ANALYSIS AND MANAGEMENT OF ISSUES IN COLD CHAIN OF FROZEN FOOD PRODUCTS

A thesis submitted to the
University of Petroleum and Energy Studies

For the award of
Doctor of Philosophy

In

School of Business

By

Madhu Arora

June 2022

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With the blessings of the Almighty,

I dedicate this thesis to my parents and my family

for their endless love, immense support, and encouragement

June 2022

DECLARATION

I declare that the thesis entitled "ANALYSIS AND MANAGEMENT OF ISSUES IN COLD CHAIN OF FROZEN FOOD PRODUCTS" has been prepared by me under the guidance of Dr. Rupesh Kumar, Assistant Professor (Selection Grade), School of Business, University of Petroleum & Energy Studies and Dr. L.R. Thapar, Managing Director, Hind Terminals. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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CERTIFICATE

I certify that **Madhu Arora** has prepared her thesis entitled "**Analysis and Management of Issues in Cold Chain of Frozen Food Products**", for the award of PhD degree of the University of Petroleum & Energy Studies, under my guidance. She has carried out the work at School of Business, University of Petroleum & Energy Studies.

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Date : June 22, 2022

ABSTRACT

Owing to the changing demographic profiles of the consumer, globalization, western influence, increased spending power, the cold chain is sure to dominate in future. With the increased health consciousness, growing concerns for the quality and safety of food, increased losses and wastage in food, it becomes imperative that the cold chains are technologically equipped, sustainable and integrated to be able to address those concerns. The key focus of the future cold chain will be innovation, integration and sustainability. The presence of several challenges and issues prevalent in the cold chain of frozen food has affected its performance and led to huge wastage and losses. These issues also thereby affect the competitiveness and profitability of the partners involved in the cold chain. India being second biggest producer of food crops grown, especially the F&V, is still not able to contribute significantly as a food supplier to the world or in exports too its contribution is minimum.

The frozen food products' cold chain is a rising sector still and hence there are few research studies on this relatively newer concept. There are more studies focussing on pharmaceutical products and few on frozen food products. The ones that exist on frozen food products deal with a few specific issues or with a specific technological solution. There exists no study that proposes a model exhibiting issues as a synergistic whole and suggests strategies and solutions to either overcome or mitigate the influence of the issues on the complete chain's performance. This leads to a prominent research gap.

The current research has further funnelled down to frozen food products in Uttarakhand region of India. First, the categories and sub-categories of issues influencing performance of CC were established and analysed. Classification of issues and its sub-categories was based on an exhaustive review of literature and inputs from the cold chain stakeholders themselves. Subsequently, SEM was employed to look at the effect of the issues on the performance. AHP / FAHP and DEMATEL were employed to prioritise the issues and their sub-categories as well as examine the inter-influence of the issues. Based on the analysis, 'Lack of Infrastructure' appears as the most dominant issue trailed by 'Lack of Awareness & handling practices', ' Lack of Safety & Quality' and 'Lack of Responsiveness' while the issues 'Lack of

Traceability', 'Lack of Sustainability' and 'Lack of Integration' are the issues where extensive efforts are still required by all the cold chain stakeholders.

In the second stage, strategies and solutions were recommended to be implemented to overcome these issues or reduce their impact on the cold chain's performance. The solutions were segregated into two categories, namely the IT solutions and the Non-IT solutions. These solutions were then separately analysed using Best-Worst Method and the Fuzzy TOPSIS. While Best-Worst technique helped understand the interaction between the best/worst solution with the other solutions, FTOPSIS helped prioritise the solutions based on their preference/usefulness for overcoming or mitigating the influence of the issue on CC performance. The top two IT solutions are 'Automation of Data collection, storage, retrieval, shipment, analysis & compliance' and 'Use of electronic data loggers/time temperature indicators, digital electronic control, onboard telematics technology and other such devices for monitoring of temperature' while the top two Non-IT solutions are 'Application of best practices prevalent in frozen food industry' and 'Partnerships and alliances to be built for sharing of knowledge and resources'. Thus, the present study offers an effective environment for the purpose of taking successful decisions and implementing/executing strategies and solutions with the aim of enhancing the effectiveness of the cold chain's performance while also leading to reduced food wastage and losses.

Keywords: Cold chain; Issues; Solutions; SEM; Fuzzy AHP; Fuzzy TOPSIS; DEMATEL; BWM; Information Technology; Sensitivity Analysis; Uttarakhand; India

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Dated: June 2022
Madhu Arora

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List of Abbreviations

Abbreviations	Full Name
AFSC	Agri-Food Supply Chain
AGFI	Adjusted Goodness of Fit Index
AHP	Analytic Hierarchy Process
AI	Artificial Intelligence
AMOS	Analysis of Moment Structures
ANZ	Australia and New Zealand
APEDA	Agricultural and Processed
ASSOCHAM	Associated Chambers of Commerce and Industry of India
ASV	Average Shared Variance
AVE	Average Variance Extracted
B2B	Business to Business
BPR	Business Process Reengineering
BRC	British Retail Consortium
BWM	Best-Worst Method
CAC	Codex Alimentarius Commission
CAGR	Compounded Annual Growth Rate
CAS	Cold Air Storage
CC	Cold Chain
CCM	Cold Chain Management
CCQI	Cold Chain Quality Indicator
CEO	Chief Executive Officer
CFA	Confirmatory Factor Analysis
CFC	Chloro Fluoro Carbons
CFI	Comparative Fit Index

CI	Consistency Index
CIPHET	Central Institute of Post-Harvest Engineering & Technology
CM	Supply Chain Management
COVID-19	Corona Virus Disease-2019
CPFR	Collaborative Planning Forecasting and Replenishment
CR	Consistency Ratio/ Composite Reliability / Critical Ratio
CSC	Cold Supply Chain
CSR	Corporate Social Responsibility
DADF	Department of Animal Husbandry, Dairying & Fisheries
DAHD	Department of Animal Husbandry and Fisheries
df	Degrees of Freedom
ECR	Efficient Consumer Response
EDI	Electronic Data Interchange
EFA	Exploratory Factor Analysis
FAHP	Fuzzy Analytic Hierarchy Process
FAO	Food Agriculture Organisation
FCC	Food Cold Chain
FIFO	First in First Out
FF	Frozen Food
FFP	Frozen Food Product
FILO	First in Last Out
FNIS	Fuzzy Negative Ideal Solution
FPIS	Fuzzy Positive Ideal Solution
FSC	Food Supply Chain
FSMA	Food Safety Modernization Act
FTOPSIS	Fuzzy Technique for Order of Preference by Similarity to Ideal Solution
F&V	Fruits and Vegetables
GCCA	Global Cold Chain Alliance
GDP	Gross Domestic Product
GFI	Goodness of Fit Index

GHI	Global Hunger Index
GIS	Geographic Information System
GMO	Genetically Modified Organisms
GOI	Government of India
GPRS	General Packet Radio Services
GPS	Global Positioning System
GSCM	Green Supply Chain Management
GSI	Global Standards Initiative
HACCP	Hazard Analysis Critical Control Point
HMNEH	Horticulture Mission on North East and Himalayan States
ICAR	Indian Council of Agricultural Research
ICT	Information and Communication Technology
IFI	Incremental Fit Index
IoT	Internet of Things
IPCC	Inter-governmental Panel on Climate Change
IQF	Individual Quick Freezing
ISO	International Standards Organisation
ISM	Interpretive Structural Modelling
IT	Information Technology
KBV	Knowledge Based View
KMO	Kaiser-Meyer-Olkin
KPI	Key Performance Indicators
LAP	Learning Action Performance
LED	Light Emitting Diode
LIFO	Last in First Out
LR	Literature Review
MADM	Multi Attribute Decision Methods
MAS	Modified Atmosphere Storage
MCDA	Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Methods

MICMAC	Matrice d'Impacts Croises Multiplication Appliques a un Classement
MIDH	Mission for Integrated Development of Horticulture
Ml	Machine Learning
MOFPI	Ministry of Food Processing Industries
MT	Metric Tonne
NCCD	National Centre for Cold Chain Development
NFI	Normed Fit Index
NGO	Non-Government Organisations
NHB	National Horticulture Board
NHM	National Horticulture Mission
PFP	Perishable Food Product
PI	Performance Indicators
PLS	Partial Least Square
PP	Perishable Product
PPSC	Perishable Product Supply Chain
QR	Quick Response Code
RFID	Radio Frequency Identification
RI	Random Index
RMR	Root Mean Square Residual
RMSEA	Root Mean Square Error Approximation
RSCCS	Refined Smart Cold Chain System
RTD	Resistance Temperature Detectors
SAP	Situation Actor Process
SC	Supply Chain
SCOR	Supply Chain Operations Reference
SCQM	Supply Chain Quality Management
SEM	Structural Equation Modelling
SPSS	Statistical Package for Social Sciences
SRMR	Standardized Root Mean Square Residual
SSC	Sustainable Supply Chain

SSP	Strategy Structure Performance
SSCM	Sustainable Supply Chain Management
TAM	Technology Acceptance Model
TFN	Triangular Fuzzy Numbers
TISM	Total Interpretive Structural Modelling
TLI	Tucker Lewis Index
TOE	Technology Organisation Environment
TOPSIS	Technique for Order Preference Similarity to Ideal Solution
TRM	Total Relation Matrix
TRU	Traceable Resource Unit
TTI	Time Temperature Indicators
UK	Uttarakhand, India
UK	United Kingdom, Europe
UP	Uttar Pradesh
USDA	U.S. Department of Agriculture
VICS	Voluntary Inter-Industry Commerce standards committee
WNFDM	Weighted Normalized Fuzzy Decision Matrix
WHO	World Health Organisation
WSN	Wireless Sensor Networks

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CHAPTER 1

INTRODUCTION

OVERVIEW

India being an agriculture-intensive nation can actually become the food supplier to the entire world. The country has vast land for cultivation with fruits and vegetables produced round-the-year. However, primarily owing to a highly ineffective food supply chain, the country is not able to exploit the benefits that nature has bestowed upon it.

This Chapter attempts to explicate some relevant concepts essential for understanding the essence of the entire thesis. This chapter also throws light upon the evolution of cold chain and the various issues affecting performance of CC along with its stakeholders. The chapter also reflects upon the business problem and the research problem.

1.1 BACKGROUND OF THE STUDY

Progression from a simple and local supply chain to a global and complex supply chain has been occurring since a number of years. Traders were looking for ways to transport perishable products in a manner such that the quality and freshness were maintained. Thus, was felt a requirement for a reliable system through which the food product could be moved from point of creation to the mark of utilization while keeping up with quality. According to many research studies, the primary attributes of a food chain are: varied quality and quantity of the farm output, long production lead times, shelf-life constraints, storage facility requirement, transportation facility requirement, and above all seasonal production (Ojo, 2017).

Freezing has been recognized as truly an effective method of preservation of food for prolonged duration since the Neolithic and Paleolithic times, when ice and snow was utilized for keeping the food cold. In the Victorian times, preservation of snow and ice in houses of ice and ice manufacturing using ‘night cooling’ was a common practice. Even though the technique of freezing was known in Italy, Spain and India in the sixteenth century, it was in 1662 that chemist Robert Boyle first publicly discussed the cooling effect of ice and salt. Temperature sensitive refrigerated transportation can be traced to 1797, a time when ice was used by the British fishermen for the preservation of fish storage piles. During 1700s, William Cullen was quick to fabricate ice without utilising any natural form of cooling by vaporisation of low-pressure water. Jacob Perkins in the year 1834 was the first to make ice-manufacturing machine that operated on ethyl ether. The next 30 years led to the development of the refrigeration technology. In 1865 the first cold storage was built in New York which utilised brine for cooling. In 1868, cold air machine of the ship was used for transporting meat products from New York to Glasgow and later was transported from ANZ to UK. Refrigeration and freezing of food went through rapid developments related to refrigerants and the freezing processes in the late 19th century. Ammonia was used as a refrigerant then. In 1928, Thomas Midgley invented Freons (CFCs) thus bringing about a radical change in refrigeration. The Freons were then said to be very efficient as well as environmentally harmless. In 1929, Clarence Birdseye began developing frozen meals for long-term stability and convenience.

In the year 1930, Frederick Jones designed a movable air-cooling unit for transportation of perishable food through trucks and received a patent for the same. This set the movement of perishable food through refrigerated rail cars and trucks even over long distances (cargodatacorp.com).

Frederick McKinley Jones invented mobile mechanical refrigeration. A portable air-cooling unit was designed and patented by Jones on 12 July 1940. In 1950s, this technology was more often used to preserve animal-based cells or tissues and the technology has been frequently used since then (Wikipedia.org).

In the concluding half of the twentieth century, there were rapid developments in both freezing as well as frozen food technology. As new technologies developed that were low-cost, households' accessibility to a freezer for food storage became possible. With the culmination of 20th century, frozen food souk was seeing a 10 percent / year increase with nearly twenty-five percent of the refrigerated food belonging to the frozen category (Evans, 2009).

Freezing could now preserve food in its original form nearly. So, the food could not only be preserved but also transported worldwide. Since freezing averts the microbial growth, frozen food can be stowed for prolonged duration without the usage of additives or preservatives for prolonging the duration of shelf life. Freezing permits a more flexible approach in production and supply thus ensuring that the food can be well-preserved close to its optimum quality.

Cold supply chain is a new concept for India. It was not before 1970s that a new trend of cold stores that could store multiple products started in Maharashtra and the same was then followed with developments taking place in various aspects of food processing sector and techniques in freezing across the country. Then the focus shifted from ‘cold storages’ to ‘cold chain’ with the complete food supply chain straight from the farm as source to the retail as destination considered an imperative requirement for preservation of food. Cold chain came to be recognized as the ‘Sunrise sector’ in India (coolingIndia.in).

Recent trends in India’s cold chain sector indicated a surge in cold chain facilities including Pack houses with pre-cooling and processing facility, Controlled Atmosphere stores, and ripening units. India has huge potential for production and distribution of frozen food products.

Refrigerated transportation being an important link in cold chain is surely set to increase in numbers along with other components of a cold chain. In most of the developing nations, refrigeration is not as effective as in developed countries owing to inadequate refrigeration equipment, electricity related challenges, associated costs and not enough awareness considering the quality and safety of the perishable products (Mercier, 2017). The study also emphasized that refrigeration if applied effectively can result in huge reduction in food losses.

However, not only the performance of the cold chain but that of its stakeholders too is affected because of the presence of several challenges and issues in the cold supply chain, which is mentioned under the business problem section. There is not enough literature available on the FFP's CC in India. The goal of this study is the analysis and management of issues in the cold chain of frozen food. Hence, the main objective of this study is to identify and assess issues existing in cold chain of frozen food. Thereafter, strategies and solutions are suggested and analysed to overcome the identified issues.

During the writing of this study, the world was suffering from the coronavirus disease referred to as COVID-19 pandemic. December 2019 reported the first case of coronavirus in Wuhan, China popular as a transportation hub (Shah, 2020) while in India the first case was reported on 30th January 2020 after which the Indian government declared lockdown for the nation (Agrawal, Jamwal & Gupta, 2020). Struck by fear of spread of the deadly virus, import-export activities were banned, airports and sea docks were shut down especially with declaration of coronavirus epidemic by the WHO, a worldwide pandemic on the eleventh of March 2020 (Biswas, 2020). With the rapid spread of COVID-19, a huge uncertainty and vague disruptions occurred in the global SC. The SC experienced huge challenges in order to continue with the supplies of food, medicines and other necessary items including those that were required with extreme urgency for the sake of administering treatments, protection as well as for bringing the pandemic under control (WHO, 2020). Owing to the lockdown restrictions causing severe disruptions in the SC in the country, the supply chain faced huge pressure. With it, also came transformation of the business models and the increased use of technologies, online platforms and innovative practices thereby bringing changes in the SC structure. Preferences of people also shifted from buying more of packed food products for the sake of safety and precaution. According to Darkow (2015), the key drivers for future of FSCs are: customer focus, innovation and sustainability.

This study is expected to be of help to the firms whether in partnership, sole proprietorship, private limited or government assisted, involved in the cold chain sector. In spite of the significant benefits of implementation of cold chain management, firms continue to face various issues which prevent them from implementing CCM effectively. The real benefits of cold chain management can be attained when firms and related cold chain players are able to not just identify the issues but also overcome those issues to achieve high levels of cold chain performance as well as contribute economically, socially and environmentally. Since these issues are complex in nature, it becomes crucial for the cold chain stakeholders to comprehend them properly. With the above perspective, the study helps contribute to the cause.

1.2 CONCEPTS AND DEFINITIONS

Before understanding the data and methods for analysis, it is imperative to understand crucial concepts and definitions. Therefore, this section exhibits a brief introduction and understanding of some important concepts such as: SC and SCM; CC and CCM; frozen food; and issues in CC.

1.2.1 SUPPLY CHAIN AND SUPPLY CHAIN MANAGEMENT

SCM as a concept can be drawn back to a period prior to the 1960s (Huan, 2004). The definition of Supply chain as cited in Towill (1997) is "a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via the feedforward flow of materials and the feedback flow of information". According to Foster (2008), who has defined SC quality management as "a systems-based approach to performance improvement that leverages opportunities created by upstream and downstream linkages with suppliers and customers". Erkan (2011) in their study emphasized upon SCOR framework with five measurements estimating execution in two classifications which are: reliability, flexibility and responsiveness constituting customer-facing metrics and cost & assets constituting internal-facing metrics.

However, there have been multiple manners by which SCM is thought of, with it being defined somewhere operationally while some consider it as a management process or as a management philosophy [Tyndal, 1998 (as adapted in Mentzer, 2001)]. Lambert, Ellram and Stock have defined a SC as "the alignment of firms that brings products or services to market" (as adapted in Mentzer, 2001). Thus, a supply chain can be said to involve many players, some that supply referred to as upstream while the others that distribute products referred to as downstream and finally the consumer. Therefore, a supply chain is exceedingly complex as it involves all firms in both downstream as well as upstream stream of items, data and currency from the source to the end-destination.

Supply chain management as a concept has attained even more prominence with the increase of procurement from global sources. Owing to globalization, a need was felt to consider more efficient and effective ways of improved coordination between the various stakeholders which in turn led to improved relationships with suppliers. Effective SC operation can be achieved through seamless collaboration of manufacturers, suppliers, distributors with the help of latest technological solutions and interorganisational systems (Pramatari, 2007). The success of Dell in the IT sector, Walmart in retail sector and GM in automobile sector proves it.

While the product flows downwards, the information flows both upwards and downwards. For a supply chain to be referred to as a seamless chain, there should be minimum entropy in the chain. This means that every one of the partners in a supply network function in a synergistic whole to achieve benefits for all through enhanced level of customer service and satisfaction. For the SC to be unified, it is important that right information flows through it. Fast reaching the product, free of any defects, to the customer has become a necessary requirement today than being considered as a competitive advantage. Today's supply chain though being highly complex must still be flexible to be able to meet the uncertain demand. The product life cycle influences the environment of a SC at each stage right from the stage of raw material procurement till the manufacturing stage, also considering the stages of reuse, recycling and its final discard (Zhu, 2007).

Food Supply Chains are distinct as notwithstanding the difficulties looked by other supply chains the FSCs are also faced with challenges related to product deterioration, perishability and wastage of the food (Amorim, 2012; Gobel, 2015). The performance of the complete food SC depends upon the performance of its partners. A food supply chain entails advanced handling systems to efficiently handle SC profitability, perishability of item, unforeseen variations in the SC, properties of food safety that influence sustainability, and furthermore shopper's wellbeing & loyalty (Khedkar & Singh, 2018). Not only that but it becomes even more challenging and complex because of the presence of different heterogenous and autonomous partners like manufacturers/processors, suppliers/farmers, cold storage service provider, cold logistic service providers, distributors, retailers and certification agencies (Roth, 2008). But operating in an autonomous manner will not help achieve supreme SC performance hence it is imperative that there is intense collaboration amongst the partners in the SC of the food sector and the partners at different stages are motivated to track their performance on continuous basis. This will result in the food sector SC achieve competitiveness in the form of reduced lead time, costs, food waste (Aung, 2014; Shashi, 2018) along with improved responsiveness, quality, customer satisfaction and energy efficiency (Shukla, 2013; Beske, 2014). The supply chain for food products has considerably altered as owing to globalisation food has to be transported across larger distances which results in increased number of players in the SC, reduced transparency, more chances of contamination, deterioration, adulteration, etc. (Roth, 2008). Though efforts like labelling products and certifications have been put to reduce the above-mentioned influences of the large mile (Bhaskaran, 2006; Magkos, 2006) but even then considering the complexity of the supply network today, a great degree of efforts in the form of strategies, solutions need to be implemented. Food integrity, considering quality, food safety, and traceability and appropriate communication to consumers has been highlighted in the study of Elliott (2013). Ensuring food integrity is a wholistic perspective as it considers integrity of the following: raw material; production; service; and the integrity of information as well (Ali, 2017).

1.2.2 COLD CHAIN AND COLD CHAIN MANAGEMENT

CC is a term used to describe a specific SC where temperature control is ensured for activities and processes involving products that are perishable in nature (Shabani *et al.*, 2015). Out of numerous benefits provided by cooling, some benefits are extension of shelf life; reduced water loss; reduced ethylene production; delayed ripening; diminished development of miniature organisms; reduced textural loss, as well as spoilt flavour and loss in nutrients. With the purpose of meeting quality and safety needs of the consumer, CC helps in adding value, extending shelf life and maintaining the quality of the products (Titlo, 2019).

Cold chain as per a study done by CAC (1994), is defined as "embracing the continuity of successively employed means to maintain the temperature of foods, as appropriate, from receiving through processing, transport, storage and retailing" while Quick frozen food is a "Food which has been subjected to a quick freezing process, and maintained at -18°C or colder at all points in the cold chain, subject to permitted temperature tolerances". Foods have been categorized as: a) Frozen, requiring temperature less than -18°C, that includes processed F&V, frozen ingredients, frozen meats like fish, livestock, poultry, ice cream, etc.; b) Chilled, requiring temperature ranging from 0°C - 10°C, that includes fresh F&V, milk, fresh meats, butter, etc.; c) Mild-Chilled, requiring temperature ranging from 10°C - 20°C, that includes chocolates, sub-tropical fresh F&V, some milk products and seeds; and finally d) Normal, requiring temperature above 20°C, that includes oils and extracts, jams, dehydrated foods, pickle and whole onion (Chintada, 2018).

Therefore, Cold chain contributes towards shelf life extension, ensuring integrity while also conserving the product quality for the products that spoil fast. A cold chain that performs low is a major cause of food and health related risks which has become highly apparent especially in the COVID-19 times (Singh, Kumar, Panchal & Tiwari, 2021). According to Khan (2018) cold chain infrastructure should encompass: cold storage; refrigerated trucks; pre-cooling facilities; pack-houses; warehouses; traceability system; and information management systems.

Subsequently, an extraordinary sort of supply network alluded as Cold Chain Management CCM) is laid out for staying aware of the freshness and nature of an item. Thus, the expression "cold chain" alludes to two particular parts, 'cold' alludes to the need to control temperature in forestalling the development of microorganisms in food while keeping up with its healthiness and its ideal credits as it is handled, sent, conveyed and put away at the stores. The term 'chain' centers around observing the 'chain of care' in which each portion of the handling, stockpiling, transport and conveyance capabilities are connected to the step when in a legitimate succession with legitimate documentation and records (Yuen, 2017;Cold chain management). Fig 1.1 exhibits the cold chain management.

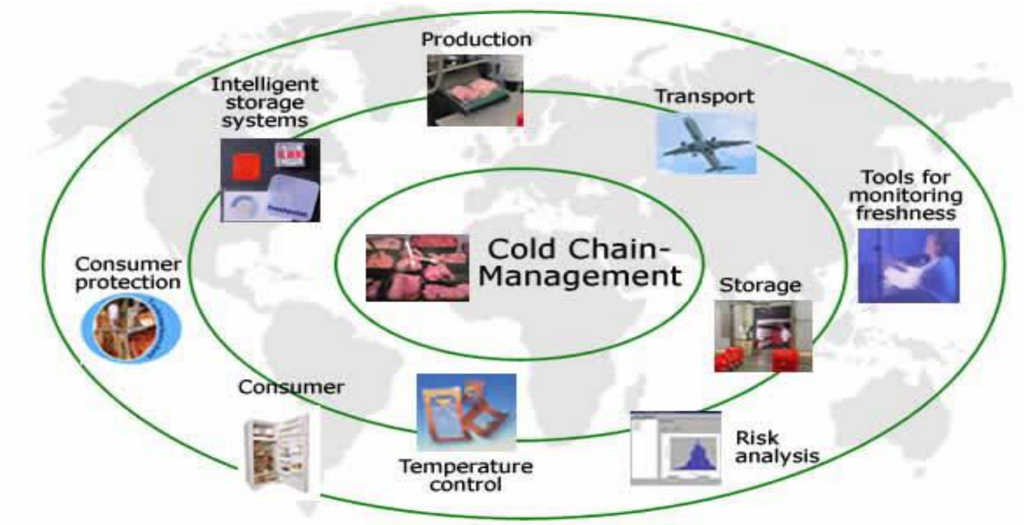


Fig 1.1 Cold Chain management [Source: Oliva, 2008]

As per a study by Kitinoja (2013), an integrated cold chain consists of primary activities that comprises: freezing; packing & cooling fresh food products; cold storage; distribution under temperature-controlled conditions; and marketing. Fresh green vegetables, for instance, can stay for one month at 0°C, for two weeks at 10°C, for one week at 20°C and for less than two days at 30°C (Kitinoja, 2013). A product perishable in nature experiences changes in the quality characteristics based on two reasons: for products that are still unripe, the temperature and atmospheric conditions affect its process of ripening (Jedermann, 2014); for products that are ripe, there may be microbiological growth which further deteriorates the process (Raab, 2008). FCC is a specific kind of supply chain designed to retain the food product in appropriate and usable condition. Thereby, food CC management comprises of supply chain practices deployed to preserve atmosphere that is appropriate for the perishable products as well as resist spoilage due to presence of microbes (Joshi *et al.*, 2011).

Actually, it is due to the cold chain that the process of decaying is effectively delayed. Considering the current statistics, India ranks second in the world in terms of F&V production and certainly has a huge potential to acquire the position of number one if it is able to use and sustain its food supply chain in an effective manner without compromising the food quality and safety. The United Nations as an initiative towards their SDGs (sustainable development goals) has plans to bring about a 50% reduction of food wastage both at the consumer level and the retail level thereby decreasing the post-harvest food losses by 2030 (UN, 2018). However, certain factors that act as impediments to effective CCM are: lack of transportation grids, inadequate infrastructural facilities, lack of required knowledge on techniques of preservation and technological advancements and implementation of these has a dominating role to play in the relevant framework (Gunaratne, 2020). The study also emphasized upon the key factors: manpower expertise; infrastructure; product attributes; and specialised resources; which have positive effect on each other as well as enhanced sustainability of the cold chain.

Comes *et al.* (2018) in their study stressed upon the causes of disruptions in cold chain as: critical infrastructure failure; Failure of paraphernalia and redundancies; Failure of monitoring and tracking systems; poor or absent tracking of both maximum and minimum temperatures; Interruption in information and communication systems; inadequate ability to manage the complex stream of information, and deal with delayed, insufficient or indeterminate information; Deficiencies in handling, storage and inadequate training; dearth of reduction & the management choices for possible interruptions and insufficient planning; and Lack of operational decision support.

1.2.3 FROZEN FOOD AND ITS COLD CHAIN

Frozen foods are generally those which have sufficient water content like dough, ice cream, fish, meat, fruits, vegetables and ready meals. Freezing is a technique of preserving food to possibly deliver a high gradation of nutritional value, sensory quality, safety and convenience. Earlier, maximum frozen foods were generally pre-cooked thus making them microbiologically safe. However, with the focus shifting to convenience and variety, the foods now may be pre-cooked components or whole meal requiring reheating prior to consumption or thawing or even eaten directly. This makes safety an imperative pre-requisite. The food industry therefore needs to specifically consider not just the safety of the food product but also the nutritional quality which is a consumer's increasing concern. Fig 1.2 displays the life-cycle of perishable food product.

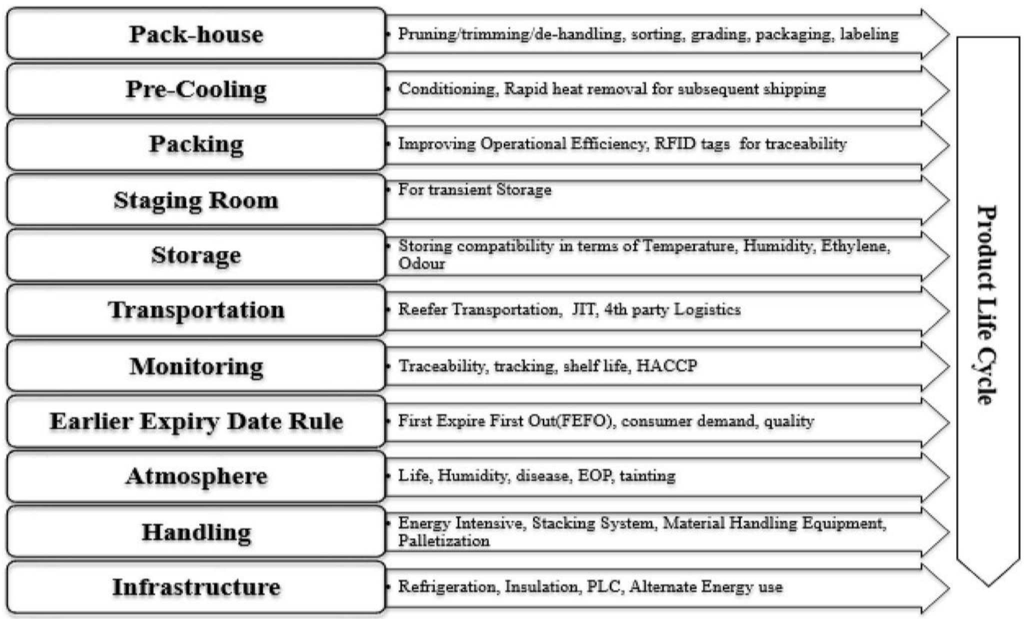


Fig 1.2 Perishable product life-cycle (Source: Vrat, 2018)

The word frozen is used for those products which must be stored at temperatures lower than 18 °C. Frozen food falls under processed food products. These food products, the output of processing factories or of farms, must reach rapid freezing with the help of IQF/blast freezers. The products are stored in deep frozen state in order to preserve them.

The need for refrigerated foods has been growing with the growth in foodservice industries and retail outlets. It is the effective management of CC that ensures success in continuation and helps essentially preserve quality and safety of food products. Wastage & losses in food have arisen to be an enormous problem and so has gathered excessive attention especially with the incessant growing of the nation's population (Chen, 2020). An annual loss estimated to be greater than $750 billion in the food market is due to inappropriate handling and transportation (FAO, 2013).

Life of foods can be extended with the help of freezing, which slows down the process that promotes spoilage of food and reduces the shelf life. But, if appropriate production, handling and storage conditions are not met then the biochemical and physical reactions can still take place spoiling the food and rendering it a waste. The CC begins from the provider and expands right till the buyer's utilization. Figure 1.3 and 1.4 display the technologies, mechanical or non-mechanical, available for cooling.

S. No.	Cold chain Step	Small-scale Large scale	Large scale
1	Pre-cooling systems	Portable evaporative forced air-cooling system	Slurry Ice
2	Cold Storage	Zero energy cool chambers (ZECC) Evaporatively cooled cool rooms (charcoal coolers) Underground storage (root cellars) Night air ventilation High altitude storage Radiant cooling Solar chillers	Evaporatively cooled warehouses Underground storage (caves) High altitude storage Radiant cooling
3	Processing- chilling and freezing	None available	None available
4	Refrigerated transport	Evaporatively cooled insulated transport boxes or trailers	Passive cooling (insulated pallet covers)

Figure 1.3: Few cooling technologies (non-mechanical) available [Source: Kitinoja, 2013]

S. No.	Cold chain step	Small-scale Large scale	Large scale
1	Pre-cooling systems	Portable forced air-cooling systems	Vacuum cooling Forced air cooling Hydro-cooling
2	Processing- chilling or freezing	"Direct expansion" chilling of bulk milk "instant" chilling of milk	Blast freezing IQF Vacuum cooling of packaged meats
3	Refrigerated transport	USDA Porta-cooler	Reefer vans Refrigerated marine containers Refrigerated intermodal containers (for road, rail and sea shipping)

Figure 1.4: Few freezing technologies (mechanical) [Source: Kitinoja, 2013]

A typical cold supply chain management encompasses chilling / freezing, cold storage, packaging, transportation to storage, transportation to distribution centre, and then transportation to retail store from where the consumer picks it (Raut, 2019). Thus, CC infrastructure consists of refrigerated carriers commonly known as reefers, containers; cold storage/warehouses; pre-cooling facilities; cold storage/warehouses; and packaging tools. Each and every link in CC is inter-dependent and correlated and therefore occurrence of any problem in any one of the links will result in increased food losses and wastage along with the wastage of resources too (Han, 2021).

Pre-cooling Systems Shortly after harvesting of a crop, the rapid removal of field heat is called as Pre-Cooling. Field heat can be characterized as distinction in temperature of yield when it is reaped and the ideal stockpiling temperature ("Pre-cooling of Agricultural Products",2020). Generally, the temperature should be reduced through cooling until it touches present alteration's 88% in temperature & its storage temperature. The process of reducing field heat should be fast for maximum of the produce since even one hour of delay can lead to reduced shelf-life even when the storage conditions are optimum. As reported by FAO, United Nations, it is "amongst the most efficient quality enhancements available" and considered an important value-adding activity in the food chain. (FAO, 1995). It is this step of pre-cooling which can slow down the physio-chemical activities in the food as well as minimizes the deterioration of food attributes and its nutrients (Han, 2021). Benefits of Pre-cooling benefits are: minimizing and restricting respiratory activity, reducing the workload of a cold storage, avoiding enzymatic degradation and conserving the weight of the harvested produce; thus, checking loss in H_2O content, wilting, softening; reducing the decay rate; decreasing rate of ethylene production; and delaying chilling injuries for certain fruits. The method selected for pre-cooling the produce depends upon the characteristics of the produce, efficiency, skilled labour, packaging, and finally the economic viability. Different methods for pre-cooling are water cooling, air cooling, ice cooling, vacuum cooling and shade. Careful consideration needs to be given on the design of packaging as it can significantly influence the efficiency of the pre-cooling process.

Cold Storage Cold Storage is an exceptional sort of extra space whose temperature is kept extremely low utilizing accuracy instruments and concentrated machines. The prime infrastructural components for commodities that are perishable in nature, are the cold storage facilities. Cold storages are an essential requirement in order to extend shelf life, reduce bottlenecks during transportation, avoidance of glut and maintaining the produce quality. Hence, improvement of cold stockpiling industry assumes a significant part in squander decrease of transient food items. The cold storages / warehouses are a critical link in the FSC as it offers centralized storage, product management, balance between demand and supply and also influence transportation related decisions (Han, 2021).

Storage options are of two types: dry storage and plain freezers. Export being a major industry in a number of countries, products like F&V are regularly shipped across oceans. Practically, many industries would not be able to exist without the support of a reliable cold store equipment. CAS and MAS methods are commonly used methods for storing fresh agri-products where while air is used as the cooling medium in cold air storage method but modified atmosphere storage method is also able to regulate the structure of storage atmosphere thus leading to extension of shelf life better than through CAS.

Processing – Chilling and Freezing low temperature preservation of food consists of two processes: freezing and chilling. Chilling is the process where temperature applied is within 0°C - 8°C, which is higher than the food's freezing, and the process of freezing applies temperatures much lower than the freezing point, nearly lower than 18°C. Freezing represents a point of abrupt break in the relationship between sensory properties and stability of food and the temperature. The same phenomenon of 'freeze concentration' may accelerate reactions, leading to changes that are irreversible in nature like faster oxidation of lipids, annihilation of the colloidal configuration and protein denaturation. Freezing rate affects the quality of frozen food. Rapid freezing can however, lead to the small ice crystals getting formed. However, frozen storage, is not indicative of the absence of deteriorative processes, some of them being protein–lipid interaction, denaturation of protein leading to hardening of muscle foods, oxidative changes in general and lipid oxidation and the process of recrystallization (Berke, 2018). Freezers should be designed in a manner to ensure the quick-freezing process requirements being met. Though freezing the food product cannot improve the quality of the food but it can certainly help maintain the quality. As there are many food products whose quality deteriorates fast, there is need to handle them carefully and initiate the freezing process to maintain their quality and enhance their shelf life.

Refrigerated transport - The downstream and upstream links in the CC are connected through refrigerated transport. Several transportation modes are available some of them being air transportation, road and rail transport, and marine transport, and the selection of the suitable mode is done on the consideration of cost, shelf life, and the consumer demand (Yavas, 2020). Refrigerated transport helps maintain a steady and uniform temperature during the transportation and maintaining the right temperature and other environmental conditions is very crucial for the shelf life, quality and safety of the food product (Han, 2021). With the increasing demand for perishables, the need for refrigerated transport will also increase which translates into increase in energy demand and hence effective techniques need to be determined to mitigate the impact on the environment.

There has not been much development in the refrigerated transport sector as compared to the storage industry. Cold chain logistics, also known as refrigerated logistics developed around 1900s, to transport perishable products over large kilometres thus leading to reduction of losses. Reefers, as they are often termed, were able to transport products with temperature sensitivity, products such agri-produce, marine food, animal products among other products. Such products needed to be stored at requisite temperature for preventing deterioration in product quality. The technology is just like the refrigerator or an air-conditioner, trying to remove heat from the storage space. So, reefers are trucks, containers, vans or any type of carrier used to store and transport the products in confined cooled spaces with surroundings that are temperature-monitored (Vrat, 2018).

Temperature Monitoring and Control

Maximum deterioration in quality, namely change in texture, flavour, colour or odour are primarily because of growth in microbes or activities due to enzymes present. Appropriate and regular control of temperature and other required conditions like humidity, moisture loss, duration of storage, etc. can significantly minimize adversarial effects of microbes or any biological or chemical changes. It can therefore affect a food item's quality & security. Therefore, it becomes imperative that food products are cooled and transported or stored under appropriate frozen conditions to minimize deterioration. Also, inappropriate temperature control in food products is one of the main reasons of illnesses occurring because of spoilt food. So, there should be appropriate temperature management or control systems for effective monitoring and controlling temperature. Refrigerated storage of perishable crops helps in retardation of following: undesirable metabolic changes and respiratory heat production; ageing due to ripening, softening, etc; undesirable growth like sprouting, etc.; moisture loss; textual and colour changes; and spoilage due to wilting a result of invasion by bacteria, yeast, fungi etc. (Bhatnagar, 2019).

There are various devices available for monitoring of temperature. One such device is known as a Time-temperature indicator which is a colorimetric tag whose colour changes because of the microbiological, chemical, enzymatic or mechanical change, when the temperature is higher than the pre-defined threshold (Taoukis, 2008). The tag can be used for varied temperatures and is disposable. For monitoring temperature, thermocouples and RTDs are largely utilised, especially in food and beverage products (Chou, 2013). They can be coupled with a datalogger for constant monitoring. There are also techniques like thermistors, fluorescence and infrared thermography however their application is restricted owing to limited applicability and high cost (Badia-Melis, 2018). But it is technologies like bluetooth and RFID (radio frequency identification) which have wide use for monitoring of temperature. It is affordable and allows tracking the real-time status from production till it is sold to consumer (Want, 2006; Abad, 2009). RFID tags are available as passive, semi-passive and active modes: an external electromagnetic field powers the passive tags while the semi-passive and active tags make use of battery or a power source. Passive tags are more recommended for product traceability use being long lasting and of low cost. The RFID tag can be modified to simultaneously capture information from multiple packages without direct contact. Also, the threshold limit can be modified by changing its composition based on the product types (Vivaldi, 2020).

Cold chain helps in maintaining the shelf life and integrity while also preserving the quality of perishable products. FCC is a specific kind of supply chain designed to save the food product in appropriate and consumable condition. Therefore, food CCM comprises of supply chain practices deployed to preserve atmosphere that is appropriate for the perishable products as well as resist spoilage due to presence of microbes (Joshi *et al.*, 2011). The food CC begins at the farm and culminates at the buyer end. As per the MOFPI (2019) report, till 31st March 2019, 146 CC projects were completed thus creating following infrastructure: cold storage of capacity 5.24 lakh MT; 804 reefer carriers; 135.70 MT per hour of IQF; and 58.45 LLPD Milk processing/storage. Table 1.3 presents list of CC projects.

According to a study by Gallo (2017), the stages of a food supply chain can also be represented as: (i) Growers node (farmers), where raw crop is ready for transformation; (ii) Processing/packaging node where the crop is processed and/or packed; (iii) Consolidation/storage node where product is consolidated, stored either before distribution or while it is passing through distribution; and finally (iv) the demand node where food product is put on display for consumer purchase.

Frozen foods need some form of processing depending upon the type of food product. Processing may be done in the following forms: first level where sorting, grading, cleaning, etc. could be carried out on the food; next level where there could be some form of alteration done to the product like freezing, etc; and the last level where the product is converted to another form like juice, etc. (Ojo, 2017).

There are four domains for a cold chain which are very important for consideration: perishable product; infrastructure and equipment; information technology; and regulatory framework (Bremer, 2018). The product's intrinsic and extrinsic (eg. packaging) attributes can be altered to help mitigate its environmental footprint. Intrinsic attributes can be altered by preventing use of harmful chemical, using organic ingredients, etc. and it can be presented through logos and labels. Extrinsic attributes can be altered by either redesigning packaging or changing the material used in packaging to environment-friendly material (Magnier, 2016). Product sustainability thus achieved can also influence its quality (Tobler, 2011).

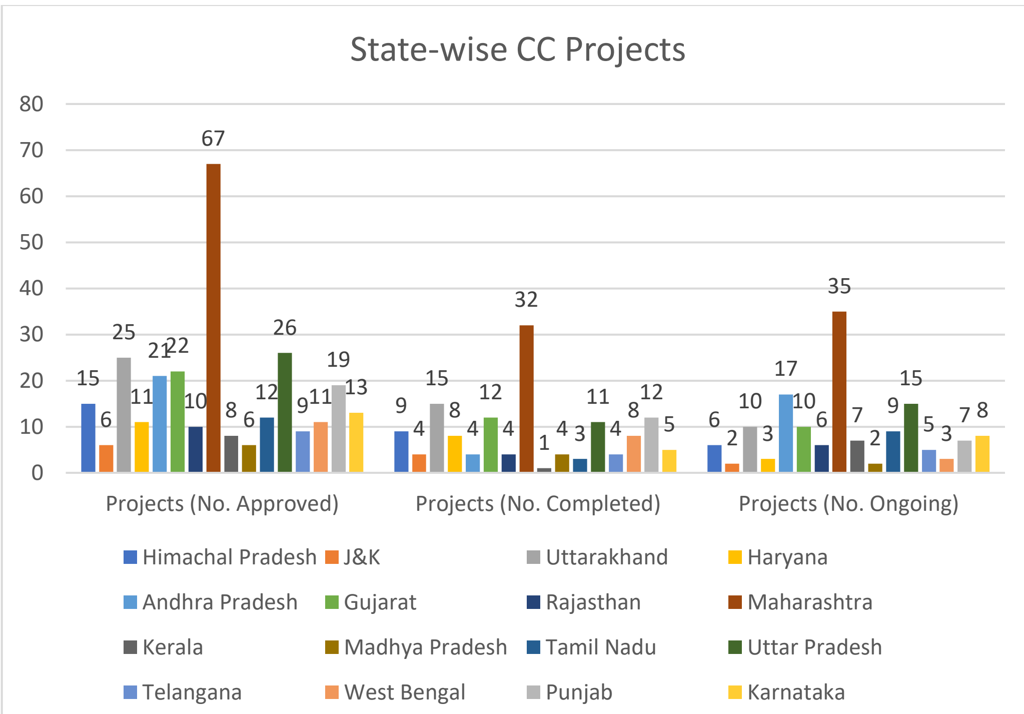


Figure 1.5 Details of State-wise CC projects as on 31st March 2019 **[Source: National Center for Cold-chain** Development (NCCD) / Global Cold Chain Allianz (India Chapter) / Secondary Source]

Regulatory frameworks for the CC have been established by the government authorities in order to ensure compliance of the regulations. Also, certain standards have been imposed and guidelines recommended for efficient practices in the cold chain. WTO's Codex Alimentarius governs the standards framework for CC which defines the primary hygiene controls and practice. HACCP is an approach for identification, evaluation and control of stages in SC that are crucial to the safety of the product. ISO 22000 series of standards is a framework of international requirements for the SC for food products and is used as reference for the purpose of certification and audit. The CCQI standards (cold chain quality indicator) is a standard that specifies points for 15 operations in the CC (adapted from Bremer, 2018). Regular checks of the firms operating in the cold chain need to be carried out by the concerned relevant surveillance authorities and the certification bodies.

