Cold Chain: An interaction analysis of Performance Attributes using Graph Theory

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Abstract

In India it is estimated that around 35% to 40% of the total production of fresh fruits and vegetables, is wasted only because of inadequate cold storage, poor logistics, ineffective cold chain facilities at retail points and lack of other infrastructure supports. In the business of perishable products, there is a direct correlation between the cold chain performance and the quality delivered to customer. Since long time, the cold chain data has been underutilized and used solely for the purposes of evaluating the integrity of individual shipments. The purpose of this paper is to identify Key Performance Indicators of Indian Cold Chain and to develop a Consistent Measurement Scale.A Graph Theory based methodology is developed to support the cold chain Performance Measurement System. The proposed framework can assist managers to understand the present strengths and weaknesses of their cold chain as compared to market leaders. They can identify good practices from the market leader and can benchmark them for improving weaknesses as per the current operational conditions and strategies of the company. This framework also facilitates the decision makers to better understand the complex relationships of the relevant cold chain indicators in the decision-making.

Keywords
Cold chain, Performance improvement, Graph theory, India

Introduction
An extensive range of food, pharmaceutical, and chemical products is degraded by inappropriate disclosure to temperature, humidity, light or particular contaminants. The equipments and processes used to protect these products and to keep them chilled and frozen are referred as "cold chain". The cold chain is a physical process that dominates the supply chain of perishable products. A cold chain starts at the farm level (harvest methods, pre-cooling) and continues during first handling, processing, distribution and finally covers up to the consumer level (cooling practices and behavior) as shown in Figure 1.

The procurement, production, logistics facilities and consumers in the cold chain are the links between the origin and the consumption. 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 supply chain. The impact of these disturbances is major point of concern, which can result in significant loss of quality and hygiene (Bogataj et al., 2005).

The perishable products are one of the main drivers in today's competitive retailer environment. Heller has stated that the quality of perishable goods assortment is becoming the core reason many customers choose one retailer over another (as cited in Thron et al., 2007). With the changing lifestyles and overall declining prices the global market for perishable foods is growing.

In the business of food products, which are mostly perishables in nature, the quality delivered to customer is directly dependent on the performance of cold chain. Since long time, the cold chain data has been underutilized and used solely for the purposes of evaluating the integrity of individual shipments (i.e. facilitating the accept or reject decisions). These data can be gathered to measure performance of the cold chain, which in turn can identify flaws and weaknesses in the processes for eliminating problems before they occur. Performance Measurement System (PMS) allows comparison of planned and actual parameter values and taking certain reactive measures in order to improve performance or re-align the monitored value to the defined value (Gunasekaran et al. 2001). A well defined PMS aims to support the setting of objectives, evaluating performance, and determining future courses of action on a strategic, tactical and operational level (Beamon, 1999).

