

Indian cold chain scenario



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Indian cold chain: modeling the inhibitors Rohit Joshi, Devinder Kumar

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Institute of Technology, Delhi, New Delhi, India Abstract Purpose - The cold

chain has become an integral part of the supply chain of perishable items.

Recent studies have shown a critical absence of a strong and dependable

cold chain in developing economies. The purpose of this paper is to set out

to identify and inter-relate the inhibitors that significantly influence the ef-

iciency of a cold chain in developing economies like India.

Design/methodology/approach - The synthesis and prioritization of inhibitors

are done on the basis of an extensive literature review as well as

consultation with academicians and industrial professionals. Using semi-

structured interviews and Fuzzy Interpretive Structure Modeling (FISM)

approach, the research presents a hierarchy-based model.

Findings - The end result is a model that establishes the relationships among

the identified inhibitors with their respective dominance. The research

shows that there exists a group of inhibitors having a high driving power and

low dependence with strategic importance and requiring maximum attention

and another group includes inhibitors that have high dependence and the

consequential actions. Research limitations/implications - At the time when

cold chain is the key domain for the food sector, these findings will be

immensely helpful for industry professionals, Government, non-government,

academia and the community in developing strategies and impounding the

root causes responsible for the inefficient and weak cold chain in India. The

Indian situation echoes to the situation in most of the developing economies

and similar solutions can apply there also. These findings will be truly useful

for organizations that are planning to operate food chains in developing nations. Originality/value - Presentation of inhibitors in hierarchy and their classification into driver and dependent categories with their respective dominance on the system is a unique effort in the area of cold chain management.

This would help decision makers to better utilize the limited resources.

Keywords Supply chain management, Modelling, India Paper type Research paper
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1108/00070700911001077 Introduction A supply chain of perishable items is referred to as a "cold chain". A cold chain protects a wide variety of food, pharmaceutical, and chemical products from degradation, improper exposure to temperature, humidity, light or particular contaminants to keep them frozen, chilled and fresh (Bishara, 2006). Any disorder in time-distance or temperature in the chain could hamper the net present value of the activities and their added value in the cold chain (Bogataj et al. 2005). The basic difference between the supply chain of non-perishable items and the cold chain is the possibility of degradation in quality and value of the product, which start from the producer's place till it is consumed. (Table I).

The cold chain starts at the farm level (e. g. harvest methods, pre-cooling) and covers up to the consumer level (cooling practices and The authors are grateful to the reviewers for their constructive comments and suggestions, which have helped to improve the paper. Supply chain of non-perishables Includes temperature-insensitive products like nuts, bolts, m/s and

equipments Produce information regarding transaction (order, shipment, payment) and location (warehouse, traffic, inventory) No degradation in value while in transport Less transportation cost as ordinary trucks, vehicles are used Can bear being stuck in traffic jam Different products can be loaded based on the space available Stops as the product reaches customer Cold chain Includes temperature-sensitive items like plant and animal-based product Cold chain includes "condition" and "time" along with transaction and location (Fearne et al. 2006) Continuous degradation in value right from the producer till final consumption (Bogataj et al.

, 2005) Refrigerated vehicles are mandatory for transportation Require keeping the refrigeration system in a running state, which devours more cost Different temperature is required for different products, e. g. milk is to be kept at 4°C to 10°C, whereas ice-cream requires -2 to -8°C (Manning et al. , 2006) Includes customer practices related to temperature sensitivity (Ovca and Jevsnik, 2008) Indian cold chain 1261 Table I.

Difference between supply chain of non-perishables and cold chain behavior). A typical cold chain infrastructure generally consists of pre-cooling facilities, cold storages, refrigerated carriers, packaging, warehouse, traceability, retailer, and consumers, under the aegis of information management systems (Montanari, 2008). A typical cold chain is shown in Figure 1. The integrity of the cold chain must be preserved from the point of production, processing, through each of the transport stages - handling, loading, unloading, and storage - and extends to storage at the consuming household (Salin and Nayga, 2003). An efficient management of the cold chain is the key to prevent unnecessary losses and maintaining the bottom line.

Literatures on cold chain management have discussed about various performance variables and factors that influence the cold chain efficiency and integrity. Donk et al. (2008) have explored the specific problems of food manufacturers seeking supply chain integration and suggested that food supply chains are in the front line with respect to supply chain practices, coordination of the chain, and the use of concepts like EDI, VMI, QR and CPFR. Fearne and Hughes (2000) discussed supply chain developments in the UK fresh produce industry and identified Figure 1.

A typical cold chain business has various success factors like improvement in cost control and innovation etc. Bogataj et al. (2005) and Valeeva et al. (2006) have studied the stability of perishable goods in at farm level and in logistic chains. In this regard Jahre and Hatteland (2004), Blanco et al.

(2005) and Berger (2007) have stressed upon the standardization in packaging and distribution of perishable goods. To counter the traceability problem many researchers (Montanari, 2008; Kelepouris et al. , 2007; Regattieri et al. , 2007; Berger, 2007; Folinas et al.

2006) have stated the need for reliable IT infrastructure of cold chain. In supplement to this, Rijswijk and Frewer (2008) investigated that traceability is linked not only to food safety, but also to food quality. Sahin et al. (2007), Mangina and Vlachos (2005) and Salin (1998) highlighted the importance of the changing role of information technology in food and beverage logistics management. Taylor and Fearne (2006) have observed that most significant

challenge in cold chain management is continuous imbalance between supply and demand which is supported by Gorton et al.