The key public sector authorities that support growth of the cold chain sector include:

1. **NHB** – Government of India in April 1984 set up NHB on recommendations of the "Group on Perishable Agricultural Commodities" with the objective to improve integrated development of Horticulture industry as well as to help in sustaining production and processing of F& V along with coordination of various activities.

2. **NHM** – Being a scheme sponsored by the central government, MIDH was framed for holistic growth of the horticulture sector. Under MIDH, the contribution of the Government of India towards developmental programmes for all states excluding Himalayan states and North Eastern states is 60% while 40% is the contribution of the State Governments whereas the GOI's contribution for the Himalayan and the North Eastern States is 90% (MIDH, 2020).

3. **HMNEH -** This scheme sponsored by the Centre is being implemented since 2003-04 aiming at holistic development of the horticulture industry; covering production, processing, post-harvest management, marketing; and ensuring backward and forward associations by adopting cluster approach(MIDH, 2020). HMNEH continues to be implemented in Uttarakhand.

4. **APEDA** - APEDA was laid out beneath the Act titled 'Agricultural and Processed Food Products Export Development Authority Act' which the parliament passed in 1985. The responsibility of development of F&V and their products along with export promotion has been mandated with PEDA ("Welcome to Agriculture & Processed Food Products Export Development Authority", 2015).

5. **MOFPI** - A food processing sectors that displays strength and dynamism can strongly contribute to wastage reduction, extension of shelf life, value addition, diversification & commercialization of agriculture, employment generation, surplus creation for export of food products. The Ministry seeks active participation from all sectors whether public, private or co-operative. MOFPI facilitates and acts as a catalyst with the aim of attracting quality investments from across the world aiming to make food processing as a national initiative (MOFPI, 2019).

6. **DAHD** – Initially called as DADF, the department came into existence on 1st February 1991. A separate department was formed of Department of Agriculture and Cooperation namely Animal Husbandry and Dairy Development. With effect from 10th Oct 1997, Fisheries Division of the Department of Agriculture and Cooperation and a section of the MOFPI were shifted to this department. The Department undertakes matters relating to preservation, improvement of stocks and dairy development, livestock production, and protection from diseases including matters relating to National Dairy Development Board and Delhi Milk Scheme. (DAHD, 2019).

7. **NCCD** - was established as an autonomous organization in public private partnership mode with Government and the industry with the aim of developing and promoting integrated CC in the country for produce of perishable nature. The primary objectives of NCCD are: recommendation of protocols and standards for infrastructure required for the cold chain, suggestion of guidelines for development of human resources; and recommendation of policy frame-work that would be appropriate for cold chain development. (NCCD, 2013).

An effective supply chain can be beneficial for all the stakeholders including customers and society at large. In India, the growth of Cold chain sector is driven by various factors like: Changing consumer behaviour, farming behaviour, growth in organised food retail, development in processed food sector and increasing demand from the healthcare industry. Frozen food falls under processed food products. Supply chain of frozen food is as given below in Fig 1.6.

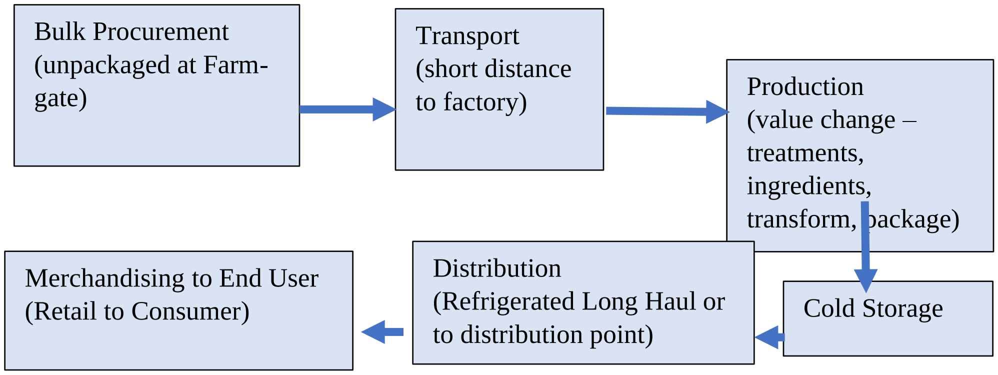


Fig 1.6 SC of Frozen Food [Source: NCCD, 2015]

1.2.4 STAKEHOLDERS IN COLD SUPPLY CHAIN

A cold SC is facilitated by various players participating and contributing to the entire chain. Thus, there exist multiple players linked with each other to fulfil the aim of cold supply chains. This section explains in brief about the major players who have a significant contribution in the success of cold SCs.

Farmers

Majority of people within the food-producing or agriculture sector work at the level of farmers, small or big, generally within rural areas of the nation. With the growth in population, the importance of the food-producing sector too has grown significantly. Especially with more emphasis on safe and value-added products, it becomes important that the food is traceable and safe right from the point of origin. There are huge number of farmers nationally, who can be segmented by farm size, type of crops grown, etc. As farming depends upon weather and other environmental conditions, it is a risky venture. Majority of the farmers in Uttarakhand are of type Small owning land of area 1 - 2 ha or Semi-Medium/Medium with land spanning 2 - 10 ha and very few are in the category of Large possessing land more than 2 ha (refer Table 1.1). Demographic profiling presented in subsequent chapters will be indicative of the same.

Table 1.1 Operational holdings' details (UK)

Type of Operational Holdings	Number as of (2015-16) ('000s)	Area under the holding ('000 hectare)
Marginal holding (<1.0 hectare)	659	284
Small holdings (1 - 2 hectare)	149	206
Semi-medium and Medium holdings (2 - 10 hectare)	73	234
Large holdings (> 10 hectare)	1	23
Total	882	747

Source: UK at a Glance, 2019-20

Frozen Food Producer/Processor

The food manufacturer/processor has a dominant role in the SC as by catering to the demands of consumers it contributes to the sustenance of the economy and by increasing the products' shelf life, it contributes to the drop in the food products' wastage and losses. It therefore becomes imperative that the food processor is well integrated with the downstream supply chain so that the food product can reach the consumer in the desired state. Hence, the onus to quite an extent lies on the food processor to utilize latest techniques, technology, innovative and sustainable processes to meet the demands of the consumer as well as the environment. As per report titled 'Uttarakhand at a Glance' (2017-18, 2021-22), the state has around 386 registered Food Processing Industries and in the year 2021 there were around 47 producers/processors of frozen food products in Uttarakhand.

Retailers/Distributor/Private Agent

Distributors are the link between the manufacturers, processors and the consumers or markets. The distributors procure raw produce from the farmers or processed food from the processors and then distribute it further to retailers, other processors, etc. in the supply chain. They generally procure in bulk. They use godowns or distribution hubs for the purpose.

Retailers are the entities who finally sell the product to the end-consumer. They can be stand-alone shops or large supermarkets dealing with different types of products. The convenience of buying and the product variety offered by the retailer are the reasons of consumer's preference of buying from the retailers. Retailers operating in perishables' business experience direct correlation between quality of the perishable delivered to consumer and the performance of the cold chain (Joshi, 2011). So, the retail outlet becomes a space for showcasing their products, both for the retailer as well as the food manufacturer/processor. Hence, the other channels in the food supply chain must accordingly respond to retailer requirements.

Around 1990s, the retailers were more engaged with secondary distribution from distribution centres to retail outlets. But since the last decade, there have been investments made in technology and just-in-time systems to enable centralized distribution to the stores and reduction in lead time. Retailers also concentrated on primary distribution whereby the primary consolidation centres were used for the conduit of the supplier orders. This practice is used more so for the frozen food. For enhanced utilization of logistics, onward delivery, supplier collection and amalgamation of primary and secondary distribution operations were included. Thus, was felt the need for improved collaboration between the suppliers and the retailers. However, this is primarily the case only for large retail supermarkets, especially in India and more so in Uttarakhand where usage of technology is limited to inventory management and billing purposes only.

Considering the dynamism in the retail sector owing to changing customer expectations, as well as regulatory pressures, it becomes imperative that the retailers tackle these challenges and the fierce competition not just nationwide but globally in order to deliver enhanced customer service and performance (Ganesan, 2009). It therefore becomes important that their resources and capabilities along with that of suppliers and other chain partners are integrated to offer superior value to customers while sustaining competitive advantage. The strategic approach to collaboration with processors, manufacturers, etc. can even help drive the demand.

USA and Europe introduced ECR initiatives in 1994. Efficient Consumer Response was defined as a worldwide drive in the edibles industry concentrating upon the entire SC - processor, suppliers, retailers, and the other distributors - collaborating closely with the aim to meet the consumer demands (adapted from Fernie & McKinnon, 2003). Sharing of information is important for achieving optimization of supply chain. In 1995, VICS (Voluntary Inter-Industry Commerce standards Committee) developed CPFR and with that collaborative arrangement became an important feature of SC collaboration. It brought about major benefits in both cost and service. In the contemporary retail situation, it becomes imperative that retailers tackle the increased domestic as well as global competition using both non-traditional and traditional channels. With continuous variations in customer expectations related to services and assortment of products, regulatory pressures for precise data (e.g., Sarbanes-Oxley Act5), and businesses targeting the “more for less” approach, are all leading to increase in efforts to furnish increased customer service and finally an effective business performance.

Logistics

Logistics is the physical movement of agri-food material beginning at the point of production to the place where it is stored, processed and ultimately reaching to the end-consumer. Logistics and distribution management encompasses various processes involving transportation of products from farmers or supplier to producers or processors to distributors or retailers to the final consumer (Duclos, 2003).

The logistical systems should aim to provide the chain partner at the receiving end with uninterrupted supplies of food products that are safe and within the pre-determined environmental conditions. The classical logistics approach comes with 8Rs’: right item, right amount, right cost, right client, ideal spot, perfect opportunity, right environmental obligation and right condition (Wajszczuk, 2016). In a study in 1997, Kearney emphasized upon the inefficient use of warehouse, vehicle and store space owing to inappropriate sizes of the pallet/roll cage.

University of St. Gallen (2000) [adapted from McKinnon, 2003] conducted a study on ‘transport optimisation’ and assessed that efficiency is improved by reduction in empty running of vehicles, by increase in ‘vehicle fill’ and by maximization of the productive time with reference to vehicle scheduling. A SC can benefit more when the SC partners work in collaboration for not only improved efficiency in logistics but also improved social, economic and environmental sustainability. One of the significant parts of SC process is logistics that encompasses planning, executing and monitoring the productive movement, storage of products/services coupled with shared knowledge (adapted from Mentzer, 2001).

An all-inclusive logistic process is essential to sustain the integrity of the shipment i.e the shipment doesn’t not suffer any anomalies owing to temperature during its movement across the SC. Right from preparing the shipment to final check at delivery link, there are various phases: (I) preparation of shipment, where the shipment is prepared to be kept at the desired temperature along with the shipment destination and the weather conditions there; (II) Mode of transportation, where the mode used for transportation is decided based upon the origin, destination, size and weight of product, other environmental requirements, etc; (III) In case of exports of products, following custom procedures is very important; and finally (IV) the ‘last mile’, where the shipment is delivered to customers (Yuen, 2017).

1.3 STATUS OF COLD CHAIN IN INDIA

India is a country with an abundance of natural resources and a land that is highly lush and fertile. Primarily, the Indian economy has been agrarian while also being globally the principal producer of F&V (Shrivastava *et al.*, 2017). Even then, only 60% of the agricultural produce is used. According to the (MOFPI, 2019), India’s contribution globally w.r.t. export of food is just 2.31% as of 2018 (refer Table 1.4) while in fruits and vegetables, the cumulative wastage falls in the range of 4.58-15.88% which is the maximum (Khedkar, 2018) (refer Fig. 1.7). In spite of all the projected growth and support from the government, the cold chain sector still faces number of issues and challenges. As cited in a study by Sakina (2019), India falls far behind countries like the Philippines, USA, and China in its capability to reduce wastage and enhance shelf life or value addition of food products. The huge wastage of food products is certainly a critical issue for the country. As per the report by UN's FAO , out of entire production of F&V, 20% to 40% is wasted because of negligence or accidents occurring during the stages of storage, processing and transportation ("Cold Chain Market Size & Share, Industry Trends Report, 2019-2025", 2019).

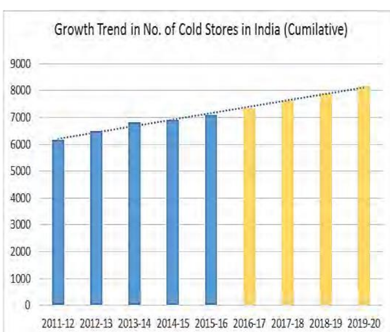
Crops	Cumulative wastage (%) as per report 2010	Cumulative wastage(%) as per report 2015
Fruits & Vegetables	5.8 - 18.0	4.58 - 15.88
Cereals	3.9 - 6.0	4.65 - 5.99
Pulses	4.3 - 6.1	6.36 - 8.41
Milk	0.8	0.92
Fisheries (Inland)	6.9	5.23
Fisheries (Marine)	2.9	10.52
Meat	2.3	2.71
Poultry	3.7	6.74

Fig 1.7 Details of Cumulative wastage (%) [Source: MOFPI 2021-22]

Since the past few decades, production of F&V has seen a continual rise along with other perishable products. The country ranks highest in dairy production, followed by 2nd ranking in F&V and number sixth in meat production globally (Chintada, 2018). However, the infrastructural development in the nation has not been aligned with this demand thereby contributing largely to huge losses in food products. According to the ICAR (Herlekar, 2014) study conducted on post-harvest losses of prominent horticultural and agricultural crops, the losses found in F&V were in the range of 5.8% - 18% while the loss in milk products was only 0.92% and in poultry and meat products was in the range of 2.71-6.74%. Such losses could be greatly mitigated by improving upon the cold chain infrastructure. The primary contributors to food losses are: inadequate storage facilities; lack of waste processing facilities; process contamination; inappropriate packaging; losses due to transportation and losses due to high inventory (adapted from Kumar, 2020).

According to NCCD (2015) report, there are around 250 functional pack-houses whereas the need is for 70,000 pack- houses to meet the current utilization needs of the urban clusters. Also, generally these pack-houses are primarily used for grading and sorting and not much value-addition is done. Integration, whether forward or backward has been neglected even though there are initiatives to shift the focus from simply building cold stores to integration of the cold chain. However, yet a lot of efforts are required in this context. Also, one of the noticeable constraints is that majority of packhouses are focussed on fruits and hardly any care is extended to the vegetables with the exception of a few exotic or high in demand vegetables like peas, beans, carrots, etc.

Owing to the seasonality of the produce, maximum cold storages in the country are owned privately and are single-purpose and hence they are not in use for nearly six months. As per NCCD report (2015), only around 75% of cold storages installed are being used. Fig 1.8 presents the growth trend of cold stores in India along with the capacity of the cold storage. Figure 1.9 presents India's stake in the worldwide food exchange giving a clear indication that even though India ranks highest in fruit and vegetable production, its global production share is negligible.



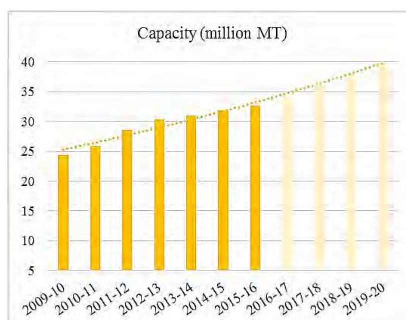


Fig 1.8 Cold storage and capacity growth trend [Source: ASSOCHAM report, 2013)

	2014	2015	2016	2017	2018
World food export	1448248.62	1304998.95	1325685.67	1433362.50	1471089.23
World food import	1459120.68	1333359.41	1336423.20	1445981.58	1505427.59
India's food export to World	37744.21	30417.56	29199.88	34434.32	34023.88
% share of India's food export in world	**2.61%**	**2.33%**	**2.20%**	**2.40%**	**2.31%**

Figure 1.9 India's Share in Food Export-Import (US$ Million) [Source: ITC Trade Map, April 2019 [adapted from MOFPI annual report 2018]

CIPHET, Ludhiana carried out a quantitative study to assess the losses, harvest/ post-harvest for forty-six agrarian producers in hundred and six arbitrarily selected districts of India. As per the study, loss is the material rendered "unfit for human consumption" (CIPHET, 2019). Maximum wastage was reported to have occurred in F&V. The sector faced major challenges, namely, seasonality of operations, inadequate innovation and product development, SC Infrastructural gaps considering facilities for storage, processing, and distribution; and not sufficient focus on the standards related to food quality and safety.

However, the report also cites enormous scope for progression in the sector, as a result of Increasing Urbanization – Lifestyle and Aspirations; Increasing number of working women & nuclear families; Changing demographics as a result of rise in disposable income; increased spending on food products; and increase in organized retail and penetration into the market with own labelled products. Some of the key players in the frozen food sector (international and national level): Mother Dairy; McCain Foods; Godrej Tyson Ltd.; Venky's; Al Kabeer Group; Hyfun Foods; Sumeru's Innovative Foods.

One of the crucial aspects of maintaining a continuous link in the cold chain is refrigerated transportation for which often reefers are utilized. However, this sector has also not been given its due significance as there are only some providers who are equipped with technology for monitoring and controlling temperature. Also, the logistic sector is highly disjointed being dominated by numerous private players. There are around 250 major & minor logistic service providers possessing reefers having 4.2 million tons capacity. As per a study conducted by NCCD (2015), there is a requirement of around 62000 reefers of 10 tons capacity each. Largely these reefers are used for pharma products, imported foods or frozen processed foods and not really used for F&V domestic supply. And around 30-40000 vehicles, whether insulated or non-refrigerated, are used for milk & fish transportation. Primary reason of this is the fact that the fruits and vegetables have not been introduced in the cold chain owing to the shortage of pack houses. Maharashtra, Gujarat and Haryana still stand better when it comes to possessing adequate reefer transport. Thus, there is an indication that the backend for the cold supply chain still remains under-developed and sufficient investments is required in the entire cold chain. Within a nation like India which is still a developing nation, it is quite a challenge for the cold chain to spread to other regions within the country where achieving economies of scale itself is challenging. There are varied economies of scale in different phases of a cold chain, whether it is cold storage services, owned or hired services for transportation as sufficient investment may be required at various phases of the chain (Salin, 2003).

Considering the current capacity of 32.86 million tons, approximately 35.1 million tons capacity of cold stores are required as distribution hubs and bulk stores. In fact, 119 cold stores were found to be not available or closed and so the functional cold stores were found to be only 5367 in number totalling to 26.85 MT worth storage capacity. The study also indicated a requirement for development of more 8000 chambers for the process of ripening, temperature-monitored retail cabinets and large number of refrigerated delivery vehicles. So, it would be highly apt to predict that the cold chain sector is fast-growing sector in the country. Considering the present ratio of wastage occurring in fruits and vegetables along with consumer increasingly emphasising upon the quality and safety of the food, the CC is therefore expected to play a dominant role in meeting not just the demand of food in the country but even in the world. And considering 34 million MT of capacity for cold storages, 60 agri-export zones, 41 Mega Food Parks and around 228 CC projects that have been approved by MOFPI (Ministry of Food Processing Industries) surely indicates huge opportunities in the cold CC sector. CSCM in

India is highly unstructured, imbalanced, disorganised owing to lack of required infrastructure, lack of modern practices and procedures (Raut, 2019).

As per the research conducted, more than 80% people have got troubled by COVID-19 pandemic since its outbreak (Roy, 2020). In fact, the use of online retail stores has increased for ordering of cold chain food thus indicating a dramatic change in the shopping behaviour of the consumers. In a study done by Su *et al.* (2021) in China during the pandemic, it was observed that the logistics companies with the ability to integrate SCs were not only able to provide logistics services for various firms but were able to quickly deliver emergency supplies to the consumers.

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1.4 STATUS OF COLD CHAIN IN UK

Uttarakhand, being the country's twenty-seventh state, was sliced out of northern UP on 9th November 2000. The location of UK is of strategic significance as the state shares its borders with Uttar Pradesh in the south, Tibet in the Northern, Nepal in the east, and Himachal Pradesh in the west. UK is blessed with varied topographical features right from snow-covered hilly ranges in the North to tropical woods in the South and hence the variation in its climate and vegetation. Uttarakhand falls in the Western Himalayas agro-climatic region spreading through a geographical area of 53483 sq. km. out of which the forest area covers 24240 sq. km. (Uttarakhand at a Glance, 2018). The GSDP of the state was 2,17,609 million and the growth rate was 11.23% with a population reported to be 10086292 (Uttarakhand at a Glance, 2018). Uttarakhand has also come foremost in cultivation of fruits owing to its favourable agro-climatic conditions that allow cultivation of various crops, fruits and vegetable throughout the year. Concerning production of peaches and plums, it ranked at first position; second situation in pear and walnut creation and third situation in apples. Fruit production of 669.9 ('000 MT) takes place in an area spreading across 178.7 ('000 hectare) while vegetable production of 989.4 ('000 MT) takes place in an area of 11.1 ('000 hectare). As per report titled 'Uttarakhand at a Glance' (2017-18), the state has around 386 registered Food Processing Industries with 47 cold storages having a total capacity of 162821 MT while the total for North Hill Zone was 167 with a total capacity of 471315 MT. In 2009 the number of cold storages was only 15 with a total capacity of 68499 MT. 11 projects (24050 MT capacity) were sanctioned as compared to 51 in HP and J& K of the North Hill Zone and a total of 1506 in the entire country. 242 pack houses were created on-farm, however, there were no pack houses created that were integrated while in J&K 563 on-farm and 1 integrated pack house and in HP 331 and one integrated pack house were created. Considering farm holdings, the state has 9127 holdings with a total area of 8157 (ha). The number of different categories of holdings were: 283 marginal holding spanning across area <=1 ha; 206 Small holdings with area between 1-2 ha; 156 in the category of Semi-Medium having area between 2-4 ha; 79 under Medium with area between 4-10 ha; and 23 falling in the Large category having area >10 ha; thus leading to a total of 747 holdings (2016-17 census). As per a study by CIPHET (2018-19), majority of the farmers are employed in the farm activities only for 100-150 days in a year. In the year 2021 there were around 47 producers/processors of frozen food products in Uttarakhand. It has today Himalayan mega food park and Patanjali food & herbal park limited, two very prominent Mega Food Parks. As per report by food processing sector profile Uttarakhand (2018), the total capacity of CC chain projects was 254108 MT. The state of Uttarakhand which comes under the North Hill Zone, has around 25 projects under approval out of which 15 projects have already been complete. So, that does indicate the potential the state possesses.

The processing of peas to make them ready to take the shape of frozen peas is as follows (refer Fig 1.10): peas in their pea pods are supplied by the farmers or mandis; they are then cleaned and deshelled in the deshelling machines. After deshelling happens, the peas are now passed through a blancher where boiling takes place at a temperature of 90-95°C. They are then passed through normal water, after which they are passed through chilled water at around 4°C. In order to remove excess water from the peas, they are passed through a Vibrator and then a Rotary Cooler. Once the excess water has been removed, they are passed through an IQF (Individual Quick Freezing) which operates at approximately -40°C and a capacity of around 4 tons/hr for the purpose of pre-cooling the peas. Thereafter it is put in cold storages till they are transported to distributors or retailers.

Fig 1.10 Peas processing machine IQF Cold Storage

1.5 ISSUES IN COLD CHAIN

A huge proportion in volume of wastage occurs in the food produced globally owing to failures in the SC right from the farm i.e. source to its merchandizing. In fact, of the food produced globally, 30% is said to be lost indicating either a huge failure in the food supply or the inability to handle more than 25% of the food production. Food production in excess to the ability of what the Supply Chain can deliver is actually a 100% loss (Sodhi, 2018).

According to Fearne (2000), the chief success factors are cost control and improvement in food safety. Responsiveness encompassing lead time, level of quality and savings in cost at strategic level; quality assurance and cash flow at tactical level; and reduced or no complaints were considered as important criteria for supplier evaluation (Gunasekaran, 2004). The efficiency of a SC depends heavily upon effective long-term partnerships between the chain partners with the critical success factors being collaborated problem-solving approach, trust and information sharing (Parwez, 2013). The study also highlights the necessity of educating farmers in post-harvest handling which includes drying, sorting, cleaning, food safety, packaging and also selecting the right quality seeds and other inputs.

Cold chain infrastructure is insufficient as proper and effective mechanisms for ensuring product safety during its handling, storage, and transportation to the marketplaces is conspicuous by its absence. There are huge shortages in infrastructure requirements in different links of a cold chain, namely, pre-cooling, cold storage, reefers, and refrigerated distribution centres. There are numerous issues existing in the entire cold chain and these significantly affect the CC's performance. With reference to a supply chain, issues are problems and challenges that act as hurdles in the path of achieving high results or performance. There are losses in perishable food category owing to an inadequate and ineffective cold chain. For a product to retain its quality throughout the chain, appropriate temperature and other environmental conditions must be necessarily maintained. As per a study by Bogataj (2005), a disorder caused in temperature or time-distance in a CC can negatively influence the net present value of activities and have an adverse effect on the total performance (Joshi, 2011).

A Supply chain environment can be managed well when collaborative relationships are formed with the immediate chain partners as well as other levels in the SC. Forecasting, whether inter-firm or intra-firm, carried in a collaborative and integrated manner can yield substantial benefits. However, inadequate technology, poor real-time coordination, poor scalability, nonexistence of synchronised changes and dearth of investment in infrastructure are deterrents to the benefits that can be achieved through collaborative forecasting (McCarthy, 2002). Timely, accurate and complete information is a must for chain partners to function in a collaborative manner. Food safety is when the perishable product is maintained under the appropriate temperature and other environmental conditions (Oliva, 2008). But developing countries face miscellaneous challenges for a robust CC logistics such as: shortage of competent manpower; lacking infrastructural facilities; insufficiency of regulatory framework; outdated technologies (Khan, 2018). It is vital to possess extensive comprehension of the chemical and biological processes that leads to perishability for effective CCM. Along with adequate understanding, the cold chain must be equipped with dedicated warehouses, loading/unloading facilities; vacuumed pre-cooling technology; refrigerated units; Global Positioning systems; automatic identification; EDI and automatic temperature control systems for a well-performing cold chain.

A major challenge of cold supply chain is assurance of item's security and quality alongside augmentation of its timeframe of shelf life (Adekomaya, 2016; Kumar *et al.*, 2021). It is also essential to use good processing and handling practices during the stages of processing, storage, distribution, transportation and retailing of frozen food. Of the total energy production in the world, 15% stands utilized to distribute power to the CC and cooling techniques and technology (Coulomb, 2008). According to another perspective of sustainability brought about by Conforti (1997), FSC is said to be sustainable when its energy consumption is not more than the nutritional value of the food delivered. The study referred to the index of sustainability as an indicator of cold chain with respect to environment sustainability, where the index is a ratio of energy supplied (energy content of food in kcal/gr) to consumption of energy while the item goes through phases of creation and dispersion. Energy reduction in CC is very important world-wide as refrigeration is imperative for 40% of the food items while it consumes nearly 15% of electricity (James, 2010).

In the forthcoming chapters of the present study, the presence of issues in the CSC of FFPs is established and supported by extensive review of literature conducted and also based on feedback received from experts in the relevant area.

1.6 MOTIVATION/NEED FOR THE RESEARCH

The value of Indian frozen foods which was estimated to be around Rs 74 billion in 2018 is projected to touch Rs 188 billion by the year 2024 with the compounded annual growth rate expanding approximately 17% considering the period 2019-2024 (Goel, 2020). As the awareness towards frozen food products as products being easily available and brand that can be trusted, once can see such products gaining in popularity. The study also indicated that owing to the COVID pandemic which has led to increased health consciousness while making purchases of the essentials, the frozen food industry is set to grow by 17% per year in the period from 2020 to 2024. Hence, it would not be incorrect to assume that consumers will shift towards products that are safe and pure and towards manufacturers that not only produce products that are clean and safe but also give importance to safe handling of products and processes and are responsible towards the impact on the environment. In times to come, frozen food product consumption will certainly see an upsurge in India. A similar trend is evident even in Asian markets. However, growth in frozen food is not only due to Covid-19 but being largely inspired by the Western culture changes are visible in the lifestyle and food habits. The competitively growing electronic commerce sector lends a higher visibility to such products as compared to the brick and mortar stores. Also, because of the growth in organised retail sector frozen food products have been made easily available to the consumer. Thus, shifting shopping patterns, changing psychologies and, shortage of time owing to hectic lifestyles with more disposable income being available are surely going to lead to higher demand for frozen food products.

Even though generally frozen food is consumed owing to convenience but a general perception of the consumer is that the frozen food product is unhealthy. Fresh is assumed to be better, however, that is not the case always since the time taken from harvesting to final purchase may render the product non-consumable even though it may not be markedly visible.

Freezing can help prolong the usability of the food item without occurrence of any loss of nutritious components. So, the product does not lose its healthy attributes on being frozen. The healthy attributes of a food product depend upon the way and the conditions in which it has been preserved. So, frozen food can surely be given enough consideration and a practical alternative. Increased environmental consciousness related to products in general indicates a shift towards products that are environmentally safe.

However, the main challenge in front of the processors/ makers and buyers is saving the original quality of the food item. In the present market, frozen food comprises frozen F&V, vegetable snacks and frozen meat. Especially frozen snacks are preferred by the consumers. Such products, as they are available round the year, is also one of the reasons for increase in demand. Lifestyle and food habits that are seeing marked shifts, and rise in number of young working population will surely result in a substantial increase in demand for FFP in India. Thus, arises the need for an efficient and sustainable cold chain.

1.7 BUSINESS PROBLEM

Cold chain mainly focusses on monitoring and controlling the temperature during the duration that the product passes through it. Lack of infrastructure, traceability, sustainability, integration, inadequate training of personnel can not only affect the performance of the CC but truly influence the item quality & safety and also have adverse impact on the environment and economy. Therefore, the cold chain players need to have proper monitoring and tracking of product during its transition from farm to fork. Technological solutions must be taken advantage of and appropriate training given to the personnel handling the product.

Earlier, consumers were not too aware regarding the food products' safety & quality of food products. Owing to the spread of various diseases, consumers have become extra health-cautious and quality-conscious. Demand for fresh food is increasing because of the cautiousness. But fresh is not always safe, which has been proven during COVID-19 times. It is also time that we look for an alternative, which is as good as fresh. Hence, the need for increase in frozen food products including frozen vegetables. The only concern is the quality of such a food product. Consumers generally believe that FFP suffers loss in nutrient when frozen or that they contain preservatives. But that is not always true. There is opportunity for organisations to focus on improving the quality of frozen food by taking better advantage of data and technology to achieve sustainability, minimized food wastage and losses while not losing a business opportunity.

The value of Indian frozen foods which was estimated to be around Rs 74 billion in 2018 is projected to touch Rs 188 billion by the year 2024 with the compounded annual growth rate expanding approximately 17% considering the period 2019-2024 (Goel, 2020). To take advantage of this boom, the CC industry has to be ready for the futuristic times by rapidly adopting novel and sustainable practices along with state-of-art technologies thus attaining an edge in a global market that is highly competitive and ever-expanding.

Food integrity can be safeguarded and also the product's time span of usability can be improved by checking and controlling temperature of the item while it passes through various links of the CSC. However, various issues like lack of proper traceability, sustainability, infrastructural facilities, integration, etc. result in affecting the performance of a CC, the quality of a product gets affected and this results in wastage or food loss. According to the MOFPI (2018-19) report, aggregate wastage in F&V is the maximum amongst perishable products.

Also, though there is demand for fresh food, however, fresh is not always safe and of good quality. The best alternative to fresh food is frozen food. So, if the various issues in cold chain can be overcome and performance be enhanced then it can lead to increased consumer adoption and finally reduced food wastage and losses.

Resolving issues in Cold chain network of Frozen food items is hence of extreme significance so that CC performance is enhanced ultimately leading to reducing food wastage and losses.

1.8 RESEARCH PROBLEM

Firms participating in a Cold Supply Chain are not able to perform effectively because of the presence of various issues and challenges in the entire chain. The cold chain has many weak links, one of them being at the retail end. So, it becomes extremely essential to ascertain and analyse the issues. Overcoming these issues along with usage of advanced technologies will help improve the performance of cold chain leading to reduction in food losses. Knowledge-based View, Stakeholder theory, Triple Bottom line and Network perspective has been used for studying issues and performance parameters for supply chain in general but it has not been used specifically for cold supply chain of frozen food products. In our study, these theoretical foundations shall be applied for an enhanced understanding of the significance of knowledge transmission, stakeholder management and collaboration, the three dimensions of sustainability across the CSC partners for enhanced performance.

If the demand of Frozen food products, which are perishable in nature, needs to be increased then the issues existing in the cold SC need to be overcome. The cold chain performance needs to be enhanced by overcoming the issues existing in CSC of frozen food products.

For that purpose, a model has been developed to suggest solutions for overcoming or resolving the issues in cold supply chain and enhancing performance of cold chain of frozen food products and hence leading to reduction in food wastage and losses.

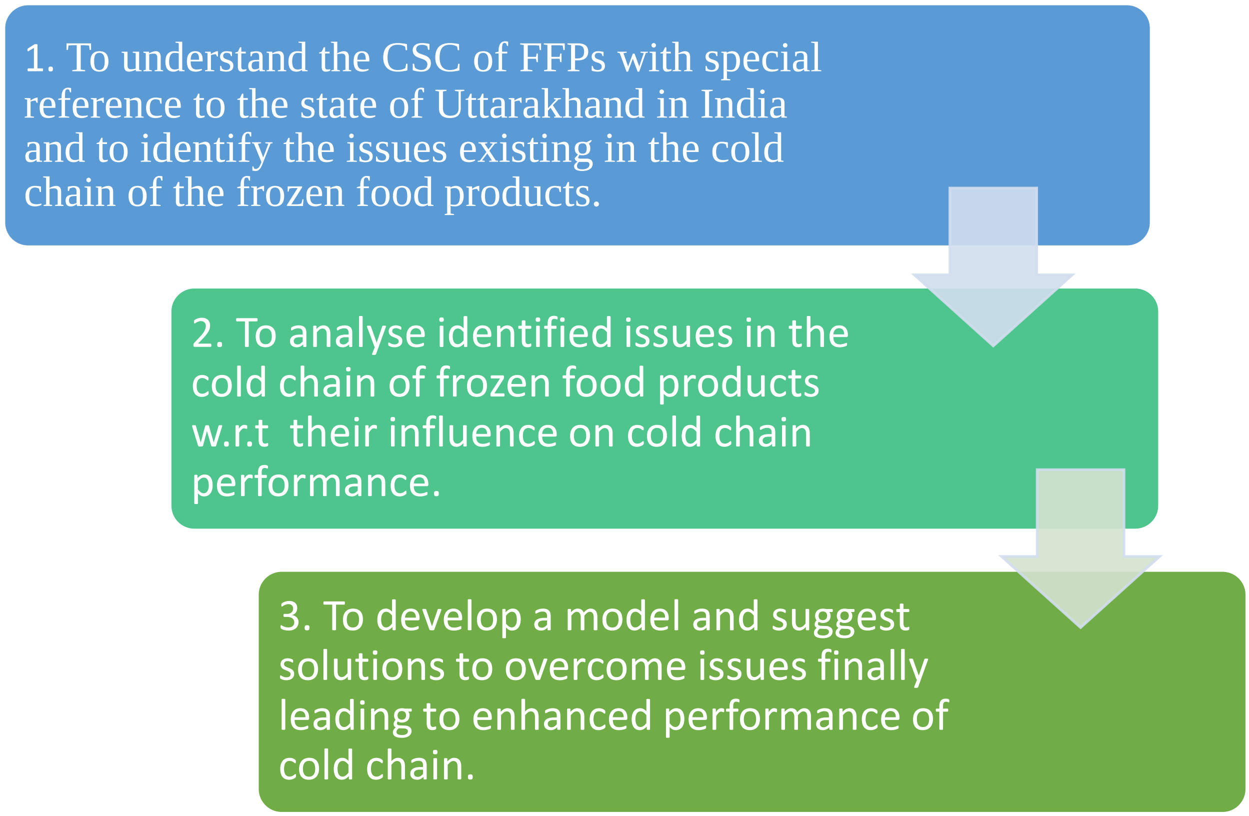
1.9 RESEARCH QUESTIONS (RQs)

RQ1. How the cold supply chain of frozen food products works in Uttarakhand and what are the prevailing challenges and issues**?**

RQ2. How do the identified issues affect the cold chain performance?

RQ3. What will be the suggested solutions to overcome the issues for achieving enhanced performance of cold chain?

1.10 RESEARCH OBJECTIVES (ROs)



1.11 STRUCTURE OF THE THESIS

The current study is organised across seven chapters as exhibited in Table 1.5. Details of each chapter are given below:

Chapter 1

This chapter focusses upon the basics of cold chain, frozen food, CC for FFP and the issues prevalent in the cold chain. The chapter also highlights the present CC status in the country. Motivation/need to pursue the research is also covered along with the business problem, research problem, RQs and ROs to address the gaps. The chapter also discusses about the various stakeholders and their contribution in the cold chain. Finally, the chapter also gives a short brief on the remaining chapters.

Chapter 2

This chapter reviews the literature on six themes:

- Literature on SC and SCM
- Literature on CC and CCM
- Literature on Frozen Food
- Literature on Issues in cold chain
- Literature on SC Performance
- Literature on Suggested solutions

The theoretical foundation considered for the study is ‘Knowledge-Based View’, ’Stakeholder theory’, ‘Triple Bottom Line theory’, and the ‘Network perspective’ . This chapter also reviews present literature on the relevant theory on which prior studies have been conducted on ‘cold supply chain’.

Chapter 3

Research methodology is exhibited in the third chapter. Also, elucidated are the nuances of research design, questionnaire design, sampling, data collection procedure and tools, and research methods for conducting analysis, research problem, and research objective to address gaps.

Chapter 4

This chapter gives detailed explanation on the statistical tests applied for testing the competency of the research problem under study. Collection of data, assessment of validity and reliability of the data along with testing for model fitness have been considered in this chapter. Existing literature and feedback from the experts in relevant domain have been used as a major source of data/literature. The steps adopted for the DEMATEL, SEM, AHP, FAHP, FTOPSIS, and BWM methods of analysis are also explained.

Chapter 5

This chapter is an important one as it provides detailed information on the eight issues along with empirical validation of the constructs. Finally, the influence of the issues on the performance of cold chain is evaluated and the competing model for the research problem is exhibited. The model including measurement model and structural model with their respective results have been discussed. Prioritisation of the issues and their inter-influence is also examined in the chapter.

Chapter 6

Chapter 6 also contributes significantly to the study as it suggests the identified solutions to overcome the issues. This chapter also describes the analysis conducted with the suggested solutions for an enhanced understanding for the cold chain stakeholders. The chapter thus suggests solutions for resolving each issue which significantly contributes to the purpose of conducting this study.

Chapter 7

A complete synopsis of the exploration performed and the major conclusions derived have been offered in the seventh chapter. How the study contributes to the existing literature is emphasized too. The chapter also deliberates upon the practical inferences and benefits of this research work to the cold chain sector. The limitations of the work and areas for future research too have been highlighted in the final chapter.

Chapter 8

Chapter eight lists all the sources and references that have been referred to for conducting the present study.

1.12 CHAPTER SUMMARY

The fundamentals of cold chain have been discussed in this chapter. The way cold chain evolved in the recent years was also discussed along with a review of the presence of issues in the entire cold chain. The business problem and research problem were propounded in this section total with the clarification of exploration questions and exploration goals. The second chapter reviews theme-wise literature on issues in the cold chain of frozen food.

Table 1.2 Organization of the Thesis

Chapter I Introduction and Background	• Background of the Study • Concepts and Operating Definitions • Stakeholders in Cold Supply Chain • Status of Cold Chain in India • Status of Cold Chain in Uttarakhand • Issues in Cold Chain • Motivation/need for the Research • Business Problem • Research Problem • Research Questions • Research Objectives • Organisation of the Thesis • Chapter Summary

Chapter II
 	
Literature Review
	• LR at a Glance
	• Collection of Literature
	• Theme-based LR
	  ○ Major Theme 1 - Issues in CSC
	  ○ Major Theme 2 - CSC Performance
	  ○ Major Theme 3 - Suggestion of Solutions
	• Theoretical Underpinning
	  ○ Knowledge-based View
	  ○ Stakeholder theory
	  ○ Triple Bottom Line
	  ○ Network perspective
	• LR on data analysis techniques
	• Major Inferences derived from LR
	• Major Gaps derived from LR
	• Chapter Summary

Chapter III
 	
Research Methodology
	• Rationale for the Study
	• Problem Statement
	• Research Questions
	• Research Objectives
	• Research Design
	• Research Methodology
	  ○ Phase I - Identification of Issues
	  ○ Phase II- Analysis of Issues
	  ○ Phase III - Suggestion of Solutions
	• Research Hypotheses
	• Sources of Data Collection
	• Questionnaire as Survey instrument
	  ○ Development of Questionnaire
	  ○ Pilot Testing
	  ○ Administration of Questionnaire
	• Sampling
	• Proposed Research methods and techniques
	• Chapter Summary

Chapter IV Research Outline and Preliminary Analysis	• Demographic Profiling • Data collection • Phase I: Identification of CC Issues - Main categories and Sub-categories • Phase II: Analysis of Issues using DEMATEL, SEM and AHP/FAHP • Development of Final Model and Suggestion of Solutions • Sensitivity Analysis: Analyzing the Robustness of Rankings of Issues • Chapter summary
Chapter V Analysis of Issues in CC of FFP	• Introduction • Analysis of issues using DEMATEL • Analysis of issues using SEM • Influence of Issues on Cold chain performance: Hypotheses testing & Model Development • AHP and FAHP: Ranking of Issues • Final Model and Discussion of Results • Sensitivity Analysis: Analyzing the Robustness of the Rankings of Solutions • Chapter summary
Chapter VI Suggestion and Assessment of Strategies and Solutions to overcome Issues	• Introduction • Identification of Strategies and Solutions to overcome Issues • Categorization of Solutions • Prioritization of Solutions • Sensitivity Analysis of the Prioritized Solutions • Discussion on Suggested Solutions to overcome Issues • Chapter Summary
Chapter VII Recommendation, Conclusion and Future Research	• Introduction • Research Objectives and Research Hypotheses • Data base and Research Methodology • Findings of the Study

	• Recommendation • Conclusion • Managerial and Strategic Implications • Theoretical Implications and Contribution of research • Limitations of the Study • Scope of Future Research • Chapter Summary
Chapter VIII References	• Reference

[**Source:** Author's composition]

CHAPTER II

REVIEW OF LITERATURE

OVERVIEW

Review of Literature is a concise presentation related to a specific context that leads to formulation of specific research questions. Literature review can largely be explained as "a more or less systematic way of collecting and synthesizing previous research" (Snyder, 2019). On the basis of exploration of the past literature, research hypotheses can be formulated. The second chapter exhibits a thorough review of the literature related to CC of frozen food, challenges encountered across the chain, food losses and wastage, performance of cold supply chain. The relevant literature has been categorized and presented on the basis of three major themes. This has been done for simplification and systematization of the review. Literature on Stakeholder theory, Knowledge-based view, Triple bottom line and Network viewpoint is likewise contemplated to furnish a total view associated with the subject of the examination.