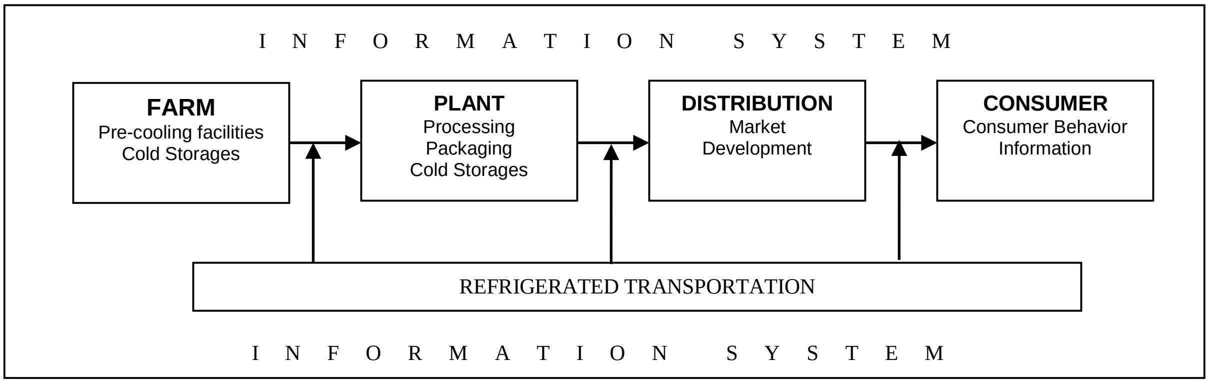

Figure 1. A typical cold chain

Measuring performance of a cold chain is not an easy task as this includes many characteristics that are different from other types of supply chains. Seasonality in production, shelf life constraints, physical product features like appearance, taste, odor, color, size and image, refrigerated transportation and storage requirement etc. (Aramyan et al., 2007; Mangina and Vlachos, 2005). As perishbility is a key characteristic in the food sector, an effective development of the cold chain is becoming an important issue. Today it is vital for companies to pay more attention to performance of the cold chain they maintain. In this context if we see the current status of India, it is estimated that around 35% to 40% of the total production of fresh fruits and vegetables, is wasted only because of inadequate and inefficient cold storage, poor logistics and lack of other infrastructure supports (Viswanadham, 2006). Although, India is the second largest producer of fruits and vegetables in the world, but at the current level of production, the farm produce valued at Rs 70,000 million ($1400m) is lost in wastages which is tantamount to the total production of the Great Britain (Khan, 2005). A high margin of product losses offers a significant opportunity for improvements and advocates for technology and research advancement within this domain.

With these understanding, this paper explore into the performance issues of the cold chain in Indian context. Here, a framework is proposed for evaluation of the cold chain performance of a company. A Graph theory (GT) based methodology is developed to support the PMS. The first step is the identification of Key Performance Indicators (KPI). In the second step, the consistent measurement scale is developed for a reliable data collection. The scale has made data collection relatively easy and accessible due to this quantification. In the third step performance evaluation of the selected company is done using GT based methodology, against its competitors, so as to observe company's cold chain performance on each KPI. Finally cold chain performance index of the companies are obtained to decide the market leader. The relevant information is collected from the field visits to various companies in India and also through extensive literature review and consultation with the experts.

The scope of the research includes the companies dealing in perishable food products like fruit & vegetable, flowers, milk and milk product, meat and meat products etc. Authors specifically targeted on cooperatives governed by the Government and privately owned supermarket chains offering fresh and processed vegetable and fruits under the same roof.

Literature survey

Many researchers (Kotzab and Otto, 2004; Brewer and Speh, 2001; Gunasekaran et al. 2001; Lambert and Pohlen, 2001; Morgan, 2004) have significantly contributed for PMS and stressed the need for a well-defined set of chain performance indicators for establishing benchmarks. However, very few studies have been done on agri-food supply chain performance. Aramyan et al. (2007) discussed the performance indicators, which included return on investments and customer satisfaction along with other indicators. Shister (2004) and Light (2003) stated that temperature is the key to maintaining integrity and quality in cold chain management. Van der Vorst (2005) proposed a framework for the development of innovative food supply-chain networks. Temperature variations may result in the breeding of bacteria and other deterioration. If the quantity is higher than the safe range, it will lead to microbial hazards and losses of product quality (Bogataj *et al.*, 2005). Cadilhon et al. (2003) stressed that both production and price stability affect food security. Therefore, the ability to provide enough products to guarantee an adequate supply to meet food needs is an important performance indicator (Da Silva and Filho, 2007). Practices and technologies throughout the chain determine the performance of the chain, and the peculiarity of the cold chain is that all the practices and technologies employed focus on temperature maintenance (Smola and Bear, 1999). Beamon (1999) stressed that suitable performance indicators are needed to answer whether consumers getting the products demanded, in terms of quantity, quality, timeliness and prices.

