5	3,4,5,6,7,8,10	1,5,9	5	V
6	6	1,2,5,6,9	6	I
7	1,10	1,2,3,5,7,8,9	1	II
8	3,7,8,10	2,5,8,9	8	IV
9	1,2,3,4,5,6,7,8,9,10	9	9	VII
10	10	2,3,4,5,7,8,9,10	10	I

The resulting ISM model is illustrated in Fig. 1.

Fig. 1: Diagram



MICMAC Analysis

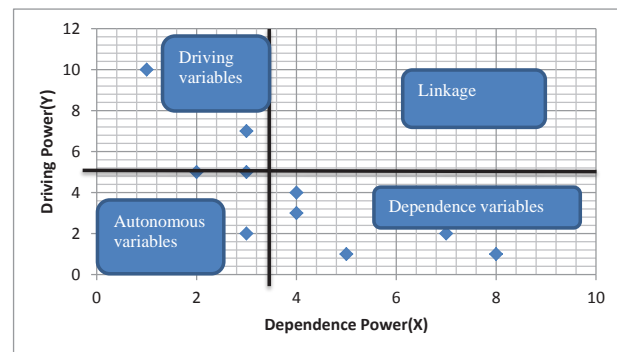
MICMAC analysis helps to analyse the drive power and dependence power of variables. Based on the drive power and dependence power the variables have been classified into four variables: autonomous, linkage, dependent, and independent variables and presented in Fig. 2.

Table 7 shows the dependence and driving power of variables which is derived from final reachability matrix (Table 5) of ISM steps.

Table 7: Position coordinates of identified variables

Variables	Dependence Power (X)	Driving Power (Y)
1	2	5
2	3	5
3	4	3
4	3	2
5	3	7
6	5	1
7	7	2
8	4	4
9	1	10
10	8	1

Fig. 2: MICMAC analysis



Findings from MICMAC analysis

Cluster 1: Autonomous Variables

These variables have a weak drive power and weak dependence power. They are relatively disconnected from the system, with which they have few links, which may be very strong. In this cluster we have three variables i.e., 1 (High Capital costs of renewable projects), 2 (Outdated technology), and 4 (Lack of skilled manpower).

Cluster 2: Dependence Variables

These variables have a weak drive power but strong dependence power. In this cluster we have five variables, i.e., 3 (Poor Cold chain network), 6 (Cold chain sterilisation with chemicals), 7 (Lack of reverse logistics), 8 (Lack of Information system infrastructure), and 10(Non-recyclable packaging).

Cluster 3: Linkage Variables

These variables have a strong drive power as well as strong dependence power. In this cluster we do not have

any variables.

Cluster 4: *Driving Variables*

These variables have a strong drive power but weak dependence power. In this cluster we have two variables i.e. 5 (Poor cold storage Infrastructure) and 9 (Lack of government support).

CONCLUSION

Green cold chain management is at a nascent stage in India. The present study employed ISM analysis which yields an hierarchy in which the elements are Non-recyclable packaging (the top level), Lack of reverse logistics (second level), Poor Cold chain network (third level), Lack of Information system infrastructure (fourth level), Outdated technology and Poor cold storage Infrastructure (fifth level), High Capital costs of renewable projects (sixth level), and Lack of government support (bottom level). Eliminating the bottom level barriers will improve the green cold chain management in India. The revival of the cold chain sector is expected to open up a plethora of opportunities for players having strong linkages in the agriculture value chain. Significant investment opportunities are yet to be tapped in the areas of supply chain management, cold storages, financing, retailing and exports. This can only be achieved by carefully designing a sustainable cold chain network by removing the barriers. This will help in minimizing losses, damages and build efficiency for enhancing performance of agricultural sector in India. There is a requirement of forming an association in India like South African Refrigerated Distribution Association (SARDA) which will create a communication forum for all cold chain role players to address matters of common interest and keep updated of latest green technologies. Government support is essential for developing cold chain centers and subsidies for operating refrigerated vehicles. There is a need to open vocational training centers since vocational training is required to train manpower for operating the green cold chain system. Finally proper infrastructure is required to operate a green cold chain which necessitates installation of green energy efficient technologies, exploit information technology and RFID usage to track and manage the entire system.

Managerial Implications

The research output provides valuable insights to a supply chain practitioner in food processing sector. Designing the green cold chain require careful designing of the entire

network and utilizing the right technology to exploit benefits.

Government should implement a scheme for human resource development in the cold chain sector on developing technologists, managers, entrepreneurs and manpower for green cold chain management in India.

LIMITATIONS

The first drawback is that only limited number of variables is considered in the development of ISM model to avoid complexity of the ISM methodology. Secondly experts' assistance is taken to analyze the driving and dependence power of variables under study and may be influenced by the expert's knowledge and familiarity with the firm, its operations, and its industry. Thirdly the model is not statistically tested.

FUTURE RESEARCH DIRECTIONS

Structural Equation Modeling approach will be used to test the validity of the developed hypothetical model.

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