(2006) while discussing the issues overcoming the supply chain failure in agri-food sector. Collaborative approach to demand management can improve customer service to the benefit of both supermarkets and suppliers (Dunne, 2008; Kottila and Ronni, 2008; Fearne et al., 2006). At the retail level maintaining cold chain, inventory control and return policy of perishable items are also some issues which have been referred to in the literature (Hsu et al. 2007; Donselaar et al., 2006; Likar and Jevsnik, 2006; Hahn et al.

, 2004). In addition, Bourlakis and Bourlakis (2005) discussed the critical importance of formation of the retail logistics network engaging a fourth-party logistics. Ovca and Jevsnik (2008) and Zokaei (2006) have brought forward consumer opinions in maintaining a cold chain from purchase to the home and at home. The literature on cold chain management describes the reliance of strong and dependable cold chain on the characteristics of these factors, but the influence of interrelationships among the factors on the cold chain efficiency has been hardly taken into account in the literature. If not properly dealt with, these factors can be inhibitors.

The impact of these inhibitors is a major point of concern that can result loss of quality, hygiene and overall efficiency of a cold chain. Literature review also reveals that especially in Indian context not much independent research has taken place. Kumar (2008) identified commonalities and differences between the supermarket industry and its logistics capabilities in developed

and developing economies. Maheshwar and Chanakwa (2006) have suggested solutions to post-harvest losses due to gaps in cold chain in India. Viswanadham (2006) and Khan (2005) elaborated food market in India.

Saha (2005) has talked about an inter-regional evaluation of dairy farming systems in India. Mahmood et al. (2005) compared milk practices in Asian countries like India, Bangladesh, Pakistan, Thailand and China whereas Ruben (2007) talks about the vegetable procurement by Asian supermarket. Therefore there is a need to identify the inhibitors that are influencing the Indian cold chain's efficiency and dependability, and then to develop a generally applicable framework, which establishes interrelationships between these inhibitors. India: an emerging economy India, a billionaire plus populated nation has a strong economy with GDP growth 9 percent for the fiscal year 2007-2008 (CMIE, 2008). As the fulcrum of the Indian economy, agriculture accounts for about 30 percent of GDP, concerns the entire population and employs over 60 percent of it (Khan, 2005).

The agricultural sector is based mostly on perishable products, which in turn depend upon a strong and dependable cold chain to survive and grow. India is the world's highest producer of milk with a total of 100.9 million tonnes (MT) for 2007 at a record compounded annual growth rate (CAGR) of 4.5 percent against 650 MT world's milk production for 2007 at a CAGR of 1.1 percent (NDDDB, 2007). India is the world's second largest producer of fruits and vegetables.

The annual production of fruits is 46.8 MT while the annual production of vegetables is around 91 MT that accounts for 10 percent and 14 percent of

the global production respectively; India is 7th largest producer of eggs and sixth largest producer of fish with harvesting volumes of 5. MT (Viswanadham, 2006). Within this context, although India has been the world's largest milk producer since 1995 not a single Indian dairy company featured in the list of global top 20 dairy companies (Banerjee, 2007; Brouwers, 2006). Estimates says around 35 percent to 40 percent of the total production of fresh fruits and vegetables, is wasted in India, which is about the total production of the Great Britain (Khan, 2005). Even at current level of production, farm produce valued at Rs 70, 000 million (US\$1, 400 m) is being wasted every year only because there is no adequate storage, transportation, cold chain facilities and other infrastructure supports (Viswanadham, 2006).

The cold chain in India is very complex with numerous small stakeholders like farmer, wholesaler, processor/manufacturer, retailer etc. They are not connected with proper information network. Each partner works in isolation. Indian products have low yields, which together with inadequate preservation increase the end product costs considerably with lack of suitable processing-grade varieties. There are number of inhibitors which not only affect the efficiency of cold chain but also influence one another significantly.

It is therefore, important to understand their mutual relationship so that those inhibitors that are at the root of some more inhibitors (called driving barriers) and those which are most influenced by the others (called driven barriers) can be identified. Fuzzy interpretive structural modeling (FISM) (Saxena et al. , 2006; Anantatmula, 2007) has been used which is a step

ahead of Interpretive structural modeling (ISM) (Warfield, 1974; Sage, 1977).

The 13 inhibitors under consideration in this study have been identified from the literature review and the opinion of the experts, both from industry and the academia. Thereafter, in this research, these inhibitors have been analyzed using the FISIM approach, which shows the interrelationships of the inhibitors, and degree of dominance of their driving power and dependence.

The main objectives of this paper are: . to identify and rank the inhibitors to efficient cold supply chain in India; . to establish the relationship and their respective dominance among these identified inhibitors using FISIM; and . to discuss the managerial implications of this research and suggest directions for future research.

The remainder of this paper has been organized as follows. The next section discusses the brainstorming methodology followed by the identification of inhibitors to efficient cold chain in India. Then the FISIM methodology model development has been explained. The results of this research are then followed by discussion and conclusion.

Indian cold chain 1263 BFJ 111, 11 1264 Methodology Brainstorming Two sectors, Milk and Milk Products (MMP) and Fruits and Vegetables (F&V) were selected for this study because the MMP and F&V temperature range (2 188C to 108C) covers most types of perishable items. Further the supply chain of these products extends beyond state geographical boundaries so the study will determine the ability of the cold chain infrastructure to meet market requirements. In the first phase, an initial visit was made in three selected organisations in two Northern states of India, to understand their cold chain

integrity in managing supply chain of perishable items. Six experts, two from each organization, holding position of Manager and above were identified.