The cold chain is researched mainly in the industries of food, pharmaceuticals and retail businesses. Many researchers (Sahin et al., 2007; Blanco et al., 2005; Mangina and Vlachos 2005) have discussed about various issues of the cold chain on different links (farmer/ producer-processor-distributor-retailer). They discussed how the cold chain with broken points drastically reduces the overall performance. Valeeva et al. (2007), Bogataj et al. (2005) have studied the stability of perishable goods in at farm level and in logistic chains. For perishable goods, maintaining the hygiene, safety, and expectedness of quality and freshness requires efficient equipment with guaranteed thermal characteristics, appropriate operating modes and proper information system (Amjadi, 2005 and Tijskens,1996). Many researchers (Montanari, 2008; Regattieri et al., 2007 and Berger, 2007) have raised traceability related issues and they stated the need for reliable IT infrastructure of the cold chain. 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 (Donselaar et al., 2006; Likar and Jevsnik, 2006)

This can be observed from the literature review, some researchers developed PMS for agri-food supply chain but the cold chain performance measurement is never much discussed. To the best of authors' knowledge no PMS exists in cold chain that combines different aspects of performance into measurement system. Within this research authors will therefore emphasize on identification of the key performance indicators and than development of framework for performance measurement.

A Graph theory (GT) based methodology is developed to support the PMS. Graph theory is a very natural and powerful tool in combinatorial operation research, transport network, activity of stochastic process useful for modeling representation proved to be useful for modeling and analyzing various kinds of system in many fields of science and engineering. (Rao and Padmanabhan, 2007; Narsingh, 2001). The matrix approach is useful in analyzing the graph/graph models expeditiously to derive the system function and index to meet the objectives. The graph theoretic approach has been used prior in many applications like rapid prototype selection (Rao and Padmanabhan, 2007), web mining and data analysis (Blazewich et al., 2005), contractor rating (Darvish et al., 2008), TQM evaluation (Groover et al, 2006), supply chain risk mitigation (Faisal et al., 2007) etc. In view of these advantages, graph theory is proposed in this paper for supporting the cold chain PMS.

The framework for consistent rating scale of cold chain KPI

There are number of indicators of a cold chain PMS. In this study, these indicators are identified based on exhaustive literature survey and discussion with academicians and practitioners. A brainstorming session was organized to identify the KPI. In all, thirty-six indicators were identified in this session. The number was reduced to twenty-seven as some overlapped and some were combined. These indicators are further grouped under seven major indicators (Figure 2). Based on these KPI, case company's performance is measured and evaluated. Although graph theory includes both quantitative and qualitative indicators, the measurement of qualitative indicators may be different for various cold chain companies. So, a consistent measuring system is defined for all the qualitative and quantitative indicators. The performance level of the selected company and its competitors are calculated against the overall performance index to find out the best-in-class company. The definitions of KPI and how KPI affect a company is explained below for more clarity and knowledge.

Cost: Microbial spoilage in the food industry represents a huge cost and waste of a valuable resource. Spoilage of fresh fruit and vegetables may occur at any stage between harvesting and consumption, such as handling, processing, packaging, storage, transport, distribution, retail display, and use by the consumer. Lower product losses, energy costs, cost of operation and maintenance of refrigeration system and lost time costs can enhance the competitiveness.

Quality and safety: Consumers are increasingly concerned with food quality and safety, and give freshness very high priority when purchasing chilled foods.

Service level: A good service always delights customer. For a cold chain it an be viewed as a feature distinguished from other competitors and can increase sales and image e.g. refrigerated home delivery, operating hours and convenience etc.