2.1 LITERATURE REVIEW AT A GLANCE

Literature is reviewed on three major themes along with literature on knowledge-based view, stakeholder, TBL and Network theory thus aligned with the topic of dissertation. Major inferences and gaps were derived from literature review that became an inspiration to conduct current research. Thus, Literature collected from the above search is compiled and segregated according to the following major themes:

1. Study of Issues in Cold Supply Chain

The studies referred here deal with diverse issues and challenges faced in cold SC. The issues identified in the study are as follows: Lack of Infrastructure; Lack of Traceability; Lack of Sustainability; Lack of CC Integration; Lack of Safety and

Quality; Lack of Awareness and better Handling practices; and Lack of Responsiveness. It is these issues and challenges that lead to food losses and wastage, lower consumer adoption, even health issues and finally whole CC's performance.

2. Study of Supply Chain Performance

These studies lay emphasis on understanding the various measures / indicators for effective SC performance.

3. Suggestion of Solutions for Overcoming Issues of Cold Supply Chain

These studies focus on recommendation of strategic solutions which can help overcome issues in cold supply chain of frozen food products and suggest strategies and solutions including the use of information technology. Both together will help contribute in reduction in food wastage and losses and enhancement in CC performance.

The chapter presents a rational flow of research starting with the understanding of the present state of cold chain, to identification of research gaps, formulation of research problem and applicability and suitability of the theoretical premise. The literature review also supports in designing research objectives, variable selection and development of the questionnaire as instrument for data collection. The significance of enhanced performance of cold chain is highlighted too. Analysis of literature thus conducted leads to major inferences and gaps derived. Keeping business problem in purview, a rigorous review of literature was conducted under the following six minor themes:

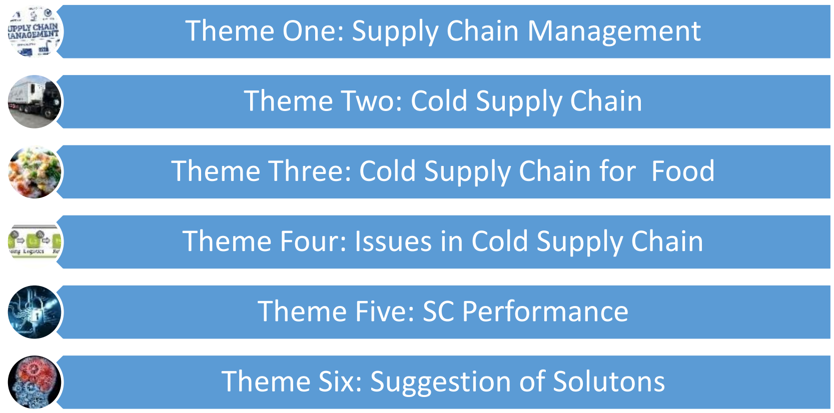


Fig 2.1 Diagrammatic representation of the Minor Themes for Literature Review

In addition to the above themes, literature has also been reviewed for the theories considered under theoretical premise as well as on the methods and techniques applied for conducting analysis of data. Each theme is elaborated upon in the current chapter.

Thus, as depicted in fig 2.2 , exploration started with a study of the broader aspect, the analysis of preliminary theoretical foundation resulting in collection of studies relevant to the research domain. By following a methodical approach, it becomes easy to arrive at the scope and review the studies related to a specific topic selected for the research work. The research gaps are thereafter determined that serve as a foundation for exploration of further research with the purpose of filling the gaps.

Fig 2.2 Identification of Research Gap [Source: Author composition]

To foster a decent comprehension of the relevant branch of knowledge, work in the area of CCM is presented in the beginning. The study of literature will also help in building theoretical framework. The findings from the literature review will thus guide towards development of a model to guide future research work.

2.2 COLLECTION OF LITERATURE

Literature is collected to support the research needs of the researcher specific to a domain in a manner that studies related to the domain can be cited. In this study, a theme-based approach has been used to search varied sources of literature. Sources reviewed were reports from the industry, research papers and articles and newspaper articles. Table 2.1 exhibits the list of keywords on the basis of which search was conducted in a widespread range of journals with the aim of finding relevant literature helpful in conducting current study. The table also illustrates a set of databases searched in order to obtain relevant research papers/articles. Table 2.2 shows number of papers read under the different minor themes.

Table 2.1 Keywords used/Databases referred

S.No.	Keywords	Name of Journals explored	Databases
1	Supply Chain Management (SCM)	Journal of Retailing Journal of Advances in Management Research International Journal of Productivity and Performance Management Benchmarking: An International Journal International Journal of Logistics Management Journal of Marketing Channels International Journal of Engineering Technology, Management and Applied Sciences	Scopus Taylor & Francis Elsevier Google-Scholar Science Direct Web of Science Emerald InderScience Springer Sage Wiley University of Bath
2	Cold Supply Chain (CSC)		
3	CSC for Food		
4	Issues in CSC		
5	SC Performance		
6	Suggestion of Solutions		

	Journal of Supply Chain Management Systems International Journal of Production Economics International Journal of Refrigeration Journal of Food Engineering IUP Journal of Supply Chain Management International Journal of Production Research Inter. Journal of Sociology of Agriculture and Food International Review of Retail, Distribution and Consumer Research Journal of Humanitarian Logistics and Supply Chain Management Food Control Food Quality and Preference British Food Journal European Review of Agricultural Economics Comprehensive Reviews in Food Science and food Safety Trends in Food Science & Technology Journal of Business Logistics American Journal of Agricultural Economics	Food Science & Technical Abstracts JSTOR Mendeley NBER(National Bureau of Economic Research) Directory of Open Access Journals

[Source: Author]

Table 2.2 Summary of LR for Minor Themes

Theme	Author	Inference	Gaps
Supply Chain Management	Ganesan *et al.* (2009) Chandra & Kumar (2020) Mor (2018) Kumar (2017) Gurumurthy (2013) Wang (2010) Burch (2005) Gardas (2019) Turi (2014) Brockhaus (2013)	1.Performance of existing SCs has to be enhanced. 2.IT will help in bringing transparency among SC partners. 3.Retailers must bring about revision in their strategies, management practices and SC structures to adapt to dynamic env.	1.Factors influencing performance of a CSC can be identified for Frozen food SC. 2.Role of IT in frozen food SC needs to be understood. 3.Challenges and issues in CSCM need to be identified 4.Ways and strategies to overcome them should be determined by CSC partners including retailers
Cold Supply Chain	Bhatnagar(2019) Bremer(2018) Ali(2018), Bag(2016), Yakum(2015) Joshi(2011) Bogataj(2005) Jedermann(2014)	1.Temperature breakdowns, substandard packaging, and deterioration of quality negatively impacts the performance of the firm. 2.Companies need to encourage innovative means to create the most relevant operational strategy resulting in competitive advantage. 3. Waste reduction can be achieved by using proper SCM systems and monitoring shelf life.	1.Need to study effect of temperature breakdowns, quality deterioration, waste reduction and other issues on performance of CSC for frozen food products in particular. 2. Need for designing innovative CC IS integrating all information flows to achieve competitive advantage. 3.Study can be applied for frozen food sector as well.
Cold Supply Chain for Food industry	Cerchione(2018) Osorio(2017) Derens-Bertheau(2015)	1.The most sensitive links in a CSC are transportation and storage.	1.Need for adequate mechanism to share knowledge required for preservation of the product quality during their movement

	Manzini(2013) Mahajan(2013) Chaowarut(2009) Rathore(2010) Vrat(2018) Aung(2014) Mercier(2017) Rong(2011)	2.Integration of competencies, issues, problems and decisions is the most important future challenge in FSC. 3.Effective & direct control of quality, safety, sustainability and efficiency is required. 3.Demand for FF is sure to substantially increase in India. 4.Customer perspective plays the most important role for FF industry. 5. Product safety is very important. 6. There is surge in research on CC for PFP, being of the most prominent areas.	along CC and for problem solving. 2.Role of advanced technologies to assure quality, safety of product and efficiency of CC needs to be studied. 3. Customer perspective towards FFP needs to be analysed.
Issues in CSC [Integration, Infrastructure]	Negi (2015) Singh (2016) Dong & Srivastava (2013) Ndraha (2018) Koen (2018)	Fragmented chain leads to wastage and losses 2.Inadequate CC infrastructure facilities, poor quality of distribution, are the weak links in SC. 2.It is possible to reduce food waste provided temperature is managed is appropriate in FCCs.	1. There needs to be more study done on resolving issues of fragmentation, inadequate infrastructure in CSC. 2.SEM can be applied to examine the relationships between various constructs developed for FFP. 3. Role of IT in making CC integrated can be emphasized.
Issues in CSC [Infrastructure]	Shashi (2016) Negi (2015)	1. One of the prime areas for improvement is the cold chain infrastructure.	1. Role of CC infrastructure needs to be analysed wrt performance of CC

		2. In India there is improper SCM, lack of CC infrastructure resulting in ultimate inefficiencies reason for wastage & losses in the F&V.	2. Infrastructure needs to be improved for better performing supply chain. 3.The same can be studied for frozen food.
Issues in CSC [Integration]	Negi (2015) Rathore (2010)	1. Owing to a fragmented but lengthy SC, it is loaded with the wastages and post-harvest losses 2. Development of integrated CC is required	1. Integration of CC needs to be done for reduction in losses and wastages. 2. Integration of CC needs to be considered for Frozen food products.
Issues in CSC [Traceability]	Aung (2014) Olsen (2013) Rijswijk (2008)	1.Information requirements will rise across the food chain and so a well-structured traceability system will be required. 2.Sharing of information across CSC partners will enhance traceability 3. With the aim of keeping track of huge information, Computerized traceability systems and tools are required which can also help in analysis and visualization 4. In developed countries, consumers associated traceability with health, quality, safety and	1. Impact of sharing traceability information across CSC on performance needs to be studied. 2. Traceability needs to be tracked more effectively using latest technology 3. Study needs to be done to analyse relation of traceability with quality & safety for FFP

		control, trust and confidence	
Issues in CSC [Sustainability]	Vrat (2018) Gardas (2019) Shashi (2016)	1. Proper temperature-control and use of technologies will help in maintaining quality during distribution 2. Less studies on sustainability have been carried out. 3. Performance of the entire agricultural SC can be significantly enhanced by implementation of green practices. Was exhibited using SEM. 4. Firms have not been able to reap benefits of sustainability owing to unwillingness and neglect w.r.t handling this issue.	1. Role of innovative technologies for assuring the PP quality while in transit needs to be studied. 2.Sustainability needs to be given more emphasis 3. Model's reliability and accuracy can be enhanced by the application of TISM method. 4. The model can be applied for PFP 5. Sustainability needs to be given due consideration for CA
Issues in CSC [Safety, Quality, Awareness]	Mercier (2017) Magnier (2016) Sharma (2015)	1. Enough awareness regarding temperature requirements affecting safety and quality is not there 2. Quality is also affected by Sustainability 3. Usage of appropriate temperature monitoring systems and appropriate handling practices will ensure food safety 2. Traceability is required to reduce wastage	1. Awareness needs to be enhanced for better safety and quality 2. Relation between Sustainability and quality need to be studied 3. The relation between food safety, quality and awareness needs to be identified. 4. The impact of food safety, handling practices, awareness, traceability, infrastructure, integration on CC performance needs to be analysed

		3. Integrated infrastructure will improve performance of CSC	
Issues in CSC [Responsiveness]	Blome (2013)	1.SC flexibility and responsiveness can be achieved with the help of improved knowledge availability	Relation between availability of knowledge and SC flexibility, and between flexibility and performance can be studied
SC Performance	Ali(2013) Machado(2016) Sukati(2012), Akyuz(2010) Gunasekaran(2004) Shepherd(2010) Hausman(2004)	1.Customer relations, strategic supplier partnership and sharing of information strongly predicting the performance of a SC. 2.Effective SCM helps to win customers and improve customer adoption leading to competitive advantage	1.A study of various factors influencing performance of a cold supply chain for frozen food product needs to be carried out. 2. A link between performance of CSC and Competitive advantage needs to be established.
Suggestion of Solutions	Parthasarthy (2017) Comes(2018) Badia-Melis(2018) Tian(2016) Haan(2013) Kumar(2013) Aravindraj (2020) Yahia (2009) Shashi (2018) Cerchione (2018) Lan (2012) Pramatari (2007) Tsironi (2015)	1.IT can enhance traceability with reliable information in the entire agri-food SC, thus guaranteeing food safety through acquisition, transmission and sharing of authentic data in the connections of creation, warehousing, handling, conveyance and deals.2. Use of Wireless sensor networks results in improved process quality	1. Role of IT and latest technologies in FF industry needs to be studied for enhanced traceability, food safety and quality and improved integration of different links of a CSC. 2. Different strategies need to be implemented for resolving issues in CC

	Gulati (2008) Tsang (2017) Singla (2016) Bremer (2018) Surange (2013) Gautam (2017) Kumar (2020)	and also reduction of wastage in CC. 3. Training is extremely important 4. Collaboration amongst players of CC is the need of the time 5. Support from Govt. in the form of financial assistance, infrastructural development, is needed.

2.3 THEME-BASED LITERATURE REVIEW

There is a very limited amount of research work available in context to cold supply chains of frozen food products. Cold supply chain is not a very old area of research and though there are number of studies on it, most of the studies done are on pharmaceutical sector and very few done on frozen food products. Therefore, it becomes important to review articles that help in contributing towards better understanding of this area and indicate relevant research gap. To do justice to the subject, old as well as recent and relevant topics/issues are reviewed. The literature review deemed both qualitative and quantitative aspects for a better comprehension of the content and relevancy of the research area.

2.3.1 Major Theme 1: Literature on Issues in the Cold Supply Chain of Frozen Food

Studies under this theme draw focus on understanding Supply Chain Management, Cold Chain Management (CCM), how CCM evolved, its need, its significance in the present global scenario.

Minor Theme One: SCM

Mentzer (2001) in his study defined SC as "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances and information from source to customer". Kilger (2008) characterized SCM as "the task of integrating organizational units along the supply chain and coordinating material, information and financial flows in order to fulfil (ultimate) customer demands with the aim of improving competitiveness of a supply chain as a whole".

Oliver (1982) defined SC as "the systematic collaboration between people, processes and information of alike organisations to create tangible or intangible values and deliver them to the customers". Supply chain management is defined by Borade (2007) as "the management of money, material, manpower and information both within the supply chain and across the supply chain with the aim of maximizing customer satisfaction and achieve competitive advantage". As cited by Borade (2007), SCM has been defined by Simchi-Levi (2003) in the following manner: "a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements".

For a growing globalized economy where the environment is extremely competitive and dynamic, an organisation can achieve or sustain competitive advantage to a great extent through its Supply Chain Management. Thus, SCM is not only considered highly significant for creating but also for sustaining competitive advantage. Hence, the efforts put forth to not only manage but also for the improvement of productivity and efficacy of a supply chain are exceedingly critical to remain competitive on a globalized marketplace since the competition will only get tougher in the times to come (Garcia *et al.*, 2013). Also, the firm's Supply chain should be highly flexible so as to adapt according to the complex fluctuations in business environs (Gosain *et al.*, 2004).

Firms across the globe apply supply chain management because of the results demonstrated by it such as diminished conveyance time, improved monetary execution, expanded consumer loyalty, expanded trust among providers, to give some examples (Quesada, 2012). Hence, the primary reason why the firms employ SCM is to increase their performance. Thus, the 1980s saw a steady increase in the adoption of SCM practices.

As the SCs are becoming increasingly intricate since the last few decades, the frequency and severity of disruptions in the chain has increased too. Owing to this, SC protection is deliberated upon as a priority by 80% of the companies world-wide (as cited in Shrivastava, 2017). Supply Chain Management is considered by most organisations as a competitive strategy with the aim of increasing productivity and profitability (Gunasekaran, 2004 as adapted by Mor, 2018). As per a study by Verma and Seth (2014) cited in Mor (2018), supply chain coordination, cost efficiency and SC cycle efficiency are the various enablers of a SC.

Also, as pointed out by Mor *et al.*. in 2018, effective coordination amongst its supply chain players can help an industry achieve its long-term corporate goals. To achieve sustained competitive advantage, it is essential to ask four questions with respect to firm resources: is the resource rare, imitable, valuable and whether there are substitutes available for it (Barney, 1991). As per Narasalagi & Hegade (2013), supply chain management is very critical for agricultural products owing to the fact that the products have a petite shelf life and so are perishable. The stakeholders of a SC face diverse challenges some of them being: management of the perishability of products (for products that are perishable in nature); competition; reduction in operating costs; maintaining customer and supplier relationships; and managing uncertainties (adapted from Theophilus, 2021).

In the study on significance of Cross-docking terminals, Theophilus (2021) mentioned that globally, the supply chain decision-makers are continuously seeking for effective techniques to enhance the efficiency of distribution of products while meeting SC goals: efficient utilization of resources; improvement of customer satisfaction; cost minimization; maximization of profits; and value creation.

According to the study, the incoming products from the manufacturers and suppliers reach the cross-docking terminal where they are unloaded, deconsolidated, sorted, re-consolidated in the storage areas and then loaded into reefers for delivery to the customer (refer Fig 2.3). This strategy of cross-docking facilitates product distribution and so has been applied by many SC players including big firms like Target, Walmart, FedEx etc. However, though it is used extensively for non-perishable products, its use for perishable products is still a challenge as it needs to address the concerns of preserving quality of products while reducing the distribution costs. One way suggested is to segregate storage areas for perishable products and non-perishable products as depicted in Fig 2.4.

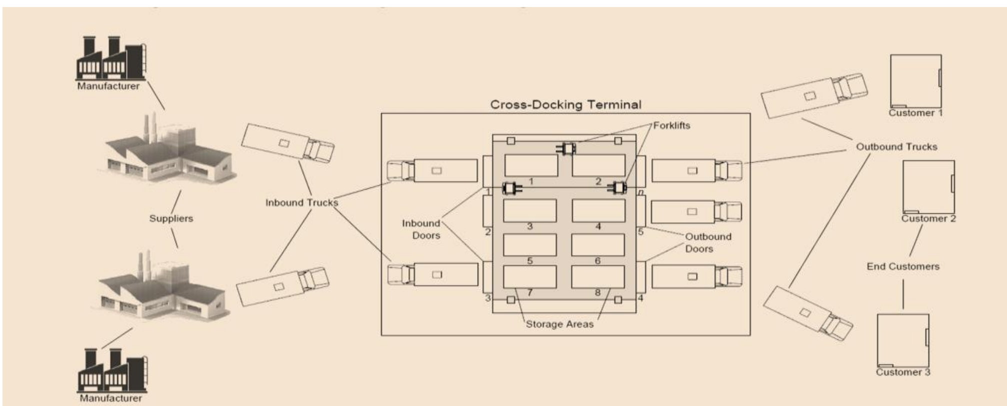


Fig 2.3 Use of Cross-docking terminal [Source: Theophilus, 2021]

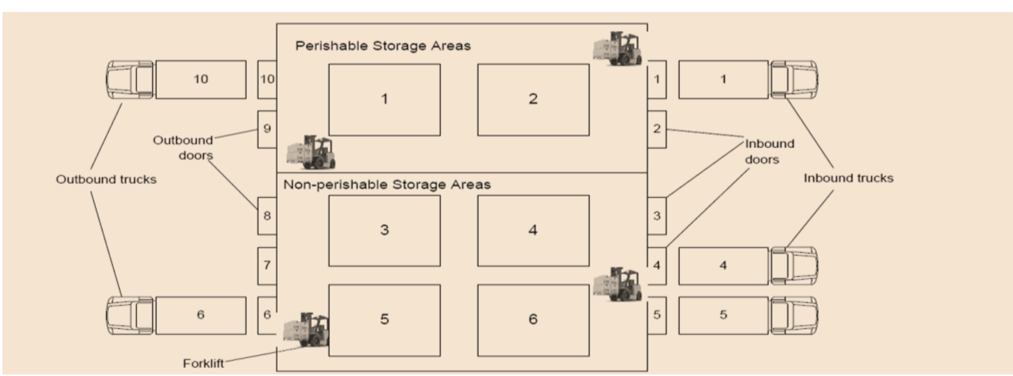


Fig 2.4 Use of cross-docking terminal (segregated on product type) [Source: Theophilus, 2021]

Ali (2017) emphasized that SC concentration aids in direct interaction between buyers and sellers, which facilitates food product quality control. As suggested by

Stevens in 1989 (adapted from Ali, 2017), an integrated Supply Chain has three components that are significant in supporting theoretical constructs: Internal Supply Chain, the Suppliers and the Customers.

Since the past two decades, supply chain management has evolved into Green supply chain management and Sustainable supply chain management. Green SCM is defined as integrating ecological dimensions with the SC network (Carter, 2008). Fig 2.5 depicts different stages of an integrated supply chain.

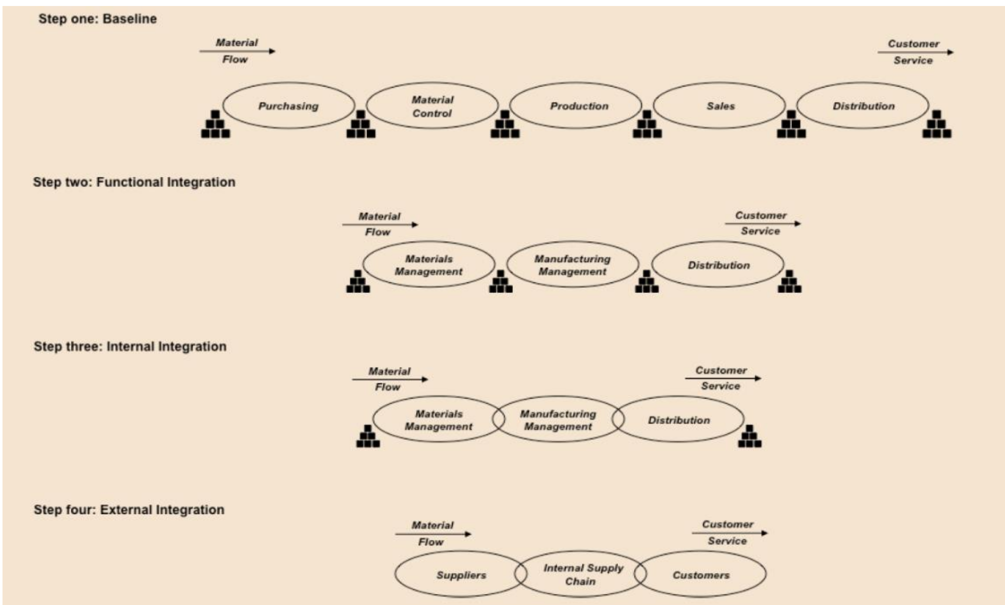


Fig 2.5. Stages of SC Development [Source: Stevens, 1989 (as cited in Stevens, 2016)]

In a practical scenario, there are firms that are a stakeholder to a supply chain i.e. they more appropriately are a constituent of supply chain networks. A supply chain is said to be seamless when all the SC players act as one integrated community so that performance benefits can be achieved in the entire SC. Fig 2.6 exhibits the schematic view of a supply chain. The material flows downstream while orders flow upstream and information flows in both directions. For every echelon in the supply chain, the immediate supplier is the business upstream while the immediate customer is the business downstream. Each echelon in the chain consists of:

perceived demand, process, performance related information, procedures along with disturbances due to lags in transmission or breakdowns in equipment, etc. (Towill, 1997). A seamless supply chain is highly effective in its performance. A supply chain becomes a strategic supply chain when its members become integrated not just technologically but operationally as well as strategically (Hult, 2004).

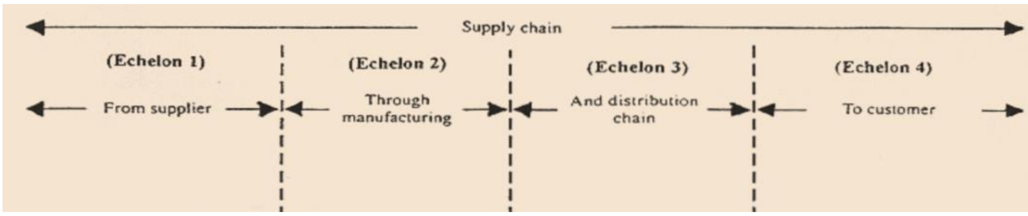


Fig 2.6 Schematic view of a Supply Chain [Source: Towill, 1997]

In a study by Biswas & Das (2020), the barriers in supply chain management of manufacturing industries are: unclear organisational objective, weak ICT infrastructure, reluctance to apply SC practices, insufficient collaboration among allies, lack of integration among SC partners, want of commitment and support from top management, insufficient funds, inadequate training and education of employees and suppliers, poor corporate culture, lack of responsiveness, trust issues among employees and SC partners, lack of customer satisfaction index and employee empowerment. So, when we look at supply chain for the agri-products industry, some of the barriers remain common.

Minor Theme Two: Cold Supply Chain

Zhang in 2007 (as cited in Mahajan, 2012), defined cold chain as “a series of interdependent equipment and processes employed to ensure the temperature preservation of perishables from the producer to the consumer in a safe, wholesome, and good-quality state”. A CC is a specific SC meant for products that are sensitive to changes in the temperature. The processes and equipment used in order to protect chilled and FFPs form the cold chain (Salin, 2003). A cold chain is actually a supply chain of items that are perishable in nature and hence it protects perishable products from unsuitable exposure to light, humidity, temperature, etc. finally preventing them from degradation by keeping them in a frozen or chilled state.

Cold chain (CC) is a term used to describe a specific SC where temperature control is ensured for the activities and processes involving PPs (Shabani *et al.*, 2015). Today, the cold chain has certainly become a vital component of SC domain. The cold chain ensures maintenance of product quality and safety through procurement, processing, logistics, storage and show-cased for sale or utilization of different food varieties, including frozen food. While a huge number of individuals overall experience the ill effects of yearning, 33% of the world's food creation is lost or squandered before consumption. It is not only the society that ends up paying for this cost attributed to food wastage and loss but it is a threat to both the environment and the economy.

The significant parameter to ensure food safety is temperature control. Hence, it is essential to install systems for monitoring temperature in order to exercise sufficient control on quality of food. A cold chain's physical infrastructure comprises of cold storages, pre-cooling facility, and reefers (Sharma, 2015). Fig 2.7 exhibits a typical cold chain.

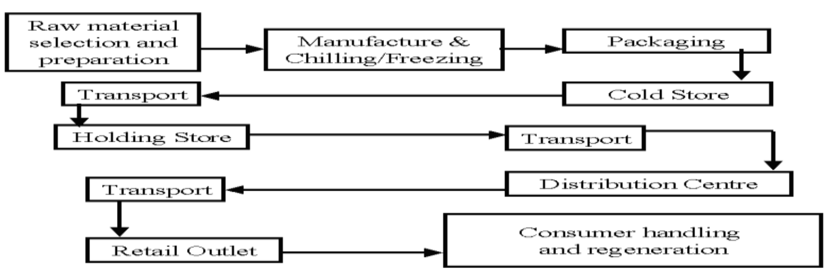


Fig 2.7 A typical Cold Chain

With the process of chilling, the food temperature can be reduced to below existing environment temperatures, but should be above –1°C (Asadi, 2014). Thus, with the help of chilling, short-term preservation can be achieved effectively as many physical, chemical, biochemical and microbial reactions can be retarded thus reducing food spoilage and deterioration. It is of critical importance that the quality, health and safety are given central consideration in food distribution since continuous variations in quality occurs across the SC (Akkerman, 2010). Continuous monitoring and tracking of temperature and humidity level to sustain the controlled atmosphere of a cold chain along the timeline of transit and proper availability are the core functions in cold chain management, especially for food chains. Efficient maintenance of the controlled atmosphere for the cold chain delivers sustainability to the absolute SC of the concerned business. Cold chain is ensured of integrity when the required temperature is maintained and used (Oliva, 2008). As per a study by Forcinio (2013), the temperature range (in °C) for different storage types is as follows: For frozen storage type, the temperature range is within -20 to 0; for refrigerated storage type, the temperature range is within 2 - 8; and for controlled room temperature storage type, the temperature range is within 15 - 25.

Cold chain may be of many types, categorised by location, duration of transportation, carriage mode, or by commodity (Heap, 2006). Fig 2.8 exhibits the types of cold chains.

	Mode of Transport					
	Air	Sea Container	Sea Reefer ship	Land International	Land Local Developing countries	Land Local Developed countries
Commodity						
Frozen Bulk		Y	Y	Y		
Frozen Retail		Y		Y	Y	Y
Chilled Bulk	Y	Y	Y	Y	Y	Y
Chilled Retail	Y	Y		Y	Y	Y
Chilled Pharmaceutical	Y	Y		Y	Y	Y

Figure 2.8 Major categories of CC [Source: Heap, 2006]

The cold chain encompasses a number of partners involved in manufacturing/processing, storage, logistics, and distribution of frozen / chilled food to the consumers (Yuen, 2017).

The important domains of cold chain are: infrastructure perishable product, regulatory framework and information technology (Bremer, 2018). According to a study done by Fernie and Sparks (2004), there are four categories of refrigerated product based on storage temperature established to meet requirements of different types of food products: frozen kept at temperatures less than or equal to -18 °C; cold-chilled kept from 0 - 1°C; medium-chilled kept at 5 °C; while exotic-chilled kept within 10 - 15 °C. Mor *et al.* (2018) in their study categorized perishable products into two types: non-living products comprising of dairy products, meat, medicines, processed food, frozen food, blood, etc.; and living products that comprise of F&V, flowers, sea-food, etc. both requiring proper atmospheric conditions in order to prevent the product from microbial spoilage.

Right from the stage of harvest to consumption, maintaining temperature is extremely vital aspect for preserving quality. Extremely low temperature can result in chilling damages to the produce and if the temperature is very high, then it will result in shrinkages (Bhatnagar, 2019). Maintaining humidity and ethylene sensitivity are other important factors for maintaining produce quality. As per the NCCD (2015) report, cold chain can result in extending the produce's holding life thus creating adequate opportunity for manufacturers and processors. Crops having high water loss and metabolic rate get spoilt faster and have short storage life and require optimum conditions for maintaining quality.

Thus, following have influence on the perishability of fresh crops:

Temperature - Owing to respiration taking place in the plants, heat is generated due to oxidation of sugar, fat and proteins in the cells. So, maintaining temperature is very important so that the excessive respiration does not result in deterioration in the form of loss of flavour, loss of weight, reduced food value, etc. Refrigeration can help reduce the process of deterioration.

Ethylene production - Certain fruits and vegetables produce ethylene, a natural gas and because of it, the process of ripening speeds up which can result in the spoilage of the fruit and/or vegetable. So, there should be separate storage for such fruits and vegetables.

Relative humidity - Presence of moistness in the air affects F&V as it determines the water loss from the produce. Hence, maintaining relative humidity of storage is important taking into consideration the type of product being stored.

Odour - Products should be stored in a manner that cross-transfer of odour amongst the products does not take place.

Controlled environmental conditions are required for storage and transportation facilities for safe and effective distribution of perishable items in order to avoid deterioration of the time span of usability (Defraeye, 2016) and quality (Smith, 2004). Complexity and presence of numerous challenges in perishable products' cold chain when compared to other SCs is because of the perishability of food and the uncertainty of environmental conditions. (Soto-Silva, 2016). A 2-hour break in CC can cause 10-14% decrease in shelf life depending upon the type of the product (Loisel, 2021). Improvement in SCM of F&V is essential in all links of the chain and can be achieved by adoption of world-wide best practices used in packaging, storage, handling, transportation and any other practice that adds value (Bhatnagar, 2019). Estimation of actual shelf life remaining and real-time valuation of quality is possible only if temperature and humidity are constantly monitored which can be finally translated to effective decisions.

Minor Theme Three: Cold Supply Chain for Food

Being a heterogeneous sector, frozen food comprises of a wide array of products which vary not only on the basis of relative profitability but even the growth rates (as cited in McKinnon, 1998). These products not only differ on growth rates and profitability but also on specific environmental requirements to ensure safety and quality. Frozen food is stored at the cold storages for primary distribution which may be done in following forms: delivery directly from the processor to distribution centre; or direct collection from the processor arranged by the retailer; distribution through distributor or private agent. As the products are perishable in nature, the buyer is not only uncertain about the wellbeing, and nature of the item but also unsure about the supply reliability. This uncertainty prevails even on the seller's side. As the seller is uncertain about the buyer but still the seller needs to move the perishable products to the point of sale fast enough to avoid any deterioration in the product's quality and safety. Perishability could be either fixed life time or random life time perishability (Jia & Hu, 2011). In case of random life time perishability, products are discarded on spoilage, time of which is uncertain while in case of fixed life time perishability, products are retained for a fixed time and discarded after that time is over. It is perishable items with fixed life range that the vast majority of writing has focussed. Time of rot fluctuates for food items, the snapshot of decaying is variable as it relies upon circumstances like temperature, humidity and other environmental conditions.

It is essential to maintain control over the cold chain to preserve the quality as well as safety of the FFP as it is the weak links in the CC that straightforwardly affects such angles. As per a study done by Heap (2006), in order to handle perishables successfully, certain requirements that must be met are: transport equipment, produce temperature; packaging; produce quality; pre-cooling; journey time; pre-shipment handling; temperature control; cross-contamination from other cargo; air circulation; time without refrigeration; air freshening; retail sale and insect infestation. Joo (2013) in his report suggested: cross-docking for inventory reduction; consolidation for enhanced distribution efficiency and an appropriate temperature assessment method to ensure quality of food to the consumer. According to a review study by (Han 2021), lot of research in the area deals with primarily three aspects: improving efficiency (Ruiz-Garcia, 2018; Duan, 2020); ensuring control and integrity of the cold chain (Bouzembrak, 2019); and promoting sustainable development of CC (Wu, 2019). As per a study by Kitinoja (2013), an integrated cold chain consists of primary activities which include: freezing; pressing and cooling new food items; cold capacity; promoting; and dispersion under temperature-controlled conditions.

Cold Chain industry and frozen food sector both are new and vast areas and are certainly inter-related. Therefore, this research integrates both areas and calls it as Cold Supply Chain of Food Products.

Minor Theme Four: Issues in CSC

Frozen food is an area that is non-homogenous as it comprises of a diversified range of products, each different from the other in its growth rate and profitability. There is a steep upsurge in user demand for convenience food products (Osman *et al.*, 2014). A cold chain typically has many players like farmers, manufacturers, suppliers, transporters, wholesalers, retailers, exporters and end consumers, each having their own interests. This makes the food industry highly challenging and dynamic (Vorst *et al*., 2007). As per the United Nation's FAO (2015) report, occurrence of food losses primarily takes place in the stage of post-harvest circulation because of poor knowledge regarding handling and poor facilities and poor practices (Goedhals-Gerber, 2020).

Around one-third of global fresh F&Vs are discarded since their quality drops to a level that is much below the acceptable limit (Gustavsson, 2011). There are a few weak spots in cool chains, commonly, temperature maltreatment during transport, holding up times during stacking and dumping, precooling of items prior to delivery, and during movement of items starting with one chain player then onto the next (Raab, 2011).

Many factors like improved awareness about the effects of over-production and under-consumption on the ecology resulting in increased social, environmental and ethical concerns have ultimately resulted in consumer groups, policy makers and environment groups pressurizing the food companies to be more socially-oriented while also having environmental concerns for their SCs (Joshi, 2020). As per the estimate of World Bank, demand for food is going to rise by fifty percent owing to the growth in population world-wide (Gunaratne, 2020).

Negi in his work on Fruits & Vegetables SC (2015) identified Quality standards; Safety standards; SC losses and wastage of produce; Fragmented Supply Chain; CC Facilities; Infrastructure Facilities; SC inefficiency; Linkages between the CC partners; Technology and Techniques; packaging material cost; Farmer's Knowledge & Awareness; Processing and Value Addition; Farmers income; Transportation infrastructure, etc. as some of the issues which cause grave challenges for the F&V segment ultimately affecting the overall agricultural progress of the country.

Losses in food is attributed to the falling sustainable performance of cold chain resulting in depletion of resources and environmental pollution (Islam, 2021). Through various studies done, it is estimated that consumption of resources including land, water and fertilizers is to the tune of 23-24% for production of food however there are huge losses in that and does not ultimately reach consumer along with 0.66 G tonnes of carbon footprint, the volume of greenhouse gases emitted by an activity or organisation, released in atmosphere (Kummu, 2012).

In their study on sustainable cold chain, Singh and Shabani (2016) highlighted that sustainability issues like environmental issues and social responsibility have not been given enough importance; more emphasis has been given on individual and immediate benefits; renewable energy sources; life cycle analyses, and passive ones are many times the least used CC practices; training programmes are not as rigorous as per the actual requirements. The study also highlighted that infrastructure is a chief area for development. Full integration with upstream and downstream partners is required for total performance. Suppliers need to focus more on quality, freshness, sustainability and product pricing.

According to a study by Towill (1997), refrigeration itself accounts for approximately 40% of the overall energy requirement. Reductions in energy would bring about reduction in distribution costs as well as reduction in atmospheric emissions. Shrivastava (2014) in his study on green supply chain emphasized that organization culture(s) need to be changed to eliminate waste and look for reuse/ recycling, reverse consumption and if required use waste effectively. Even the workforce needs to be trained on green practices and processes. A framework was proposed in the study where green purchasing, manufacturing and marketing has impact on sustainable business performance.

In a study on time temperature abuse, Ndraha *et al.* (2018) highlighted that management of temperature for FFPs was the main concentration of research with highly explored food types being F&V, meat, fish and the dairy products. The study, also suggested that better temperature management can lead to reduction in food waste. Characteristics like unorganized structure and limited customer orientation high extent of perishability, restricted outsourcing, differentiate SC of agri-food products from other SCs (Sagheer *et al.*, 2009). It is assessed that around 35–40% of the total production of fresh F&V in India amounts to wastage owing to ineffective cold chain facilities, poor logistics; inadequate cold storage, and lack of other infrastructural facilities (Viswanadham, 2006).

SC from the farms to the souks is exceedingly fragmented. There is insufficient infrastructure for packaging, handling, storage and logistics from the place of creation to marketplaces resulting in huge loss occurrence post-harvest (CIPHET, 2018-19). The post-harvest losses in the country that have been accounted for are around 3-16% for food commodities and the level of processing & value addition is still lower than 10% in F&V (CIPHET, 2018-19). Such high losses have resulted in monetary loss to the tune of approximately Rs. 1 Lakh crores (CIPHET, 2018-19). Frozen foods require appropriate processing, packaging, storage and distribution else they get spoilt in very short time and can cause health concerns for the consumer. In a study by FAO, USA (2011), it was reported amongst the various agricultural products, roots, fruits, vegetables and tubers suffer the highest rate of wastage and losses which is 40-50% while for cereals it is 30% and for dairy, oil seeds and meat it is 20% (adapted from Goedhals-Gerber, 2020).

While determining the shelf life, average temperature is the temperature that is generally considered across the cold chain (Giannakourou, 2020). This assumption could result in unrealistic predictions of change in quality along with the residual shelf life at a particular point in the chain. It therefore becomes decisive that the temperature history is taken at a real-time mode while the product passes through different stages of the cold chain. This will help predict changes in quality more accurately.

Infrastructure Issue (INTG)

In spite of being the second highest producer of F&V, 25-30% of it is wasted and lost owing to damages due to not enough logistics facilities including reefer vehicles, cold storages and specially earmarked fleet (Raut, 2019). While according to the GHI survey (2017), India was at 119th position in the world which is ironical. As per a study by Van Donselaar (2006), the supply and demand incongruity are because of lack of infrastructural facilities, lack of awareness and government policies, etc. According to the World forum CEO (www.weforum.org), the population of the world will rise till 9.1 billion and hence it becomes essential to intensify production of food by 70% (adapted from Raut, 2019). He also indicated that food losses and wastage is due to inadequate infrastructure and improper handling practices. The food quality degradation happens due to poor processing, storage, packaging and/or transportation facilities. Even in developing nations like India, there are 20-30% losses in the F&V owing to lack of infrastructure (Singh, Gunasekaran, Kumar, 2018).

Focussing on a distribution network, warehouses and the distribution centres are the main links in a CC which lead to inefficiency and waste (Manzini, 2013). Bhatnagar *et al.* (2019) in their study on agro-based perishables in CC emphasized the significance of effective development of storage and transportation infrastructure finally resulting in optimum usage of space and reduction of food wastage. There can be occurrences of temperature abuses leading to variations in the quality of product during dispersion and furthermore toward the finish of time span of usability causing spoilage and expiration ultimately resulting food waste and economical losses (Bruckner *et al.*, 2012). For predicting the residual shelf life or status of quality of the food product, it becomes necessary to monitor the temperature on a continuous basis throughout the cold chain. Real-time information about temperature will help maintain quality of the production during its distribution. Poor quality of packaging used for the products results in the product getting damaged as well as the shelf life decreases while in transportation.

According to a report by Census India, the population of the country is anticipated to rise from 121.1 to 152.2 crores considering the period 2011-2036 indicating a rise of 25.7 % in twenty-five years at the rate of 1% annually. With increasing population, there will be a rise in the food products' demand that will further translate into increased requirement for enough CC facilities as specialized storage services, reefers, pack-houses, etc. According to a study by Parwez (2013), there is huge dearth of cold storage & warehousing services in the country and many more cold storage facilities need to be established. There is a huge requirement of refrigerated carriers for the transportation and in-transient storage of perishable commodities. The study also highlights on the insufficient application of technology and technological solutions as presented below (MOFPI, 2019-20): a) For integrated pack houses, the existing capacity is 250 numbers while requirement is that of 70,000; b) Presently there are less than 10,000 reefers and approximately 62,000 more are required; c) Existing capacity of cold stores is 32 MT while requirement is at least 35 MT; and d) Presently there are 800 ripening chambers but nearly 9000 more are required.

Monitoring of temperature, humidity and other such desired environmental conditions on a continuous basis will help assess the quality, remaining shelf life of food products real time (Chaudhari, 2018). In a study on fruits, Wu *et al.* (2019) mentioned that if the temperature of the product is reduced by 10℃ then it will result in the shelf life getting doubled. Hence, it is important that after the produce is harvested, the field heat is rapidly removed by cooling and thereafter the temperature must be maintained across the entire cold chain for preserving the quality and minimizing losses. However, cooling too consumes energy and large share of consumption of energy is owing to transportation. Losses in food also mean there have been losses related to energy loss. Hence, optimization of CCs by extending shelf life, reduction in energy consumption, and reduction in losses and is extremely crucial for reducing environmental impact (Owen, 2018).

For products that are perishable, breaks in CC can significantly affect the value of the produce. It is therefore required to monitor and prevent temperature breakdowns in the chain for an accurate estimation of food quality, its deterioration and at the same time try to prevent the same (Loisel, 2021). Effective transportation ensures the quality of food products along with their safety and freshness for consumption at the destination (Pusporini, 2020). In their study on perishable products which are highly temperature-sensitive, they stressed upon the importance of temperature monitoring throughout the chain (Haflioason, 2012). Lack of required storage facility could be a major cause of food waste (Biswas, 2014). As per Tsang (2018), performance of the CSC is reduced owing to improper or insufficient monitoring of temperature and other desired environmental conditions at distinct steps of the chain.

In the developed nations, the event of food misfortunes is for the most part situated at the buyer end stage while in developing nations, the event of misfortunes in food is situated at the post-reap stage owing to lack of required infrastructural facility for transportation and insufficient knowledge with respect to the handling of perishable products. All this points to the need for investments in cold chain and various infrastructural facilities along with increased awareness about the security and quality necessities of food items (Goedhals-Gerber, 2020; Gustavsson, 2011). Improvements in cold storages, cooling facilities, use of reefers, information and knowledge sharing will contribute to not only enhancing CC performance but also in reducing food losses thus protecting the environment (Venkatesh, 2015).

According to Kumar (2021), lack of appropriate infrastructure results in the failure of the cold chain in delivering the product in desired condition to the consumer and therefore further resulting in increased wastage cost. A well-structured and appropriate infrastructure for a cold chain will contribute towards reduction of waste, environmental cost as well as operational cost.