Three experts from academia and five Government officials working in departments related to MMP and F&V were also identified who could provide additional support. Literature related to CCM was circulated among the experts. Further using semi-structured questionnaire technique, individual interviews were conducted. The personnel interviewed were in charge of the cold chain integrity functions in the selected organisations. Within a period of 15 days, a brainstorming session was organized to identify the variables. A formal invitation was extended to all the experts but it was not feasible for the whole group to meet so it was decided to meet in small groups note suggestions then review the combined views at a later date.

In the brainstorming session participants were asked to identify and define inhibitors to efficient cold chain in India. After two sessions, twenty-four variables had been agreed, but this number was reduced to thirteen as some variables were overlapping and some were of same nature. The next step was to establish any mutual relationships between variables (how a particular variable leads/helps to the other variables). In this session experts were asked to establish the relationship between the variables, which was done in two phases. In the last session, the list of variables as identified and the diagram representing the mutual relationship were circulated among the experts for any modification and finally the values of degree of dominance among the interactions are put upon. With a consensus on these 13 variables the FISM based model was developed.

The flow diagram followed is shown in Figure 2. The selected variables are shown in Table II. Fuzzy interpretive structural model Interpretive Structural modeling (ISM) is an interactive learning process whereby a set of different directly and indirectly related elements are structured into a comprehensive systemic model (Warfield, 1974; Sage, 1977). FISM is a step ahead of ISM. While ISM considers only the existence of an interaction between sub-elements, the dominance of interaction is also considered as an extension in FISM (Saxena et al.

, 2006). Ill-defined problems tend to be dynamic problems that involve human factors. Soft systems methodology (SSM) is generally used for dealing ill-defined problems as to what shall be done, because at the onset there is no obvious or clearly defined objective. But the main limitation of SSM is that it can be used to solve only some ill parts of the system and not for building the system as a whole (Jharkharia and Shankar, 2005). For the complex problem under consideration here, an efficient cold chain management depends upon number of variables and certainly there are number of respective inhibitors which may be affecting its successful implementation.

A model depicting relationships among these key inhibitors would be of great value to the top management and policy makers to delineate the focus areas. Also, the direct and indirect relationships between the inhibitors describe the situation far more accurately than the individual factor taken into isolation. FISM can rightly be employed under such circumstances because on the basis of relationship between the variables, an overall structure can be extracted for the system under consideration. The various

steps involved in the FISIM technique are: (1) By survey or any group problem solving technique, elements that are relevant to the problem or issues are identified. (2) A contextual relationship between elements is established. (3) A Structural Self-Interaction Matrix (SSIM) of elements, which indicates pairwise relationship between elements of the system, is developed.

4) An Initial Reachability Matrix is developed from the SSIM, and the matrix is checked for transitivity to convert it into a final reachability matrix. Transitivity of the contextual relation is a basic assumption in ISM which states that if element A is related to B and B is related to C, then A is necessarily related to C. (5) The final reachability matrix is converted into fuzzy reachability matrix by assigning the respective dominance of interactions. (6) Then final reachability matrix is partitioned into different levels. 7) Based on the relationships given above in the reachability matrix directed graph (DIGRAPH) is drawn, and transitive links are removed. (8) The resultant digraph is converted into an FISIM, by replacing element nodes with statements and the interactions as per the dominance.

(9) FISIM model is reviewed to check for conceptual inconsistency, and the necessary modifications are made. Inhibitors to efficient cold chain in India The 13 inhibitors that were identified from the literature review and the opinion of the experts are discussed as under without any specific order. Lack of awareness about the use of information technology (IT) In India, the major IT systems are implemented at retail level, which gives an opportunity to retailers to lead the whole cold chain through their information advantage (Kumar, 2008). This uneven adoption of IT along the farm to retail chain has result in fragmentation and lack of cognitive culture (Matani, 2007). The cold

chain needed to be designed and built in integrated manner with well-designed information system (IS) throughout the chain.

As by now information has become a strategic resource for competitive advantage, it would be a great opportunity loss if there were any delay in adopting IS. Improper collaboration planning and compatibility of partners A cold chain includes a set of interdependent companies that work closely together to manage the flow of goods or services, information and funds to recognize superior customer value at the lowest possible costs (Fearne et al. , 2006). Improper collaboration planning among these links can lead to many discrepancies in different levels like: share forecasts, manage inventories, schedule labour, or optimize deliveries etc.

Dunne, 2008). Khan (2005) stressed that, there is a need to bring together the numerous loosely integrated players - like seed companies, farmers, cooperatives, third party logistic providers, educational institutions, commodity, value-added producers and finally the customer. Indian cold chain 1267 BFJ 111, 11 1268 Incompetent professional skills Rapid evolution in the cold chain management processes, operations with technological change and changing customer requirements have lead to the existing skill gaps in this sector. The fragmented and unorganized nature of the Indian food industry resulted in poor working conditions and relatively lesser attractive pay and promotional incentives, which in turns to poor image or lack of attractiveness for new recruits (KPMG, 2007). Cold storage managers, loading supervisors and refrigerated truck drivers are the work profiles in these segments that need to be developed most both in terms of quality and quantity (KPMG, 2007).

Some areas where existing skills are lacking include: familiarity with modern equipments (reach stackers, pallet trucks etc. , with IT systems (temperature time indicators (TTI), data-loggers, handheld, RFID), industry specific stocking and handling practices for perishables, practices around safety and security of stock etc. (Swaminathan, 2007). High cost for installation and operation Operating costs for Indian cold storage units are over \$60 per cubic meter per year compared to less than \$30 in the West (Khan, 2005).