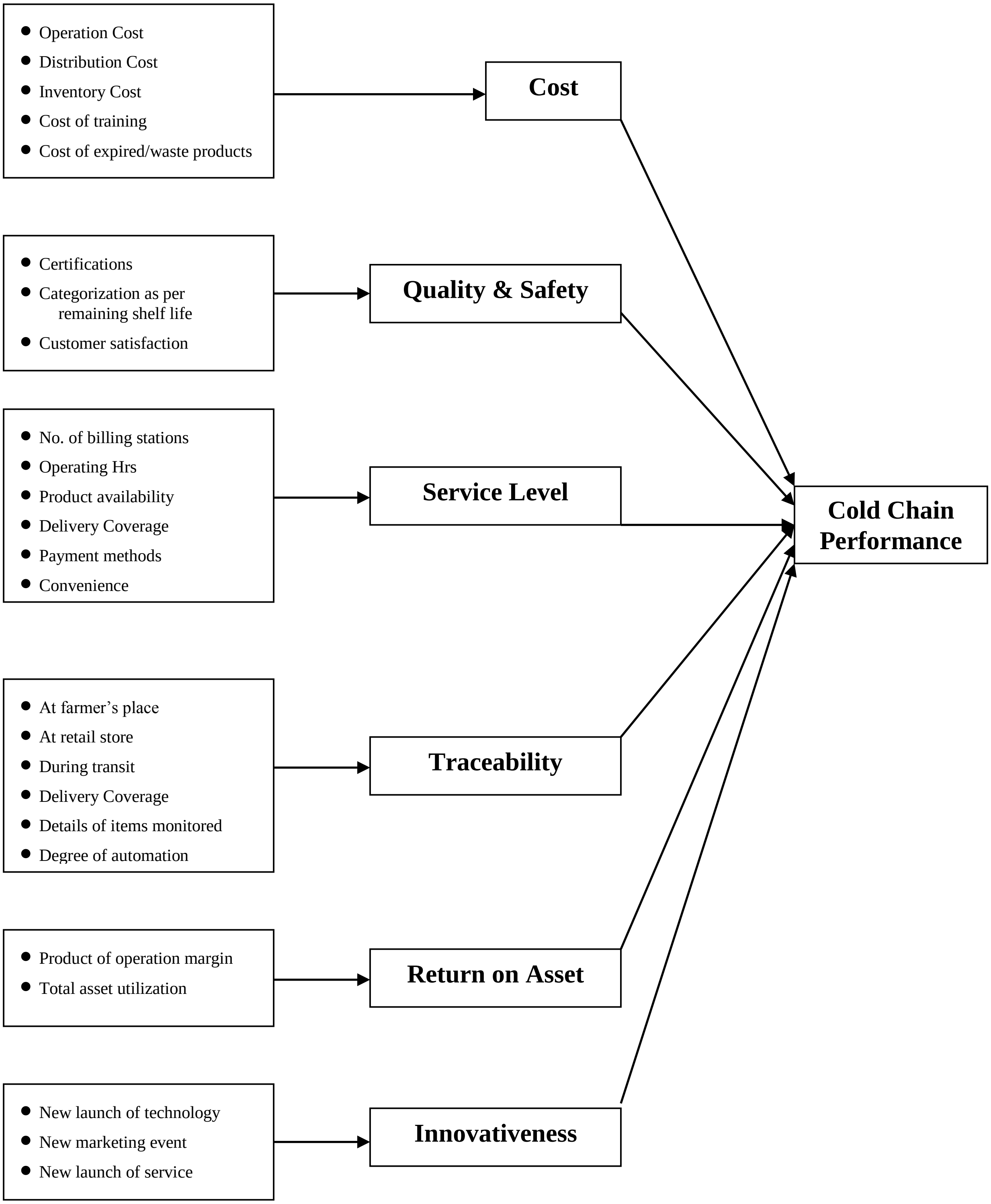

Figure 2: Attributes contributing to cold chain performance

Traceability: Product temperature may vary in each step, especially when loading and unloading is performed outside controlled temperature conditions and traceability is today a key concept. Traceability is becoming understood as a method of receiving information on the time-temperature history of the products from one stage to another in the cold chain.

Return on asset: This is the product of operation margin (profit/sales) and the total asset utilisation or turnover (sales/assets), as given by the well-known DuPont model (Van Landeghem and Persoons, 2001). Efficiency in utilizing refrigeration assets can enhance productivity at a low cost without hampering the quality.