Food loss & wastage is a resultant of incongruity between demand and supply and therefore depends upon factors like dearth of storage facilities and dearth of transportation facilities (adapted from Raut, 2019). 20-30% losses in F&Vs is owing to lack of logistics infrastructure, especially in a country like India (Singh, 2018). Quality of food products depends upon the processing, storage, packaging and transportation facilities. As per a study done by UN FAO in 2015, occurrence of food losses is due to inadequate logistics infrastructure (Goedhals-Gerber, 2020). Temperature breaks and disruptions in CC can affect the quality of a product (Jedermann, 2014). Even the type of packaging material used can influence the product quality (Singh, 2016). Even Gardas *et al.* in their study in 2018 suggested that lack of storage facilities, lack of packaging facilities and thereby inadequate infrastructure are the three main causes for post-harvest losses.

Traceability Issue (TRAC)

The information regarding product batches or lots is identified, recorded and processed and this process is known as traceability. The information is stored as TRUs (traceable resource units) and then shared across the supply chain. The traceability in agri-food chain represents the acquisition, storage, maintenance, distribution and sharing of information to the chain stakeholders with respect to the status of process along with the product (Antonucci, 2019; Costa, 2013). Traceability can be measured through four aspects: precision which is the extent to which information related to product movement or characteristics is available; breadth which is the attributes' extent covered; depth which is the extent to which information is covered upstream or downstream; and access which is the speed at which traceability related information is communicated to the members (McEntire, 2010; Golan, 2004).

Dabbene *et al.* (2014) in their study have mentioned that traceability to a certain extent is followed by the companies in terms of mentioning information related to ethical issues, absence of GMO (genetically modified organisms), organic production methods and/or other environmental related information. The ISO in its 9000 series regarding quality management systems has included traceability concerning standards; ISO 22000:2005 related to food safety requirements. ISO 22000:2007 relates to traceability system design and implementation principles and fundamental requirements while ISO 22000:2008 introduces the concept of identification of the product. Some other standards

(15418,15434,15459,15962,15961,24791) consider regulations regarding RFID and barcodes. In addition, there are certain commercial standards: GSI, GlobalGAP and BRC for commercial purposes (GSI US,2013; GlobalGAP, 2013; BRC, 2013). The study also suggested the significance of traceability coupled with HACCP, etc in enhancing the performance of the entire SC.

According to a study by Bosona (2013), driving forces for traceability for food products are: regulatory, safety, social, quality, technological & economical concerns. Traceability can help achieve benefits such as: improvement in food crisis management; increase in consumer satisfaction; contribution to sustainability; improvement in SC; technological and scientific contribution and competence development and while following are the barriers to implementing extensive traceability: scarcity of resources; want of information availability; absence of uniformity; absence of integration; scarcity of trained manpower; lack of awareness and willingness.

Traceability can be best enabled through implementation of information system that with the help of various techniques and technologies ensure reduction in food losses. The techniques may include: real time monitoring of essential product conditions and required environmental conditions ; accuracy in inventory counting (Bertolini, 2013); quality and history of products (Balbino-Alfaro, 2019) and distribution planning based on the remaining shelf life (Jedermann, 2014).

An effective traceability system can offer complete transparency and visibility of food right from the farmer till the retailer. The chances of degradation of food reduces owing to constant monitoring at various stages of the SC. It ensures movement of only good quality food across the chain (Farooq, 2016). Proper implementation of traceability in a cold chain will not only result in improvements in food safety and quality but will also link suppliers, manufacturers/processor, distributors and can help reduce recall time and efforts along with achieving cost reduction and sustainability (Óskarsdóttir, 2019).

Traceability is a vital issue that has to be tackled for improved performance and reduced food wastage. As per a study done by Manzini (2013), a highly effective traceability system is significant for managing the safety & quality risks and also for promoting the progress of effective CC management. Traceability is connected to both quality and security in the mind of buyer (van Rijswijk, 2008). Traceability is actually a preventive strategy for safety and quality management of food products.

According to Opara (2003), having a good traceability system in place will help substantially during product recall or when determining the liability especially when there are occurrences of food scares or hazards. Traceability can result in value addition to quality by identification, verification and isolation of those aspects that are reasons for noncompliance to customer expectations and agreed standards. An effective traceability system must be able to determine product traceability i.e. actual area of the item; and process recognizability for example process type and sequence that has influenced the product. Hence, there is an emerging need for information that is transparent with respect to the quality of the whole chain maintained by effective traceability systems (Aung, 2014). Customers now look for food not only of high quality but also ones that possess safety guarantee, integrity and transparency especially because of the occurrence of many food scandal incidents. And the quality as an attribute of a food product changes continuously right from the point when it leaves the farmer to the time it arrives at the consumer-end thereby requiring real-time traceability (Apaiah, 2005). Hence, it is advocated that traceability is not just a means for improvement of food safety but also can be used strategically to enhance raw material quality as well as achieve strategic advantage.

Islam (2021) presented that traceability once enabled to include inventory counting, real-time monitoring; communication of quality and history of products and product distribution planning based on shelf life can contribute to reduction in food losses. Identification of temperature changes taking place during transportation and storage is very important so that consumers can receive good quality products and traceability can help identify these changes (Zhang, 2009). Wang and Li (2006) highlighted that integrating traceability functions with processes of supply chain management is important for traceability information to possess the ability to improve as well as manage business processes. An effective traceability system will also help resolve a problem related to food safety (Ruiz-Garcia, 2010)

Sustainability Issue (SUST)

Since a few years there is lot of research and focus on SC's sustainability leading to the term Sustainable SC. The term Sustainability appeared first in 1713 in the German forestry industry during wood supply shortage period in Europe and later post-oil crisis in 1973, when concerns related to uncontrolled industrial growth, population growth and non-renewable resource depletion increased. As a result, focus shifted towards preservation and planting of more tree and forest conservation (Du Pisani, 2006). And now, sustainability is a challenge amongst the top ten global concerns that are still unresolved (Global Agenda Council on Climate Change, 2018).

Few years back, cost leadership and profit enhancement were the area of emphasis for SC management. But, with the increase in depletion of resources and degradation of the environment the emphasis on sustainability is also increasing and so the concept of SSC (sustainable supply chain) (Taghikhah, 2019). As per NielsenIQ's (2020) study, in order to re-awaken eco-friendly practices, there will be a shift towards purchase of sustainability-focussed products (Charlebois, 2021). Owing to the growing awareness and increasing concern for environmental, social and economic bearing on food production and consumption, there is additional pressure from social responsibility groups, consumer and agri-firms and policymakers to develop SSCs (Allaoui, 2017). Hence, considering the responsibility towards the society and the environment, it becomes important to tackle the issue of sustainability. According to Seuring (2008), SSCM is characterized as "the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements".

Sustainability is generally said to be "the way the needs of the human beings can be met without compromising the ability of future generations to meet theirs" (adapted from Akkerman, 2010). As per a study by Hunter (2017), by 2050 there would be increased requirement of around 70% for agri-production. However, nearly half of it can be sustained by pre-dominantly slashing food wastage and losses that contributes towards reduced environmental impact.

So, sustainability needs to be made an integral component of decision-making process in the firms. In USA, 24% of the consumers are ready to switch to products offering natural-sustainable ingredients. Very soon this change in consumer preference will start affecting the entire globe and India will not be untouched. Packaging firms should minimize use of plastic packaging especially with consumer awareness against use of plastic growing. As per a study by Joshi (2020), European Commission reported that considering resource use at global level, the contribution of food sector is 23% and 18% towards greenhouse gas emissions.

The supply chain is said to be sustainable when as per the TBL theory it fulfils social, environmental, and economic requirements of the SC, the main aim being reduction of waste or minimization of food losses. Owing to globalization, food today travels long distances and that leads to increase in carbon footprint. The more duration the perishable products remain in the cold chain the more is the consumption of energy. Such perishable products will be unsafe as the quality will deteriorate. Safety & quality of these products leads to understanding the need and importance of CCM for FFP. Using a sustainable CC will help in reducing adverse impact on environment, reduce food wastage and losses, increase consumer satisfaction and also lead to an increase in profitability and reputation.

The social aspect of sustainability is linked to well-being of the human beings including dimensions of food security, health, quality of life, etc. (Farooq, 2016). Hence, it is important to safeguard food safety & quality for the health of consumer ultimately for the sustainable social development in food sector.

The management of cold chain requires critical temperature control and quick responsiveness when fluctuations or disturbances appear in temperature or when time delays occur. Hence, proper visibility and control are needed. (Bogataj *et al*.., 2005). Safety, quality, logistics efficiency, sustainability must be controlled for not just the food products but even for the processes throughout the food supply chain (Manzini & Accorsi, 2013).

Jermsittiparsert *et al.* (2019) in their study re-iterated that many firms in the developed countries have adopted the Green SCM (GSCM) to achieve competitive position and improve performance however it is still an area of serious concern in developing countries like India. An effective GSCM tends to achieve its objectives through efficient logistics, making availability of the products/ services to consumers at the right time, social progress, collaboration between customers and its suppliers, reducing communication barriers and time taken in the process of decision-making. Fig 2.9 presents a Green SC where Green Manufacturing, Green procurement, Green logistics, and Green distribution are accommodated to reduce wastage and adverse environmental impact.

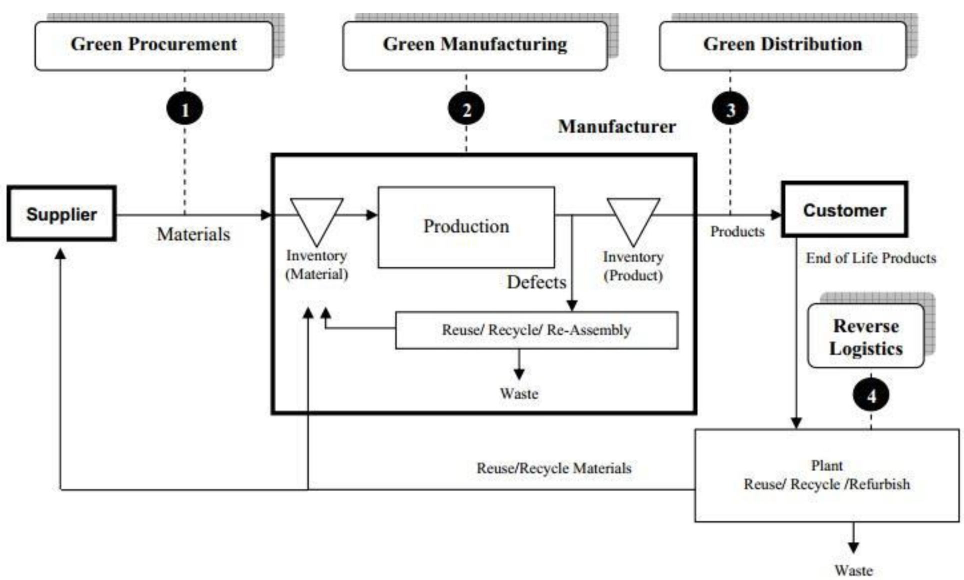


Fig 2.9 Green SC [Source: adapted from Jermsittiparsert, 2019]

Green procurement can be achieved by selection of suppliers based on their performance related to the environment. The firms can encourage and provide support to the suppliers by helping them improve their sustainability performance through development of environmental management systems (Noci, 2009), complying with the legislation, sharing environment related information and meeting the required standards and compliances. Green logistics is when the product is supplied to consumers using raw material that is environment-friendly (McKinnon, 2010) and the process of return, repair, recycling also is environment-friendly. The various aspects to achieve green logistics are: use of vehicles with low emission, efficient scheduling and transportation, environment-friendly packaging (McKinnon, 2010; Aziz, 2016; Chung, 2011). Government has intervened and developed various incentive programs and regulations for encouragement and adoption of green practices by the organisations. As a result of the different legislations and acts passed by the Government for green SCM, organisations have started to put efforts towards greening the chain. According to Gereffi *et al*. (2005), efforts towards sustainability need to be put in four distinctive areas: certification schemes; initiatives pursued; code of conduct; and audits. The sustainability program of a firm needs to consider both external activities in the SC as well as internal activities.

Initially the SSCs were only considered from the TBL perspective but later on recycling and reuse (borrowed from the concepts of circular economy) augmented the sustainable concept. And then followed the need of implementing green production, green packaging, green marketing, green distribution, waste management, etc. When contrasted with developed economy, in India which is a developing economy, the most important sustainability dimension is social dimension and the least important is environmental dimension (Kumar, 2019). For developing a good image and customer satisfaction, possessing certifications is a significant means (Ali, 2018) apart from following of regulations.

Food processing, transportation and cold storage cause about two-third of total HFC (hydrofluorocarbon) emissions (Saif, 2016). As per the IPCC report (2015), energy-related emissions, a cause of global warming, can be reduced to < 2℃ above pre-industrial point by simply substituting with responsible energy consumption along with increased consumer awareness on sustainability (IPCC, 2015). As per data estimated, cold chain is imperative for approximately 40% of the entire food and for the maintenance of cold chains around 15% energy consumption takes place globally (Coulomb, 2008) and therefore putting efforts to reduce consumption of energy in the CCs is a grave concern.

As per a study done by Manzini (2013), it is imperative that models and decision support systems are developed that have natural, social and financial aspects integrated. The performance and sustainability measures need to be collected in a continuous manner while the food product journeys from the stage of harvesting to that of consumption. This will help quantify environmental impacts, cost contributions and social effects. Hence, sustainability is an imperative and an important challenge for a sustainable growth and development. In their study Kumar, Tyagi & Sachdeva (2021) indicated that consumption of energy is the utmost serious criteria and that energy consumption must be considered as a crucial factor while considering the performance of a cold chain.

According to a study by Azmi (2017), decrease in energy utilization and food loss across the various phases of the CC will prompt improvement in cold chain economics as well as contribute environmentally. Energy consumption because of CSC is a serious factor requiring consideration while measuring performance of the chain (Gallo, 2017). A sustainable supply chain can help in waste reduction and increase in efficiency of the chain (Joshi, 2020).

Food production and consumption widely influences the society economically, socially and environmentally (Aung, 2014). Food that is unsafe for consumption results in serious and life-long ailments and affects the public health at large. This levies a huge burden on the health-care of the public and drastically reduces economic productivity of the people and the nation at large. Also, the food chain requires solutions that are more ecology-friendly for achieving reduction in adverse environmental impacts. Prior studies on the sustainability of food products indicates a positive bearing on quality perceived by the consumer (Park, 2015). Consumers especially post-pandemic will tend to shift to products that are sustainable (Charlebois, 2021).

In a study by Mangla *et al.* (2018) on sustainability of food chains, there were six enablers: pressure by government and NGOs; consideration of stakeholders and customer requirements; support of agencies and provision of incentives for undertaking sustainable initiatives; comprehending the significance and advantages of sustainability initiatives; involvement, commitment and support of the management; audit and monitoring of the continuing SC activities were suggested as influencing indicators while resource allocation; information sharing; planning, combined efforts, and capacity building to deliver sustainability for products; cost effectiveness; competitive advantage; and improvement in all-inclusive performance were classified under the influenced cluster.

Gallo *et al.* (2017) in their study suggested that the overall energy consumption is assessed basis the following: mode of transportation used and vehicle type; energy consumed during movement of products depending upon distance travelled; energy consumed for maintenance of warehouses and vehicles at the desired temperature range where energy consumption will be low if temperature is similar to temperature outside however different products required different ranges for preventing deterioration; energy required during processing, packaging and storing; and finally the energy consumed by products which deteriorate and result in wastage and losses.

The various factors pushing firms for pursuing sustainability as a strategy and implementing practices relevant to sustainable supply chain management are: external factors like regulation, social and environmental issues, brand image, firm reputation, consumer demands, pressure from other chain partners; and internal factors like welfare, values of the organisation and cost reduction (Walker, 2008).

Integration Issue (INTG)

According to Gulledge (2006), integration refers to processing of relevant data for a set of business processes by software, updates reflected throughout the process and real-time sharing of data across all business processes. Integration helps focus on instantaneous sharing of information with external entities, typically customers, suppliers, etc. ensuring appropriate security measures in place. The study indicated that integration could be: database-to-database integration; data warehouse integration; point-to-point integration; application server integration; enterprise application integration; and B2B integration. With the aim of conducting the current research, the emphasis is more upon B2B integration as it will make collaboration of cold chain stakeholders smooth and effective.

The integration of a SC is the practice applied by organisations in strategically collaborating with other partners in the chain (Ali, 2017). When applied as a strategy, inventory network joining is the course of joint effort and cooperation through practices ensuring food integrity (Basnet, 2013). The integration of a SC is the linkage, coordination of processes, information, people and knowledge, alignment and strategies amongst the various associations of the chain for optimized movement of products (Stevens, 2016). Owing to the asymmetry of information sharing at distinct nodes, it results in inefficient SC. It is only with the use of modern technologies that the complete potential of the SC can be understood and integration can be achieved through real-time sharing of information thus also reducing uncertainty in the system. It is crucial to sustain the integrity of CC logistics to help reduce food wastage and losses which is possible through transparency and sharing of data between the various cold chain stakeholders (Han, 2021). Synchronization between the different firms in the network entail data communication and sharing between those firms.

With customer demands increasing in various dimensions, the future lies in integration of different links of a cold chain. A cold chain when well-integrated will help in controlling the levels of safety, quality of food products and sustainability and performance of the chain (Manzini, 2013). A robust collaboration and integration are required between the government, main organisation and other chain partners to provide availability of CC infrastructure (Pusporini, 2020). For optimizing the performance, desired level of interaction and sharing of information between the cold chain partners is required (Peng, 2020). Mohanty and Shankar (2019) emphasized upon integration of all the partners for enhancement of CSC performance. Halloran (2014) in their study emphasized upon the high significance of the presence of a system supported by high level of information sharing and coordination within the supply chain to achieve reduction in losses. A supply chain can be effective when it enjoys intra- and inter-organizational relationships along with diverse levels of collaboration (Mena, 2009). The collaboration between retailer, distributor and producer needs to be highly efficient for an effective movement of the product without deterioration of quality of the product (Akkerman, 2010). A crucial factor for a sustainable cold chain is efficient and effective coordination amongst the different participating nodes involved in the cold chain (Gunaratne, 2020). Richey (2009) also had re-iterated that even though maximum decision-makers realize the critical significance of integration of the supply chain but very few have actually adopted it. According to the study, the barriers to integration were failure in internal planning and in external monitoring. The scenario remains the same even after so many years especially where cold chain sector is concerned in India.

Safety and Quality Issue (SAFQ)

The safety and quality of a supply chain is considered in an implicit way and so there is significant influence upon every one of the partners considering the society and the general ecological environment in a direct or indirect manner (Manzini, 2013). For maintaining customer satisfaction, food products that have the desired attributes and appropriate quality should reach the consumers and this level will decide the type of production process, distribution, transportation or quality systems used (Trienekens, 2008). Food safety and quality can be achieved, either through standards/certifications and regulations or through operations/production, logistics and storage processes and this together will help build customer confidence (Hong, 2011). Undesirable quality of food results in food wastage by the consumers or retailers (Ndraha, 2018). The quality of food gradually deteriorates and hence there is increased focus on deriving different attributes of food products in order to estimate the rate of deterioration which will help estimate shelf life (Giannakourou, 2020).

Safety and quality are two very important issues because if they are unidentified, then consumption of such products may result in social and financial loss. It is therefore extremely crucial that refrigerated store network or cold inventory network is used for providing safety from biological degradation and losses in food products (Raut, 2019). According to the GCCA year 2018 report, which surveyed around 200 food firms in 14 nations, food organisations consider CC providers as their brand extensions and they are also the chief performers for ensuring safety of food. The top response amongst various others with reference to the question about amongst the topmost business trend which will have maximum influence on their firm, was "food safety and protecting the brand" ("Customer Demand", 2018). This clearly reflects on the importance being given to food safety. Facilities like back-up electricity, alarms, incident alertness and security are the important safety and quality requirements of a business operation in a cold supply chain (Yuen, 2017). Reefers (refrigerated vehicles) are an essential requirement in the logistics of cold chain for ensuring food integrity when it is transported.

Awareness & Handling practices Issue (AWHP)

Just as safety and quality is an important issue to be dealt with, so is awareness and handling practices which contributes to safety and quality along with responsiveness, etc. Improper handling of the food product can result in texture and the quality of products getting damaged. One of the critical elements of a cold chain are people who must execute procedures correctly keeping the safety and quality intact. They should be able to take suitable actions in the incidence of a problem. The people involved must possess the knowledge and requisite skills in order to carry out the various processes properly and also have a good understanding of maintaining and enhancing the entire operation. According to Christopher & Towill (2002), it is the final consumer who actually determines the failure or success of cold chains. It is also necessary that the tools and technologies to be used by the people are easily accessible, user-friendly, reliable and flexible so that there is no reluctance in using them (Eddie, 2001).

The handling and manufacturing practices presently used at processing facilities, storage facilities, at suppliers or retailers need to be improved for improved preservation of the food product across the chain (Mercier, 2017). If sufficient training is not provided, it can lead to poor quality making the product unsuitable for usage and hence it has effect on the global market as well. Training the personnel will help improve the cold chain performance (Sainathan, 2018) as it will bring about increased awareness about latest techniques, technologies used, and improved practices. Training to improve the awareness and knowledge of personnel is a primary factor for enhanced cold chain performance (adapted from Kumar, 2021. UNFAO reported in 2015, incidence of food losses is due to inadequate knowledge of handling of perishable products (Goedhals-Gerber, 2020). As per the study, occurrence of losses in food is due to inadequate logistics infrastructure (Goedhals-Gerber, 2020). A high amount of losses in food products is the result of improper handling, unsatisfactory training for manpower in the cold chain and of course shortage of appropriate facilities (Ndraha, 2018). Lack of appropriate training provided to the handling staff as well as insufficient awareness of the consumer can result in the product getting damaged with respect to its texture and quality (Rathee, 2019).

In a study, Morelli (2012) suggested that the handling practices including various protocols for placing products on appropriate shelves, adequate and appropriate preservation are central to effective operation of the CC. The temperature profiles collected of refrigeration units in the study indicated that in 70% cases the temperature was above the threshold of safety requirements. Even if the temperature requirements were met, the handling practices indicated that the recommended safe points were not being considered properly.

Operational knowledge gained is implemented through the handling practices which when adequate delivers consistent results, like proper placement of similar and dissimilar products. Inadequate or inappropriate handline practices can have and undesirable effect on the quality of products. Standardized handling practices and knowledge availability when combined are very effective in improving the cold chain performance. Knowledge is not simply awareness of the requirements but awareness of also the practices that need to be put into operation or developed or implemented to ensure product integrity. In their study on supply chain performance, Katiyar (2018) emphasized that lack of awareness, training and lack of technology implementation and usage are amongst the significant barriers to SC performance.

In developing countries like India, though being agriculture-intensive economy, farmers' lack of awareness and knowledge is one of the prominent issues for a sustainable FSC others being lack of technology deployment and lack of government policy (Sharma, 2019).

Though the operational consideration of use of refrigeration units for preserve the CC are present but the relevant knowledge requirements for appropriate selection and operation of these units is inadequate (Blackhurst, 2011). Therefore, for achieving improvement of the cold chain performance as well as reduction in wastage, the staff handling the produce/product needs to have the desired awareness and requisite training regarding the storage period, storage space volume, optimum temperature range to build the manageable time span of usability of the item during packaging, storage or transportation (Kumar, 2021).

Responsiveness Issue (RESP)

Responsiveness is directly proportional to customer satisfaction. Hence, it is a significant issue to be tackled. Donk (2007) defined responsiveness by the pace at which the system can modify its products, product mix, volume and delivery with response to customer requirements. It is a crucial factor in developing a competitive advantage (Yu, 2001). Firms formulate strategies to enhance responsiveness towards customer requirements by delivering variety of products with reduced lead times. Aramyan *et al.* in their study in 2007 indicated responsiveness as a SC performance metric along with quality and total cost. Responsiveness is a very vital aspect for customers especially on e-commerce platform (Charlesbois, 2021). The food supply chain can be evaluated on the basis of its flexibility and responsiveness amongst other factors (Moazzam, 2018). Dreyer (2015) also in his study emphasized the magnitude of responsiveness in food chains. In their study, Jothimani and Sarmah (2014) defined responsiveness as “the velocity at which the SC provides products to the customer” and used order accomplishment lead time as metric for responsiveness. With the demand for perishable products on a constant rise and the increasing usage of e-commerce sites coupled with consumers expecting lower lead times, cold chain will certainly see a marked increase in its operations. There is huge pressure from the customer demanding for reduced order lead time along with recurrent delivery of products in small quantities. This initiative for ‘quick-response’ mainly comes from the supermarket which account for a major percentage of the sales.

According to a study by Singh (2015), the different and independent players in the cold chain need to coordinate to ensure responsiveness towards market demands. Responsive supply chain ensures lead time reduction, reliable service, speedier response and improved flexibility. In fact, owing to lack of responsiveness firms are not able to compete globally or sustain global competition. The study listed critical parameters for a responsive SC some of which are as follows: data sharing among individuals; cooperative decisions; utilization of data innovation; composed SC; collaboration; lead time decrease; and responsiveness.

Research Gaps in Theme 1

- Literature indicates that there are a few studies on SCs for food products. Mentioned studies are on general context.
- There is a lack of studies performed on supply chains specific to food products especially frozen food products.
- There is an absence of studies that intends to enhance understanding on integrated perspective of various issues existing in the SC of food products.

- Studies have considered either cold chain in general or frozen foods in general. There are not many studies considering cold chain of frozen food products.
- There is hardly any study done on cold chain for food products in Uttarakhand region of India.
- There is hardly any study done which considers a synergistic view of the issues in CC of FFPs with the aim of achieving enhanced performance.

2.3.2 Major Theme 2: Literature on Cold Supply Chain Performance

SC's performance can be determined in view of level of customer service, lead time, cost and quality of products delivered through the chain (Towill, 1997). As per a study done by the Australian Food and Grocery Council (2013), in order to deliver and receive food products that are safe as well as of high quality, all the links in the chain must be able to ensure temperature requirements throughout the chain (Yuen, 2017). The grocery SC in UK has been said to be highly efficient in terms of movement of product from production to consumption and this it owes to the transformation from practices that were manufacturer and supplier-led to practices that were retailer-led, customer-focussed and high usage of technology (adapted from Fernie & McKinnon, 2003). The performance indicators suggested by Aramyan (2007) in the study were: quality, proficiency, adaptability, and responsiveness. In a study on evaluation of performance of a CC, Kumar *et al.* (2021) emphasized the significance of lowest environmental influence of the cold chain for achieving optimum cold chain performance. Energy consumption owing to the cold supply chain is a serious factor requiring consideration while measuring performance of the chain (Gallo, 2017). The system of refrigeration used in the cold chain is highly energy-intensive and hence sustainability becomes a great challenge and once this issue is tackled, the country will have a reduced carbon footprint with better quality of food products available at economical price (adapted from Bag, 2016).

In a study on food CCM, Shashi *et al.* (2018), highlighted the factors causing inefficient cold chain performance as: weak logistics infrastructure, lack of cool storages, not enough of reefers, not enough awareness about application of IT, inaccessibility of water and power, absence of scientific harvesting techniques, absence of coordination, high cost, lack of modern processing and packing methods, improper traceability, lack of expertise in the FCC, ill-advised taking care of, absence of farmers' schooling, absence of normalization, absence of data sharing, government regulation, large number of intermediaries, and lack of customer knowledge. The metrics used for performance measurement were: reduction in carbon emission, energy consumption, water consumption, food waste, solid waste, hazardous/toxic material use; shelf life; cooling rate; shipping accuracy rate; lead time; total cost reduction; green packaging; traceability; product quality and safety; recycling rate; machine breakdown; passive food cold chain rate; temperature monitoring errors; total cost; inventory levels; customer satisfaction; growth in market share; empty running; and fuel efficiency. Infrastructure and Integration were suggested to be key factors contributing to cold chain performance finally.

Titlo and Sopadang (2019) in their study highlighted that the factors affecting cold chain performance for export of a special fruit of Thailand were: safety & quality; cost; traceability; and responsiveness. As per the analysis done, safety and quality were found to be a highly important issue followed by cost, responsiveness & traceability in the descending order.

Mor *et al.* (2018) in their study on dairy SC, suggested following as indicators of performance: product marketing; management of supplier relationship; quality management; traceability systems; Responsiveness in shipment accuracy, order-fill-rate and on-time delivery of products; effective CC infrastructure; Information systems; production management; wastage management; and technological innovations.

Chaowarut in his study (2009) stressed that for analyzing the success of a SC and enhancement of its efficiency and effectiveness, the SC's performance needs to be measured by emphasizing on the metrics for measuring performance. The criteria using which the performance of products, processes, and services can be evaluated are known to be the performance indicators. As per the study, four perspectives were identified and analysed for performance measurement: customer; internal business; financial; and learning & innovation perspectives. Customer perspective was emphasised upon as being the most important and having a critical role in the SC's performance. Chen (2011) also highlighted that in order to measure the performance of a SC effectively, it is important to not only explore the internal structure but also focus upon the inter-relatedness of the chain.

There is an immediate linkage between the exhibition of a CC and food quality conveyed to the customer, a known fact with the retailers. The net present value can be hampered by the disorder in temperature or time-distance factors in CC and this could affect the complete performance (Bogataj *et al.*, 2005). According to Cohen and Roussel (2005), one primary basis for competition should be decided by the companies belonging to the SC. Quality & cost leadership are highly relevant when considering competition in the food chains.

Research gaps in Theme 2

- Frameworks or models have concentrated more on performance of Supply Chain in general and not cold supply chain for frozen food products in particular.
- Studies are done either on SC performance or on issues in supply chain or barriers to performance or on role of IT in enhancing performance, however, there is hardly any study done that analyses the issues in cold supply chain for frozen food products, with the aim of achieving enhanced performance.
- Maximum studies are conceptual or review studies and there are very few empirical studies on cold chain.

2.3.3 Major Theme 3: Literature on Suggestion of Solutions

Frozen food demand is being driven to a great extent by the changing lifestyles and dietary patterns (Sen *et al.*, 2019). Food industry can achieve competitiveness by selling products that are not only able to meet necessities w.r.t. the demand considering the quantity, quality and price but also helps a business increase its profitability, and thus thrive sustainably. However, owing to consumers quick and sophisticated changing preferences and demands, this sector's competitiveness is a challenging concern. To tackle this concern and still gain and/or sustain competitive advantage, the food industry has to accordingly respond and quickly adapt to the circumstances. Owing to the customer orientation of present-day, cold chains need to use strategies and solutions incorporating technologies for meeting their customers' value perception by accurately management of flow of materials, money, and information of right degree of consistency (Barney, 1991).

Cold chains, regarded as sustainable environments, protect the products from degradation, and keep them as fresh as possible. Each link in the CC, therefore, needs to keep the same level of integrity for the end customers by monitoring and controlling the parameters of the cold chain to keep up with the item life. The CC in disengagement or as a piece of a coordinated SC requires a greater need for using appropriate technologies to for extension of shelf life for advertising; staying away from over use of limit; diminishing vehicle bottlenecks in top long periods of creation; while keeping up with the general quality. The use of technology can be implemented in storage, quality control, transportation, packaging and quality control and can be considered as significant in effective production and distribution (Fernie, 2003). Use of various strategies and solutions incorporating ICT can contribute towards activities being monitored effectively.

One of the serious barriers in the advancement of agri-food area in the country is poor adoption of latest technology and modern tools of management (Mangla, 2018). Sagheer (2009) have emphasized that in order to make agri-food sector in the country more competitive, the supply chain should be one that is well-planned, well-designed and well-executed.

The delivery of perishable products needs to be on-time limited by its shelf-life period and IT-enabled cold chain management systems can make it possible. Using IT, monitoring of cold chain activities becomes efficient (Kakhki, 2019; Bosona, 2013); cost of food products lying in warehouses is moderated (Jagtap, 2019; Manzini, 2013); response time reduces and performance improves (Han, 2017; Th€oni, 2017).

Implementation of effective technology can also help increase the distance between the point where crop is grown, to where food is produced/processed to the point where it is actually consumed. However, this could lead to issues of trust in consumer's mind. But with full traceability of the product, the issue of trust can be overcome. Use of technology along with a supportive infrastructure can influence supply chain partnering (Beverly, 2002). The information system architectures need to be aligned with the information requirements of the organisation so that it can respond to the varying customer demands (Duclos, 2003).

Sustainability results from the optimal use of various logistics and supply chain techniques and technologies like GPS, GPRS, GIS, ICT and RFID. RFID's role is certainly an enabler from the worldwide-judged criteria of economic, environmental and social dimensions (Arora, 2018). Technology can help to maintain complete temperature traceability across the supply chain while leading to increased transparency, capacity to target the food waste directly and at the same also trying to increase security, safety, and integrity of global SCs (Badia-Melis, 2018). The study therefore suggested technological solutions using WSN and RFID, neural networks, thermal imaging, internet-of-things with the purpose of monitoring and controlling temperature across the global food supply network. The study also emphasized that it is when a combination of these technologies, rather than in isolation, are adopted then significant value and improvements in the SCM happen. Using wireless sensing networks and radio frequency identification technologies in a strategic combination can be of benefit to monitoring in the cold chain. IoT is a highly suitable platform to monitor the continuous status of perishable goods remotely in a CC (Luo, 2016). IoT along with wireless temperature sensors can measure temperature in real-time across the cold chain at affordable costs (Bouzembrak, 2019). It is possible to establish a traceability system for the agri-food SC by using RFID and Blockchain technology (Tian, 2016). Asadi (2014) also suggested certain important tools like RFID and time-temperature indicators for not only traceability but additionally for really looking at quality and security of the horticultural items in the chain. Loisel *et al.* in their study (2021) suggested use of AI & Ml to detect the point of occurrence of breaks and analyse their impact on the cold chain.

Chen (2014) proposed a RSCCS which used passive tags in place of semi-passive tags for cost reduction. A new application named as 2G-RFID System was applied for scalability and availability. Grunow (2013) suggested RFID as a cutting-edge technology to assist with bringing down wastage in perishable FSCs. Gogou *et al.* (2015) suggested use of software based on databases to help calculate status of the shelf-life while the product moves through different links of the chain. Farooq *et al.* (2016) in their research related to sustainability research proposed an electronic pedigree traceability system integrating the use of sensor technology and RFID to enable remote monitoring of agricultural food for preventing distribution of hazardous and adulterated food products. Tian (2016) established a SC traceability system for agri-food based on RFID and the Blockchain technology. The system thus established encompassed data acquisition and knowledge-management at each linkage of the chain thus monitoring, tracing and managing traceability for food product's quality and safety from source to the destination.

Parthasarthy (2017) in their research conducted experiment and field trials by remotely monitoring using cloud-based systems with the aim of tracking humidity, light and internal temperature of the containers along with alerts generated automatically. Application of such a system could improve real-time continuous tracking, automatic detection and alerting and geo & epoch tagging. Tsang (2017) suggested the application of IoT-based cargo monitoring system coupled with remote sensor applications for continuous checking and management of alerts while providing storage guidance effectively for a cold chain.

In their study on Machine learning techniques Loisel *et al.* (2021) pointed out how these techniques can be used for predicting the food quality on the basis of the changes in temperature of a CC. These techniques can also be used to predict the incidence of breaks in the CC based on the existing status of links or their prior history rather than mere detection of the breaks. On detection of a break, either the product can be destroyed or it can be transformed or moved towards a shorter chain. So, better decisions can be taken for enhanced checking of the quality and security of the product and finally efforts can be exerted for reduction in food wastage.

Wilson and Clarke (1998) suggested a software system to handle location, collation and dissemination of data holding traceability related information both locally and globally through the use of electronic communication and internet. Towill in his study in 1997 recommended the use of simulation models to examine the benefits of a seamless SC and emphasized that the flow of information is crucial for a seamless supply chain. Cheng *et al.* in their study (2001), proposed a model for e-business infrastructure to support SC activities in construction. They also suggested that a virtual network structure that can help improve communication, coordination and sharing of competencies as well as resources within organisations. Zhang *et al.* (2009) in their study described a temperature-managed traceability system using RFID , mobile communication and GPS. The results of the study indicated that usage of such a system could have significant influence on the quality and cost for the stakeholders in a SC. Xiao (2017) in their paper presented a quality and safety system based on QR code and WSN for the traceability of marine products in the CC logistics. Technology using wireless sensors could enable real-time data acquisition while QR code helped the workers, managers and consumers to assure quality and safety of the products through information, both static and dynamic monitored. Information sharing can help improve supply chain performance.

However, planning technology use is a strategic decision and hence the cost-benefit analysis must be done at the time of implementation of any technology. Improper choice of technology or technological solutions can affect operational performance negatively and result in economic losses for the organisation and inappropriate resource usage and allocation will have adverse environmental impact (Jadhav, 2009). Therefore, it is important to select appropriate advancements to meet the necessities that are well defined for the firm and supply network as well as help achieve enhanced levels of performance (Tu, 2021).

In a study done in 1998, Kinnon and Campell highlighted the requirement of studying the influence of pressures on the supply chain due to quick-response. They also suggested that changes need to be done connected with logistics & distribution to tackle the conflicting requirements of not only customers but the frozen food manufacturers as well. There have been many studies (Regattieri, 2007; Kelepouris, 2007) suggesting the requirement for a solid innovation empowered framework for the CC (Joshi, 2011). The study suggested automation through RFID, programmed assortment at creation point, geographic situating framework and advance bundling as solutions for working on CC execution. All the stakeholders including government and cooperatives; producers/processors; retailers; intermediaries; need to put an integrated effort in the planning and development of efficient, effective and integrated cold chain networks (Rathore, 2010). Such efforts will contribute towards increase in GDP; generation of improved employment; increasing wealth of farmers; increase revenue generation through exports leading to a richer and self-sufficient nation.

Studies under this theme focus on management and analysis of various strategies and solutions identified to mitigate the impact of issues in CSC of FFP upon CC's performance. As discussed in the previous theme, there are numerous issues in the cold chain of frozen food and as is apparent from this section that there are studies suggesting IT solutions but hardly any study with suggestions to overcome all the issues with a holistic view. Most of the studies have been conducted for the supply chain and few on cold chain of frozen food. Therefore, this section will help in understanding to what extent work has been done for improving upon cold chain performance and thus the persistent research gap.

Research Gaps in Theme 3

- There are studies on use of IT in supply chain but there is limited research on cold supply chain for frozen food products.

- There are not many studies on the role of IT and latest technologies in Frozen food industry that consider a combined view of traceability, food safety and quality and integration of different links of a CSC.

- There is dearth of studies focussing on overcoming issues while also suggesting solutions and use of IT in cold supply chain.

- There is limited research on cold supply chain for frozen food products focussing on overcoming issues while also suggesting solutions and use of technology in CSC which will help in achieving enhanced performance in cold chain and thereby reduction in food wastage and losses.

2.4 THEORETICAL UNDERPINNING

In this study, the Knowledge-based view, Stakeholder theory, Triple Bottom Line and the Network perspective have been considered towards theoretical foundation. The application of KBV hypothesis in the area of cold chain has critical commitment to enhance CC performance through availability and sharing of knowledge across the chain. Hence, this theory is exceedingly important considering the research problem. The Cold chain being an unorganised sector is facing major challenges owing to either absent or negligible stakeholder management along with poor inter-organisational relationships which are influencing the entire chain's performance. It therefore becomes important to consider the Stakeholder theory and the Network perspective for improved performance of not just one cold chain firm but the entire cold network. The TBL focusses on sustainability consideration and hence contributes significantly towards the research problem in the study.

2.4.1 Knowledge-based View

Knowledge development as a concept started in 1970s when information processing as a concept was used popularly. Information processing capacity is the volume of data utilized by an organisation for taking decisions for the success of the organisation (adapted from Craighead, 2009). Later the emphasis shifted towards understanding how organisations develop knowledge. And thereafter, knowledge development capacity came to be defined as "a firm's ability to create new knowledge and understand its impact on SC action and finally the firm performance". As per the study, knowledge, SC strategy and action are the main antecedents to the performance of the firm.

As a concept in management emphasizing upon organizational learning, Knowledge-based view helps equip firms with strategies aiming at competitive advantage as firms exist to produce, transfer and alter knowledge into competitive advantage (adapted from Curado, 2006). Owing to globalization, dynamic market, and technical advancements, there is need for continuous requirement of knowledge which also forms the basis of organizational learning. The availability of information and knowledge is imperative for enhanced performance. Hence, in the current economy, if an organization wants to be efficient and effective, it should be a knowledge-based organisation. Having such a view will ensure that the organisation is a learning organisation and so it will enable the firm to acquire and transform its capabilities to face the dynamic environments. In fact, as quoted by

Nonaka (2007), “ the only true lasting competitive advantage is knowledge”. Thus, it is knowledge that drives the new economic order.

Significant contributions were made to different dimensions for the development of KBV by Grant (1996), the dimensions being: evolutionary economics, organizational learning, innovation, firm competencies; and development of new products. The view thus emphasized upon knowledge-sharing, creating value through sharing of knowledge in both external as well as internal SC collaboration. Based on knowledge view, the influence of external and internal transfer of knowledge was investigated on the flexibility of a supply chain by Blome (2014). In their study in 2004, Hult, Katchen and Slater, drew attention to the fact that across nodes, coordination of knowledge helps in reducing redundancy, duplicacy, waste and ultimately leading to enhanced performance. They proposed a model depicting four components representing activities related to knowledge acquisition, memory, distribution of information and shared knowledge. The study also mentioned that knowledge being a significant strategic resource can help a firm achieve competitive advantage provided each player in the supply chain utilizes and shares its knowledge across the chain (adapted from Lavastre, 2014).

Piramuthu in 2005 mentioned that it is important that timely information is available across different stages of a SC and hence stressed upon the need for effective utilization of information for enhanced performance. In their study in 2004, Ketchen highlighted upon applying KBV in strategic management of SCM for an organization while explaining the impact of sharing of knowledge across the SCs on the outcomes of the firms involved. Craighead *et al.* (2009) did a study linking a phenomenon in the supply chain that was driven by knowledge, innovation-cost strategy and performance at the firm level. In a conceptual research, Dubey, Gunasekaran and Papadoupoulos (2017) used knowledge-based theory to propose Green Supply Chain Management framework.

Knowledge-based view coupled with information processing and sharing can result in better supply chain management (Hult *et al.,* 2004). According to a study by Patil and Kant (2014) on Fuzzy MCDM hybrid approach with FDEMATEL, knowledge management has a significant role to play in a supply chain as it supports efficient planning and resource utilization. Knowledge needs to be translated as a resource to implement GSCM (Dubey, 2017).

For ensuring food integrity, easily shareable knowledge across cold chain partners is required i.e. from manufacturers, processors, distributors, retailers and intermediaries to consumers (Gunders, 2012) . In absence of requisite knowledge, there is a risk of inappropriate handling of food during storage, transportation and distribution rendering it unsuitable for final consumption (Osorio, 2017). The study highlighted that the KBV emphasizes on acquisition, transfer, storage and application of knowledge which is essential for preserving the food product quality, reduce costs, retain customer loyalty and finally helps sustain competitive advantage for the chain members. It can result in efficiency of the chain to reduce disruptions across the chain (Blackhurst, 2011). Access to operational knowledge that is crucial for effective cold chain operations and help reduce disruptions in the cold chain and enhance its performance.

Knowledge in synchronized form is important specifically because the affiliates of the chain are not from one organization (Hansen, 2002). Thus, knowledge-based view offers a basis for the expectation that development and sharing of knowledge leads to enhanced performance of the cold chain and improved outcomes.

2.4.2 Stakeholder Theory

As defined by the Stanford Research Institute (1963), stakeholders are those individuals, firms, etc without whose support the organisation will not be able to exist (adapted from Boland, 2016). The study also highlighted that the stakeholder theory also emphasises upon the significance of sustainability efforts for the firms. The theory additionally also explains causal relationships; suggests practices constituting management of varied stakeholders. The essence behind the stakeholder theory is to embrace the opinions and obtain inputs from all those who have interest in the final outcomes of the organisation.