Energy expenses make up about 28 percent of the total expenses for Indian cold storages compared to 10 percent in the West (Khan, 2005). An ordinary truck that costs about Rs 8-9 lakhs (\$18, 000), when fitted with refrigeration facility will cost Rs 18-20 lakhs (\$40, 000)(Viswanadham, 2006). The high capital costs involved in setting up the cold chain facility are a major disincentive. Installation cost is higher also because of the cost of equipment import.

High import duties, excise duty, and high running cost due to industrial rate of power tariff are discouraging investments. These factors make setting up cold storages difficult, unviable and uneconomical. Lack of quality and safety measures For perishable goods, maintaining the hygiene, safety, and expectedness of quality and freshness is not a small job. This requires efficient equipment with guaranteed thermal characteristics, appropriate operating modes and proper information system (Amjadi, 2005). Perishables are often transported by reefer trucks under tough conditions from farms to processing centers, warehouses, distribution centers and finally to retailers (Sahin et al. , 2007).

Companies generally have limited access to when, where and under what conditions a malfunctioning of perishable goods occurred. Agricultural quality and freshness data are often lost from the farm to the distributor (Tijskens and Polderdijk, 1996). Inadequate education and training of growers/farmers Farming is constantly changing and is becoming more and more complex. To manage the farms effectively and efficiently, farmers require new skills and knowledge in business management and technology in order to adopt innovative management practices and production methods. In India, there are very few training centers for farmers, with no organized institutions to perform this function (Viswanadham, 2006). Technologies are developed but they are not properly propagated to root level of farmers.

With main thrust to women members, farmers at village level require planned learning activities that are directly relevant to their farm to develop competencies. Too many intermediaries The complex food chain in India from the farmer to the consumer involves many intermediaries with multiple-point handling and long transit periods. The middlemen and poor supply chain facilities have increased agricultural prices up to 60 percent without actually adding any value (Ruben, 2007). Indian production of 127 million tones of fruits and vegetables is one of the highest in the world (India, 2005). But, small farmers have no choice in today's monopolistic environment other than to push fresh produce at any cost. At each stage the new ownership is supplemented such as processors, distributors, packers, third party service providers etc.

and the cost and profits are part of the business. Lack of standardization Standardization can be a powerful tool for improving cold chain efficiency.

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There can be standards like content, processing, temperature, packaging, logistics and transit time, IT systems, etc. Standardization in packaging has become the competitive tool to reach the consumer and it helps in efficient loading, unloading and cross-docking (Berger, 2007). Cost of packaging ranges from 10 to 64 percent of the production costs. Standardization efforts reduce these costs through use of manufacturing automation and economies of scale (Blanco et al.

, 2005). Government regulations In India, there are several regulatory measures handled by large number of departments divided between State and Central governments. The cold chain in India is miserably insufficient to meet the growing production of perishable items for the domestic and export markets (Viswanadham, 2006). The cold chain industry is yet not awarded priority status as a continuous process industry for power and facing the power shedding at peak hours. In processed foods, India is amongst the highest taxed in the world (Khan, 2005). If we take all taxes like, excise, sale taxes on both product and the packaging used in processed food industry into account, it will range from about 25 to 40 percent of total product cost (MOFPI, 2005).

There is an urgent need of quick action and demonstration effect from the government. Improper tracing Improper product tracing and tracking is a major hurdle to achieve an efficient cold chain. Product tracing states access to when, where and under what conditions a product is from the agricultural origin or point of manufacture through distribution to retailer (Montanari, 2008). Tracing and tracking status in Indian cold chain is at deplorable stage and need to exploit the existing potential.

Owing to worse monitoring and security, most of the Indian cold chain companies are not able to determine what they have in inventory at any point in time at various points along the cold chain which result in increase in operational expenses (out-of-stock, shrinkage, and labor costs). Poor infrastructure India is a fragmented country with 70 percent of the population residing in rural areas. The deficiency in infrastructure and logistics system results difficulty in transporting goods and reaching consumers. Roads, highways and public transport systems are fundamental with growing urbanization.

India has a fairly organized and developed Indian cold chain 1269 BFJ 111, 11 1270 non-perishable supply chain where as the cold chain is fragmented and unorganized (PWC, 2007). Quoting from a study undertaken by Transport Cooperation of India, a typical truck driver would need to stop 49 times during his 2, 400-km journey from Kolkata to Delhi because of bad roads, and corrupt officials and innumerable toll gates which operate on different billing systems causing delays and an unproductive journey (Hindu, 2007). Owing to limited infrastructure support, it is common even for the industrialized zones to suffer from frequent power outages, inadequate water supply and poor roadway connections. This causes unexpected delays in production as well as prevents firms from attaining their best performance. Firms often have to create a contingency plan for basic infrastructure needs. Top-level commitment Direct participation by the highest-level executives in a specific and critically important aspect or program of an organization is termed as "top management commitment" (Hingley, 2005).

Top management commitment is amongst the most frequently cited success factors of corporate change programs. The top management in the partner companies should be committed to the integration of various facilities in order to take advantage of cold chain efficiencies. Customer ignorance towards quality Customers are the vital part of the cold chain (Zokaei, 2006) but “ cold chain” is not well known among consumers (Ovca and Jevsnik, 2008). In India, usually people go for unbranded product just for cost reasons, which shows their unconsciousness towards health.