Innovativeness: Innovativeness is the only answer to continuously changing customer requirement and highly intense competition.

Relationship: An association between customer, employees and partners has direct effect on whole performance. This is measured indirectly through randomly selected people in all three categories.

In order to evaluate performance more consistently standard evaluation measures for each sub-indicator is shown on Table 1 (last column). Evaluators can judge the performance of the indicators in a better way, as data collection is relatively easy and accessible due to this quantification.

Table 1: Consistent rating standard of attributes and sub-attributes for performance evaluation

Attributes	Sub-attributes	Rating	Evaluation Standard	
Cost	Operation Cost	VH	(Corresponding cost/ total cost) x 100	>50%
	Inventory Cost	H		35%-50%
	Distribution cost	A		20%-34%
	Cost of Expired/ wasted product	L		10%-19%
	Cost of staff training	VL		<10%
Quality & Safety	Certification	VH	No. of certifications (HACCP, GMP, GAP, GLP, ISO 2000, ISO14000 etc.) a company have	>3
		H		3
		A		2
		L		1
		VL		0
	Customer Satisfaction for Q&S	VH	How likely is that you will recommend (company X) to a friend or colleague? (0 to 10 scale). Random customers are asked and the average score is calculated.	9-10
		H		7-8
		A		4-5
		L		2-3
		VL		0-1
	Categorisatoin as per remaining shelf life	VH	Sorting on information on the remaining shelf life of entity updated in the function of temperature condition experienced n cold chain	Automatic
		H		Semi-automatic
		A		Manual
		L		Occasional
		VL		Never
Traceability	At farmer's place During transit At retail store	VH	No. of points the products is traces with RFID/ barcode/ smart tags and Trucks with temperature indicators/ GPS etc.	>10
		H		7-9
		A		5-6
		L		2-4
		VL		0-2
	The degree of details of information about items monitored	VH	No. of information (time, temperature, humidity, expected shelf life, price, color, weight, volume, sell by date etc.) secured about the product while monitoring.	>10
		H		7-9
		A		5-6
		L		2-4
		VL		0-2
	Degree of automation	VH	The degree of automation (Manual, semi automatic, automatic) of item	Automatic
		H		In between

		A	identification and data collection	Semi-automatic
		L	process.	In between
		VL		Manual
Service level	No. of billing stations	VH	No. of counters/ $1000m^2$	>4
		H		4
		A		3
		L		2
		VL		≤1
	Convenience	VH	No. of store in a city	>10/ city
		H		8-10/ city
		A		5-7/ city
		L		3-4/ city
		VL		1-2/ city
	Operating hour	VH	Operating time for store	16-24hr
		H		9-16
		A		7-9
		L		6-7
		VL		<6

Attributes	Sub-attributes	Rating	Evaluation Standard	
	Payment method	VH	No. of methods (Credit card, Debit card, Cash, membership card, on-line payment, phone payment , other payment gateways)	> 4
		H		4
		A		3
		L		2
		VL		1
	Delivery coverage	VH	Refrigerated home delivery area covered	>¾ area of the city
		H		¾ area of the city
		A		½ area of the city
		L		¼ area of the city
		VL		<¼ area of the city
	Product availability	VH	Average no. of items out of stock	<3
		H		3
		A		4
		L		5
		VL		>5
ROA	Net profit to sales	VH	(Net profit/ total sales) x 100	>80%
		H		60-80%
		A		40-60%
		L		20-40%
		VL		<20%
	Total asset utilization	VH	Total sales/ total asset owned	>80%
		H		60-80%
		A		40-60%
		L		20-40%
		VL		<20%
Innovativeness	New launch of technology	VH	Reduction in time (or cost)/ total time (cost) x100	>80%
		H		60-80%
	New launch of service	A		40-60%
		L	(Sales after new service or event/ total sales) x 100	20-40%
	New marketing event	VL		<20%
Relation	Customer	VH	Average satisfaction of selected customer/ farmer/ employee (0-10 scale)	8-10
		H		6-8
	Farmer	A		4-6
		L		2-4
	Employee	VL		0-2