According to Drucker, in the modern business environment, the firms do not exist or compete as exclusive autonomous entities but their SCs also exist and compete (Habib, 2011). With this realization, identification of key stakeholders is extremely complex and the Stakeholder theory is very useful for the purpose, as suggested by Tate *et al.* in 2009. This theory was first proposed by Andriof, Waddock, Husted and Rahman in 2002 at the Stanford Research Institute (adapted from Lavassani, 2010). The process of identification and evaluation of groups possessing interests in the company and then formulation of plans for managing the groups is the essence of 'Stakeholder theory' (Sunita, 2021).

As per a study by van den Berg (2004), all stakeholders should be considered in the operation of activities in the firm along with decision-making and hence the theory addresses both processes at individual level along with an integrated view of the SC. It has a managerial perspective as it does not focus on just the present scenario or predict the cause-effect relationships but also suggests practices implemented in integrated manner resulting in effective stakeholder management.

As far as a supply chain is considered, the stakeholders are the logistics service providers, suppliers, government, distributors, employees, retailers, funding sources and customers. Firms which are able to manage stakeholders effectively perform better with respect to resource utilization, demand fulfilment, customer service and decision-making (adapted from Shashi, 2018). Hence, it is vital that appropriate strategies are executed for effective stakeholder management. Stakeholder management is categorized as one of the important sustainable CC practices amongst other practices being: risk management; cold logistics integration; technical integration; learning; strategic orientation; SC continuity and innovation (Singh, 2016). Bhattacharya and Fayezi (2021) elaborated on multi-stakeholder collaboration for reduction of food losses and wastage from the entire SC. The study explained how vertical and horizontal orientation resulting in collective stakeholder orientation can help mitigate food loss & waste.

2.4.3 Triple Bottom Line

The term 'Triple Bottom Line' was created by John Elkington in 1994. According to Elkington, "Sustainable development involves simultaneous pursuit of economic prosperity, social equity and environmental quality. Companies aiming for sustainability need to perform against the triple bottom line". The concept of TBL goes beyond that of Corporate Social Responsibility (CSR) and Sustainable development as it integrates the TBL i.e. social equity, economic prosperity, and environmental quality for conducting business considering its long-term impact (Arowoshegbe, 2016). Thus, the perspective promoted is that for sustainability, an organization or group should be: financially secure; eliminate or minimize adverse environmental impacts; and meet social expectations with all three being inter-related. Therefore, sustainability implementation requires a TBL approach (Ahi and Searcy, 2015), according to which developments are pursued in social, monetary, and ecological aspects.

Utilisation of resources and energy along with the trailing carbon footprint left by organisations because of their SC operations is referred to as 'environmental sustainability' which is generally related to energy efficiency, pollution reduction, emissions reduction, waste reduction, reduction in consumption of toxic materials, and reduction in the frequency of environmental accidents (Gimenez, 2012). According to Pullman (2009), the focus of social sustainability needs to be internal as well as external. Thereby firms are said to be socially sustainable when they offer impartial opportunities, promote connection within and outside the firm, are democratic in nature and ensure quality of life. Hence, environmental, social and economic considerations need to be mixed into the planning and work culture at all levels of the supply chain.

2.4.4 Theory of Network Perspective

Network analysis encourages a structure of inter-organisational relationships (Granovetter, 1973). In their study, Lazzarini (2001) introduced Netchains with the following definition: " a set of networks comprised of horizontal ties between firms within a particular industry which are sequentially arranged based on vertical ties between firms in different layers". The study therefore emphasized on inter-organisational collaboration and interdependencies (Thompson, 1967) with three kinds of interdependence: sequential interdependence, when a firms' activities precede that of another like in logistics; pooled interdependence, when each firm in the group contributes in a discrete and well-defined manner like in B2B transactions; and the reciprocal interdependence, when the firms involved have ongoing, simultaneous relationships like in partnerships and alliances (refer Fig. 2.10). While a SC focusses more on sequential interdependencies, Network analysis focusses on reciprocal or pooled interdependencies.

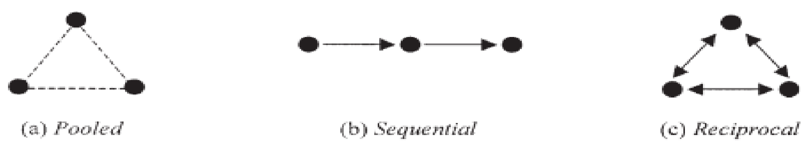


Fig 2.10 Types of interdependencies (adapted from Lazzarini, 2001)

Identification of Gap by Reviewing Literature on Theoretical Premise

- There are very few studies available on the application of knowledge-based theory for CSC and/or cold chain for frozen food.
- Knowledge based theory has been used to propose green SCM, however, use of this theory can be extended to CSC of FFP for enhanced quality, safety of frozen food products along with enhanced performance and innovativeness of the chain.
- The stakeholder theory has found application in the domain of SC and can be very effectively applied to an entire cold chain for efforts towards resolving issues of integration, sustainability, traceability, etc and hence the stakeholders can significantly help achieve performance and reduced food loss and wastage.
- There are many studies applying the triple bottom line theory in the Supply chain and production-related areas but not as much in CC of FFP.
- The network analysis is a very important concept in terms of application in the cold chain but there is not much literature on the same with respect to cold chain.

2.5 LITERATURE ON DATA ANALYSIS TECHNIQUES

Cox *et al.* (1997) in their study employed simple and hierarchical regression analysis to evaluate barriers to fruit & vegetable intakes. Lockie (2004) applied path analysis to assess demographic, attitudinal, behavioural and motivational factors that influenced the choice of food products. The study was done for organic food. Bechini (2005) in this study proposed a generic data model for transmission of traceability information in a safe and secure manner. They also suggested a modular suite of specifications over Internet applying which the enterprises were able to conduct business in an easier and efficient manner. Rijswijk *et al.* in their study in 2008 applied Hierarchical Value Map and arrived at the results indicating that quality and safety were related to traceability and help in enhancing consumer confidence.

Piramithu (2005) developed a framework for automated SC configuration using machine learning, and proposed that with developments in internet and ecommerce applications, dynamic configuration of supply chains could lead to performance improvements. Bogataj *et al.* (2005) used input-output analysis, MRP approach and Laplace transforms to present the evaluation of retarded changes in the temperature in different stages of a cold chain.

In a study on CCM, Oliva and Rivetria (2008), adopted System Dynamics methodology, a modelling and analysis tool with the aim of tackling strategic issues for cold chains for meat products. It helps understand that with the passage of time, changes take place in a system and thus analyse relation between a system's structure and its behaviour. The study thus employed all-inclusive modelling exertions to arrest the extended SC enterprise strategically and thus help CCM optimization using new technological instruments.

Levai (2012) used chi-square test and cluster analysis to assess the then present situation of food safety and traceability. Mallik (2011) employed Anova, chi-square and t-test to examine the variations occurring in the status of CC once intervention was implemented as well as to assess the responsiveness of cold chain handlers w.r.t CC maintenance. Joshi (2011) developed a benchmarking framework using Delphi-AHP-TOPSIS based methodology to evaluate cold chain performance, identify strengths and weaknesses as well as arrive at potential alternatives for improvement. With the help of Delphi method, key performance factors were identified, synthesized and prioritized. AHP was used to gauge the CC performance of the company against its competitors. TOPSIS was used to examine the different alternatives for performance improvement. Efficiency, responsiveness, flexibility and quality are the KPIs for AFSC (Aramyan, 2007).

Rathore (2010) in his study suggested the need for integrated effort by all cold chain stakeholders towards an effective cold chain network. Such an effort would help country earn increased revenues from export, increased GDP, improved employment, wealthier farmers thus finally helping country become richer. Sagheer (2009) developed a framework using two management streams – Value Chain Analysis and strategic competitiveness with the aim of analysing Indian agri-food chain's competitiveness. In their study in 2011, Raab presented a model based on theory of linear programming with the aim of production & distribution planning while focussing on product quality. The model was based on food supply chain with a generic configuration for wider applicability.

Zanoni (2012) proposed a numerical model that helped understand relationship between quality, temperature and energy with the purpose of food supply chain optimisation. The study also indicated that the energy effort produced while maintaining and cooling the products has a vital role in the effectiveness & sustainability of the FSC. Bourlakis in 2014 conducted a comparative analysis for the chain partners of the Greek dairy. The analysis was done to monitor sustainability performance of whole chain and the individual members on the basis of key indicators namely , flexibility, efficiency, quality and responsiveness. The study used one sample T-test to discover those areas where the performance of a chain partner is considerable better or worse than chain average.

Joshi and Singh (2020) proposed a framework identifying factors that impact the implementation of sustainable agricultural practices in UK, India. The study used Principal Component Analysis for analysing the influence of the factors which were efficiency & flexibility; responsiveness; product reliability, convenience & characteristics; and environmental aspect and marketing. Mahajan (2013) in the study presented LAP-SAP model to analyse challenges of frozen corn processing and its SCM.

Jothimani *et al.* in 2014 in their study illustrated the application of integrated approach of FAHP, SCOR and TOPSIS in order to measure the performance of supply chain for the third-party logistics providers. Kumar and Agarwal in their study (2013) applied ISM (interpretive structural modelling) to develop mutual relationship among the empowering agents of e-applications in the Indian AFSC. The ISM was applied in order to exhibit a hierarchical model at multiple level exhibiting the enablers along with a digraph depicting the independence and driving power of identified enablers.

Sharma and Pai (2015) developed a model using Bayesian Network to study efficacy of CC. The model also depicted the interdependencies influencing the efficacy. In his study, Bag (2016) identified barriers to green cold chain management and also determined contextual and hierarchical relation between the variables affecting green CC practices. ISM (Interpretive structural methodology) was used in the study to construct directed graph while MICMAC technique was employed to categorize dependence & driving power of variables.

Ali (2017) established a conceptual model based on S-S-P paradigm with an aim of exploring relation between SC integrity, SC integration and impact of food integrity on firm’s performance. The SEM software was used for the purpose of testing the hypotheses and conducting data analysis. Osorio *et al.* in their study in 2017 developed a model with the aim of assessing the influence of knowledge in prevention of disruptions existing at the retail outlets. A knowledge-based perspective was used to conceptualize the way cold chain disruptions impact the quality and safety of food products sold at retail outlets. For estimating the likelihood of occurrence of cold chain disruption at the outlet SEM was used.

Song *et al.* (2017) used statistical technique of stepwise regression to explore the influence of inter- and intra-food SCQM on the quality and security of food items as well as the impact of food SC on both domestic and export performance. Gardas in 2017 modelled the performance indicators of GSCM in agro-sector by application of ISM methodology with the aim of establishing interrelationship between PIs as well as identify the PIs having high influential power.

The research carried out by Shashi *et al.* (2018) using a 5-stage performance measurement model aimed to investigate the dependence of complete FSC performance on the partners' performance. The analysis was done using SEM to highlight that performance of the producer has positive impact on performance of supplier, processor and the distributor. The study proposed a conceptual framework consisting of five factors: FCC integration, infrastructure, value addition, stakeholder's interest and partner's performance. The relationships between these factors and their effect on the food cold chain performance is exhibited.

Joshi (2018) utilized a coordinated numerical demonstrating way to concentrate on the impact that biological as well as cold chain parameters have on mushroom's quality throughout the distribution supply chain. Pool, Doosti and Mortazavi in their study in 2018 adopted the TOE and TAM as a theoretical base to propose a model tested for usage of RFID. Structural Equation modelling was used for testing and analysis.

Gunaratane and Jayaratne in their study in 2020 applied analytical methods like EFA,CFA and SEM technique to derive the relationship between the factors facilitating sustainability of the cold chain. Wu (2019) proposed a novel computational method by merging virtual CC with optimizing logistics of CC after harvesting is completed. Such a holistic approach helped not only track cooling process's thermal history and the decay of product throughout the chain with the help of computational fluid dynamics but also helped quantify the carbon footprint of the chain.

Kamble, Gunasekaran and Gawankar in their study in 2020, proposed an application framework to identify SC visibility and resources as chief driving strength for emerging analytics ability and attaining sustainable performance. Kumar, Singh and Modgil (2020) proposed a theoretical framework using PLS-SEM for testing as an outcome of analysis. The study investigated the role of ICT in agri-food SC while also determined the influence of SCM practices on the firm's performance. LR of few selected papers on the techniques used in the study are showcased in table 2.3 while Table 2.4 presents certain selected studies performed using SEM method.

Table 2.3 Studies on SEM, AHP, FAHP, FTOPSIS, DEMATEL and BWM

Technique	Authors
SEM	Sezhiyan (2011); Hox (2011); Westson (2006); Fawcett (2011); Dissayaneke (2018); Gawankar (2017); Nunkoo (2011); Masudin (2021); Hsiao (2016); Su (2021); Cruz (2009); Gunaratne (2020); Hsiao (2019); Ongsakul (2019); Bhatnagar (2021); Suhr (2006); Lin (2005); Awang (2016); Joshi *et al.* (2009)
AHP	Kumar (2021); Islam (2021); Pusporini (2020); Buyukselcuk (2020); Xiong (2019); Faisal (2011); Joshi (2011); Dissayaneke *et al.* (2018); Hossain (2020)
Fuzzy AHP	Raut (2019); Singh, Gunasekaran & Kumar (2018); Kashav (2022); Liu (2020); Leung (2000); Sun (2010); Kahraman (2003); Kutlu(2012); Yang (2004); Ghosh (2022)
FTOPSIS	Sun (2010); Kutlu (2012); Zandkarimkhani (2020); Kozarevic (2018); Singh (2018); Wang (2014); Ghosh (2022)
DEMATEL	Khan (2018); Prakash (2021); Chandra & Kumar (2019); Gardas (2018); Susanty (2020); Hossain(2020)
BWM	Salimi & Rezaei (2018); Khan (2022); Lau (2021); Wen (2019)

Table 2.4 Few Studies on the SEM methodology

S.No.	Author/year	Analysis & Modelling technique used	Context of application
1	Sezhiyan (2011)	SEM	Relationship among logistics competences, supply effort management, and SCM strategies on firm performance
2	Hox (2011)	SEM	Introduction to Structural Equation Modelling
3	Westson (2006)	SEM	Guide to SEM
4	Fawcett (2011)	SEM	Influence of IT on SC performance
5	Dissayaneke (2018)	SEM and AHP	Relationship between SC performance and SCP management areas
6	Gawankar (2017)	SEM	Relationship between SCM practices and SC performance measures
7	Nunkoo (2011)	SEM	Concept of SEM
8	Suhr (2006)	SEM	Comparisons between “traditional statistical” and SEM analyses
9	Lin *et al.* (2005)	SEM	Factors influencing SC quality management
10	Awang (2016)	SEM	Compare performance of measurement scales
11	Joshi *et al.* (2009)	SEM	Inhibitors in cold chain
12	Masudin (2021)	SEM	Effect of managerial initiatives on food cold chain performance
13	Hsiao (2016)	SEM	Time-temperature information sharing
14	Su (2021)	SEM	Satisfaction of online retail consumers
15	Cruz (2009)	SEM	Effect of temperature abuses
16	Gunaratne (2020)	SEM	Sustainable cold chain performance
17	Hsiao (2019)	SEM	Capability for CCM
18	Gunaratne (2018)	SEM	Evaluation of Srilanka perishable CC
19	Ongsakul (2019)	SEM	Connection between retailer value, provider value, SC value, maker value
20	Bhatnagar (2021)	SEM	CCM for agro-based perishables

2.6 MAJOR INFERENCES DERIVED FROM LITERATURE REVIEW

- The two areas where research seems to be significantly growing are Sustainable transportation and cold chain for perishable food products.
- There is still scarcity of appropriate CC infrastructure and food processing units, improper supply chain management leading to high inefficiencies, high losses and huge wastage of F&V. Efforts can be made for reduction in wastage with better cold SCM. Food loss & waste reduction can be achieved by using proper Supply chain management systems and monitoring shelf life.
- Weak links in cold chain are: pre-cooling, ground activities during transportation, show at retail, and capacity in home fridges. Variations in temperature during movement of the product and handling practices are also areas requiring efforts towards improvement. After purchase, the movement and household storage are links that are extremely sensitive.
- A company needs to practice organisational learning and be adaptive and innovative in creating the practices that are relevant according to demand and its operational strategy, rather than simply duplicating the accepted practices of the industry. And so, they will not only be able to achieve competitive advantage but also contribute to reduction in wastage and losses of massive amount of food.
- Focus of consumers has shifted from price to food safety and quality. Consumer is ready to pay best price for quality and safety. Customer is a major force driving supply chain management activities along with suppliers, government and competitors. Better traceability may contribute to increasing consumer confidence. Hence, customer perspective plays the most important role for frozen food industry.
- In times to come, customers demand for exact information of the products they buy and/or consume will increase and food industry supply chain can utilize it for their competitive advantage.
- Frozen vegetables are best alternative in certain situations. Demand for frozen food will certainly increase to a great extent in India.

- Last link, the retailer, is extremely important in the cold chain. As a step towards fast adaptability to the dynamic environment, distributors and retailers must be able to revamp their supply chain management practices, strategies along with supply chain structures. The emergence and dominance of own supermarket-labelled products are not only signalling towards a noticeable alteration in the relation between consumers, producers, retailers and/or processors but are indicative of a larger change in the entire SC.
- With the help of information technology, traceability can help generate reliable information in the whole AFSC. This will effectively ensure food safety by collecting, transmitting and sharing real-time and accurate data during the different links, like processing/production, storage, distribution and sales, of a supply chain. IT can significantly contribute in resolving or mitigating most of the issues and significantly enhance efficiency and effectiveness of a cold chain while also ensuring faster and increased responsiveness. Use of Information Technology not only contributes in making cold supply chain more efficient, effective but also contribute in increased responsiveness.
- Performance enhancement of a CSC will also help make the performance of the related firms better.

2.7 MAJOR GAPS DERIVED FROM LR

Following gaps were evident on the basis of literature studied:

- Studies have considered either cold chain in general or agri-products. Not much attention has been given to frozen food. Extensive research needs to be conducted in this area with respect to food quality and safety, food wastage and losses, and performance of the cold chain. Various issues, and challenges need to be identified in cold supply chain of frozen food.
- Frameworks or models have concentrated more on performance of Supply Chain in manufacturing sector/pharma related CC but there are very few studies on entire CC of FFP.

- Most of the studies have been conducted considering a specific issue of cold chain like infrastructure, logistics, traceability, sustainability, etc. and are conceptual or review studies with very few empirical studies conducted.
- Most of the studies have focussed upon SC performance or on issues in SC or barriers to performance or on role of IT in enhancing performance. There is hardly any study done considering both issues and strategies and solutions to overcome these issues together. In case any study is done, it concentrates on specific issue category and discusses only IT solutions. Hence, there is no study done suggesting solutions, both IT and Non-IT.
- No study has applied integrated framework of SEM, AHP/FAHP, DEMATEL, FTOPSIS
- Role of advanced technologies need to be studied to assure the quality of perishable products along the supply chain. An intelligent cold supply chain can help in overcoming issues and challenges.

Thus, there is limited research on cold supply chain for frozen food products focussing on overcoming issues while also suggesting solutions and use of technology in CSC. This together will aid in achieving enhanced performance in cold chain and thereby extensively contribute towards reduction in food wastage and losses.

2.8 CHAPTER SUMMARY

The key objective of chapter two is to conduct exploratory study based on relevant literature which helped to recognize gaps in research. The various writings were reviewed on the basis of three major themes: Literature on understanding the cold chain of frozen food ; literature on the SC performance; and the literature on suggestion of solutions. For each theme, the research gaps have been discussed. The chapter also has a section on the theoretical underpinning and how they can contribute in overcoming the issues in cold chain. Also, a review of literature is done on the techniques utilized in the assessment of issues in the cold chain. The next chapter shall focus on the RM adopted for the study.

CHAPTER 3

RESEARCH METHODOLOGY

OVERVIEW

This chapter of the report portrays how the study is steered and the methods used in the data collection and analysis. According to Murray and Hughes (2008), the general approach to the research process is referred to as 'methodology' whereas the different ways in which data is collected and analysed is referred to as 'methods'. The questionnaire designed has also been discussed in detail here along with the methods applied for collection of data.

3.1 RATIONALE FOR THE STUDY

The value of Indian frozen foods which was estimated to be Rs 74 billion in 2018 is likely to touch in 2024 to the value of Rs 188 billion with the compounded annual growth rate expanding approximately 17% considering the period 2019-2024 (Goel, 2020). As the awareness towards frozen food products as products being easily available and brand that can be trusted, one can see such products gaining in popularity. The situation for Indian frozen food industry is projected to develop by 17% every year during 2020-24 as the Corona infection pandemic has settled on individuals cognizant about solid decisions while purchasing daily essentials (Goel, 2020). Hence, it would not be incorrect to assume that consumers are going to shift towards products that are safe and pure and towards manufacturers that not only produce products that are clean and safe but also give importance to safe handling of products and processes and are responsible towards the impact on the environment. In times to come, frozen food product consumption will certainly rise in India. A similar inclination is visible even in the Asian markets. However, growth in frozen food is not only due to Covid-19 but also due to the large influence of

Western culture because of which lifestyle and food habits have changed. Even the competitively growing e-commerce sector lends a higher visibility to such products as compared to the brick and mortar stores. Also, because of the growth in organised retail sector frozen food products have been made easily available to the consumer. Thus, shifting shopping patterns, changing psychologies and, shortage of time owing to hectic lifestyles with more disposable income being available are surely going to lead to higher demand for frozen food products.

Even though generally frozen food is consumed owing to convenience but a general perception of the consumer is that the frozen food product is unhealthy. Fresh is assumed to be better, however, that is not the case always since the time taken from harvesting to final purchase may render the product non-consumable even though it may not be markedly visible.

Freezing can help extend the shelf life of the food product without the occurrence of any loss of nutritious components. So, the product does not lose its healthy attributes on being frozen. The healthy attributes of a food product depend upon the way and the conditions in which it has been preserved. So, frozen food can surely be given enough consideration and a practical alternative. Increased environmental consciousness related to products in general indicates a shift towards products that are environmentally safe.

However, the main challenge in front of the consumers and processors is saving the initial attributes of the food item. In present market, the frozen food comprises of frozen fruits, frozen vegetables, frozen snacks, and frozen meat items. Especially frozen snacks are preferred by the consumers. Such products, as they are available round the year, is also one of the reasons for increase in demand. Lifestyle and food habits that are seeing marked shifts, and rise in number of young working population will surely lead to a substantial upsurge in demand for frozen food products in India. Thus, arises the need for an efficient and sustainable cold chain.

3.2 PROBLEM STATEMENT

Firms participating in a Cold Supply Chain are not able to perform effectively because of the presence of various issues and challenges in the entire chain. The cold chain has many weak links, one of them being at the retail end. So, it is necessary to ascertain and examine the issues. Overcoming these issues along with usage of advanced technologies will help improve the performance of cold chain leading to reduction in food losses. Knowledge-based View, Stakeholder theory, Triple Bottom line and Network perspective has been used for studying issues and performance parameters for supply chain in general but it has not been used specifically for cold supply chain of frozen food products. In our study, these theoretical foundations shall be applied to understand the part of knowledge transmission, stakeholder collaboration, three dimensions of sustainability across the CSC partners for enhanced performance.

If the demand of Frozen food products, which are perishable in nature, needs to be increased then the issues existing in the CSC need to be overcome. The cold chain performance needs to be enhanced by resolving the issues existing in the cold supply chain of frozen food products.

For that purpose, a model has been developed to suggest solutions for overcoming the issues in cold supply chain and enhancing performance of cold chain of frozen food products and hence leading to reduction in food wastage and losses.

3.3 RESEARCH QUESTIONS

To address the gaps in the existing literature of cold chain of frozen food products, few vital research questions are considered. They are as follows:

- How the cold supply chain of frozen food products works in Uttarakhand and what are the issues and challenges present in it**?**
- How do the identified issues affect the cold chain performance?

- What will be the suggested solutions to overcome the issues for achieving enhanced performance of cold chain?

3.4 RESEARCH OBJECTIVES

The objectives of the present research are mentioned below:

- To understand the CSC of FFPs with special reference to the state of Uttarakhand in India and to identify the issues existing in the cold chain of the frozen food products
- To analyse identified issues in the CC of FFP w.r.t their influence on cold chain performance
- To develop a model and suggest solutions to overcome issues finally leading to enhanced performance of cold chain.

3.5 RESEARCH DESIGN

Research is defined as "systematic and scientific search for relevant information on a particular topic". As indicated by Kothari (2019), research configuration is characterized as "arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure". As cited in Fagade (2011), in light of the reason for research, it can be of three types: Exploratory, descriptive and explanatory. Exploratory study is used to investigate and explore the areas relevant to the problem. This technique therefore provides a brief understanding of the relevant area and is used primarily to arrive at the objectives for the study. Descriptive research is to depict and analyse characteristics of persons, events or situations. Explanatory studies help explain and establish causal relationships between variables by focussing on a problem or a situation.

Based on techniques used for data collection and analysis, approach to research can be qualitative or quantitative. Questionnaires as the data collection techniques and methods for analysis of data that use or produce numerical data are used in quantitative research. According to Bell and Bryman (2007), quantitative research is a deductive approach to research involving testing of hypotheses. Qualitative research on the other hand is a research that does not use statistical techniques or any other form of quantification for arriving at the findings. Hence, qualitative is an inductive approach to research where research is primarily exploratory and focus is on theory generation. The information assortment methods for Qualitative methodology are contextual investigations or semi-organized interviews.

In the present research, Exploratory study has been used to examine the problem area like the issues in CSC of frozen food; Descriptive research has been used for analysis of the issues and the extent to which they are present in the cold chain of frozen food; and Explanatory approach has been used to establish causal relationship between the issues and the cold chain performance. Thus, it is not only one approach that has been used in the study but a blend of these different approaches has been applied to have a synergistic and systematic view of the research problem. This research is quantitative in nature. Fig 3.1 displays the Research Process below while Fig 3.2 presents the Schematic flow diagram.

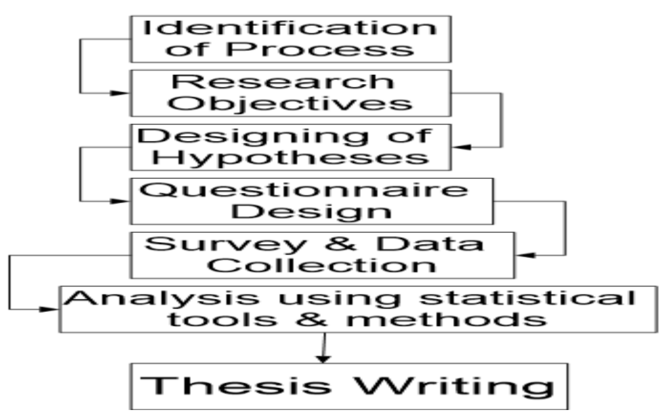


Fig 3.1 Research Process

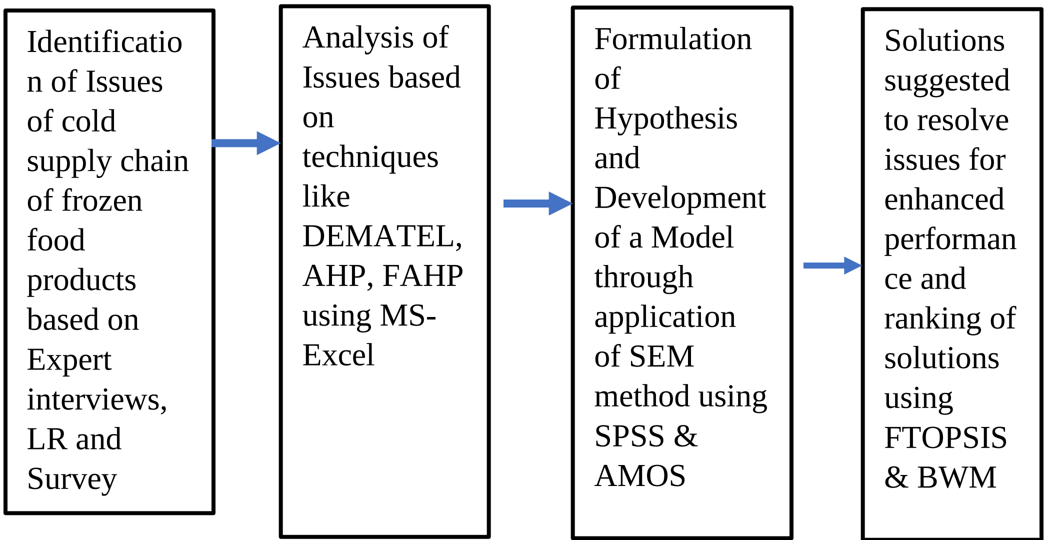


Fig 3.2 Schematic flow Diagram

The step-wise detail of research design is as follows:

Step 1:

The study helps understand the cold supply chain used for frozen food products and identify issues existing from various sources. The secondary data was taken from published reports/journals/articles/papers or other sources such as Global Cold Chain Alliance, Industry Arc, IMARC Group and many more. Techniques such as Expert Interviews, Questionnaire, analysis of available literature and survey reports, analysis of researchers' and consultants' reports and field visits were conducted to identify various issues in the cold supply chains of frozen food products.

The study identified key categories and sub-categories of issues from the sources as mentioned. The identified categories of the issues are:

- Lack of Infrastructure
- Lack of Traceability
- Lack of Sustainability
- Lack of Safety and Quality

- Lack of Awareness and Handling practices
- Lack of Responsiveness
- Lack of Integration

Step 2:

The significance of the issues, based on their significance and influence on the cold chain performance, was obtained from the domain experts. Thereafter, the MCDM methods, DEMATEL, AHP/Fuzzy AHP was employed on the categories and sub-categories of the issues. While DEMATEL was primarily employed to understand the inter-influence amongst the issues; AHP/FAHP were employed to prioritise the key and sub-categories of issues for an enhanced understanding to arrive at the final priority list.

Step 3:

Multi-variate method like SEM was employed to assess the critical issues which are resulting in reduced performance of the cold chain of frozen food products. Using SEM, hypotheses formulated were tested and significance of the issues on the cold chain performance understood. The proposed model was thus tested to arrive at the Final model.

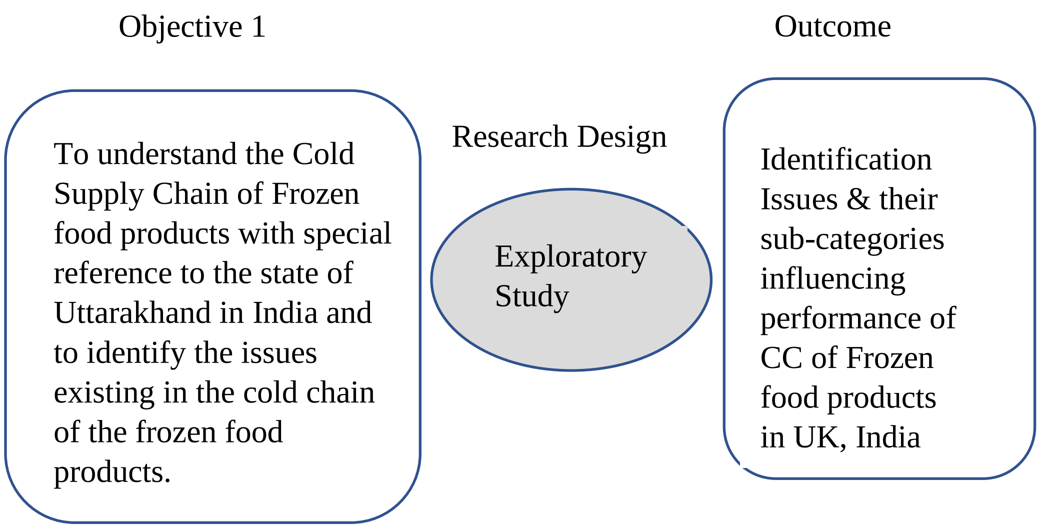
Step 4:

In this step, considering issues in cold supply chain, solutions to resolve these issues are suggested. Solutions include using information technology i.e. IT solutions and non-IT solutions, to finally achieve enhanced performance of cold chain. The solutions are prioritised using the MCDM methods, Fuzzy TOPSIS and Best-Worst method for a clear understanding of the preference and usefulness of the strategies and solutions in improving cold chain performance.

3.6 RESEARCH METHODOLOGY

The necessary steps followed to accomplish Research objective 1, 2 and 3 have been shown in brief below:

<u>RM for Research Objective 1</u>

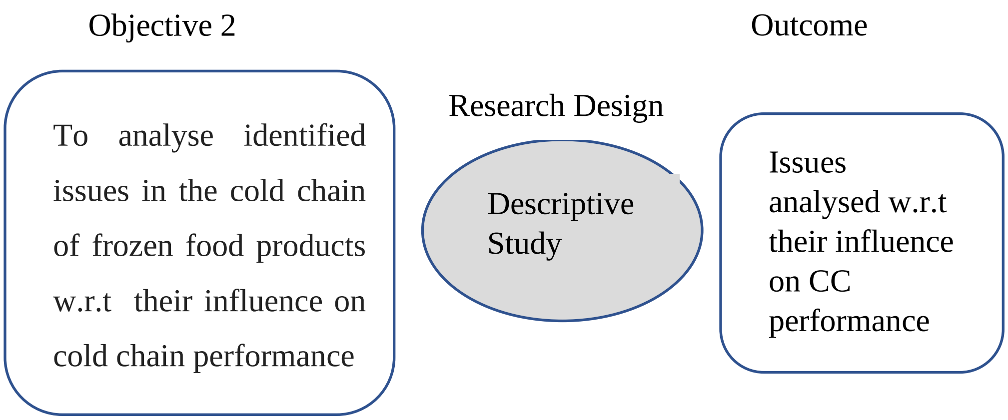


- ❖ Exploratory Research conducted to understand the CSC and identify issues
- ❖ Data collection through Expert Interviews, field visits and Literature Review

Steps for RO1:

- Conduct Literature Review
- Conduct Unstructured interviews with five CC stakeholders
- Preparation of Questionnaire based on LR and unstructured interviews
- 5-point Likert Scale used
- Testing of Questionnaire with 8 people (3 academicians, 5 CC stakeholders)
- Conduct Pilot Study
- Finalize Questionnaire

RM for Research Objective 2



- ❖ Descriptive and Explanatory Research conducted to analyse the issues identified
- ❖ Data collection using Survey Questionnaire
- ❖ Purposive sampling technique used
- ❖ Sample Size = 315 (as shown in table 4.1)
- ❖ Data Analysis done by application of DEMATEL, AHP, FAHP using MS-Excel and SEM with the help of IBM SPSS Ver 22.0 and AMOS Ver 23.0 software. The process employed for the SEM method has been depicted through Fig 3.3 (SEM).

Steps for RO2:

- Administering Questionnaire to the respondents
- Expert consultation for collecting responses on significance of issues w.r.t CC performance
- Reliability test of the Questionnaire responses using Cronbach Alpha
- Kaiser-Meyer-Olkin and Bartlett’s test for Sampling Adequacy
- Analysis of data

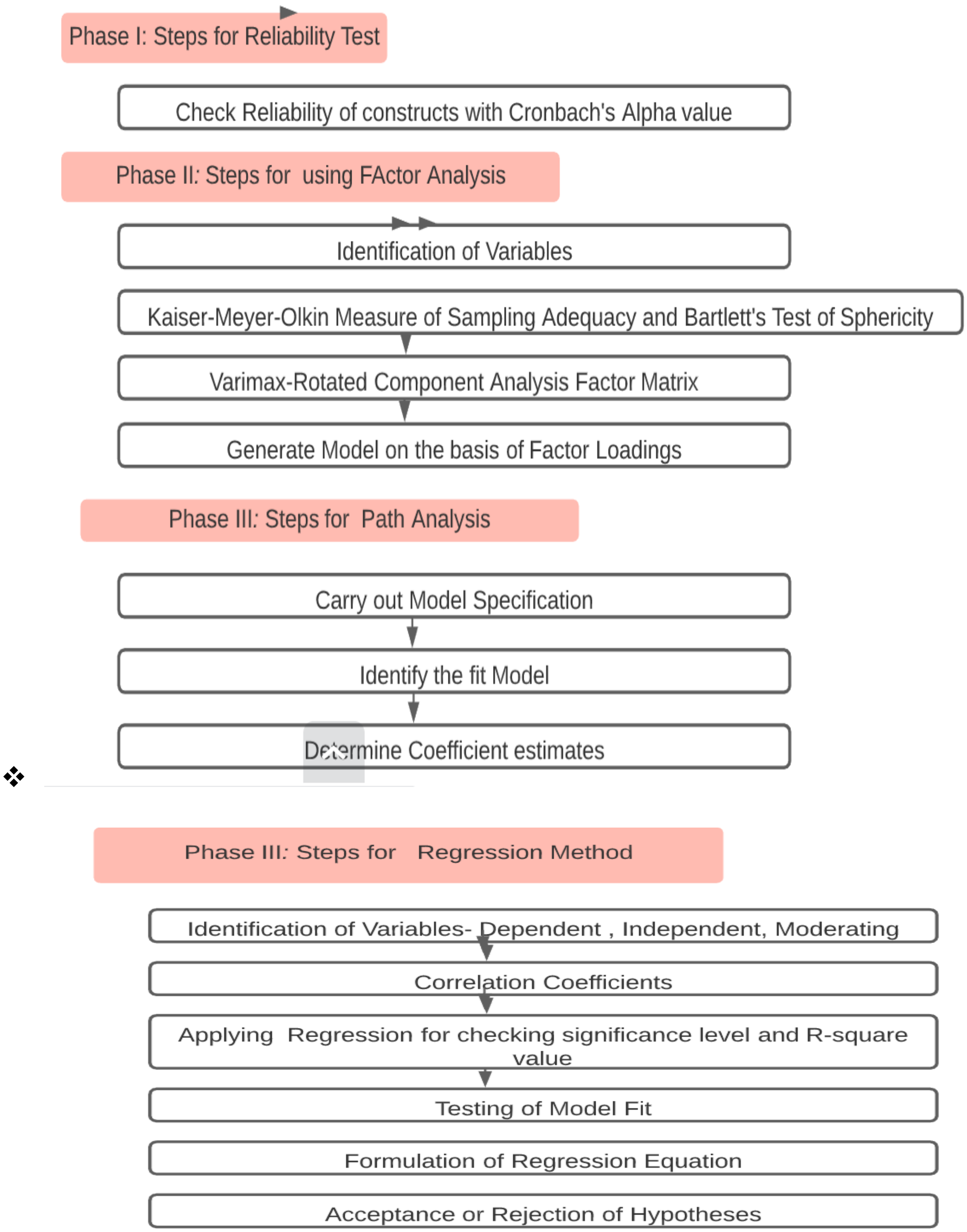
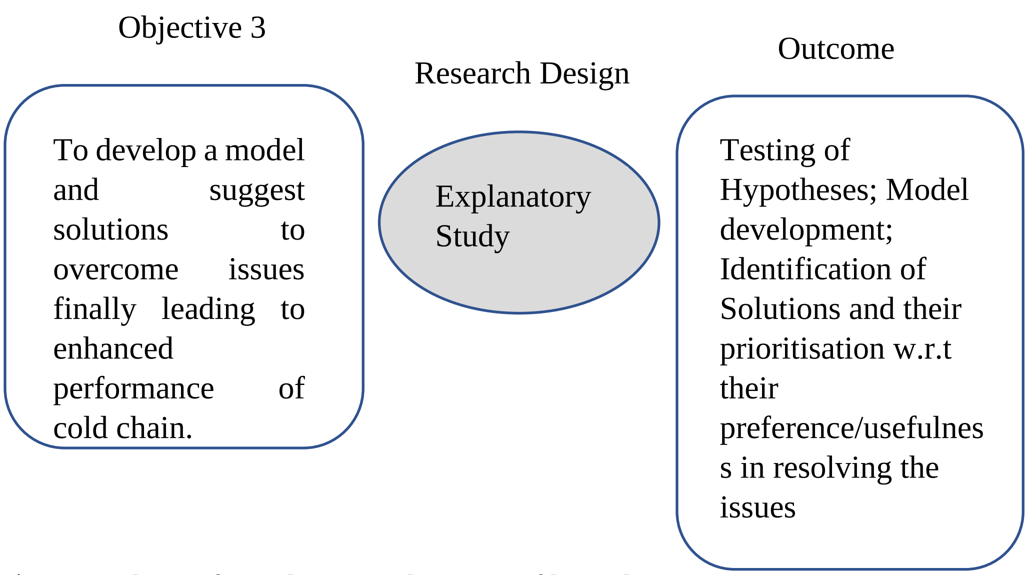


Fig 3.3 Steps of Data Analysis- RO2 [Using SEM]

RM for Research Objective 3



- Hypotheses formulation and testing of hypotheses
- Development of Model
- Ranking of solutions on the basis of their preference/usefulness using the FTOPSIS method.

Steps for RO3:

- Testing of Model Fit
- Development of Final Model
- Hypotheses Testing
- Identification of Solutions on the basis of LR conducted and inputs from Survey respondents
- Categorisation and Prioritisation of solutions

The study thus needed to identify various issues existing in the entire cold supply chain and suggest solutions for resolving the issues in the CC of FFPs in Uttarakhand state of India. Hypotheses were then formulated based on the identified issues. In this thesis, the methodology applied for assessment of cold chain issues is three-stage. Fig 3.4 presents the research framework for the thesis showcasing the three stages. In stage 1, the researchers have investigated, identified, and finalized the cold chain issues through the process: of conducting interviews and consulting group of experts, including the cold chain stakeholders and academicians; and through an all-embracing review of literature. In the second phase, assessment of identified issues was performed using DEMATEL to segregate issues into influencing and influenced issues; SEM modelling for hypotheses testing and model development; and finally, the pairwise comparison techniques, AHP and Fuzzy AHP for ranking the issues and their sub-categories. In stage three the strategies and solutions, both IT and non-IT have been suggested and thereafter Fuzzy TOPSIS and BWM method were used for ranking the solutions. A sensitivity analysis was performed separately for issues and IT/Non-IT solutions to ensure consistency and reliability of results and therefore the robustness of the framework. Thus, for the assessment, this study has considered an integrated approach by applying DEMATEL, SEM, AHP/Fuzzy AHP, Fuzzy TOPSIS and BWM methods.

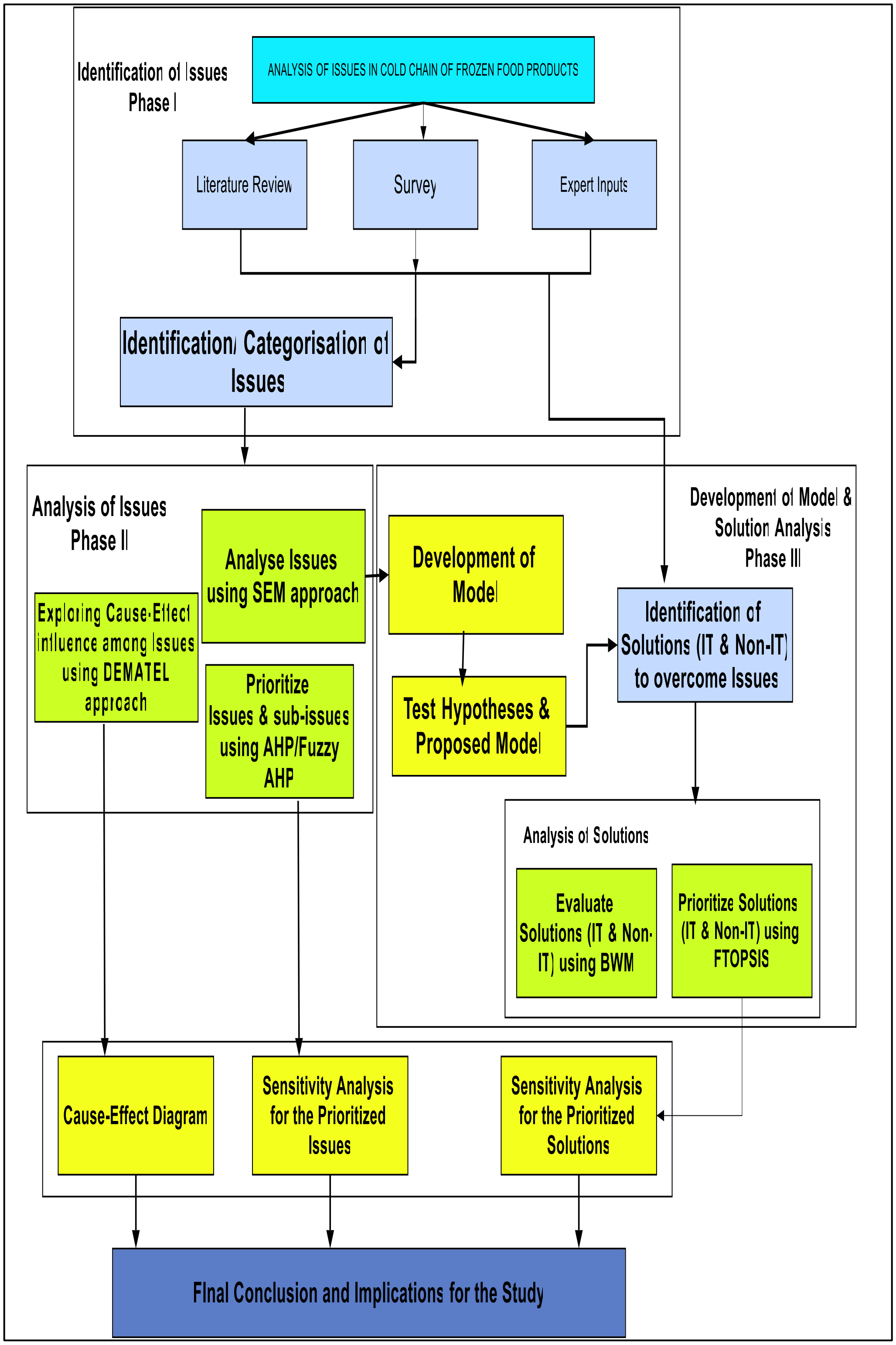


Fig 3.4 Proposed Research Framework

To conduct the research work for the purpose of testing of these hypotheses, an extensive survey needed to be carried out.