This encourages the poor handling practices, especially in unorganized sector. Only in the past few years have Indians, mostly in cities, been exposed to supermarkets as west. Still semi-urban, non-metropolitan, and rural areas have yet to feel the impact of large-scale retailing (PWC, 2007).

Fuzzy interpretive structural model development The various steps, which lead to the development of FISIM based model, are illustrated below.

Structural self-interaction matrix (SSIM) As FISIM methodology suggests the use of expert opinions (based on management techniques such as brain storming, nominal group technique etc) in developing the contextual relationship has been done.

The inhibitors identified are not isolated or independent to each other. There is a “ lead to” relationship existing between and among the inhibitors. For analyzing the inhibitors in developing SSIM, the following four symbols have been used to denote the direction of relationship between inhibitors (i and j):

V A X O Inhibitor i will lead to inhibitor j; Inhibitor j lead to inhibitor i;

Inhibitors i and j lead to each other; and Inhibitors i and j are unrelated.

Based on contextual relationships the SSIM is developed (Table IV).

Inhibitors 1. Lack of awareness about the use of IT 2. Improper collaboration
3. Incompetent professional skills 4.

High cost 5. Lack of quality and safety 6. Inadequate education of farmers 7.
Too many intermediaries 8. Lack of standardization 9.

Government regulation 10. Improper tracing 11. Poor infrastructure 12. Lack
of top level commitment 13.

Customer ignorance toward quality 13 O O O O O A O V V O O O 12 A A A V A
A A A O A V 11 A O O X A O A A V A 10 V O V V O O O X O 9 O A A O A O O V
8 V V V V V V V 7 O X O V A A 6 X O O O A 5 X V V V 4 A V A 3 A X 2 O Indian

cold chain 1271 Table IV. Structural self-interaction matrix (SSIM) Fuzzy
reachability matrix The SSIM has been first converted into a binary matrix,
called the initial reachability matrix by substituting V, A, X and O by 1 and 0
as per the case. The substitution of 1s and 0s are as per the following rules
(Warfield, 1974): . If the (i, j) entry in the SSIM is V, the (i, j) entry in the
reachability matrix becomes 1 and the (j, i) entry becomes 0. . If the (i, j)
entry in the SSIM is A, the (i, j) entry in the reachability matrix becomes 0
and the (j, i) entry becomes 1.

. If the (i, j) entry in the SSIM is X, the (i, j) entry in the reachability matrix
becomes 1 and the (j, i) entry also becomes 1. . If the (i, j) entry in the SSIM
is O, the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry
also becomes 0. While V, A, X and O were converted into 0s and 1s, the
dominance of the interaction between the inhibitors is now taken into
consideration. The final reachability matrix is extended by giving degree of

dominance factor among the inhibitors as discussed in step 5 on the scale of 0-1.

Now the driving power for each inhibitor is the total number of inhibitors (including itself), which it may lead. On the other hand dependence is the total number of inhibitors (including itself), which may lead it, as shown in Table V. These driving power and dependencies will be later used in the classification of inhibitors into the four groups of autonomous, dependent, linkage and independent (driver) inhibitors. Level partitions From the ?nal reachability matrix, the reachability and antecedent sets (War? eld, 1974) for each inhibitor are found.

The reachability set consists of the element itself and other elements, which it may help achieve, whereas the antecedent set consists of the element itself and the other elements, which may help achieving it. Then the intersection of these sets is derived for all elements. The element for which the reachability and intersection sets are same is the top-level element in the FISMBFJ 111, 11 Inhibitors 1. 2.

3. 4. 5. 6.

7. 8. 9. 10.

11. 12. 13. Dependence Rank 1 1 0. 3 0. 7 0.

9 0. 1 0. 1 0. 1 0 0.

3 0 0. 5 0. 5 0. 3 4.

8 5 2 3 4 0 0. 5 0. 1 1 0 0 0. 7 0 0. 5 0 0. 9 0.

1 0.1 3.9 9 5 0.5 0.7 0.

5 0.7 1 0.9 0.3 0.

5 0.3 0 0.5 0.7 0 6.

6 2 6 7 8 0.1 0.5 0.3 0.

5 0.7 0.3 0.5 1 0.7 0.1 0.

9 0.3 0 5.9 3 9 0.5 0.1 0 0.7 0.

5 0.1 0.3 0.7 1 0.1 0.3 0.

1 0 4.4 8 10 11 12 13 0.7 0.1 0.3 0.5 0.

3 0 0.3 0.3 0.5 0.3 0.

5 0.3 1 5.1 4 Driver Rank 4. 2 5. 4 4.

7 7.3 3 2.9 5.2 3.4 4.6 1.

5 7.6 6.1 1.7 8 4 6 2 10 11 5 9 7 13 1 3 12 1272 Table V.

Fuzzy reachability matrix 0 0 1 0.1 0.7 1 0.7 0.

3 0 0 0 0 0.9 0.3 0 0 0.1 0.

1 0 0 0.3 0.1 0.9 0.7 0 0 4.6 2.

6 6 12 0.5 0 0.3 0.7 0.3 0.

5 0 0.3 0.3 0 1 0 0.3 1 0.

3 0 0. 1 0. 1 0 0 0. 3 0. 7 0. 5 0.

5 0. 3 0 4. 2 3. 8 7 10 0. 9 0 0 0. 7 0.

1 0. 3 0. 3 0 0 0. 7 0. 3 0. 7 0.

1 0 0 0. 5 0 0 0. 5 0 0 0. 5 0.

1 0 0. 3 0. 5 0. 1 1 0 0 0. 9 1 0.