Cold chain performance indicators (CCPI) digraph

The CCPI digraph models indicators and their interrelationships. This digraph consists of a set of nodes $M=\{m_i\}$ with $i=1,2\ldots M$ and a set of directed edges $E=\{e_{ij}\}$. The node m_i represents i^{th} indicator and edges represent the relative influence (relationship) among the indicators. Thus, the relative influence exists between these two indicators in both the directions. In the same way relative influence can be represented between the other indicators and sub-indicators.

Matrix representation of the CCPI digraph

The CCPI digraph gives a graphical representation of indicators and their interrelationship for quick visual judgment. As the number of nodes and their interrelations increases, the digraph becomes complex. The digraph is represented in a matrix form to overcome this constraint. Matrix representation of the CCPI digraph gives one to one representation. A matrix called the cold chain performance indicators matrix is defined. This matrix C*C* for a diagraph having M nodes is represented as:

$$CC = \begin{array}{c} \textit{Indicators} \\ A \\ B \\ C \\ - \\ - \\ M \end{array} \begin{array}{c} \begin{array}{cccccc} A & B & C & - & - & M \end{array} \\ \left[\begin{array}{cccccc} A_1 & r_{12} & r_{13} & - & - & r_{1m} \\ r_{21} & A_2 & r_{23} & - & - & r_{2m} \\ r_{31} & r_{32} & A_3 & - & - & r_{3m} \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ r_{M1} & r_{M2} & r_{M3} & - & - & A_M \end{array}\right] \end{array} \quad \textbf{(1)}$$

where A_i is the inheritance value of the i^{th} indicator represented by node m_i (in diagraph) and $r_{ij}$is the relative influence of the i^{th} indicator over the j^{th} represented by the edge *eij* (in diagraph).

The value of A_i should preferably be taken from available or estimated data. If quantitative values of the indicators are available, normalized values of an indicator assigned to the alternatives are calculated by v_i/v_j, where v_i is the measure of the indicator for the i^{th} alternative and *vj* is the measure of the indicator for the j^{th} alternative which has a higher measure of the criterion among the considered alternatives (Darvish et al., 2008).

In case, a quantitative value is not obtainable, then a ranked value judgment on a fuzzy conversion scale can be used. By using fuzzy set theory, r_{ij} can be first decided as linguistic terms, converted into corresponding fuzzy numbers and then converted to the crisp scores (Rao and Padmanabhan, 2007). A numerical approximation system to systematically convert linguistic terms to their corresponding fuzzy numbers is proposed by Chen and Hwang (1992). It may be noticed that any scale may be chosen, for e.g., 0–1, 0-5, 0–10, 0–100 for A_i and r_{ij}, the final ranking will not change as these are the relative values. It is, however, recommended to choose a lower scale for A_i and r_{ij} to obtain a handy value of the index (Faisal et al., 2007; Darvish et al., 2008).

Once the values of A_i and r_{ij} are obtained the next step is to calculate the permanent of matrix *CC*, i.e. per (*CC*). The per(CC) is defined as the CC performance indicators function. The permanent is a standard matrix function and is used in combinatorial mathematics (Darvish et al., 2008). Application of permanent concept will lead to a better appreciation of cold chain performance indicators. Moreover, no negative sign will appear in the expression (unlike determinant of a matrix in which a negative sign can appear) and hence no information will be lost (Rao and Padmanabhan, 2007). The per (CC) function for matrix expression in equation (1).