3.6.1 Phase I Identification of the Issues Present in the Cold Chain of Frozen food

It was profoundly basic to comprehend the ongoing cold network of frozen food items in UK i.e. from farmers/suppliers to manufacturer/processor to distributors and finally to consumers. With such a purpose, executives/managers/owners holding relevant positions were interviewed and a visit was made to conduct the interviews with the farmers. This helped understand the process of present cold chain. It was also important to identify the various cold chain stakeholders like farmers, private agents, logistic service providers, distributors, Information Technology companies, Quality bodies and Frozen food manufacturers or processor.

To do the review, recognizing different issues faced by the cold chain partners of the frozen food product sector was required. A broad investigation of the studies was conducted for ascertaining the issues predominant in the cold supply chain. The literature was reviewed both from global context and Indian context for a better understanding of the cold chain status with reference to the Indian context. Hence, based on literature review and interviews of cold chain partners including farmers, processors, distributors and logistics, issues in the cold chain of frozen food products were identified. Primary data has been collected through field visits and expert interviews while secondary data collection is based on information gained from research papers from peer reviewed journals, market research reports, articles, etc.

For the study, 30 experts both from the cold chain industry and academicians were interviewed. Based on this explorative analysis, it was deduced that the cold chain performance is majorly influenced from various and diverse issues. In view of the

LR and consultation by experts, issues were segregated and categorized into seven primary categories. The study thus identified key categories and sub-categories of issues, arrived at from various sources, present in CC of FFPs. Thus, the recognized classes of issues are:

- Lack of Infrastructure
- Lack of Traceability
- Lack of Sustainability
- Lack of Integration
- Lack of Safety & Quality
- Lack of Awareness & Handling practices
- Lack of Responsiveness

The sub-categories of issues identified are presented in Table 3.1 along with a few selected references.

Table 3.1 Identified categories and sub-categories of the issues along with CC performance

Category (Issue)	Criteria Code	Sub-Criteria	Sub-Criteria Code	References
Lack of Infrastructure	(INFR)	Production/Processing facilities	PFAC	Shashi (2016); Negi (2015); Ndraha (2018); Hong (2012); Koen (2018); Salin (2003); Dong (2022); Rathore (2010); Joshi (2009); Shashi (2018); Manzini (2013); Loisel (2021); Arora (2022); Theophilus (2021); Bhatnagar (2019); Expert Inputs
		Storage Facilities	SFAC	
		Loading/Unloading Facilities	LFAC	
		Transportation Facilities	TFAC	
		Packaging Facilities	KFAC	
		Distribution Facilities	DFAC	
		Marketing/Retail-end Facilities	RFAC	
Lack of Traceability	TRAC	Access to Information about Geographic Origin	INGO	Aung (2014); Olsen (2013); Rijswijk (2008); Opara (2003); Zhang (2009); Arora (2022);
		Access to Information about Ingredients	INIG	
		Access to Information about Method of Processing	INMP	

		Access to Information about Compliance to Legislation	INCL	Islam (2021); Ruiz-Garcia (2010); Farooq (2016); Tian (2016); Luo (2016); Dabbene (2014); Bosona (2013); Karlsen (2013); Piramuthu (2013); Fritz (2009); Folinas (2006); Expert Inputs
		Access to Information about Best Before date	INBD	
		Access to Information about Environmental conditions	INEN	
		Information coverage about product at farmer level	INFL	
		Information coverage about product at packaging level	INPL	
		Information coverage about product at storage level	INST	
		Information coverage about product at distributor level	INDL	
		Information coverage about product at retailer level	INRT	
		Information coverage about associated costs	INCO	
		Extent of information provided about product	PINF	
Lack of Sustainability	SUST	Losses & Wastage	LOSS	Vrat (2018); Gardas (2019); Shashi (2016); Du Pisani (2006); Taghikhah (2019); Kumar (2019); Ali (2018); Arora (2022); Saif (2016); Seuring (2008); Akkerman (2010); Zanoni (2012); Turi (2014); Bourlakis (2014); Brockhaus (2013); Soysal (2012); Beske (2014); Boland (2016); Dubey (2017); Gallo (2017); Expert Inputs
		Human Rights followed	HRFO	
		Consideration of Product Responsibility	PDRP	
		Consideration of Social Welfare	SOWF	
		Cost	COST	
		Resource usage	RESU	
		Use of Automation	AUTO	
		Energy Consumption	ENRG	
		Carbon Footprints	CRBF	
		Consideration for storage compatibility	STOR	
		Vehicle insulation	VEHI	
		Use of Alternate source of energy	ALSE	
		Adverse environment impact	ADEV	

		Green Cold chain practices	GRNC	
		Complying to Certification	CMPL	
		Use of Organic production methods	ORGP	
Lack of Cold Chain Integration	INTG	Backward Integration	BACK	Negi (2015); Rathore (2010); Srivastava (2013); Ndraha (2018); Hong (2012); Koen (2018); Mena (2009); Gunaratne (2020); Manzini (2013); Pusporini (2020); Arora (2022); Peng (2020); Mohanty & Shankar (2019); Stevens (2016); Sabir (2014); Flynn (2010); Expert Inputs
		Forward Integration	FORW	
		Linkage between firm and government	FIGO	
		Linkage between farmer/producer and firm	FARM	
		Linkage between firm and distribution channels	FIDC	
		Linkage between firm and marketing	FIMK	
Lack of Safety & Quality	SAFQ	Handling Practices	HNDP	Mercier (2017); Magnier (2016); Sharma (2015); Trienekens (2008); Hong (2011); Ndraha (2018); Giannakourou (2020); Arora (2022); Kartoglu (2014); Xiao (2017); Joshi (2018); Expert Inputs
		Storage Practices	STRP	
		Processing Practices	PRCP	
		Distribution Practices	DSTP	
		Quality Control Practices	QUCP	
		Access to Information to all CC partners	INCC	
		Food attributes like taste, flavour, weight, nutrition, shelf life & required environmental conditions maintained	ATTR	
		Reduction of Chemical content	CHEM	
		Compliance to standards for assurance of safety & quality	CMPL	
		Real-time monitoring using IT	REAL	
Lack of Awareness & Handling Practices	AWHP	Awareness about latest techniques & technology	AITT	Mercier (2017); Magnier (2016); Sharma (2015); Sainathan (2018); Goedhals-Gerber (2020);
		Knowledge of handling practices	KNHP	
		Knowledge of quality parameters	KNQP	

		Knowledge of safety requirements	KNSR	Arora (2022); Rathee (2019); Kumar (2021); Expert Inputs
		Knowledge of compliance standards	KNCS	
		Knowledge of environmental sustainability	KNES	
		Knowledge about traceability requirements	KNTR	
Lack of Responsiveness	RESP	Catering to varieties in products	VART	Blome (2014); Sukati (2012); Aramyan (2007); Charlebois (2021); Moazzam (2018); Dreyer (2015); Arora (2022); Singh (2015); Expert Inputs
		Lead time reduction	LTRD	
		Synergy with firm supply to	SYNG	
		Customer-centric in terms of response time and customer complaint	CUST	
Cold Chain Performance	CCP	Proper storage of frozen food	STFF	Joshi (2011); Erkan (2011); Sarmah (2014); Ganesan (2009); Sharma (2015); Tatoglu (2016); Arora (2022); Song (2017); Bigaj (2017); Katiyar (2018); Mor (2018); Chandra (2018); Kumar (2020); Titlo (2019)
		Restore texture	TEXR	
		Proper storage of frozen fruits & vegetables	STFV	
		Quality maintained	QLTY	
		Moisture retained	MOIS	
		Nutrients retained	NUTR	
		Shelf life increased	SHLF	
		Freshness retained	FRSH	
		Spoilage & wastage minimized	WAST	
		Protected from bacteria	PBCT	

[Source: Author]

3.6.2 Phase II Analysis of the identified issues using DEMATEL, SEM, AHP and FAHP methods

The experts were also consulted to obtain their preferences on the weightage of the models for applying DEMATEL, AHP / Fuzzy AHP, FTOPSIS, BWM. The selection of experts was based on convenience sampling depending upon their area of expertise and knowledge. The experts were from all areas of a cold chain including retail, logistics, manufacturers, processors, distributors and IT specialists. All these experts were either owners or from the top or senior level of management. Inputs were also taken from the academicians for a wholistic knowledge. The experts were asked to rate the seven elements deduced as main issues in the cold chain in terms of their influence and importance.

An integrated approach using the multi-criteria decision-making methods, SEM, DEMATEL, AHP, FAHP was employed to analyse all the above identified issues. The assessment of the issues by ranking them in the order of influence or importance is done through the methods of DEMATEL, AHP and FAHP. The issue categories were sub-categorised which were the actual measured variables. The issue categories were the latent constructs which were indicated through the sub-categories or the indicators or the measured variables. The methods have been considered for attainment of reliable results covering different aspects of the various identified issues. DEMATEL is a very useful approach to identify the issues falling into the cause group and the ones falling into the effect group and also clearly depict the inter-influences amongst the issues.

The SEM method is a very useful technique to analyse data in situations that involve measured variables and latent constructs and to look at the connection among autonomous and subordinate factors. It is one of the projecting statistical technique as it considers multiple variables simultaneously while being free of measurement error. To analyse and apply SEM technique, combination of SPSS Ver 22.0 and AMOS Ver 23.0 have been used. Measurement model was arrived at in this step and was tested for goodness-of-fit after having made numerous changes to achieve a good-fitting model. In this method, CFA is employed to achieve measurement model's fitness (Zainudin, 2015).

The MCDM techniques are employed for ranking of criteria in order of relative importance. AHP and Fuzzy AHP are highly suitable methods for identification of the importance of the issues. In the decision science, the AHP method is used for problem-solving (adapted from Hossain, 2020). Both AHP and FAHP have been used in the study to analyse the hierarchy of the issues in cold chain. Fuzzy AHP has been applied since the AHP method is said to suffer from unbalanced scales, uncertainty, biasness and therefore impreciseness. To overcome the impreciseness, FAHP has also been used and then the ranking results of both AHP and FAHP have been compared. Since both AHP and FAHP do not consider the cause-effect relationship amongst the issues, DEMATEL approach has been applied to analyse the influence of one issue over others in the form of cause-effect relationship. In view of written literature, three strategies used in this study have been applied in many studies, especially the AHP and FAHP methods. DEMATEL method is also a highly useful and simplistic method in determining cause and effect influence. Hence, the three methods are useful and applicable methods for analysing the importance and influence of factors for effective decision-making and bringing improvements in the relevant fields.

The three techniques of MCDM in combination are able to analyse the cause-effect relationship as well as the rankings amongst the issues for a more accurate analysis of the results The seven issues: Lack of Infrastructure, Lack of Traceability, Lack of Sustainability, Lack of Safety and Quality, Lack of Awareness and Handling practices, Lack of Integration and Lack of Responsiveness have been analysed in terms of ranking them on their relative order of importance with respect to cold chain performance using AHP and Fuzzy AHP methods. The methods help determine the weights associated with the issues and their sub-categories in the study.

3.6.3 Phase III Development of Final Model and Suggestions of Solutions (IT/Non-IT) and use of FTOPSIS and BWM for Ranking of Solutions

Relevant hypotheses and the model are tested to understand the influence of various issues on the performance of frozen items' supply chain. In this step, considering issues in cold supply chain, solutions to resolve these issues were suggested. Also, use of Information Technology was suggested, to finally achieve enhanced performance of cold chain. The strategies and solutions were ranked in their order of preference/usefulness and the best and worst solution was also identified. Fuzzy TOPSIS as a technique was employed to obtain more clarity regarding the preferences and usefulness of the solutions in resolving the issues.

3.7 RESEARCH HYPOTHESES

Following hypotheses were formed based on LR (refer chapter 2) and identification of issues in the cold chain at various levels, the levels being farmers, frozen food manufacturing/processing companies, logistic service providers, distributors and retailers :

H1: Resolving the issue of Infrastructure at various levels has significant influence on enhancing the performance of the cold supply chain.

H2: Resolving the issue of Traceability at various levels has significant influence on enhancing the performance of the cold supply chain.

H3: Resolving the issue of Sustainability at various levels has significant influence on enhancing the performance of the cold supply chain.

H4: Resolving the issue of Integration at various levels has significant influence on enhancing the performance of the cold supply chain.

H5: Resolving the issue of Safety & Quality at various levels has significant influence on enhancing the performance of the cold supply chain.

H6: Resolving the issue of Awareness & Handling Practices at various levels has significant influence on enhancing the performance of the cold supply chain.

H7: Resolving the issue of Responsiveness at various levels has significant influence on enhancing the performance of the cold supply chain.

On the basis of discussion mentioned in chapter 1, 2 and the present chapter Fig 3.5 presents the proposed model. The theoretical framework proposes link between the seven issues, namely, lack of infrastructure, lack of traceability, lack of sustainability, lack of integration, lack of safety and quality, lack of awareness and handling practices, and lack of responsiveness and the cold chain performance. The conceptual model suggests that resolving these issues impacts the cold performance. This study will thus contribute to the existing literature of cold chain via its strategies/solutions to resolve the issues in the cold chain of frozen food products to enhance the performance of the cold chain.

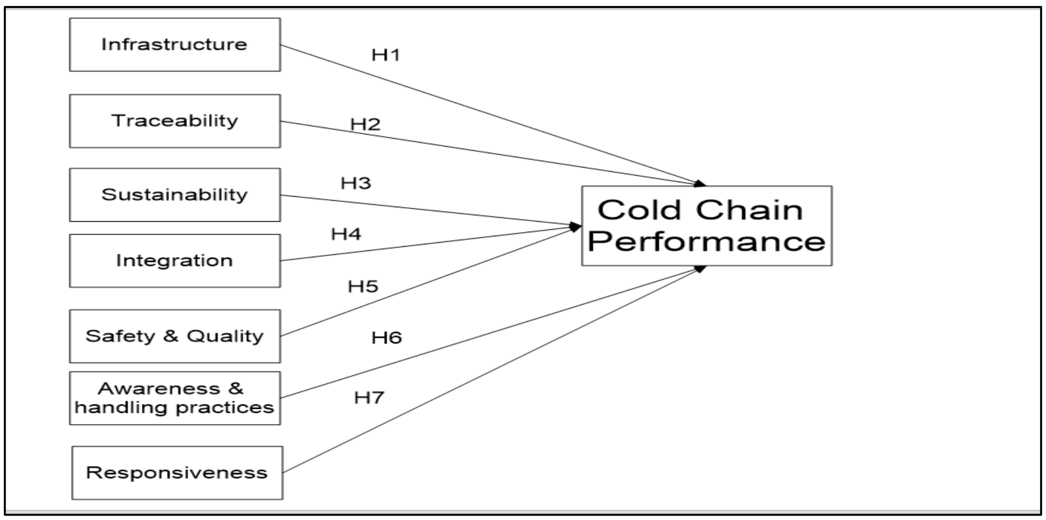


Fig 3.5 Proposed Model

3.8 SOURCES OF DATA COLLECTION

Often the success and failure of research depends on data and its collection. Therefore, it is very important that appropriate methodology is selected for the collection of data. As far as the current study is concerned, data is gathered from primary as well as auxiliary sources. This is exhibited through Fig 3.6.

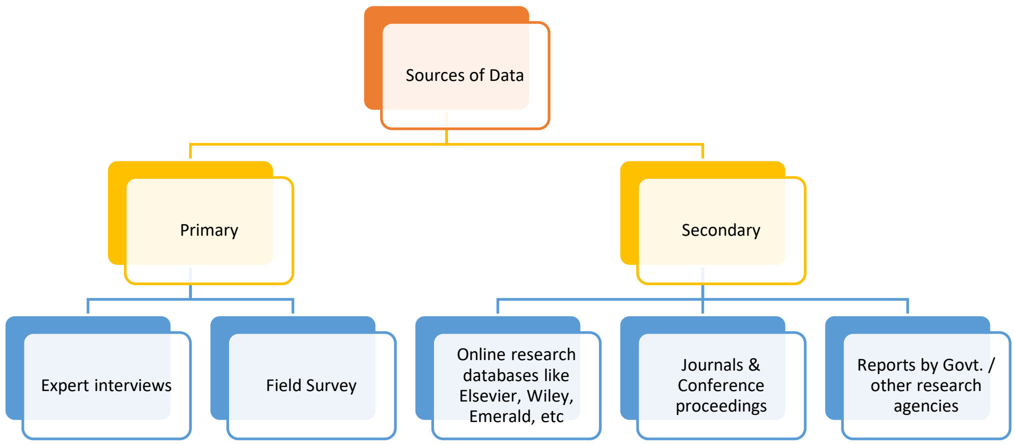


Fig 3.6 Sources of data collection

3.8.1 Secondary Source of Data Collection

Secondary data was collected on the basis of literature review with the help of online research databases like Elsevier, EBSCO, Emerald, Taylor & Francis, InderScience etc. Various journals, both national and international , related to agriculture, horticulture, supply chain management were referred along with industry reports, books, conference proceedings and newspapers. The required information was also available on internet which largely contributed to obtaining overview about the cold chain specifically for frozen food products. It was also observed that there was very little research done on the issues of cold supply chain specifically for Uttarakhand.

Based on the secondary sources, various issues were identified prevalent at all levels throughout the cold chain of frozen food through publications in journals, articles, various government reports and other such relevant sources. For the purpose, various survey and market research and consulting reports by public sector and semi-public companies like MOFPI, NCCD, NHB were referred. Some reports referred were as given below:

- All India Cold Chain Infrastructure Capacity - Assessment of Status & Gap (by NCCD)
- Horticulture Statistics at a Glance (by Department of Agriculture, Cooperative & Farmers Welfare)
- CIPHET Annual Report (ICAR)
- YES Bank Report on Cold Chain Opportunities in India
- ASSOCHAM - Report on Cold Chain Technology Transforming Food Supply Chain
- Food Processing Sector Profile by State Horticulture Mission, Govt. of UK, India
- World Food Logistics Organisation Manual for Food Handling & Storage

3.8.2 Primary Source of Data Collection

For data collection through primary sources, expert interviews were conducted with owners, and managers and other stakeholders of the cold chain with the aim of understanding the current cold chain of frozen food products. The data collection was done using field visits, expert interviews, observation and conducting Survey. For the study, 30 experts with experience greater 10 years in their applicable field were consulted to obtain their preferences on the weightage of the models for applying DEMATEL, AHP and Fuzzy logic based FAHP, FTOPSIS. The selection of experts was based on convenience sampling depending upon their area of expertise and knowledge. The experts consulted included: 3 logistics service providers; 9 frozen food processors; 4 refrigerating/cold solution providers; 2 cold storage service providers; 2 retail outlets; 4 IT executives; 2 distributors; and 4 experts working in public sector. The experts were asked to rate the seven elements deduced as main issues in the cold chain in terms of their influence and importance for the issues and preference/usefulness for the solutions identified (refer Appendix I).

Inclusion of more than one expert was considered to include a diversity of opinion in the analysis. Behavioural and mathematical are two techniques for combining the opinion of experts (Hammit, 2013). While the behavioural methods ensure working with the experts in a group till the group reaches a consensus, mathematical methods use some form of averaging the opinions of experts. Delphi is a popular behavioural method while simple averaging or classical model are examples of mathematical methods. For the purpose of this study, Simple averaging has been used where all participants have equal weights. As the experts belonged to different firms in a cold chain, different experiences, from different locations, therefore inputs from them were collected during personal visit or through mail. Though it is subjective, but since it involves aggregation being math-based, it has an element of objectivity in the final response. Also, cognitive biases arising due to group think, majority rule, etc are reduced as experts can research, think and then submit their responses. Hence, simple aggregation using mean was applied leading to more accuracy in the final response.

Initially owners, store managers and unit in-charge of various cold chain stakeholders were interviewed in an unstructured way to discuss the challenges faced in the cold chain and identify the issues. Observation also was used as a procedure to comprehend the working of the cold chain particularly with the viewpoint of the issues present in it. In order to obtain response from the farmers, frozen food processors, logistics, retailers and other stakeholders involved, structured questionnaire was used as a survey instrument.

Questionnaire aligned with the objectives was developed and administered on the respondents' sample. Based on this sample, the researcher was able to draw a conclusion. The survey questionnaire was developed for all the cold chain partners (such as farmers, frozen food processors, distributors, logistics service providers, retailers and other stakeholders) In all there were three questionnaires developed:(1) Questionnaire for Farmers; (2) Questionnaire for logistics, distributors, retailers, frozen food companies and quality bodies; (3) Questionnaire for IT companies. The responses thus collected were analysed statistically with the help of Statistical package for social sciences version 22.0 and Analysis of moment structures version 23.0. The consequence of the investigation shall provide help in further testing of the research hypotheses. The final survey responses were collected from the period Jan 2021 to August 2021.

3.9 QUESTIONNAIRE AS SURVEY INSTRUMENT

3.9.1 Development of Survey Questionnaire

The construction of questionnaire has been more of art than science. The questionnaire should contain questions that are standardized to operationalize the constructs for measurement thus bringing in uniformity in the responses of different (Martin, 2006). While constructing a questionnaire, care should be taken with respect to the sequence of questions, the wording of both questions and response categories, the technique used while administering the questionnaire as well as the introduction and explanation of the survey.

The essential goal of the ongoing review is to recognize the issues and their impact on the performance of the cold chain of frozen food products in Uttarakhand. The issues need to be resolved not just at the firm level but it is important to resolve them at various levels of a CC to deliver powerful outcomes. With the objectives under consideration, questionnaires were created in view of writing survey and well-qualified assessment (refer Appendix H). There were three questionnaires designed to collect responses from each stakeholder across the CC stages i.e. the farmer, frozen food manufacturers/processors, distributors/private agents, logistics service provider and the retailer by stressing upon the issues faced by them with the aim of resolving them. The questionnaires and their corresponding sections were as follows:

a) Questionnaire to collect responses from FF company/Distributor/Logistics/Quality bodies

b) Questionnaire to collect responses from the Farmers; and

c) Questionnaire to collect responses from the IT company executives.

The questionnaires were designed in the languages, English and Hindi both for easy understanding of the questions to avoid any biasness in responses due to inadequate understanding of the questions. While (a) and (b) were questionnaires administered in both the languages, (c) was administered by mail in English language only owing to the assumption that IT professionals possess adequate English language skills for the understanding. The first two questionnaires were developed in both Hindi and English as majority of the respondents were not very well-versed with English and so Hindi was used to avoid any understanding related issues while responding. Especially for the farmers who are not very literate, questionnaire in Hindi was a near mandatory requirement. The third questionnaire was developed in English only as the respondents being literate and qualified were well-versed with English. The primary data was collected from the information technology companies as well along with the quality agencies to get a synergistic view on the presence of the issues.

Questionnaire was developed utilizing a five-point Likert scale (Extremely poor/No present -1, Poor - 2, Average - 3, Good, - 4, Extremely Good - 5) for a broader check on relevance. Primarily, closed ended questions which were short and easy to process were used, however, there were certain open-ended questions too for detailed responses or wide-range of responses. The questionnaire was tested with face and content validity by taking the opinion of three academicians and five respondents working in the cold chain firms. As a result, both syntax and semantics of the questionnaire language was improved along with modifications to the presentation of the questions which helped in making questionnaire design more appropriate for accuracy in responses. The questionnaire was designed in a way to be aligned with the hypotheses as well as to avoid any biased opinion while maintaining their relevance.

The questionnaires consisted of following sections for a wholistic response collection:

Section I: General Information (to be filled by FF company, Distributor/Private Agent, Retailer)

- This segment was centered around getting the general subtleties of the respondent like name, education level, age, experience, and the form of business held.
- The demographical information related to type of products dealt with, size of the facility, manpower used, turnover, maintenance of temperature and other environmental conditions, logistic related information, information about loading, customer response time, complaints, and packaging related information
- Nominal category scale was used for collecting the relevant information

Section II: General Information (to be filled by Quality agency)

- This section focussed on collecting general details of the certifying agency along with the details on the quality accreditation certificate

Section III: Performance of Cold Chain

- This section used 5-point Likert scale (1= Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree) to collect responses on various parameters used towards performance of the cold chain

Section IV: Scope of Presence of Determinants w.r.t current status

- This section was focussed on to identify the issues related to the cold chain of frozen food products at the level of frozen food companies, distributors, retailers, and quality agencies. To check the scope of the presence of these issues, the degree of their current status was measured on five-point Likert scale (where 1 means Extremely poor/No present and 5 means Extremely Good). Some of the issues are Lack of Infrastructure, lack of traceability, lack of sustainability, lack of integration, lack of safety & quality, lack of awareness & handling practices and lack of responsiveness.

For Farmers, the questionnaire consisted of following sections:

Section I: General Information about farmers

- This section was focussed on procuring general details of farmers like name, age, number of family members, educational qualification, relevant knowledge, and type of farmer.
- Demographical information related to types of crops grown, distance, time taken to transport along with means of transport used.

Section II: Performance of Cold Chain

- This section used Five-point Likert scale (Strongly Disagree - 1, Disagree - 2, Neutral - 3, Agree - 4, Strongly Agree - 5) to collect responses on various parameters used towards chain's performance.

Section III: Scope of Presence of Determinants w.r.t current status

- This section was focussed on to identify the issues related to the CC of FFP at farmers' end. With the aim of checking scope of the presence of these issues, the degree of their current status was measured on five-point Likert scale (where 1 means Extremely poor/No present and 5 means Extremely Good). The issues are dearth of: Infrastructure, traceability, sustainability, integration, safety & quality, awareness & handling practices and responsiveness.

For IT company, the questionnaire consisted of following sections:

Section I: Demographic Profile

- This section focussed on collecting demographic information like name, age, qualification and experience.

Section II: General Information about Company

- In this section, information is collected on the number of projects, including cold chain projects, that the company has, type of companies that approached them for development and the type of issues dealt by the software developed.

Section III: Current Use of IT in areas related to Issues in Cold Chain

This part of the questionnaire was constructed to check the scope of Information technology in different areas related to the identified issues. The questionnaire was administered with the aim of checking if the IT companies too agreed that there is need as well as scope of technology for overcoming the identified issues and thereby enhancing performance of the cold chain. Five-point Likert scale was used for the purpose of examining the questionnaire.

3.9.2 Pilot Testing

A pilot study is undertaken by a researcher with the aim of practicing and assessing the effectiveness of techniques of data collection and analysis (Doody, 2015). It helps the researcher to focus or expand/narrow the study in question and gain an enhanced understanding of the study. The main benefit of carrying out a pilot study is to provide a researcher with insights on areas where adjustments are required to be done in the main study (Kim, 2011). For the reasons as cited above, a pilot study was conducted with the cold chain partners, specifically the distributors, retailers, frozen food processors. However, their responses are not a part of the sample of the main study. For the pilot study, stakeholders like IT companies and quality agencies were not considered. Pilot study was led with 20 respondents including: 2 Frozen food manufacturers/processors; 2 distributors; 10 retailers; 2 logistics service providers; and 4 farmers. Initially based on inputs from LR and experts, 8 categories of issues and 78 sub-categories were identified. However, two main insights obtained from pilot study, which were accordingly implemented in the main study were: (1) Usage of information technology which was initially the eight issue was redundant as IT was either not present or used only for billing and/or stock management and hence it was not considered as a dominant construct for conducting the main study; (2) Initially, cold storage service provider was also accounted for, however it was observed during the pilot study that in Uttarakhand there were no separate firms (public/private) operating as cold storage service providers. The various cold chain partners had their own cold storages. Hence, the cold storage service providers were not separately accounted for in the sample of the main study. Also, as the questionnaires were discussed while conducting the pilot study, which immensely contributed to the improvement of the questionnaire in terms of wording, addition/deletion of relevant/irrelevant questions, rephrasing the questions to overcome ambiguity/vagueness. This resulted in questionnaires that were concise and corresponding to the desired objectives.

Thereafter, the categories of issues finally considered were seven and 63 sub-categories under the seven issues were finalized and the cold storage service provider was removed from the final survey instrument. Thus, based on the pilot study led, adjustments were made to the last poll to eliminate any extent of biasness and additionally mistaken responses.

3.9.3 Administering of Survey Questionnaire for Collection of Responses

Just as development of questionnaire is important, similarly administration of a questionnaire is important to ensure that the objectives of the survey are met in order to obtain precise research data. The consistency of the questionnaire has been maintained and along with that reliability and statistical techniques have also been used for analysis. The consistency of a measurement procedure is referred to as the Reliability and the degree to which the scores delivered by estimation methodology are reproducible are known as indices of reliability (Oliver, 2000). With the aim of collecting accurate responses, the questionnaires were given in the following ways:

- On-site interaction with farmers, frozen food processors, distributors, aadtis (private agents), retailers and logistics
- Interviews conducted with owners of frozen food companies or with their store managers to get an understanding of the challenges faced.
- Interviews conducted with employees and inspectors of quality agencies to collect their responses.
- Self-administration by disseminating poll by email to executives of IT organizations.

The survey was administered and final survey responses were collected during period Jan 2021 - August 2021. For each question in the last section of the corresponding questionnaire, the respondent had to provide response based on the existing status of the determinant with reference to the cold chain of frozen food products. A five-point Likert scale was used for the responses collection (as mentioned in previous section). Five-point Likert scale is an efficient way of collecting respondents' perceptive opinion (Brown, 2011).

The questionnaire was administered to the cold chain partners and stakeholders of cold chain in Uttarakhand state of India i.e the farmers (areas adjoining Haridwar, Rishikesh, Dehradun, Mahua Khera, Paudi, etc); Frozen food manufacturers/processors (primarily from Haldwani, Rudrapur, Kashipur, Udham Singh Nagar, Haridwar, Roorkee, Rishikesh, etc.); Retailers (including big players like Big Bazaar, Reliance, Suvidha, Easy Day, and many others in Dehradun, Rishikesh, Roorkee, etc.); and wholesalers/distributors/private agents operating from Mandis (at Dehradun, Rishikesh, Roorkee, Mahua Khera Ganj, etc); Logistics service providers (primarily from Dehradun). In total, 284 substantial and complete reactions were gotten against 315 surveys dispersed to the different partners, giving a high response rate around 90%. The high rate was inferable from the way information assortment was done by the application of scheduling method with the researcher visiting the field and interacting directly with the respondents. Only in case of IT and quality companies, responses were primarily collected through mail.

This technique of collecting data is very useful in case of extensive inquiries and helps provide valuable inputs and results in reliable results (Gangrade, 1982). Table 3.2 exhibits the number of questionnaires administered to different stakeholders and the responses received from them.

Table 3.2 Response rate for the sample

S.No.	Respondent	Questionnaire Administered	Final Response Received	Response Rate %
1	Farmers	60	55	92%
2	Frozen food manufacturer / processor	35	33	94%
3	Distributor	25	15	60%
4	Retailer	100	93	93%
5	Logistic Service provider	45	38	84%
6	Quality bodies	10	10	100%
7	IT companies	40	40	100%
	Total	315	284	90%

3.10 SAMPLING

Deciding the sampling plan and sample size relies on the goals of the review and the accessibility to resources. A sample which is subset of the population, is selected in a manner that it is able to represent a larger population and this sample representativeness is determined by the sampling methodology, sample size and the response rate (Acharya, 2013). A specific plan to extract a sample from a universe or population is referred to as sample design. Thus, it is the procedure adopted by the researcher to select items for the sample. On the basis of the sample design, the sample size, the number of items that should be viewed as in the sample, has to be determined. Determination of sample design should precede data collection.

Sample designs can be of different types and therefore the researcher needs to select the sample design relevant for the study.

Sampling approaches are of two primary categories: techniques using probability approach and those using non-probability approach. Samples chosen in a manner to such an extent that each representative of the populace has equivalent chance of being incorporated are said to follow probability approach while samples when selected on the basis of the researcher's judgement are referred to as non-probability samples. The law of Statistical Regularity is followed in this type of statistical design based on which the characteristics and composition of the randomly selected sample will be the same as that of the population.

Thus, non-probability samples also referred to as purposive sampling, deliberate sampling and judgement sampling, have a distinguishing characteristic that sample selection is done based on subjective judgements. There is no specific basis to estimate the probability of inclusion of each item in the sample and so items may be selected deliberately considering that the small sample so selected will be representative of the entire population. However, in non-probability sampling design, there are chances of occurrence of personal element or bias. So sufficient care and consideration has to be given to minimize the error or bias occurring in the sampling technique so adopted. Non-probability sampling technique finds its usage when the researcher has specific reason of interest in specific members of population comprising the sample or when the researcher applies his judgement as to which type of respondent will be able to provide the best information pertaining to the objectives under study. Also, in exploratory research situations when the analyst is having a tendency to establish existence or non-existence of a problem, non-probability can be a practical approach. However, the technique should be used with care as its usage increases the uncertainty or biasness in using sample for representing the population.

While selecting the sample, it is important that the sample is selected from the relevant sector as each sector faces certain issues and challenges since only if the chosen sample is from the specific sector relevant for the study, will the researcher be able to procure specific feedback and thus plug in the gaps through findings of the research for that sector. In such a sector-specific study, it is important that the selection of respondents is such that their knowledge and experience in the relevant sector is given sufficient consideration. This will help precise identification of areas that are still not sufficiently explored and are problematic. In the present study, the respondents are selected from various players of the cold chain of frozen food products. They have been so chosen since they would possess the knowledge and experience required to effectively identify areas that are full of challenges and problems. Therefore, purposive sampling technique is employed for selection of the respondents on the basis of their role and scope in the cold chain of frozen food products and in alignment with the objectives of the research. In the present study, the sampling is divided into four sections as given below:

3.10.1 Target Population

The respondents selected for the present study are personnel possessing immense knowledge, expertise and proficiency in their area of cold chain. Considering that the research involves the entire cold supply chain, it is therefore important to understand the various players who have a specific role in the cold chain and finally take their respective feedback.

3.10.2 Sampling Units and Techniques

For the study, the strategy of sampling was non-probability sampling. Purposive sampling is considered as the method for collection of information. Purposive sampling is selected as the data has been collected only from SC partners dealing with frozen food products. Therefore, it became possible to interlink all the cold chain partners.

The unit and criteria of sample selection was as given below:

(a) Frozen food manufacturers/processors - The owners of the frozen food companies or the store managers were targeted for conducting a personal interview as well as for collecting response for the review poll. Web was utilized to gather the names of the organizations along with their address and other relevant information. First a telephonic contact was made while explaining the purpose and general information was seeded. Thereafter, appointment was taken and a visit planned to their premises to meet them face-to-face and collect suitable information. Wherever possible, pictures of the machinery/equipment used were also taken. They very enthusiastically participated in the process of data collection and gave enough information as required and shared the numerous challenges faced by them. Based on the information provided by them, selection / deselection of categories and sub-categories of issues was carried out.

(b) Farmers - Farmers of all categories, marginal to large, were identified and targeted for collecting responses. A personal visit was also made to the farmers too. The selection of farmers was done on random basis by visiting a village and informing the people there regarding the research work being done. Thus, they were mentioned to impart their insights on the different aspects of the questionnaire. For the farmers, the questionnaire was in Hindi language so they could understand easily. However, most of them came in groups and depending upon their understanding the questionnaire responses were many a times filled by the researcher. The farmers also very enthusiastically shared the challenges faced by them. The interaction with the farmers was very encouraging and refreshing.

(c) Logistic Service Providers - Larger part of the service providers specialising in logistics working in the state were recognized and targeted and survey instrument was shared with them for collection of required information.

(d) Distributors - Responses were collected from distributors and private agents by visiting the Fruit & Vegetable Mandis from where they generally operated from. Visits were also made to the so-called Sabzi mandis in order to address larger number of distributors/private agents as it was possible to collect data from more in number at such places.

(e) Retailers - Various retail stores and outlets in the state were visited for collecting responses for the survey instrument.

(f) IT companies - For the study, only those IT companies were targeted which were involved with either partial or complete development of agri-based supply chain solutions. The sampling unit were team leads or project managers.

(g) Quality agencies - The professionals from quality agencies were also targeted for response collection in order to get a 360^{o} view on the identified issues.

Mails were sent to the professionals in IT companies and quality agencies to collect their responses. Thus, the process of survey questionnaire-based data collection from various cold chain partners was successfully completed.

3.10.3 Sample Size

Main Study

As the size of sample has major bearing on the statistical techniques applied, it needs to be decided carefully (Hair, 2007). To obtain a 360^{o} view, responses were also collected from IT company executives as well as from employees of Quality agencies. The respondents selected for the main study were the different cold chain partners of frozen food sector.

Area under Consideration: Uttarakhand, a state of North Hill Zone, India has been considered as the geographic region under study. The population of UK is presently 101.17 lakh (https://www.uk.gov.in/pages/view/428-demography). Survey questionnaire was designed based upon inputs from literature review and after consultation with experts and academicians. Considering the study by (Suhr, 2006; Hatcher, 1994; Bollen, 1989) where the sample-to-item (independent variables) ratio should be not less than 5:1, preferred ratio being 15:1 or 20:1 (adapted from

Memon, 2020). In the present study, the number of independent variables is 63 (indicator variables). So, 5*63=315. According to guidelines as suggested by Kline (2005,2015) and Comrey (1992) for SEM, sample size of 100 is small, 100-200 is medium and 300 is a good sample size. Even Tabachnick (2007) suggested that in situations where factor analysis is used, sample size should be 300 valid responses. Hence, going by the above statistics, the ratio of 5:1 is considered appropriate for the present study and therefore the final sample size considered is 315. The final survey questionnaires were prepared and responses were collected to check the relevance of questionnaire on five-point Likert scale (where, 1 means extremely poor or not present and 5 means extremely good). For consideration of issues for the cold supply chain table, table 3.1 represents the number of CSC partners from whom the responses were collected.

3.11 PROPOSED RESEARCH METHODS AND TECHNIQUES

For accomplishing the desired objective, complete analysis of data was conducted. Various methods were used to review and evaluate collected data with the purpose of achieving the goals and proposition replies to RQs. The techniques employed to evaluate the collected data along with the findings are presented in the succeeding chapters of the thesis.

The different statistical tools and techniques used for analysis of data in the present study are:

1. Exploratory Factor Analysis - Factor analysis is an assortment of methods applied to explain the correlations amongst variables referred to as factors (Cudeck, 2000). The factor analysis is conducted to find out the various influences over a bunch of factors, to identify how much every variable is associated with factors and to gather information about the nature of the variables by observing which factors contribute to which variables. During factor investigation extraction, the common variance is secluded from error change and unique difference completely aiming on uncovering the variable construction (Costello, 2005). For the purpose of extraction, Maximum Likelihood is most suitable technique as it permits a number of goodness-of-fit indices that allow measurable importance testing for factor loadings alongside correlations among factors and confidence interval calculations. The technique identifies the parameters that best explain the noticed data. The parameter values are estimated with the end goal that they boost the probability that the interaction depicted by the model created the information that were really observed. Hence, it is the most efficient estimating technique and results in unbiased estimates.

Once the extraction is complete, researcher needs to decide the number of factors to retain and the general default is to retain those factors which have eigenvalues>1.0 or scree test can also be used for the purpose. Eigen values shows variance elucidated by that component out of complete variance. In Structural Equation Modelling method, factor loading >=0.7 addresses that element separates adequate variance from that variable. After extraction, rotation needs to be applied with the aim of simplifying and clarifying the data structure. For this purpose, commonly used method for rotation is Varimax as it maximizes the sum of the variances of the squared loadings. Communalities < 0.40 may indicate low relatedness to the other items so researcher needs to decide whether to drop it or consider it under another factor. As per a study by Tabachnick & Fidell (2001), 0.32 could be considered as the minimum loading of an item and crossloading is when items load >=0.32 on two or more factors. Hence, the researcher employed Exploratory Factor analysis procedure to decide the suitable number of normal elements and furthermore to lay out which observed factors are reasonable signs of the chosen latent aspects.

2. Confirmatory Factor Analysis - CFA deals prominently with measurement models. Measurement model tests the relationships between indicators (observed variables) and latent variables (factors). A measurement model like Confirmatory Factor Analysis delivers a better understanding of covariation among a bunch of observed factors since the quantity of latent factors is less than that of observed or measured variables (Brown, 2012). The solution is then evaluated in terms of the extent to which it reproduces the sample covariance matrix of indicators. Also, the results of Confirmatory Factor Analysis can give adequate proof of convergent and discriminant validity of constructs with dominant relatedness of the unique indicators of overlapping constructs is exhibited by convergent validity while discriminant validity results indicate that observed variables of the constructs that are theoretically distinct are not largely intercorrelated. Therefore, Confirmatory factor analysis is generally employed as a predecessor to SEM that is used to primarily specify regression or causal relationships or structural relationships among the latent variables.

3. Structural Equation Modelling - Structural equation modelling, a Multi Criteria Decision Making technique has been applied to perform analysis of issues to achieve enhanced performance of cold chain. The multivariate analysis technique is a statistical technique to analyse relations that are structural in characteristic. SEM is a composite procedure involving Factor investigation and numerous Regression examination. It uses latent constructs and exhibits their relationship with the observed variables. The analysis technique is preferred by researchers as a single analysis can estimate multiple and inter-related dependence. SEM models consist of two main models: (1) measurement model that is arrived at to explain the way measured variables together explain the theory and it indicates the number of factors, the relation between various indicators and the factors and the relationships among indicator errors; and (2) Structural model displays the connection between the endogenous and exogenous variables and indicates how the different factors are related to each other. Before the estimation and interpretation of the structural relationships amongst latent variables, it is important to establish a measurement model that is acceptable. Latent variables may be endogenous or exogenous. An endogenous variable is a resultant effect of one or more variables in model and are thus synonymous with dependent or criterion or outcome variables. Conversely, an exogenous variable is one that isn't brought about by any variable and are accordingly known as independent, predictor or causal variables. Causal modelling is another way SEM is referred as since the proposed causal relationships are tested through this technique.

SEM technique follows the assumptions as given below:

1. **Linearity:** Endogenous and exogenous variables must share a linear relationship.
2. **Sequence:** The relation between endogenous and exogenous variables should be a cause and effect relationship with cause occurring prior to the event.
3. **Multivariate normal distribution:** For distribution that is normal and multivariate, maximum likelihood method, Chi-square test can reflect a large difference because of multivariate normality showing small changes.
4. **Non-spurious relationship:** Covariance Observed in the relationship must be true.
5. **Sample size:** Generally, in the SEM model, the sample size should be 10 to 20 times of cases as there are variables.
6. **Data:** SEM uses Interval data.
7. **Model identification:** Models that are under-identified are not considered. Either models are over identified or estimated parameters must be smaller than equations.
8. **Uncorrelated error terms:** It is assumed that the **e**rror terms and other variable error terms are uncorrelated.
9. **Outlier:** Existence of outliers should not be there in the dataset as they affect the significance of the model.