7 0. 5 0 1 0 0 0 6. 9 2 2. 8 1 13 11 hierarchy. The top-level element of the hierarchy would not help achieve any other element above their own level. Once the top-level element is identified, it is separated out from the other elements.

Then, the same process finds the next level of element. This process continues till the levels of each element are found. These identified levels help in building the digraph and FISM model. In the present case the inhibitors along with their reachability set, antecedent set, intersection set and the levels are shown in Table VI. Inhibitor 13 (Customer ignorance toward quality) is found at the level I. Thus, it will be positioned at the top of the FISM model.

Inhibitors 8, 9, 10 (Lack of standardization, Government regulation and Improper tracing) are put at level II and so on. Formation of FISM-based model From the fuzzy reachability matrix, the structural model is generated by means of vertices or nodes and lines of edges. If there is a relationship between the inhibitors j, Inhibitors 1 2 3 4 5 6 7 8 9 10 11 12 13 Reachability set 1, 5, 6, 8, 9, 10, 13 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 1, 2, 3, 4, 5, 7,

8, 9, 10, 11, 13 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13 1, 5, 6, 8, 9, 10, 13 1, 5, 6, 8, 9, 10, 13 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13 5, 6, 8, 9, 10, 11, 13 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 8, 9, 10, 13 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13 1, 4, 6, 13 Antecedent set 1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 13 2, 3, 4, 7, 9, 11, 12 2, 3, 4, 7, 9, 11, 12 2, 3, 4, 7, 9, 11, 13 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12 1, 2, 5, 6, 7, 8, 9, 11, 12, 13 2, 3, 4, 7, 8, 9, 11, 12 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 2, 4, 8, 9, 11 2, 4, 9, 11, 12 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 Intersection set 1, 5, 6, 9, 13 2, 3, 4, 7, 9, 11, 12 2, 3, 4, 7, 9 2, 3, 4, 7, 9, 11, 13 1, 5, 6, 8, 9 1, 5, 6, 9, 13 2, 3, 4, 7, 9 5, 6, 8, 9, 10, 11 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 8, 9, 10 2, 4, 8, 9, 11 2, 4, 9, 12 1, 4, 6, 13 Level III IV IV VI III III IV II II II VI V I Table VI. Level partitions and i this is shown by an arrow which points from i to j. This graph is called a directed graph or digraph.

After removing the transitivity as described in FISIM methodology, the digraph is ? nally into FISIM by replacing the interactions as per the dominance of in? uence among the inhibitors as shown in Figure 3. Fuzzy MICMAC analysis Fuzzy indirect relationship (FMICMAC) analysis includes dominance of interaction in addition as an extension (Saxena et al. , 2006). The objective of FMICMAC analysis in this study is to identify and to analyze the inhibitors according to their driving power and dependence power towards cold chain management. These inhibitors are classi? ed on the basis of driving power and the dependence. These inhibitors have also been classi? ed into four categories: (1) autonomous; (2) dependent; (3) linkage; and (4) independent.

The driver power and dependence of each of these inhibitors is shown in Table V. Thereafter, the driver power-dependence diagram is shown in Figure 4. To show this figure, it is observed from Table V that the inhibitor one is having a driver power of 4.2 and dependence of 4.8, therefore in FMICMAC diagram it is positioned at a place which Indian cold chain 1273 Figure 3.

FISM-based model with depicted dominance among the inhibitors BFJ 111, 11274 Figure 4. Driving power and dependence diagram (FMICMAC) corresponds to driver power of 4.2 and dependency of 4.8. The intention behind the classification of the inhibitors is to analyze the driver power and dependency of the inhibitors.

The first quadrant includes "autonomous inhibitors" that have weak driver power and weak dependence. These variables are relatively disconnected from the system, with which they have only few links, which may be strong. The second quadrant consists of the dependent variables that have weak driver power but strong dependence. Third quadrant has the linkage variables that have strong driver power and dependence.

Any action on these variables will have an effect on the others and also a feedback effect on themselves. Fourth quadrant includes independent variables with strong driver power and weak dependence. These variables are the most important variables that influence the impact of other variables appearing at the top of the ISM hierarchy in the overall cold chain management, implying that management needs to address these inhibitors more carefully. Findings To formulate strategies for cold chain integrity, it is important for the policy makers of government or processing companies to

understand characteristics and interrelationship of variables that influence the cold chain. In this research an attempt is made to impose order on the complexity of the items showing strong drivers at bottom most level of model with “lead to” relationship with dependent variable up in the hierarchy (Figure 3). The strong drivers may be treated as the root causes of all the inhibitors and would help decision makers to better utilize the limited resources especially in developing economy.

FISM model suggests that the lack of adequate infrastructure has come up as a biggest bottleneck and has emerged as the highest level barrier with lowest level in the hierarchy. This inhibitor has “lead to” relation to “High cost of installation and operation” and “Lack of top management commitment”, which are also at the bottom of the model with strong driving power. Therefore, the management belonging to a cold chain should collectively develop strategies to create informed decision making awareness and develop better infrastructure facilities for the integration of cold chain. It is further observed from FISM model that the inhibitors two, seven and three, namely, Improper collaboration, Too many intermediaries, Improper professional skills have strong driver and dependence power and they significantly influence the system.

These inhibitors lie in the middle level and lead to other inhibitors of level four, five and six. This has strong implications for both managers as well as researchers. The managers need to address these inhibitors more carefully in their cold chains. They need to overcome these problems by having proper collaboration planning among the cold chain partner companies.