This is the sample expression that would be solved for all sub-indicators and indicators for the complete CC performance evaluation problem. The terms are the sets of distinct diagonal elements and loops of off-diagonal elements of different sizes (i.e. $r_{ij}r_{ji}$, $r_{ij}r_{jk}r_{ki}$, etc.). The per (CC) contains terms arranged in (M + 1) groups, and these groupings represent the measures of sub-indicators/indicators and the relative influence loops. To calculate the permanent function of a square matrix (M XM), a computer program is developed using Java platform (jdk1.6.0_11).

$$per(CC)=\prod_{i=1}^{M}A_i+\sum_{i=1}^{M-1}\sum_{j=t+1}^{M}....\sum_{m=t+1}^{M}(r_{ij}r_{ji})A_kA_mA_lA_nA_o...A_tA_m+\sum_{i=1}^{M-2}\sum_{j=l+1}^{M-1}\sum_{k=j+1}^{M}...\sum_{M=t+1}^{M}...(r_{ij}r_{jk}r_{ki}+r_{ik}r_{kj}r_{ji})$$

$$\times(A_lA_nA_o...A_tA_m)+\begin{pmatrix}\sum_{i=1}^{M-3}\sum_{j=i+1}^{M}\sum_{k=i+1}^{M-1}\sum_{l=i+2}^{M}...\sum_{M=t+1}^{M}(r_{ij}r_{ji})(r_{kl}r_{lk})A_mA_nA_o...A_tA_m\\ \sum_{i=1}^{M-3}\sum_{j=i+1}^{m-1}\sum_{k=i+1}^{M}\sum_{l=j+1}^{M}...\sum_{M=t+1}^{M}(r_{ij}r_{jk}r_{kl}r_{li}+r_{il}r_{lk}r_{kj}r_{ji})A_mA_nA_n...A_tA_M\end{pmatrix}$$

$$+\begin{pmatrix}\sum_{i=1}^{M-2}\sum_{j=i+1}^{M-1}\sum_{k=j+1}^{M}\sum_{l=1}^{M-1}\sum_{m=l+1}^{M}...\sum_{m=t+1}^{M}(r_{ij}r_{jk}r_{ki}+r_{ik}r_{jk}r_{ji})(r_{lm}r_{ml})A_nA_o...A_tA_M+\\ \sum_{i=1}^{M-4}\sum_{j=i+1}^{M-1}\sum_{k=i+1}^{M}\sum_{l=i+1}^{M}\sum_{m=j+1}^{M}...\sum_{M=t+1}^{M}(r_{ij}r_{jk}r_{kl}r_{lm}r_{mi}+r_{im}r_{ml}r_{lk}r_{kl}r_{ji})(r_{lm}r_{ml})A_nA_o...A_tA_M\end{pmatrix}$$

$$+\begin{pmatrix}\sum_{i=1}^{M-3}\sum_{i=j+1}^{M-1}\sum_{k=i+1}^{M}\sum_{l=j+1}^{M}\sum_{m=1}^{M-1}\sum_{n=m+1}^{M}...\sum_{M=t+1}^{M}(r_{ij}r_{jk}r_{kl}r_{li}+r_{ik}r_{lk}r_{kj}r_{ji})(r_{mn}r_{nm})A_o...A_tA_M+\\ \sum_{i=1}^{M-5}\sum_{j=i+1}^{M-1}\sum_{k=i+1}^{M}\sum_{l=1}^{M-2}\sum_{m=l+1}^{M-1}\sum_{n=m+1}^{M}...\sum_{M=t+1}^{M}(r_{ij}r_{jk}r_{ki}+r_{ik}r_{kj}r_{ji})(r_{lm}r_{mn}r_{nl}+r_{nl}r_{nm}r_{ml})A_o...A_tA_M+\\ \sum_{i=1}^{M-5}\sum_{j=i+1}^{M}\sum_{k=i+1}^{M-3}\sum_{l=i+2}^{M}\sum_{m=k+1}^{M-1}\sum_{n=k+2}^{M}...\sum_{M=t+1}^{M}(r_{ij}r_{ji})(r_{kl}r_{lk})r_{mn}r_{nm})A_o...A_tA_M+\\ \sum\sum\sum\sum\sum\sum...\sum(r_{ij}r_{jk}r_{kl}r_{lm}r_{mn}r_{ni}+r_{in}r_{nm}r_{ml}r_{lk}r_{kj}r_{ji})A_o...A_tA_M+...\end{pmatrix} \quad (2)$$