As suggested by Suhr D. (2006), the process through which the SEM analysis proceeds is as given below:

- Research literature and the relevant theory need to be reviewed to support the model specification
- The model with the help of equations, diagram, etc. needs to be specified
- The model needs to be identified
- The measures of variables represented in model need to be selected

- Data needs to be collected
- Preliminary descriptive statistics needs to be conducted
- Parameters in the model need to be estimated
- Model fit needs to be assessed
- The results then should be interpreted and presented

The degree to which the model-implied relationships represent the relationships observed in sample data are addressed by the goodness-of-fit indices (Brown, 2012). **Model fit** can be evaluated by using any of the following indices: badness-of-fit i.e. Chi-square, RMSEA whose smaller values indicates a better fit; and goodness-of-fit i.e. CFI, GFI, TLI whose larger values indicate a better fit. Once the model is considered as an appropriate fit, then the specific elements need to be checked for the fit. A **small fit** may be indicated when the standardized path coefficients have values less than .10; **medium fit** when the values are around .30 and **large fit** when the values are greater than .50. It is critical to develop theoretical model prior to conducting data analysis using SEM technique.

Steps of Structural Equation Modelling

1. Define the Individual Constructs The constructs need to be defined theoretically. For testing measurement model, CFA is applicable.

2. Develop Overall Measurement Model Also known as Path Analysis, which consists of connections among endogenous and exogenous factors. Latent constructs cause indicators and the presence of uncorrelated error terms inside estimated factors is the premise of estimation hypothesis.

3. Design review to create observational outcomes Researcher needs to specify the model and design the study to minimize the likelihood of an identification problem.

4. Assess Measurement Model Validity CFA is assessing the measurement model where the result is associated with the constructs' validity.

5. **Specify Structural Model** structural ways are drawn between constructs with single-headed arrows used to address conjectured underlying connection between the constructs accordingly reflecting about the cause and effect relationship.

6. **Examine Structural Model Validity** Structural model validity is examined by the researcher in this last step. For a model to be considered as a well-fitting model, chi-square value ought to be inconsequential, at a minimum one of the steady fit-indices (GFI, TLI, CFI, AGFI, and so forth) and one of the disagreeableness of-fit indices (RMSEA, RMR, SRMR, and so on) ought to meet the prespecified criteria. Fig 3.7 presents the steps involved in SEM analysis.

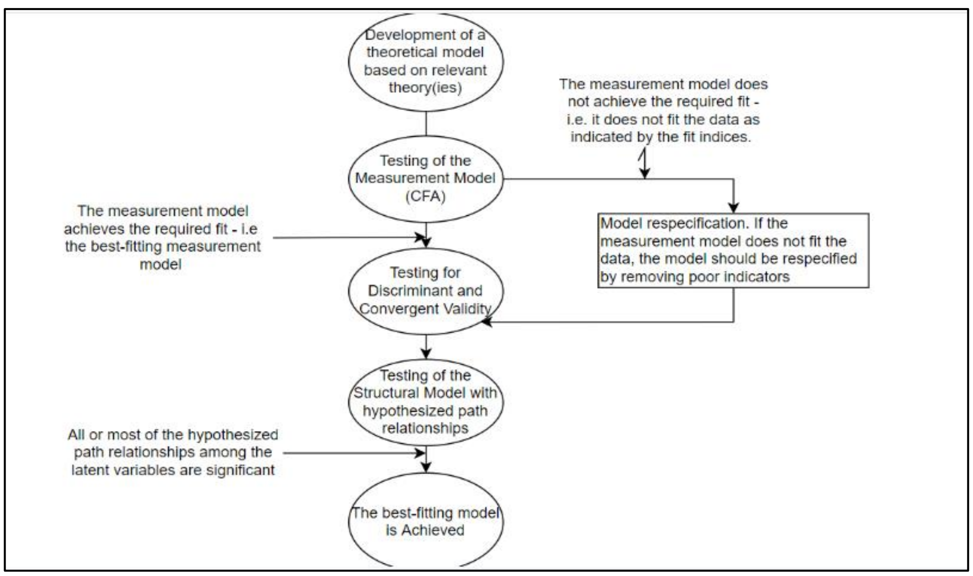


Figure 3.7 Steps in SEM analysis. Adopted from Nunkoo,2012.

4. DEMATEL

DEMATEL is an acronym for 'Decision Making and Trial Evaluation Laboratory' (Fontela and Gabus, 1976). The method was proposed by Bastille National Laboratory, USA in 1971 and was popularly used to analyse logically complex causal relationships in a visual form using a special graph referred to as digraph, short for directed graph. The technique synthesizes the inputs from experts thereby resulting in simplification of uncertainty in complex systems. The causal relationship amongst the issues is assessed using the DEMATEL approach. The technique has been embraced as a solution methodology in this study. It is a complete method to provide causal relationship among the complex factors with the help of graphs. The method has been summarised in steps as given below (adapted from Khan, 2018; Ortiz, 2016):

Step 1: **Making the direct-influenced matrix** In-order to construct a direct relation matrix, the scale is designated at five levels (0,1,2,3,4). The experts were consulted to assess the direct influence between each two-factor arrangement through the score 0,1,2,3,4 (refer Table 3.3). The x_{ij} notation represents the influence of factor i on factor j. A value of zero is put in the diagonal element where i=j. For each expert, a non-negative nxn matrix is attained as $X_k= [x_{ij}^k]$ with k being the number of experts $1 \leq k \leq N$. Thus, we obtain $X_1, X_2, \ldots, X_N$ from N experts. Based on values obtained from N respondents, overall direct-relation matrix, D is established. The average matrix X =[a_{ij}] can be attained from the equation $a_{ij} = \sum_{k=1}^{N} x_{ij}^{k}$

Step 2: **Calculating the direct-influenced matrix normalization** Normalized initial direct-relation matrix, Y is obtained using equations $Y = A.S$ where $S=1/max_{1\leq i\leq n} \sum_{j=1}^{n} a_{ij}$. The value falling between 0 and 1 is put against each element in the matrix Y.

Step 3: **Obtaining TRM (T)** Total relation matrix 'T' is calculated using the equation $T= Y(I-Y)^{-1}$ where I is the identity matrix.

Step 4: **Producing a causal diagram** Determination of causal parameters is done using equations: $r_i = \sum_{i=1}^{n} t_{ij} \, \forall_j$ and $c_j \sum_{i=1}^{n} t_{ij} \, \forall_i$ where r_i represents the sum of rows and c_j indicates the sum of columns. Causal and effect diagram is developed with the help of dataset consisting of prominence (Pi) and the net effect (Ei) depicted through the expressions: $Pi= Ri +Cj \mid i=j$ (7) $Ei= Ri -Cj \mid i=j$. The difference between Ri and Cj (Ri - Cj) represents the net effect contributed by factor i to the system. If it is positive then factor i is said to be the net cause while if (Ri - Cj) is negative then the factor i is said to be the net receiver. Whereas, sum of Ri and Cj are used to demonstrate connection degree between every criterion with others.

Step 5: **Obtaining the inner dependence matrix and impact relationship map** Mapping of the dataset (P, E) is done in this step. The threshold value is set to indicate the influence level between criteria.

Step 6: **Obtaining the inner dependence matrix** Under this step, the sum of each column in total-relation n×n matrix is equal to 1 by the normalization method and then the inner dependence matrix can be acquired: DEMATEL technique results in a visual representation used by the respondent to showcase the study results.

Table 3.3 Comparison Scale for DEMATEL method

Scale	0	1	2	3	4
Level of Influence	No influence	Low influence	Medium influence	High influence	Very High influence

5. AHP

To take into consideration both the quantitative and qualitative aspects of the process of decision-making, AHP, an MCDM (also referred as Multiple-Criteria Decision Analysis , MCDA or Multi-Attribute Decision-Making, MADM) is applied. The technique was created by Saaty in 1971 with the aim of dealing with decision-making problems in situations that were complex and involved multiple criteria. It helps establish priorities amongst decision factors by assessing them with respect to their relative importance (Darko, 2019).). Therefore, it is widely used to solve varied unstructured problems as it helps structure multiple-choice criteria in a hierarchical structure, assess relative importance of the selected criteria, then compare alternatives for those criteria and finally rank the alternatives (Kaya, 2007). It is extensively used in the research as a result of its adaptability, simplicity and convenience. The main steps in the analytic hierarchy process are: development of hierarchical structure represented graphically; construction of pairwise comparison matrix; synthesis; validation of consistency; and finally ranking based on priority weights (Ho, 2012).

The method entails following steps (adapted from Darko, 2019; Ishizaka, 2009):

Step 1: **Hierarchy formation** AHP requires the problem be broken down into a hierarchical structure with four main levels: first level representing the decision goal to be achieved (goal of current study is Cold Chain Performance); second level depicting the criteria (Issues as per the present study problem); third level representing the sub-criteria (Sub-issues as per the present study); and the fourth level showcasing the alternatives for reaching the decision goal (strategies and solutions in the current study).

Step 2: **Pairwise comparisons** Domain experts are requested to give their responses towards pairwise comparison i.e. comparisons are made between relative significance of every criteria with different measures at the second level of the order. Similarly, the sub-criterion (of level three) under the same criteria (of level two) are also compared. Consequently, pairwise correlation grids are built for the criteria (Issues) and furthermore for the sub-criteria (sub-Issues). These pairwise correlations are made in view of 7-point Saaty scale displayed below. Based on inputs from the 30 experts, average of their responses was calculated to arrive at the final matrix showcasing comparisons done pairwise.

Step 3: **Normalized pairwise comparison matrix** AHP makes use of a ratio scale (Kainulainen, 2009) that requires no units while making the comparison. The judgement is a quotient a / b where a is the value in the corresponding cell while b is the sum of the column of that criteria. Thereafter, the Normalized pairwise comparison matrix is obtained.

Step 4: **Verification of Consistency** As, AHP permits subjective judgement by the experts, consistency of the responses or judgments cannot be guaranteed. Hence, it is imperative to perform consistency verification in order to ensure optimized outcomes. According to Saaty (2000), consistency ratio should be computed to ensure consistency of the pairwise comparisons done.

The coefficient vector for criteria weights for the criteria is estimated after calculating geometric means, summation and corresponding reciprocal. The consistency index (CI) is estimated through the formula CI=(λ_{max}-n)/(n-1) with λ_{max} being the coefficient vector average and number of categories represented by n. At last, CR is assessed by dividing CI by RI as CR=CI/RI. For determining the RI value, table 3.4 can be referred. Once the consistency ratio is found to be < 0.10, expert judgments can be then synthesized for prioritization of the decision criteria .

Table 3.4 Average Random Index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

[Source: Saaty, 2008]

Table 3.5 Scale for level of importance (AHP/Fuzzy AHP)

Intensity of Importance	Fuzzy Number	Linguistic Variable	Linguistic Variable Code	Triangular Fuzzy Number (TFNs)
1	$\tilde{1}$	Equal Importance	EI	(1,1,1)
2	$\tilde{2}$	Very Low Importance	VLI	(1,2,3)
3	$\tilde{3}$	Low Importance	LI	(2,3,4)
4	$\tilde{4}$	Average Importance	AI	(3,4,5)
5	$\tilde{5}$	High Importance	HI	(4,5,6)
6	$\tilde{6}$	Very High Importance	VHI	(5,6,7)
7	$\tilde{7}$	Extremely High Importance	EHI	(6,7,7)

FUZZY AHP

According to the classical set theory, membership of an element is represented in set of binary terms 1 or 0 which signifies True or False. Zadeh (1975) developed the Fuzzy logic determined to manage vulnerability and ambiguity in the dynamic process of taking decisions. A fuzzy set is superset of classical set and permits real unit interval between the binary values 0 and 1. The intermediate values between 0 and 1 are referred to as the degree of membership and are used to represent continuous assessment. Fuzzy logic is based on human reasoning that everything cannot be categorized in 1s or 0s only there may be in between values too. For the fuzzy theory, many types of membership functions are used like triangular, sigmoid, trapezoidal, orthogonal however, the most popularly used membership function by the researchers is the triangular one. The triangular fuzzy number N is often represented as TFN (l,m,n) where l means lower value; m means medium value; and n means higher value thus $l \leq m \leq n$.

AHP suffers from impreciseness due to subjective assessment and use of linguistics (Raghuvanshi, 2018). Fuzzy AHP method can address the impreciseness of AHP as it depicts one criteria's performance over another more accurately and logically (Kashav, 2022). The process of decision-making is more effective as it involves expert opinions. For datasets that may be subjective or suffer from some form of ambiguity and so cannot be dealt with a deterministic approach, fuzzy set theory is incorporated with AHP to tackle the issue (Hamzeh, 2019).

The Triangular fuzzy scale (refer Table 3.5) is used to represent the importance level according to the experts. Diagrammatic representation of the process is exhibited in Fig 3.8. The steps followed in the FAHP method are as given below:

Step 1 - The pairwise comparison matrix determined in Step 1 of AHP method was used here after ensuring the consistency of the expert judgements.

Step 2 - The values were then replaced with the corresponding TFNs.

Step 3 - Geometric mean of the fuzzy weights are then estimated.

Step 4 - Defuzzification was done to arrive at the relative non-fuzzy load of every model (M_i) and then standardized loads of every rule (N_i) were estimated. On the basis of the values of N_i, rankings were ascertained. M_i was determined by considering the normalization of fuzzy numbers and N_i by utilizing the non-fuzzy M_is.

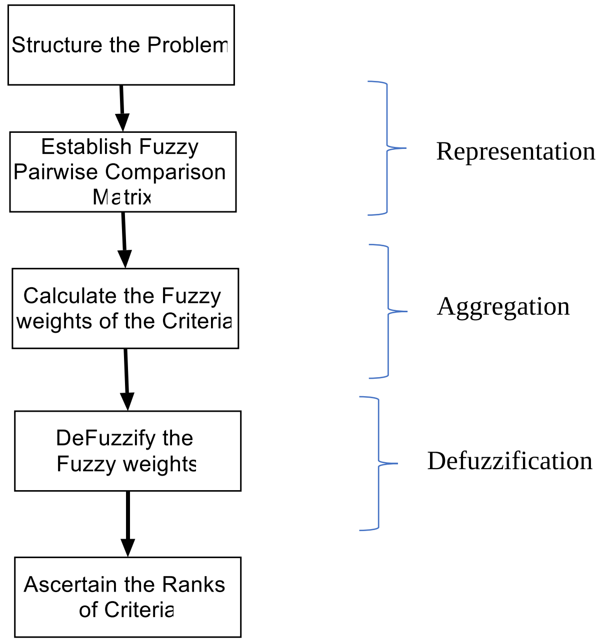


Fig 3.8 Fuzzy AHP Process [Source: Adapted from Liu, 2020]

6. Fuzzy TOPSIS

In 1981, Hwang and Yoon introduced TOPSIS and the method was stretched, through application of Fuzzy logic using TFNs, into Fuzzy TOPSIS by Chen and Hwang in 1992. The method is based on the distance of the solution from the ideal solution. According to TOPSIS, ideal solution and the negative ideal solution are the two types of solutions. The solution consisting of all the best values for the criteria being maximal benefits solution is known as the ideal solution whereas the solution consisting of the worst values of the criteria being minimal benefits solution is known as the negative ideal solution (adapted from Jothimani & Sarmah, 2014). Hence, while selecting an alternative, the one nearest to the best arrangement and farthest from the negative ideal course of action is ideal choice. Hence, the final ranking is attained by estimating the closeness coefficient values of the different solutions. The steps for executing the FTOPSIS method are given below (adapted from Shoar, 2019; Nădăban, 2016):

Step 1 **Compute the aggregated fuzzy ratings for alternatives and the aggregated fuzzy weights for criteria** Inputs are collected from the experts. The data inputs are then found the using the mean value and are then represented in a decision-matrix format utilizing the nine-point scale (refer Table 3.6).

Step **2 Determine the normalized fuzzy decision matrix** Conversion of decision matrix to its normalized format is done by converting the crisp values into triangular fuzzy numbers. Amongst various issues considered for deciding the level of importance or usefulness of the solution, each issue is categorised into either Benefit type or Cost (non-beneficial) type. For the beneficial criteria, the maximum of the upper value is considered of the TFNs (l,m,u) and the l, m, u values of each cell of that criteria is divided by that maximum value. While for a nonbeneficial criteria, the minimum of the lower value is considered of the TFNs (l,m,u) and the minimum value is divided by the l, m, u values of each cell of that criteria.

Step 3 **Compute WNFDM** Matrix is computed by calculating the products of values in normalised fuzzy decision-matrix and weights assigned to the criteria.

Step 4 **Compute the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) and the distance from each alternative to the FPIS and to the FNIS** Considering each criterion, the maximum TFN and the minimum TFN are considered. Thereafter, the FPIS is determined considering gap from the maximum TFN and the FNIS is determined by considering the gap from the minimum TFN. The formula considered for both (in excel) is SQRT((1/3)*(POWER(a1-a2,2)+POWER(b1-b2,2)+POWER(c1-c2,2)+…..)). Thereafter, the di* (FPIS) and di- (FNIS) are determined for each solution.

Step 6 **Compute the closeness coefficient CCi for each alternative** the relative closeness to the ideal solution is determined by using the formula di-/(di* + di-).

Step 6 **Rank the alternatives** Rank the solutions based on the preference order by considering the alternative with highest closeness value as topmost rank and the alternative with lowest closeness value at the bottom position.

Table 3.6 Scale of relative preference for FTOPSIS & BWM

Linguistic Expression	Value	TFNs
Very Low	1	(1,1,3)
Low	3	(1,3,5)
Average	5	(3,5,7)
High	7	(5,7,9)
Very High	9	(7,9,9)

7. BWM method

The method is employed first for gaining an understanding of the most preferred solution and the least preferred solution based on the expert inputs. The method does not require a complete pairwise comparison network as it contrasts the models just and regard to the most preferred criteria and the least preferred criteria. It is also very simple for the decision-makers to reason and make judgements using this method. The steps applied in BWM are given as below (adapted from Salimi & Rezaei, 2018):

Step 1 Fix the criteria for decision-making i.e. the criteria to be used for the analysis are identified. In the study, the criteria are the solutions, which are partitioned into two classifications, ones using information technology and the other general strategies and solutions, the analysis of which is done separately.

Step 2 Amongst the solutions, the best solution, i.e the most preferred or the most important or the most desirable solution is selected and similarly the worst solution i.e. the least preferred or the least important or the least desirable solution is selected based on judgement and inputs from the experts.

Step 3 Once the best and worst solution is decided in step 2 then the best solution is compared with respect to the remaining solutions using the nine-point scale (refer Table 3.5) . The result is a BO (Best to Others) vector.

Step 4 In this step the inclination of remaining arrangements is viewed as over the most awful arrangement utilizing the nine-point scale.

Step 5 Then the optimal weights are determined using BWM Excel Solver. The file can be downloaded and the selected solutions are put in their relevant positions and steps 3-4 are executed. By clicking on the Solver, the optimal weights for each solution are estimated based on the applicable constraints. The ξ (Ksi*) value is also calculated and with a value between 0 and 1, consistency of the comparisons determined by the experts is illustrated.

Step 6 For problems involving more than one level i.e presence of sub-categories, then the global loads can be assessed by determining the product of the weight of sub-classification and that of its primary classification.

8. Sensitivity Analysis

Sensitivity analysis is performed to examine the consistency and reliability of the applied framework. By making changes to the weight of a specific criteria, variation can be seen in the final ranking of the alternatives (Vishwakarma, 2019; Yadav, Garg & Luthra, 2021). To attain this, nine iterations are performed. The value of the solution possessing maximum weight is substituted while the other solutions' weight remains the same. Thereafter ranks are considered for all the criteria.

Sensitivity analysis aims to achieve the goal of determining how change in criteria weight results in changes in rankings of the alternatives. This way the rankings obtained from statistical techniques and selection of the alternative can be confirmed (Chen, 2010).

3.12 CHAPTER SUMMARY

In this chapter, a detailed discussion on the methodology used for accomplishing the research objectives was mentioned. The technique used for collecting data and the assessment of this data using various methods was explained. The various methods employed to analyse the issues including SEM, DEMATEL, AHP/Fuzzy AHP, Fuzzy TOPSIS and BWM were explained in detail in this chapter. The next chapter illustrates application of SEM technique on the issues in the cold supply chains of frozen food items and the outcomes acquired in the wake of utilizing this strategy are talked about exhaustively in the ensuing sections.

CHAPTER 4

RESEARCH OUTLINE AND PRELIMINARY ANALYSIS

OVERVIEW

This chapter presents a preliminary analysis of data collected from different cold chain partners of frozen food products namely, farmers, manufacturers/processors, distributors, and retailers. The chapter also details on statistical tests for testing of reliability, and validity.

4.1 DEMOGRAPHIC PROFILING

4.1.1 Sample Attributes

This section exhibits the segment qualities of the survey participants. Out of 278 participants, 38% belonged to the age gathering of 31-43 years and 34 percent of respondents were grouped in the age range 44-55 years. Most respondents were educated to the level of Diploma/Graduate whereas amongst farmers majority of respondents had completed their education only till schooling level. Experience-wise, majority (71%) of respondents had experience in the range of 2-10 years. Considering the form of business that they had, 50% of respondents indicated business being private limited companies, 26% were in partnership and 25% were in Sole Proprietorship. Maximum (66%) farmers were Semi-medium/Medium type (2-10 ha) holding of farmers and 24% farmers were Small (1-2 ha) farmers while a very small percentage were in the category of Marginal or Large. While only 28% farmers had good knowledge related to modern techniques of farming but none had knowledge of use of technology in farming.

The survey was conducted in Uttarakhand region amongst the cold chain partners including farmers, processors, distributors, and retailers. The personnel selected for the present study are professionals possessing immense knowledge, expertise and proficiency in their area of cold chain. Considering that the research involves the entire cold supply chain, it is therefore important to understand the various players who have a specific role in the cold chain and finally take their respective feedback. Also, responses were taken from IT companies who were involved in development of supply chain solutions. For the main study, 315 responses were accumulated from the various cold chain stakeholders. All responses except from IT companies and Quality agencies, were collected with a face-to-face interaction. Responses from the IT companies and Quality agencies were collected via email. However, owing to either the responses not filled properly or missing values and other validity concerns, only 278 was the final sample size considered and the final data is exhibited in table 4.1 and Fig 4.1. The demographic statistics of the sample based on the final size of 278 is presented from Table 4.1-4.6. This analysis was represented in tabular form and graphical form. In tabular form the representation exhibited percentage analysis. In graphical representation, graphs like the pie chart were specifically used to analyse and give pictorial representation of the data analysed

Table 4.1 Type of Respondents

Type of Respondent	Number contacted	Percentage
Frozen Food Company	28	10.07%
Farmer	50	17.98%
Logistics	40	14.38%
Distributor/Private Agent	15	5.69%
Retailer	95	34.17%
Quality	10	3.59%
IT Co. executive	40	14.38%
Total	278	100%

[Source: Author composition]

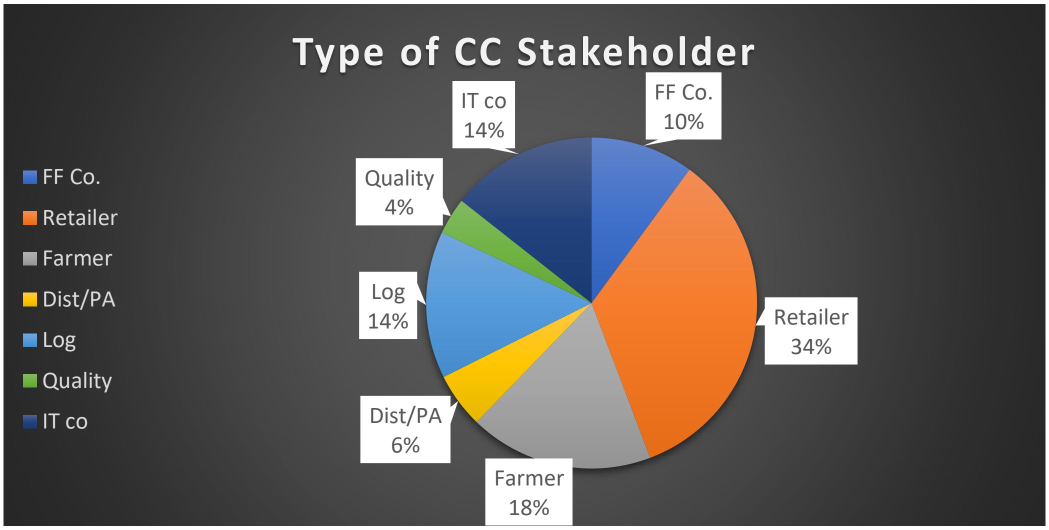


Fig 4.1 Percentage of Respondent w.r.t Type

When the profile of the respondent is being studied, it becomes significant to understand the level of experience held by the respondent. The experience means that the dependability and nature of the input given is reliable. The profile of respondent in terms of their years of experience is depicted in table 4.2 along with in Fig 4.2.

Table 4.2 Profile of Respondent in years of experience

Respondent's Experience (in years)	Number	Percentage
Less than 2 years	14	5.03%
2 – 5 years	89	32.01%
5 - 10 years	107	38.48%
10 – 15 years	40	14.38%
More than 15 years	28	10.07%
Total	273	100%

[Source: Author's composition]

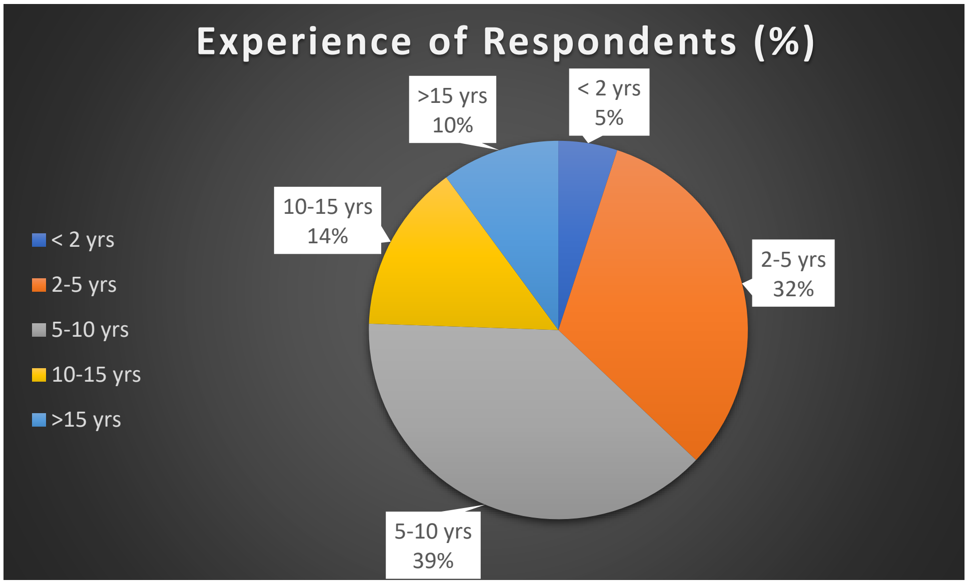


Figure 4.2: Percentage of respondent w.r.t experience

Around 32% of the participants have experience ranging from 2 to 5 years while 39% have experience in the range of 5 - 10 years. Of course, most of the farmers have been in this since generations and so their experience was anywhere between 10-15 years or more than that considering the age of the respondent.

Considering the educational qualification of the respondents is also an important indicator towards understanding of the item in the questionnaire and in providing correct response. Table 4.3 presents the information on educational qualification of the respondents and the number of individuals also depicted in Fig 4.3.

Table 4.3 Respondents' educational qualification

Respondent's Qualification	Number	Percentage
Less than 10th pass	39	14.03%
10th/10+2	28	10.07%
Diploma/Graduate	164	58.99%
Post-Graduate/Others	47	16.91%
Total	278	100%

[Source: Author]

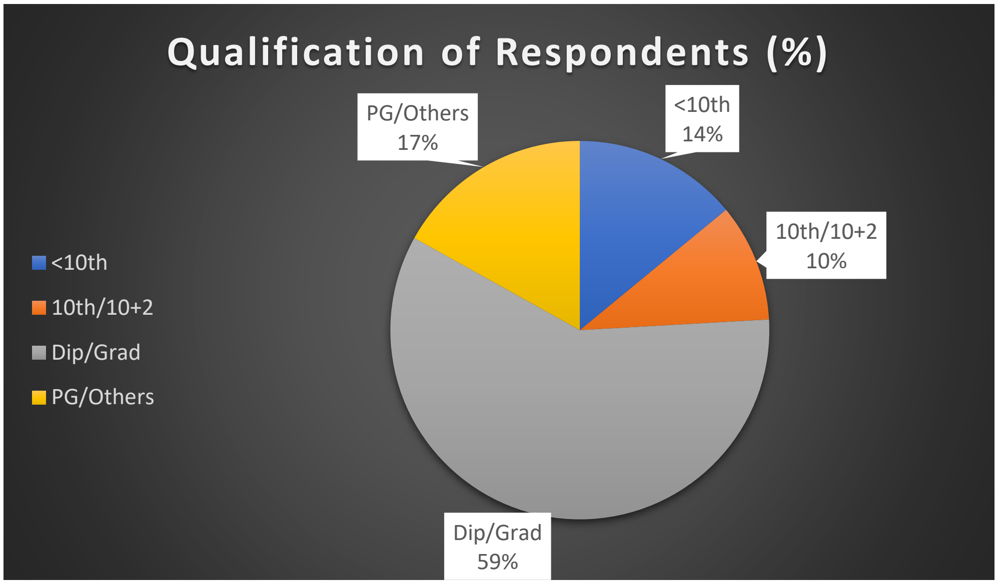


Figure 4.3 Percentage of Respondent w.r.t qualification

Around 59% of the respondents are either Graduate or hold Diploma while 17% have completed Post Graduation or equivalent. While Most of the older farmers are less than 10th standard educated, the younger lot have completed 10+2 or even graduation. Respondents from the Frozen food companies, IT companies were educated to the level of post-graduation also.

Table 4.4 and Fig 4.4 below represents the form of business held by the different CC players as it helps in understanding the extent of investments that can be afforded by the respective CC player.

Table 4.4 Form of business held by CC players

Type of Respondent	Form of Business	Number of Respondent	Percentage
Frozen Food Company	Sole Proprietorship	5	17.86%
	Partnership	10	35.71%
	Private Ltd.	13	46.43%
Retailer	Sole Prop	24	25.26%
	Partner	39	41.05%
	Private	32	33.68%
Distributor/Private Agent	Sole Prop	13	86.7%
	Partner	0	0
	Private	2	13%
Logistics	Sole Prop	0	0
	Partner	0	0
	Private	40	100%
Total	Sole Prop	42	23.5%
	Partner	49	27.5%
	Private	87	48.8%
	Cooperative	0	0

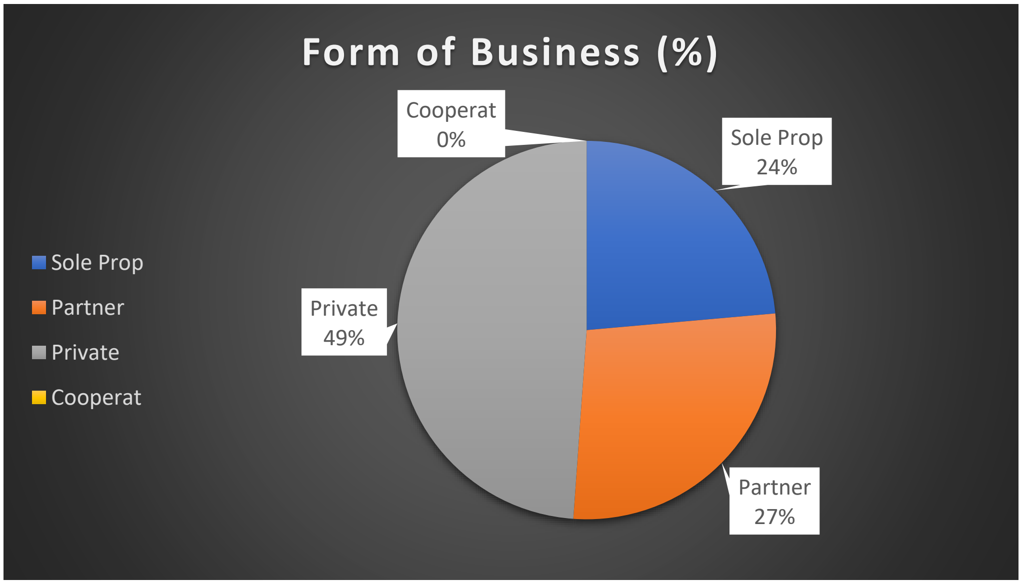


Fig 4.4: Percentage of Respondent w.r.t Form of business

Around 46% frozen food companies targeted were private limited, 39% retailers were in partnership, 87% of distributors were sole proprietors, 100% logistics were private limited. Whereas considering the form of business for frozen food companies, retailers, distributors and logistics taken together, 24% respondents were having Sole proprietorship, 27% were in Partnership, 49% were Private Limited while none functioned as Cooperatives. Farmers, IT companies and Quality agencies were not considered in this analysis as: Farmers operate individually only while contribution of IT companies and Quality bodies to this analysis was deemed to be redundant. It is likewise vital to distinguish the sort of farmers in the state of Uttarakhand. Table 4.5 and Fig 4.5 below elucidates the percentage of types of farmers in the state.

Table 4.5. Types of Farmers in Uttarakhand

Type of Farmer	Number of Respondents	Percentage
Area <1 ha - Marginal	3	6%
Area 1 – 2 ha - Small	12	24%
Area 2 - 10 ha - Semi-medium / Medium	33	66%
Area > 10 ha - Large	2	4%
Total	50	100%

[Source: Author]

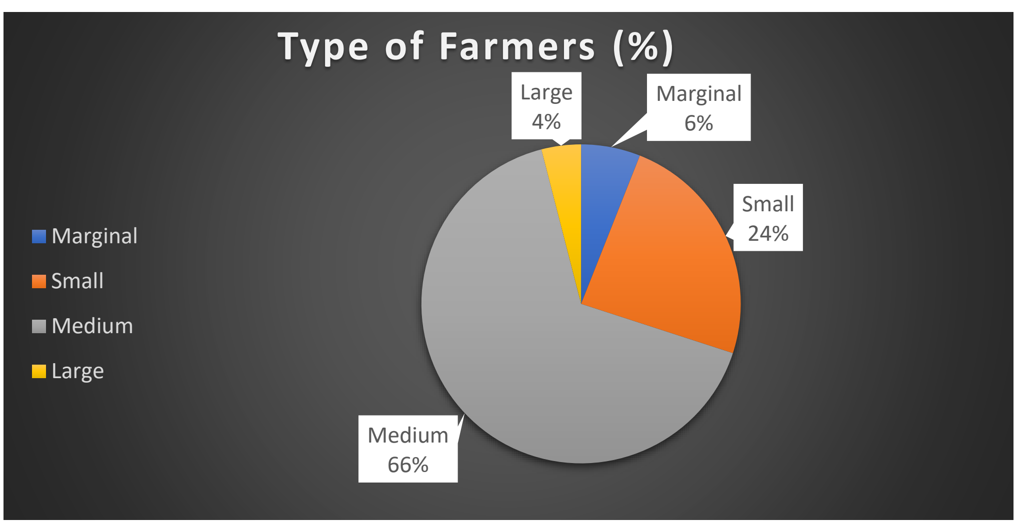


Figure 4.5: Percentage of Farmers in different categories

As can be seen only 4% of the farmers have large holdings, while 66% have medium holdings.

4.1.2 Respondents opinion w.r.t importance and effect of issues

The primary data presentation whereby the issues have been ranked for importance and effect on cold chain performance on five-point Likert scale. For importance, the scale used is from 5 - Most important; 4 - important; 3 - neutral; 2 - less important; and 1 - least important. Accordingly, for effect, the scale used is from 5 - most effect; 4 - more effect; 3 - neutral; , 2 - less effect; 1 - least effect. Table 4.6 and 4.7 indicates responses received for the importance and effect of the various issues. The values indicate high relevance of the issues in terms of their importance and effect on the cold chain performance.

Table 4.6 Responses for Importance of Issues w.r.t CC performance

Issue	Least Important (1)		Less Important (2)		Neutral (3)		Important (4)		Most important (5)		Total number
Infrastructure	0	0.0%	0	0.0%	16	6%	65	23%	197	**71%**	278
Traceability	4	1%	26	9%	99	**36%**	90	32%	59	**21%**	278
Sustainability	0	0.0%	28	10%	59	21%	66	23%	125	**45%**	278
Integration	2	0.7%	33	12%	114	41%	89	32%	40	**14%**	278
Safety & Quality	0	0.0%	0	0.0%	5	2%	110	39.5%	163	**59%**	278
Awareness & Handling practices	0	0.0%	1	0.1%	32	11.5%	106	38%	139	**50%**	278
Responsiveness	0	0.0%	0	0.0%	29	10%	99	36%	150	**54%**	278

Table 4.7 Responses for Effect of Issues on CC performance

Issue	Least Effect (1)		Less Effect (2)		Neutral (3)		More Effect (4)		Most Effect (5)		Total number
Infrastructure	0	0.0%	0	0.0%	29	10%	51	18%	198	**71%**	278
Traceability	0	0%	25	8%	67	24%	70	25%	116	**42%**	278
Sustainability	0	0.0%	27	10%	93	33%	81	29%	75	**27%**	278
Integration	11	4%	21	7.5%	50	18%	97	35%	99	**36%**	278
Safety & Quality	0	0.0%	0	0.0%	27	9%	100	36%	151	**54%**	278
Awareness & Handling practices	0	0.0%	3	1%	24	9%	74	27%	177	**64%**	278
Responsiveness	0	0.0%	0	0.0%	31	11%	117	42%	130	**47%**	278

If the values in table 4.6 and 4.7 were to be considered, it can be elucidated that 71% respondents agreed that integration is important and can have major effect on cold chain performance. Thus, greater part of the respondents concurred that every one of the above issues are significant and can substantially influence performance of cold chain.

4.2 DATA COLLECTION

4.2.1 Survey Questionnaire

For the purpose of data collection, around 35 frozen food companies in Uttarakhand were targeted out of which only 33 companies responded with a response rate of 94% as some were not very few did not respond (refer Table 3.1 Chapter 3). During the survey, the data was collected from Haridwar, Rishikesh, Dehradun, Mahua Khera, Paudi, and the adjoining areas for data on farmers; data on Frozen food manufacturers/processors was primarily from Haldwani, Rudrapur, Kashipur, Udham Singh Nagar, Haridwar, Roorkee, Rishikesh, etc; data on Retailers including big players like Big Bazaar, Reliance, Suvidha, Easy Day, and many others in Dehradun, Rishikesh, Roorkee, Haldwani, etc.; and data for wholesalers/distributors/private agents operating from Mandis was collected from areas including Dehradun, Rishikesh, Roorkee, Mahua Khera Ganj, etc; and on Logistics service providers primarily from Dehradun.

Maximum frozen food manufacturers/processors are located in Kashipur, Haldwani and its adjoining places, the area being a frozen food manufacturing/processing belt. The researcher personally visited these companies and the vegetable mandis in Rishikesh and Haldwani and their responses were collected from distributors, private agents. Also, farmers who had come there were targeted. Most of the farmers indicated usage of latest machines and equipment for farming however, usage of information technology was not indicated anywhere.

4.2.2 Sampling Adequacy Analysis

The sample size depends upon the research approach applied, the complexity of the model as far as number of factors utilized, accessibility of time and assets, completion rate completion along with the sample size that has been used for similar studies (Memon, 2020). A large sample size can sometimes make statistical significance exceedingly sensitive resulting in Type I error i.e. it depicts significance even though it is not significant (Hair, 2018). Therefore, the way information is gathered is a higher priority than really concentrating on indiscriminately gathering more information just to build the sample size. The reliability of a sample relies more upon the reasonable determination of the respondents than only targeting a larger sample size (Lakens, 2022). This approach was therefore acted upon and the sample consisted of carefully selected respondents. For determining the sampling adequacy, two measures are developed: the Kaiser-Meyer-Olkin (KMO) measure and the Bartlett's test of sphericity. While KMO tests to check if all correlations are zero, Bartlett's test performs a comparison between the partial correlations and observed correlations among the variables and checks wither the correlation matrix is significantly different from the identity matrix. Along with testing for sampling adequacy, it also is a statistical measure to evaluate the reasonableness of information for factor investigation (refer table 4.8). As suggested by Budaev (2010), KMO being independent of the sample size, correlation matrices possessing KMO value < 0.5 are not acceptable while KMO values less than 0.6-0.7 need to considered with caution. Therefore, the value of KMO should be between 0.8 - 1.0 indicating that sampling is adequate. Bartlett's test of sphericity tests for significance, and hence p-value < 0.05 indicates that it is significant.

4.2.3 Examining Reliability

To decide the reliability of the constructs in the cold chain of frozen food, dependability of the dataset is analyzed. Reliability means consistency i.e. how consistently the values measure the desired aspect. The two most prominent reliability statistics are standard error of measurement and reliability coefficient (Cronbach alpha). As per the mathematical definition, Cronbach alpha (α) - "an adjusted proportion of total variance of the item scores explained by the sum of covariances between item scores and thus ranges between 0 and 1 if all covariance elements are non-negative" (Heo, 2015). The Alpha coefficient method (Cronbach, 1951), is a suitable method that can be used for 3-point and 5-point Likert scale items (adapted from Ercan, 2007). In order to measure the degree of consistency, accuracy and stability of the data collected in the study, reliability is used. According to Sekaran(2003), value of Cronbach's alpha is reliable when it is between 0.6 and 0.7 and if it is above 0.7, it is considered as a good reliability. In order to determine overall reliability as well as construct's consistency Composite reliability, CR is used (Hair, 2010).

The coefficient of reliability is an absolute number ranging from 0.0 to 1.0 with 0.0 demonstrating total absence of consistency and 1.0 showing absolute consistency. Smaller is the value of standard error of measurement, higher will be the value of reliability coefficient. This can be explained by the formula

$$\text{Reliability coefficient} = 1 - [\text{standard error of measurement} / \text{standard deviation of scores}]^2$$

If the reliability coefficients are within the range from 0.7 - 0.9, they are said to be in acceptable range. Both alpha value and CR can be utilized to test reliability.

When items on a scale 'hang together' and measure a similar construct, then having great inner consistency reliability is said. While if all constructs when combined together give good results then it is said to have good composite reliability. For both the measures, value between 0.7 - 0.9 is an indication of high reliability. The Cronbach alpha values for the present study are determined by identifying the scope of presence of all the issues in the cold chain of frozen food in Uttarakhand.

4.2.4 Common Method Bias Test

The occurrence of common method bias (CMB) takes place in case of self-reported data. CMB signifies the variance attributed to measurement method which may create errors in measurement resulting in bias in estimates (Podsakoff, 2003). Presence of CMB can affect the unwavering quality and legitimacy of measures (Jordan, 2020). Common Method Bias test using Harman's One-factor, a technique commonly used by the researchers, was conducted to ensure no biasness in the responses collected. Common method biasness is said to be present in case the total variance extracted by one factor is more than 50% (Podsakoff, 2003). In the study, the total variance extracted by one factor is estimated to be 22.78% which is less than 50%. Hence, there is no CMB present in the study.

4.3 PHASE I IDENTIFICATION OF CSC ISSUES - MAIN CATEGORIES AND SUB-CATEGORIES

Objective 1: To identify issues existing in the cold chain of the frozen food products

Literature was reviewed exhaustively with the aim of comprehending the presence of issues in the cold chain. The categories and sub-categories of the issues, which influence/impact the performance of the cold chains have been gathered from existing studies and relevant feedback from domain experts including industry experts and academicians. Thus, based on literature review as well as the expert inputs, seven issues and 73 sub-categories of issues were ascertained.