Managers can deal with discrepancies in different levels like: share forecasts,

manage inventories, schedule labour, or optimize deliveries, fewer intermediaries with properly managing the flow of goods or services, training, information and funds to recognize superior customer value at the lowest possible costs. On the other hand, researchers may be prompted to identify various other issues, which are significant in addressing these inhibitors.

The driver power dependence diagram (FMICMAC) gives some valuable insights about the relative importance and interdependencies of the inhibitors: . FMICMAC diagram (Figure 4) indicates that there is no autonomous inhibitor, which influences the efficiency of cold chains. Autonomous variables are weak drivers and weak dependents and do not have much influence on the system. The absence of any autonomous inhibitors in this study indicates that all the considered inhibitors concern the efficiency of cold chains and management should pay attention to all the inhibitors. From FMICMAC analysis diagram it is observed that Customer ignorance towards quality, Improper tracing, Lack of standardization and Inadequate education for farmers are weak drivers but strongly dependent on the other inhibitors.

These four inhibitors are at the upper level of the FISIM hierarchy, therefore considered as the important inhibitors. The management should therefore accord high priority in tackling these inhibitors. Besides tackling these inhibitors, management should also understand the dependence of these inhibitors on lower level inhibitors in the FISIM. Three inhibitors namely: Improper collaboration, Government regulation and Unawareness about the use of IT, are the linkage inhibitors as deduced from the FMICMAC analysis

and have strong driver power as well as strong dependence. Therefore, these form the middle level of the model.

Though the lower level inhibitors induce these inhibitors, these also have some driver power to influence some other inhibitors, which are at the top of the model. The regular joint meetings of the cold chain partners, conferences and workshops on the pertinent cold chain issues may help in overcoming these inhibitors. Also, it is observed that the positive inhibitors namely Poor infrastructure, Top level commitment, Incompetent professional skills, Too many intermediaries and High cost have strong driver power and are less dependent on other inhibitors. Therefore, these are strong drivers and may be treated as the root causes of all Indian cold chain inhibitors.

As these inhibitors involve all the entities of a cold chain therefore, the major stakeholder in the cold chain (normally manufacturers/processors, cold storage owners) should take the initiative to address these. The joint meetings of all the entities of cold chain at regular interval may prove to be useful in this regard. Discussions The cold chain management is not easy even when operating in a developed economy such as the USA and UK. It gets even more challenging in developing economy like India. In most developed economies, with firm support from robust infrastructure, there is limited uncertainties in business process related to logistics. However, in developing economies logistics tends to pose several types of challenges due to unpredictable environment, weaker infrastructure and uncertainty in availability of basic necessities like water, power etc.

This is the reason why strategies, well tested and worked in developed economies fail when applied in developing nations in same format. Wal-Mart can be a good example, which has an efficient network of cross docking facilities in the USA that store minimal inventory, yet, Wal-Mart found it very difficult to run a logistic system based on such cross-docking facilities when went into operation into South America (Swaminathan, 2007). India is a fragmented country with 70 percent of the population residing in rural areas with over-reliance on the monsoons. The 52 percent of total land is cultivable as against 11 percent in the world.

All 15 major climates of the world, snow bound Himalayas to hot humid southern peninsula; Thar Desert to heavy rain areas all exist in India. There are 20 agro-climatic regions and nearly 46 out of 60 soil types in the country (FAO, 2005). With such diversity production, processing, transporting goods and reaching consumers in right time and with preserved value is not an easy task, especially when perishable goods are concerned. Indian situation echoes to the situation in most of the developing nations and similar inhibitors can be seen there also. A robust food supply chain is the solution that encompasses a strong and dependable cold chain.

This paper has tried to identify the critical factors that act as inhibitors to efficient cold chain in India. In this context, total 13 inhibitors were identified and contextual relationship was established between these critical factors through FISM approach. It is observed that lack of adequate infrastructure along with high cost for installation and operation are the biggest bottleneck for strong and efficient cold chain. Similar to most of the developing economies, logistics cost in India, is estimated around 15-25 percent of the ?

nal cost as compared to about 7-9 percent in USA and UK (Swaminathan, 2007). The major reason is lack of adequate infrastructure. Operating costs for Indian cold storage units are about double as compared to West.

Also, High import duties and excise duty make setting up cold storages difficult, unviable and uneconomical. "Government regulation" has come out as a linkage barrier as deduced from the FMICMAC analysis and have strong driver power as well as strong dependence. The Government would need to support industry players in their initiatives and provide for a more conducive enabling environment by continuing to upgrade infrastructure, accelerate drivers for organization and consolidation of the industry and providing recognition by granting "priority" industry status. Also, the Government could allow the use of reefer containers carrying import cargo for 1276 domestic use, which common practice in many countries.

It would help to cut transport costs. There should be reduction in excise duty on processed food from existing levels to 3 percent. Tax holiday for investment in the cold chain infrastructure sector should be announced. 100 percent depreciation should be allowed on freezer cabinets and other cold chain equipment.