Proposed Methodology

The main steps of the GT based approach for performance measurement are as follows:

a) First of all the KPI affecting cold chain performance of a company are identified.
b) Group these indicators (as seven indicators are framed in this study based on Figure 1).
c) Identify the sub-indicators affecting each indicator.
d) Logically develop a digraph between the sub-indicators of an individual indicator based on their relationship.
e) Develop a sub-indicator matrix from the earlier developed digraph. Obtain the r_{ij} and A_i for the company to be evaluated and for its competitors.
f) Obtain the permanent function for above sub-indicator matrix using equation (2). Evaluate and obtain the permanent value, which can be termed as an Indicator Index (AI) of a particular indicator for a particular company.
g) Similarly develop sub-indicator matrix for each indicator. The total number of sub-indicator digraphs will be equal to the number of the broadly synthesized indicators. Obtain an AI for each indicator for all considered companies.
h) The AI provides the degree of inheritance for each indicator and the next step is now to work at upper level, i.e. indicator level. Now, logically develop a digraph between these indicators.
i) Develop the indicator matrix from the digraph. Obtain r_{ij} between the indicators. The normalized values of indicators (A_i) for all considered companies will arrive from previously calculated AI for each indicator.
j) Evaluate the permanent function of the indicator matrix at system level using equation (2). This result will be the value of cold chain performance evaluation index (CCPE index), which mathematically characterizes the cold chain performance of a company based on indicators and their relationships. Likewise, CCPE for all the considered companies are calculated. The company with highest CCPE index will be considered as the market leader.

Once the CCPE index is obtained, the market leader can be identified and benchmarked for learning the best practices. So, for finding strengths and weakness of the Company as compared to market leader it is necessary to evaluate ratings of each indicator and sub-indicator. These weaknesses are the gaps in the performance. The good practices learnt from the market leader can be identified as a benchmark to close this performance gap.

Based on the result of the further step could be the selection of improvement alternatives for the company to improve its cold chain performance. However, it is essential to analyse whether the 'better processes' learnt from the market leader are suitable for implementation or not. There can be many key decision factors (current operational conditions and companies strategies) that may influence the efficiency and effectiveness of a particular alternative, favourably or adversely towards continuous improvement (Chan et al., 2006). Therefore, in continuation, for improvement assessment may be employed for providing management with a preferred order (descending order with the most benefits and lowest cost) of alternatives that could help in deciding which alternative is the most appropriate to suit their current operational condition. The framework proposed would be substantiated with relevant data and reported in a subsequent paper.

Conclusion

The development of an organization cannot take place unless the wastages are minimized and productivity is improved. In context of any food industry, cold chain technology plays a decisive role not only in food safety and health but also in economic growth particularly for developing countries where microbial spoilage in the food industry represents a huge cost and waste of a valuable resource. This paper has attempted to present a performance improvement system that simplifies and reduces the complexities of cold chain evaluation with a view to helping focus the practicing manger's efforts towards improvement. The cold chain mangers (evaluators) can judge the performance of the cold chain in a better way, as data collection is relatively easy and accessible due to the consistent measuring system defined for all the qualitative and quantitative indicators. The consistent measuring system has facilitated to evaluate performance more reliably for each indicator and sub-indicator. With the proposed performance measurement framework managers can easily understand the present strengths and weaknesses of their companies as compared to market leaders. They can identify the good practices from the market leader and can benchmark them for improving the weaknesses. One of the limitations of the framework can be viewed as the subjectivity of rating and evaluation standard of the measuring system. But, the standardizations in consistent rating scale are not restricted. Depending upon the particular requirement, these standards can be modified for better results.

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