Import duty on all capital equipment for food processing and cold chain sector should be reduced from existing levels to 4 percent. Excise duty on local freezer cabinets should be reduced from 18 percent to 3 percent (Khan, 2005). The internet and mobile communications are used to enable information and financial transfer between the stakeholders. Awareness about the use of IT has great impact on cold chain integrity. The use of the

internet in purchasing is 39 percent in India as compared to 86.7 percent in the USA, 30.1 percent companies that use internet for inventory management in India as compared to 48.5 percent in the USA, 50 percent of the firms used the internet for transportation as compared to 84.3 percent in the USA (Swaminathan, 2007). The usage of the internet as a medium in order processing, customer service, production scheduling and relations with the vendors is still very low in India. Traceability, a key cold chain issue has come up as weak driver from FMICMAC analysis but strongly dependent on the other inhibitors. This barrier stood at the upper level of the FISM hierarchy, therefore considered as the important barrier. Cold chains can take advantage of IT in improvements in data capture and processing, product tracking and tracing, auto adjustment in temperature, automation of ordering processes and payment mechanisms, control systems for quality assurance, synchronized transport transit times and reduction in lead time along the whole chain (Mangina and Vlachos, 2005, Salin, 1998). Recent advances in RFID technology will have tremendous impact in the management of the cold chain particularly for source identification and tracking and also in providing visibility through out the chain. Very few companies in India are practicing towards RFID implementation and GPS tracking which is common in countries like the USA and UK. Such practices give visibility to the in process inventory in the cold chain and enable better decision making. (Kelepouris et al., 2007) "Too many intermediaries" has been deduced as middle level barrier has a significant role to increase prices of perishable items up to 60 percent without actually adding any value (Ruben, 2007). ITC has taken an excellent initiative from "e-Choupal" to eliminate wasteful intermediation and multiple handling. Direct marketing

channel, virtually linked to the “ mandi” system for price discovery, thereby it significantly reduces transaction costs (ITC, 2005). Similar to Dairy Farmers Association in the USA, Gujarat Cooperative Milk Marketing Federation (GCMMF) has achieved a phenomenal success as cooperatives in India by reducing the intermediaries. In India, a large number of small-scale farms are there to operate together with a few very large farms. The number of manufacturing firms in the organized sector (those that are registered with the government) is estimated at 127, 000 whereas the unorganized sector comprising innumerable vendors, small processors, merchants, manufacturers and retailers, consisted of 17 million farms (Swaminathan, 2007). In most developed countries, the retail market is dominated by organized retailing. The share of organized retailing in the USA is around 80 percent, Europe - 70 percent, Brazil - 40 percent and China - 20 percent. With only 2 percent of organized retailing with 6 million retail outlets, India lags behind by a large margin (PWC, 2007). Indian cold chain

1277 BFJ 111, 11 1278 The main problem in the unorganized sector like unsanitary local conditions, unhygienic containers, substandard processing equipment, poor handling methods, breaks in the cold chain etc. contribute to poor quality. There is an increasing need to provide greater assurance about the safety and quality of food to consumers. The capacity of India to penetrate world markets depends on its ability to meet increasingly stringent food quality and safety standards imposed in developed countries. (MOFPI, 2005). Also, there is a widening skill gap in specialties like refrigerated truck drivers, loading supervisors, cold storage managers and seafarers which need to be developed most both in terms of quality and quantity. Creation of a robust institutional framework for creating logistics manpower,

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creation of incentives for development of skills for cold storage and transportation employees, and undertaking of initiatives to uplift the image of the cold chain industry can be the few initiatives required to be taken in consideration (KPMG, 2007). Customer ignorance also has come out as one of the powerful barrier. Although it is at the top in the model but decidedly relate to other ones. Until customer will demand for a quality and safe product the whole cold chain system will always look handicapped. Customer ignorance across all businesses, especially for unorganized sector has long been a reliable profit center and encouragement for poor practices. With increased awareness camps, extension-education and internet, consumers can know about the adverse effects of consuming unhygienic products and poor storage practices. Concluding remarks and scope for future work At the time when cold chain is the key domain for the food sector, these findings will be immensely helpful for industry professionals in developing strategies for tackling the root causes responsible for inefficient and weak cold chain in India. The major contribution of this research is the unique effort in imposing directions and respective dominance of various inhibitors to efficient cold chain, which would help decision makers to better utilize the limited resources especially in developing economy. This paper gained the following insights: . The critical inhibitors to efficient cold supply chain in India are identified, ranked and interrelated. Literature talked about most of them separately, but nowhere the ranking and contextual relationship of the inhibitors is analyzed. This can support decision makers to have a holistic insight into the relationships between the various inhibitors instead of looking to each of them individually. . Indian situation echoes to the situation in most of the developing nations and similar solutions will apply there also.

Mostly, in all these countries also socio-religious practices prevail, and food industry professionals and government regulators must take due observance of this fact. Government, non-government, industry, academia and the community will need to work closely to make the wholeness of cold chain from “ farm to fork”. . Strategies, well tested and worked in developed economies fail when applied in developing economies in same format (e. g Walmart in South America). These findings will be truly useful for organisations planning to operate food chains in developing nations. The discussion will provide better insight upon the various factors influencing cold chain in developing economies and their inter-relationships. It can also support decision makers in modifying their existing supply chain strategies or develop newer ones for the developing economies. FISM can provide the interpretive structure of sub-elements with one or two dominance of interaction at a time and ignoring all other dominance of interaction and giving attention to a particular set of inhibitors. For example, if the analyst is keen to study high dominance of interaction only, he focuses on all entries of 0.7 and 0.9 only replacing all other entries to 0s in the reachability matrix.

Indian cold chain 1279 Finally, it is necessary to note that the proposed model is not without its own limitation. However, more operational comments can only be applied when the developed model is utilized for decision making in real scenario. Some of the limitations are: More number of inhibitors affecting subject can be identified to develop FISM. Experts' views have been sought to develop the contextual relationships for the FISM model, which may have introduced some element of bias. The get together of all the experts could not be possible at same location because of the geographic location and paucity of their time to attend the common meeting.