4.3.1 Initial List of Issues and their Sub-criteria

The initially identified list of categories and sub-categories of issues is illustrated in Chapter 3. The identified issues have been grouped into seven categories: Lack of Infrastructure (INFR), Lack of Sustainability (SUST), Lack of Traceability (TRAC), Lack of Integration (INTG), Lack of Safety & Quality (SAFQ), Lack of Awareness & Handling Practices (AWHP) and Lack of Responsiveness (RESP) and the eighth variable is the Cold Chain Performance (CCP). Every one of these classes has inside it a rundown of sub-classifications, 73 in number including 10 of CCP and 63 sub-categories of the seven identified issues. The reliability of the dataset including 73 variables was estimated to be 0.926 (>0.7) indicating good reliability of the dataset.

4.3.2. Application of Exploratory Factor Analysis - Final List of Issues and their Sub-criteria

As per the sampling adequacy results as presented in Table 4.8 which indicated that the sample was fit to apply factor analysis. Table 4.9 exhibits the descriptive statistics. Exploratory Factor Analysis was carried out to identify the common factors and interpretation of their nature for the study by determining factor loadings of different indicators over the constructs. Factor analysis helps to attain moderately parsimonious depiction of structure of correlations (Fabrigar, 2011). Maximum likelihood estimation method was employed for extraction of factor. This was done as it allows for determination of different indices of goodness-of-fit for the model and also permits statistical significance testing of factor loadings as well as correlations among factors (Costello, 2005). Once extraction is taken care of, then the researcher needs to decide the number of factors to retain for rotation. Neither over-extraction nor under-extraction should be carried out as it could be detrimental for data analysis. The general default suggested for extraction is to extract and retain all those factors which exhibit eigenvalue greater than 1.0. Scree test is also a useful technique for choosing the quantity of variables to hold where the quantity of datapoints reflected above point of break generally is the number of factors that should be retained. In the current review both the procedures have been utilized to decide the quantity of elements to hold. For rotation, varimax rotation technique has been used.

After rotation, the item loading tables are considered where item loadings and cross-loadings are taken into consideration for the purpose of selection of which items fall into which relevant factor. In the present study, loadings below 0.40 were not given any consideration so that the study could present more accuracy in the results. However, while doing so reliability and other aspects were also given due consideration. The study employed factor analysis to validate constructs namely Infrastructure, traceability, sustainability, integration, safety and quality, awareness & handling practices, responsiveness and cold chain performance as shown in

Considering that the Eigen value is > 1.0, the factors extracted and the variables representing them are presented in Table 4.10 along with the reliability and factor loadings for the items. Figure 4.6 depicts graphical representation of different constructs along with the selected indicators.

Table 4.8 Sampling Adequacy results

No. of Items	KMO Value	Bartlett's test of Sphericity	Reliability (Cronbach alpha)
73	0.828	0.00	0.926

[Source: SPSS Analysis]

Table 4.9 Descriptive Statistics (Scale statistics)

Item	Number of Sub-items (Initial)	Number of Sub-items (Reduced)	Mean	Standard Deviation
Infrastructure	7	5	19.01	3.24
Traceability	13	3	9.69	2.58
Sustainability	16	5	10.41	4.27
Integration	6	3	10.86	2.13
Safety & Quality	10	5	14.68	3.87
Awareness & Handling Practices	7	5	20.26	3.00
Responsiveness	4	4	11.01	3.172
Cold Chain Performance	10	3	11.97	1.616

Fig 4.6 Graphical representation of constructs identified as Issues in cold chain

Table 4.10 Extracted Factors (Issues) and their Sub-categories - Reliability and factor loadings

Construct	Indicator Code	Factor Loadings	Cronbach Alpha
Infrastructure	PFAC	0.807	0.911
	SFAC	0.881	
	TFAC	0.731	
	DFAC	0.750	
	RFAC	0.639	
Traceability	INST	0.510	0.778
	INRT	0.806	
	PINF	0.983	
Sustainability	LOSS	0.844	0.941
	PDRP	0.904	
	COST	0.897	
	ENRG	0.895	
	GRNC	0.800	
Integration	FARM	0.505	0.750
	BACK	0.994	
	FORW	0.696	
Safety & Quality	HNDP	0.779	0.902
	STRP	0.671	
	QUCP	0.863	
	ATTR	0.885	
	CMPL	0.660	
Awareness & Handling Practices	AITT	0.715	0.911
	KNHP	0.786	
	KNQP	0.816	
	KNSR	0.757	
	KNCS	0.736	
Responsiveness	VART	0.728	0.833
	LTRD	0.760	
	SYNG	0.703	
	CUST	0.690	
Cold Chain Performance	QLTY	0.559	0.819
	SHLF	0.512	
	WAST	0.777	

The goodness-of-fit test conducted during factor analysis indicated fitness of the results with chi-square value estimated at 508.249, df at 292 and p-value as 0.00. The total variance explained by the eight factors was estimated at 66.920 (>60%) i.e. the factors extracted explained 67% variance which is good. As can be seen in Table 4.10, loadings of all the sub-criteria on their respective factors are above 0.50 with most of the variables having loadings above 0.70. Thus, as the sub-criteria load well onto the factors it can be interpreted that the sub-criteria sufficiently explain the variables. Also, the reliability of all the key categories is within 0.7 - 0.9 which indicates internal consistency i.e. the items sufficiently explained the key category. The Composite Reliability of all constructs when combined (i.e. 33 variables considered together) was estimated to be 0.839 (>0.80) which indicates that all constructs when combined together are giving good results. This is an indication of the suitability of the dataset. Hence, the constructs and their sub-criteria as presented in the table 4.10 can be considered for further analysis of data to obtain the desired objectives. An explanation of the key constructs is as given below:

Lack of Infrastructure

After conducting exploratory factor analysis, the items presented in the above table were the selected indicators for the factor construct ‘Infrastructure’. The items loading/unloading facilities (LFAC) and packaging facilities (KFAC) were removed owing to low factor loadings and cross-loadings. Hence, the final chosen items that loaded well (as shown in the above table) are Production/processing facility (PFAC) - 0.807, storage facility (SFAC) - 0.881, transportation facility (TFAC) - 0.731, distribution facility (DFAC) - 0.750 and marketing/retail end facility (RFAC) - 0.639. The Cronbach alpha value for the construct Infrastructure was estimated to be 0.911 which represents a good value in terms of consistency and reliability of the construct. It means that it is 91.1% reliable.

Lack of Traceability

The items presented in the above table were the selected indicators for the factor construct 'Traceability'. The items Access to Information about Geographic Origin (INGO), access to information about ingredients (INIG), Access to information about method of processing (INMP), access to information about compliance to legislation (INCL), access to information about best before date (INBD), access to information about environmental conditions (INEN), information coverage about product at farmer level (INFL), information coverage about product at packaging level (INPL), information coverage about product at distributor level (INDL), and information coverage about associated costs (INCO) were removed owing to low factor loadings and cross-loadings. Hence, the final chosen items that loaded well (as shown in the above table) are information coverage at storage level (INST) - 0.510, information coverage at retailer level (INRT) - 0.806, extent of information about product (PINF) - 0.983. The Cronbach alpha value for the construct Traceability was estimated to be 0.778 which represents a good value in terms of consistency and reliability of the construct. It means that it is 77.8% reliable.

Lack of Sustainability

The items presented in the above table were the selected indicators for the factor construct 'Sustainability'. The items human rights followed (HRFO), consideration of social welfare (SOWF), resource usage (RESU), use of automation (AUTO), carbon footprints (CRBF), consideration for storage compatibility (STOR), vehicle insulation (VEHI), use of alternate source of energy (ALSE), adverse environment impact (ADEV), complying to certification (CMPL) and use of organic production methods (ORGP) were removed owing to low factor loadings and cross-loadings. Hence, the final chosen items that loaded well (as shown in the above table) are losses and wastage (LOSS) - 0.844, product responsibility (PDRP) - 0.904, cost (COST) - 0.897, energy consumption (ENRG) - 0.895 and green cold chain practices (GRNC) - 0.800. The Cronbach alpha value for the construct Sustainability was estimated to be 0.941 which represents a good value in terms of consistency and reliability of the construct. It means that it is 94.1% reliable.

Lack of Integration

The items presented in the above table were the selected indicators for the factor construct 'Integration'. The items linkage between firm and government (FIGO), linkage between firm and distribution channels (FIDC), linkage between firm and marketing (FIMK) were removed owing to low factor loadings and cross-loadings. Hence, the final chosen items that loaded well (as shown in the above table) are linkage between farmer and firm (FARM) - 0.505, backward integration (BACK) - 0.994 and forward integration (FORW) - 0.696. The Cronbach alpha value for the construct Integration was estimated to be 0.750 which represents a good value in terms of consistency and reliability of the construct. It means that it is 75% reliable.

Lack of Safety & Quality

The items presented in the above table were the selected indicators for the factor construct 'Safety and Quality'. The items linkage between processing practices (PRCP), distribution practices (DSTP), access to information to all CC partners (INCC), reduction of chemical content (CHEM), and real-time monitoring using IT (REAL) were removed owing to low factor loadings and cross-loadings. Hence, the final chosen items that loaded well (as shown in the above table) are handling practices (HNDP) - 0.779, storage practices (STRP) - 0.671, quality control practices (QUCP) - .863, food attributes and required environmental conditions maintained (ATTR) - 0.885 and compliance to standards for assurance of safety and quality (CMPL) - 0.660. Value of alpha is estimated to be 0.902 which represents a good value in terms of consistency and reliability of the construct. It means that it is 90% reliable.

Lack of Awareness & Handling Practices

The items presented in the above table were the selected indicators for the factor construct 'Awareness and Handling Practices'. The item knowledge of environmental sustainability (KNES) and knowledge about traceability requirements (KNTR) were removed owing to low factor loadings and cross-loadings. Hence, the final chosen items that loaded well (as shown in the above table) are awareness about latest techniques and technology (AITT) - 0.715, knowledge of handling practices (KNHP) - 0.786, knowledge of quality parameters (KNQP) - .816, knowledge of safety requirements (KNSR) - 0.757 and knowledge of compliance standards (KNCS) - 0.736. The Cronbach alpha value for the construct Awareness and Handling Practices was estimated to be 0.911 which represents a good value in terms of consistency and reliability of the construct. It means that it is 91% reliable.

Lack of Responsiveness

The items presented in the above table were the selected indicators for the factor construct 'Responsiveness'. The final chosen items that loaded well (as shown in the above table) are catering to varieties (VART) - 0.728, lead time reduction (LTRD) - 0.760, synergy with firm supply to (SYNG) - .703 and customer-centric in terms of response time and customer complaints (CUST) - 0.690. The Cronbach alpha value for the construct Responsiveness was estimated to be 0.833 which represents a good value in terms of consistency and reliability of the construct. It means that it is 83% reliable.

Cold Chain Performance

The items presented in the above table were the selected indicators for the factor construct 'Integration'. The items proper storage of frozen food (STFF), restore texture (TEXR), proper storage of frozen fruits and vegetables (STFV), moisture retained (MOIS), nutrients retained (NUTR), freshness retained (FRSH) and protected from bacteria (PBCT) were eliminated inferable from low variable loadings and cross-loadings. The last chosen items that loaded well (as shown in the above table) are quality maintained (QLTY) - 0.559, shelf life enhanced (SHLF) - 0.512, spoilage and wastage minimized (WAST) - .777. Value for Cronbach alpha for 'Cold Chain Performance' was estimated to be 0.819 which represents a good value in terms of consistency and reliability of the construct. It means that it is 81.9% reliable.

4.4 PHASE II ANALYSIS OF ISSUES USING SEM, DEMATEL AND AHP/FAHP

Objective 2: To analyse identified issues in the cold chain of frozen food products w.r.t their influence on cold chain performance

The issues are initially analysed using DEMATEL for an understanding the inter-influence amongst the issues. Thereafter, analysis of the issues was done using Structural Equation Modelling. The multivariate analysis technique being a statistical technique helps analyse relations that are structural in characteristic. SEM, a multi-variate technique uses theory and research in model specification and considers errors in measurement (Suhr, 2006). Relations between variables can be explained appropriately as it is an effective technique while analysing it is possible to estimate the interrelated and multiple dependence. Relationships between variables is exhibited through a model. According to Nunkoo (2012), SEM is best suited for confirmatory modelling in order to evaluate a substantive theory with empirical data with the help of a hypothesised model as shown in Chapter 3. Finally, the issues and their sub-categories are prioritised using AHP/FAHP approach for a clear understanding of the ranking of the issues.

4.4.1 Analysis of Issues using Decision Making Trial and Evaluation Laboratory (DEMATEL)

The inter-influencing amongst the issues is assessed using the DEMATEL approach. The DEMATEL approach is applied in this section to analyse the issues in terms of influencing issues and influenced issues. The experts were approached to introduce their viewpoint on the impact of one issue over another considering the comparison scale ranging from 0-4 presented in Chapter 3. Thus, the researcher by the application of this method intends to identify the cause group and the effect group of the issues while also understanding how resolving an issue will also have an effect on resolution of other issues. Hence, this technique has crucial contribution to the study.

4.4.2 Analysis of Issues using Structural Equation Modelling

The process followed were analysing data using SEM are as given below:

Stage I: Development of theoretical model Based on literature review conducted and suggestions from the experts, a theoretical model was developed as represented in Chapter 3.

Stage II Construction of Measurement Model Applying Confirmatory Factor Analysis and Path Analysis, the measurement model is developed. This stage involves following steps:

Step 1: **Reliability Test** The test of reliability refers the extent to which data is consistent and stable in measuring what it is intended to measure. For the data under study, value of Cronbach's alpha for the information was assessed to be 0.926 (refer Table 4.8). It indicated consistency of the data for further analysis.

Step 2: **Identification of Endogenous and Exogenous variables** Structural Equation Modelling uses Exogenous and endogenous variables in its technique of analysis of data. Variables that are independent are referred to as exogenous variables while variables that are prejudiced by presence of other variables are called as endogenous variables. In the present study, there is one endogenous variable, the cold chain performance (CCP) while there are seven exogenous variables : infrastructure (INFR), traceability (TRAC), sustainability (SUST), integration (INTG), safety & quality (SAFQ), awareness & handling practices (AWHP) and responsiveness (RESP).

Step 3: **Identification of Variables: Latent and Observed** A variable that is straightforwardly noticed and estimated is known as a manifest variable, known as indicator variable while a variable that is not straightforwardly estimated is known as latent variable. In a factor analysis, factors are latent variables. The researcher employed Exploratory Factor analysis procedure to decide the proper number of common factors and furthermore to lay out which noticed variables are logical indicators of the chosen latent aspects. Maximum likelihood estimation method was employed for extraction of factor. This was done as it allows for determination of different indices of goodness-of-fit for the model and also permits statistical significance testing of factor loadings as well as correlations among factors (Costello, 2005). Once extraction is taken care of, then the researcher needs to choose the quantity of variables to hold for rotation. Neither over-extraction nor under-extraction should be carried out as it could be detrimental for data analysis. The general default suggested for extraction is to extract and retain all those factors which exhibit eigenvalue greater than 1.0. In the present study, loadings below 0.40 were not given any consideration so that the study could present more accuracy in the results. However, while doing so reliability and other aspects were also given due consideration. Table 4.10 presents the factor loadings of the reduced observed variables. Reliability test was conducted pre- and post- factor analysis, the results of which are presented in Table 4.8 and 4.10.

The complexity of an SEM model increases owing to the use of latent factors as every one of the items in survey instrument and corresponding measured responses are utilized to evaluate the latent variable or factor. For this purpose, each item in the questionnaire is a single variable which is a composite part of a set of variables influencing the variation in the latent variable. The latent variables in the study are: cold chain performance (CCP), infrastructure (INFR), traceability (TRAC), sustainability (SUST), integration (INTG), safety & quality (SAFQ), awareness & handling practices (AWHP) and responsiveness (RESP).

Step 4: **Development of the Measurement model** Post-identification of latent and observed variables and application of Confirmatory Factor analysis technique, measurement model development is done. After conducting CFA, the final number of sub-criteria were 33 (including exogenous and endogenous variables) for 278 cases.

Step 5: **Testing for Reliability, Validity and Model fit measures** Value of α, as per Sekaran (2003), is considered reliable when it is between 0.6 and 0.7, and if the value of Cronbach's α is above 0.7 it is considered as a good reliability. As shown in Table 4.10, the value of Cronbach's α was above 0.7 and near to 0.9 for the latent constructs. This is an indication of the reliability of the constructs thus explaining that the latent constructs are sufficiently explained. Convergent and discriminant validity also needs to be determined to ensure there are no validity concerns. While convergent validity ensures the construct validity, discriminant validity ensures the validity in relation with other constructs of the model. Model fit measures are then used to determine if the model is a good fit. For the purpose of this study, GFI, TLI, Normed chi square and RMSEA have been used. Only once the model fit is indicated, the next step is proceeded to.

4.4.3 Analysis of Issues using AHP / Fuzzy AHP

The main stage in usage of the Analytic Hierarchy Process is the breakdown of the entire issue into a hierarchical design. Therefore, a progressive construction is assembled where the objective is set at level I; standards at level II; sub-rules at level III; and options at level IV. In our study, the goal is the cold chain performance and hence is placed at level I; criteria are the Issues and so placed at level II: the sub-criteria of the various issues are displayed at level III and finally the solutions are at level IV (refer Fig. 4.7). So, the study identified 7 main issues: Infrastructure; Traceability; Sustainability; Safety and Quality; Awareness and Handling practices; Responsiveness; and Integration. Each Issue further had sub-criteria: Infrastructure has 5 sub-criteria; Traceability has 3 sub-criteria; Sustainability has 5; Safety and Quality (5); Awareness and handling practices (5); Responsiveness (4); and Integration has 3 sub-criteria. These sub-criteria are the reduced factors after conducting Exploratory Factor Analysis. The diagrammatic representation of the hierarchical structure is given in Fig 4.7.

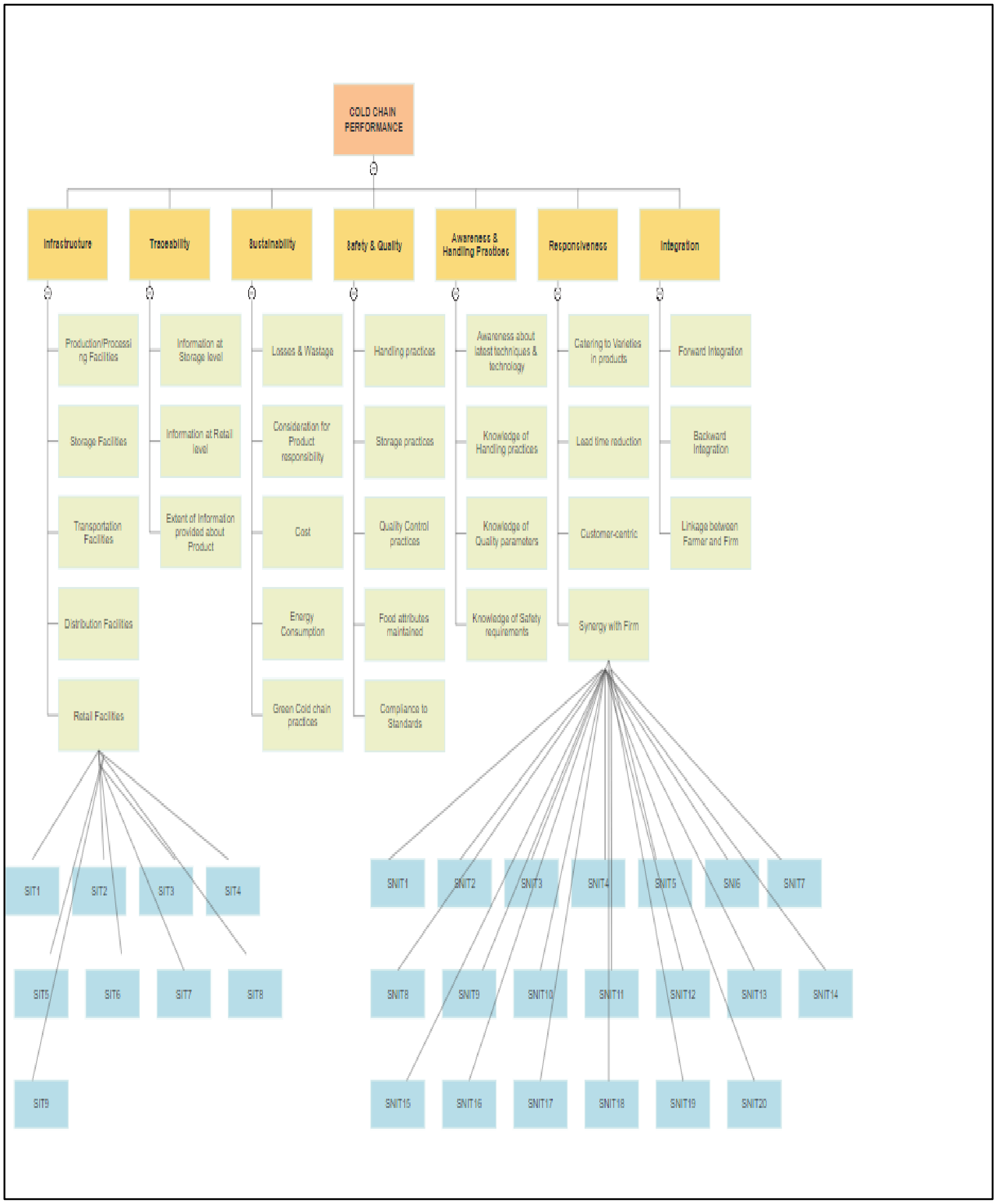


Fig 4.7. AHP Hierarchical structure

Pair-wise comparison was done by the experts for 7 main categories of issues by assigning Saaty scale for AHP (as given in Chapter 3). Thereafter, AHP steps (as explained in Chapter 2) are performed on the data involving seven issues and their sub-categories to arrive at the normalized weights and CR which when found to be lesser than 1.0, fuzzy logic process i.e. Fuzzy AHP was applied. By application of Fuzzy AHP, the researcher was able to arrive at the fuzzified and de-fuzzified normalized weights for the issues and their sub-categories on the basis of which the rankings, local and global (for the sub-category) were determined.

4.5 PHASE III DEVELOPMENT OF FINAL MODEL AND SUGGESTION OF SOLUTIONS

In this phase the proposed hypotheses are tested and the final model is developed. The hypotheses testing and development of model was done using SEM. Thereafter, in light of survey of writing and ideas from the respondents, solutions are suggested. Finally, the solutions are prioritised and recommended for overcoming the issues. The steps applied in this phase are as given below:

4.5.1. Testing of Hypotheses and Development of Final Model

In this phase, the Structural model is developed and seven proposed hypotheses are tested for significance based on the CR and the p-value. With the p-value being < 0.05 (significance level) i.e. 95% level of confidence and the CR value (Critical Ratio) being more noteworthy than 1.96, the hypotheses are said to be supported thereby indicating exogenous variable's significant influence on endogenous variable.

4.5.2 Identification and Categorization of Solutions into IT and Non-IT

On the basis of inputs from the experts and literature review, solutions are identified. They are then categorized into two categories: IT solutions and Non-IT solutions. This is done for the benefit of the stakeholders and to lend more clarity with respect to the implementation of the solutions. Also, further analysis of solutions by considering them to belong to one category only will not produce reliable and feasible results. Hence, categorisation into the two categories will result in more reliable and feasible results to enable implementation of the appropriate solution to resolve the desired issues.

4.5.3 Prioritisation of IT and Non-IT solutions

The IT and Non-IT solutions are prioritised separately on the basis of their preference/usefulness in resolving the identified issues. For the prioritisation, Best-Worst Method and Fuzzy TOPSIS are used. While Best-Worst method helps in identifying how the best and worst solution compare to other solutions, Fuzzy TOPSIS helps in ranking the solutions for overcoming the issues.

4.6 SENSITIVITY ANALYSIS: ANALYZING THE ROBUSTNESS OF RANKINGS OF ISSUES

The MADM (multi-attribute decision making) models are generally used for evaluation, ranking and selection of the alternatives amongst various alternatives on the basis of the importance attributed to the alternative. The data used by MADM models are not very stable and are also changeable (Alinezhad, 2011). Therefore, performing sensitivity analysis can help arrive at correct decision. Thus, in the present study also sensitivity examination was led to concentrate on the aftereffect of changes in the standards loads on the last rankings. Consistency of rankings thus obtained exhibit reliability of rankings determined and thus a robust framework is indicated. For the purpose of ensuring reliability and robustness of the results thus obtained, sensitivity analysis was performed for the rankings determined for the Issues as well as for the solutions, IT solutions and Non-IT solutions.

4.7 CHAPTER SUMMARY

This part shows segment examination of the responses gathered from various respondents in the CC. Additionally, reliability of the information is introduced alongside the significance credited to the various issues by the respondents. The identification of Main and sub-criteria is also presented in this chapter along with the Descriptive statistics and reliability estimates. Common method bias test results are also presented to ensure that there is no biasness in response collection owing to the survey instrument used. Further analysis on the data shall be presented in the next chapter.

CHAPTER 5

ASSESSMENT OF ISSUES IN COLD CHAIN OF FROZEN FOOD PRODUCTS

OVERVIEW

This chapter presents the results of analysis of data. Data has been analysed using SPSS 22.0, AMOS 23.0 version and MS-Excel. The different statistical tools and techniques applied for the conducting the data analysis are reliability and validity test, EFA, SEM including CFA, DEMATEL, AHP and FAHP. The analysis conducted is in the following sequence: (1) DEMATEL approach employed for understanding the influencing and influenced issues (cause and effect); (2) exploratory factor analysis for selection of observed variables and latent constructs; (3) conducting reliability and validity test for the study; (4) CFA for affirming and testing the estimation model applying goodness-of-fit indices; (5) use of structural equation modelling for final model goodness-of-fit testing and hypotheses testing; (6) AHP and FAHP for ranking the issues and sub-categories of issues (reduced after application of SEM).

Thus, the methods used discuss the issues' importance and impact on the performance of cold chain in view of CC related literature review. After that, experts from the IT companies, cold chain firm owners/high level of management and other stakeholders were consulted to get their subjective opinions for deriving the pairwise comparison matrix. On consultation with the experts, priority weights were also allocated to the issues and the sub-categories of issues. There may be cases of inconsistency of the experts' judgement however an average of the inputs given by 30 experts was taken and thereafter calculations were performed to set criteria weights as per the theory of AHP method and finally arriving at the agreement of data by calculating the value of λmax, Consistency Index and the Consistency Ratio. Since there may be imperfections in the data received through expert inputs, it is therefore necessary to validate the data using consistency check. The value of CR must be less than 0.10 for data to reflect consistency (Chaowarat, 2011). Hence, in the event that CR $\leq$ 0.1, the pairwise correlation grid is said to have adequate consistency and in the event CR $\geq$ 0.1 then it is said to be inconsistent and hence unacceptable and requires revision.

Experts have also been consulted to give their subjective opinion on the solutions suggested in terms of their preference and usefulness to resolve the issues. This has been done with the aim of prioritising the suggested solutions using Best-Worst Method and Fuzzy TOPSIS, the detailed explanation of which shall be given in subsequent chapters. For the same reason, the present chapter is based on objective two as mentioned below:

Objective 2: To analyse identified issues in the cold chain of frozen food products w.r.t their influence on cold chain performance.

5.1 INTRODUCTION

Carrying out data analysis and interpretation can be highly complex. In the present study, three analysis techniques have been applied for a comprehensive analysis of the issues identified in the previous chapters. DEMATEL, AHP and FAHP are applied to assess the issues influencing the cold chain performance for frozen food products for improved clarity and understanding of each issue and its influence. Firstly, DEMATEL has been applied to categorise the issues as influencing issues and influenced issues as well as understand the inter-influence amongst the identified issues. DEMATEL is an MCDM technique applied to deliver cause effect relation amongst the issues through data and graphs (Khan, 2018). Since traditional statistical techniques and models for data analysis do not account for error occurrence and so are not very flexible therefore structural equation modelling, a multi-variate technique is employed in the study as it considers measurement errors along with identification of multiple dependencies. According to Nunkoo (2012), SEM is best suited for confirmatory modelling in order to evaluate a substantive theory with empirical data with the help of a hypothesised model. The steps involved in SEM analysis along with the theoretical model developed have already been presented in Chapter 3. Before testing of measurement model, identification of constructs, observed variables need to be carried out which has been presented below.

Finally, AHP and Fuzzy AHP are employed for conducting the ranking of issues and their sub-categories as Integration of AHP and Fuzzy theory helps improve research outcomes (Kumar & Garg, 2017). A hierarchical structure for AHP and FAHP representing the issues and their sub-categories is exhibited through in Chapter 4. The 5-point scale used by DEMATEL method and the 7-point scale used by AHP and FAHP method has been presented in Chapter 3.

5.2 ANALYSIS OF ISSUES USING DEMATEL: CLASSIFYING ISSUES INTO INFLUENCING AND INFLUENCED

The causal relationship amongst the issues is assessed using the DEMATEL approach. The technique has been embraced as a solution methodology in this study. It is a complete method to provide causal relationship among the complex factors with the help of graphs.

The DEMATEL approach is applied in this section to analyse the complex relations amongst the issues. The experts were asked to present their opinion on the influence of one issue over another considering the comparison scale ranging from 0-4 already presented in Chapter 3. The table 5.1 presents the responses that were arrived at by first averaging and an underlying Direct-Relation framework (D).

Table 5.1: Overall Direct-Relationship Matrix (D)

Issues	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
INFR	0	4	4	4	4	4	4
SAFQ	4	0	3	4	2	4	1
RESP	3	2	0	3	2	1	3
AWHP	1	4	3	0	3	4	1
TRAC	3	4	4	3	0	2	4
SUST	3	4	2	3	2	0	1
INTG	4	4	4	3	4	2	0

Source: DEMATEL analysis

Thereafter, the Normalized direct-relation matrix, Y has been developed and transformed into Total-Relation Matrix, where the row and column sums are depicted by D and R respectively using the equation mentioned in Step 5. Di depicts the total effect of issue I to the other issues and Rj depicts net influence received by j issue from other issues. Once D and R have been determined for each row and column, then the prominence (Pi) and the net effect (Ei) is calculated as shown in Step 6. The value of Ei=D-R decides the net cause/effect of each issue. If Ei has a positive value, then issue is considered to bring about net reason and with negative value, issue is considered to bring about net impact. The cause and effect have been exhibited in Table 5.2.

Table 5.2: Issues' Cause-Effect relation

Issues	D	R	D+R	D-R	Cause/Effect
INFR	0.1108	0.044321	0.1551	0.0665	Cause
SAFQ	0.0526	0.094183	0.1468	-0.0416	Effect
RESP	-0.0222	0.066482	0.0443	-0.0886	Effect
AWHP	0.0693	0.044321	0.1136	0.0249	Cause
TRAC	0.0499	0.047091	0.0970	0.0028	Cause
SUST	0.0111	0.00277	0.0139	0.0083	Cause
INTG	0.0471	0.019391	0.0665	0.0277	Cause

Source: DEMATEL analysis

5.3 ANALYSIS OF ISSUES USING SEM

5.3.1 Identification of Variables: Exogenous and Endogenous

Variables which are not affected by factors are called as exogenous factors while variables which are impacted by different factors are called as endogenous variables. In the present study, there is one endogenous variable, the cold chain performance (CCP) while there are seven exogenous variables : infrastructure (INFR), traceability (TRAC), sustainability (SUST), integration (INTG), safety & quality (SAFQ), awareness & handling practices (AWHP) and responsiveness (RESP).

5.3.2 Identification of Variables: Latent and Observed

A variable that is straightforwardly noticed and estimated is known as a manifest variable, also known as indicator variable while a variable that isn't straightforwardly estimated is known as a latent one. In a factor examination, factors are latent variables. The complexity of an SEM model increases owing to the use of latent variables as every item in poll and their deliberate responses are utilized to evaluate the latent variable or the factor. For this purpose, each item in the questionnaire is a single variable which is a composite part of a set of variables influencing the variation in the latent variable. The latent variables in the study are: cold chain performance (CCP), infrastructure (INFR), traceability (TRAC), sustainability (SUST), integration (INTG), safety & quality (SAFQ), awareness & handling practices (AWHP) and responsiveness (RESP). Anderson & Gerbing in 1988 proposed a two-step approach to evaluate measurement model before development of structural model.

5.3.3 Development of the Measurement Model

The measurement model depicts the relation between item and its latent variable. The model is assessed through discriminant and convergent validity (Kumar, 2020). The AVE (average variance extracted) measure exhibits the convergent validity of constructs and its value should be higher than or equal to 0.5 for justification of its constructs (Fornell, 1981). Cronbach alpha and CR (composite reliability) are used to determine constructs' internal consistency. The values falling between 0.70 and 0.95 are the in the range of acceptable values (Hair, 2014). Discriminant validity depicts the fact that the constructs are different from each other and one construct will share high variance with its variables as compared to with that of other constructs (G€otz, 2010). The square root of AVE is compared with the correlation amongst latent variables to determine the discriminant validity.

To determine construct validity and reliability with both convergent & discriminant validity considered, confirmatory factor analysis was applied using AMOS version 23. In this study, the measurement model consists of eight constructs, namely, Infrastructure (INFR), traceability (TRAC), sustainability (SUST), integration (INTG), safety & quality (SAFQ), awareness & handling practices (AWHP), responsiveness (RESP) and cold chain performance (CCP).

Table 5.3 presents discriminant validity, convergent validity and composite reliability. Composite reliability (CR) of "INFR" is 0.911, "TRAC" is 0.839, "SUST" is 0.943, "INTG" is 0.801, "SAFQ" is 0.903, "AWHP" is 0.911, "RESP' is 0.834 and "CCP" is 0.828. Finally, in the measurement model composite reliability (CR) is more than 0.7 and hence all constructs are found to have good internal consistency reliability.

Table 5.3. Convergent validity, discriminant validity and composite reliability (CR)

Construct	Items	AVE	ASV	C.R	P
Infrastructure	PFAC	0.674	0.129	0.911	***
	SFAC				***
	TFAC				***
	DFAC				***
	RFAC				***
Traceability	INST	0.666	0.013	0.839	***
	INRT				***
	PINF				***
Sustainability	LOSS	0.767	0.019	0.943	***
	PDRP				***
	COST				***
	ENRG				***
	GRNC				***
Integration	FARM	0.600	0.007	0.801	***
	BACK				***
	FORW				***
Safety & Quality	HNDP	0.653	0.075	0.903	***
	STRP				***
	QUCP				***
	ATTR				***
	CMPL				***
Awareness & Handling practices	AITT	0.673	0.124	0.911	***
	KNHP				***
	KNQP				***
	KNSR				***
	KNCS				***
Responsiveness	VART	0.557	0.057	0.834	***
	LTRD				***
	SYNG				***
	CUST				***
Cold Chain Performance	QLTY	0.617	0.150	0.828	***
	SHLF				***
	WAST				***

Validity has been characterized as "degree to which indicators measure accurately what it is supposed to do, what they supposed to measure, and finally the measurement should be correct and accurate" (Hair, 1998). Validity measurements, namely discriminant and convergent validity are performed for determination of exactness and accuracy of indicators. The extent to which measured variables of a construct possess high percentage of variation is exhibited by Convergent validity. Standard regression weight is used to calculated convergent validity. The standard regression weight estimates indicate significant representation of latent variables by the observed variables. This means that the observed or measured variables are satisfactory and correspond to the latent construct, hence confirming the convergent validity. The degree to which a construct really contrasts from others is addressed by discriminant validity (Hair *et al.*, 2010).

There are two methods used to evaluate discriminant validity. One method according to which the relationship between measures of constructs that are theoretically distinct should not be high (Trochim, 2006) and the second method according to which AVE (Average variances extracted) of a specific construct should be greater than ASV (Average shared variances) between constructs as well as if the AVE square root is larger than correlation value of the constructs then discriminant validity is sufficient (Su, 2021). The normalized factor load and the AVE values were dissected to assess convergent validity. Since all normalized factor loads and AVE values were more prominent than the recommended worth of 0.5, high validity of the variables and constructs is shown. With the AVE values being greater than the corresponding squared value, the result indicate that discriminant validity is upheld.

There should be low correlation between the constructs which is a representation of independence of variables in the measurement model. Table 5.3 presents AVE of the particular constructs being higher than ASV. As shown in Table 5.4 the square roots of the AVEs are greater than the off-diagonal elements in the related rows and columns, which is an indication that in the measurement model, a construct is strongly correlated with its indicators. We can, therefore, conclude that constructs discriminant validity is satisfactory. Fig 5.1 presents the measurement model.

The model fit indices such as x 2/df = 1.736, comparative fit index (CFI = 0.942), goodness-of-fit index (GFI = .851), normed fit index (NFI = .875), Tucker Lewis index (TLI=.935) and root mean square of error approximation (RMSEA = .052) were chosen to evaluate the model fit (Hair *et al.*, 2010). The acceptable values are as follows: x 2/df < 3, GFI, CFI, TLI, NFI values more than 0.9 and the RMSEA< 0.08 (Gefen and Straub, 2000). Thus, the results suggest the presence of reliability and validity along with model fit. Hence, the measurement model is reliable and valid.

Table 5.4. Correlation matrix and root of AVE's

	RESP	INFR	SUST	SAFQ	AWHP	TRAC	INTG	CCP
RESP	*0.747*							
INFR	*0.191*	*0.821*						
SUST	*- 0.189*	*-0.057*	*0.876*					
SAFQ	*0.358*	*0.269*	*-0.235*	*0.808*				
AWHP	*0.286*	*0.575*	*-0.124*	*0.324*	*0.821*			
TRAC	*0.019*	*0.199*	*-0.018*	*0.009*	*0.117*	*0.816*		
INTG	*0.102*	*0.075*	*0.045*	*0.099*	*0.088*	*0.053*	*0.775*	
CCP	*0.321*	*0.643*	*-0.148*	*0.395*	*0.560*	*0.187*	*0.098*	*0.786*

Note: Diagonal in italics represent the square root of AVE from observed variance (items); off-diagonal represents correlations between constructs

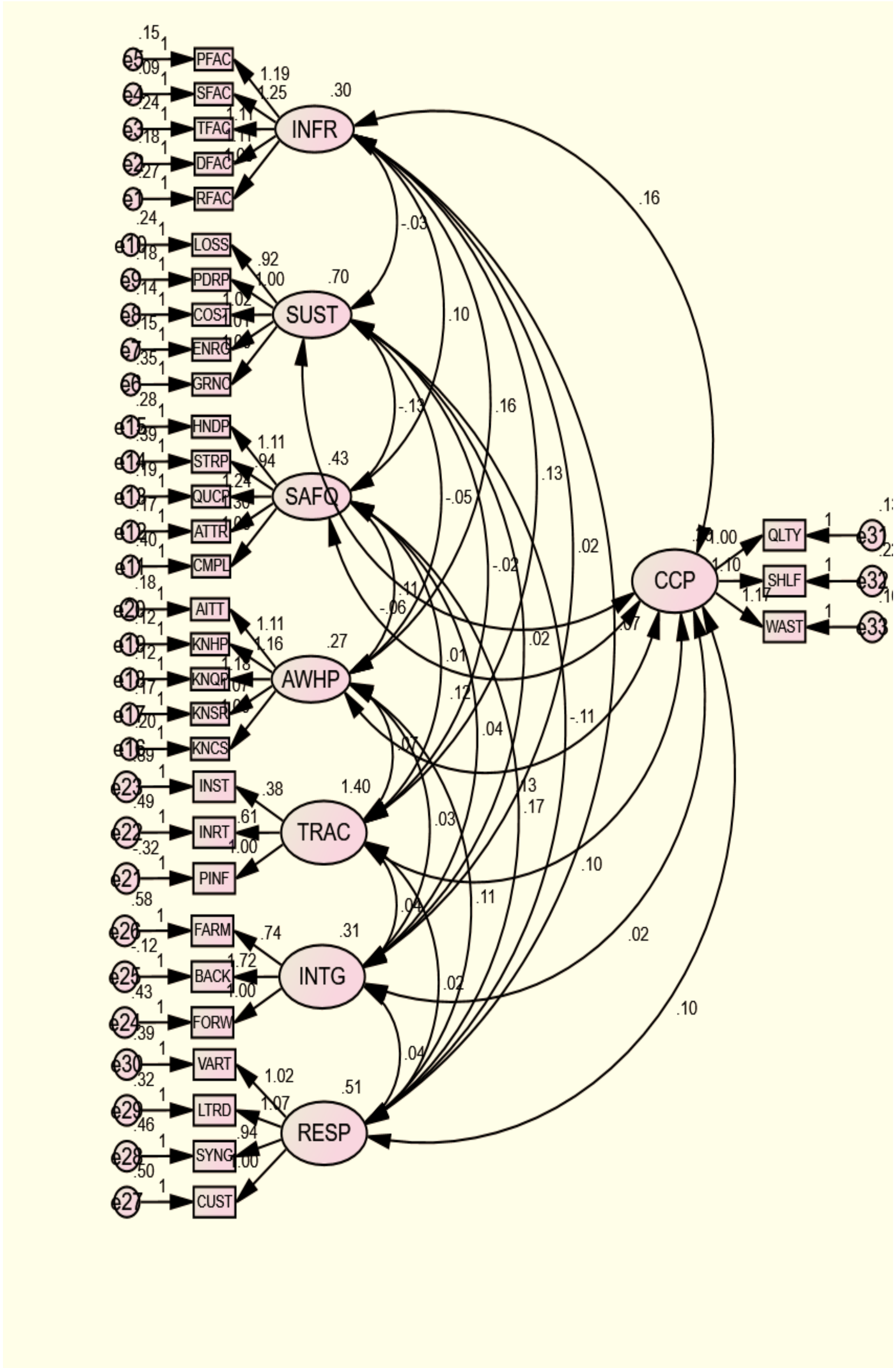


Fig 5.1 Measurement Model

SEM is hence applied in two stages: first measurement model to identify relationship between observed and latent variables and second structural model to examine strength between the exogenous and endogenous variables. The primary model (structural model) and the estimation model (measurement model) together structure the whole underlying structural equation model.

5.3.4 Development of Structural Model

SEM is a technique better than the other techniques used in statistics like multiple regression analysis. Based on two criteria, the assessment of structural model is done. The criteria are: R^2 (coefficient of determination) and significance level. The combined effect of exogenous on endogenous latent variables along with variance percentage is depicted by the coefficient of determination. SEM has been utilized to test the underlying model determined to assess the calculated model. The CFA analysis brought about the measurement model supporting the structural model through which the speculations are tested for the review. The structural equations were modelled using AMOS. Dimensionality reduction was performed and factors were reduced along with conducting tests of reliability, validity both convergence and discriminant. The final analysis of the structural model was on seven factors or the seven issues. The structural model's final fitting result is presented in Fig 5.2. The absolute fit measures exhibit the link between predicted and actual covariance matrices (Koops, 2002). They were within the acceptable range: $\chi 2$ ratio CMIN/DF = 2.070 (is < 5.0) p= 0.00; GFI = 0.815; RMSEA = 0.062 (is between .05 & .08). Then, incremental fit indices indicating the fit with reference to the null model are estimated and also were found to be acceptable: AGFI = .787 and NFI = .844; TLI = 0.905. The model is assessed through parsimonious fit indices with reference to the number of estimated coefficients and they too were acceptable: IFI (Bollen's incremental fit) = 0.913 which is more than .90; and comparative fit index CFI = 0.912 (is >= 0.90). So, the values indicated applicability of the structural model for the purpose of examining the hypotheses. Also, presented are the properties (Standard error, standard path coefficients, critical ratio and proposed hypotheses result) of the structural model. The level of significance (α) has been set at 0.05. In a multiple regression analysis, standardization of the coefficient is generally determined to identify which exogenous variables more influence endogenous variable. The R^2 is a squared multiple correlation determined to analyze the strength of the projected model. It is estimated that the predictors of cold chain performance (CCP) explain 38 per cent of its variance. Figure 5.2 depicts the structural model.

Path coefficient and hypotheses results

Maximum likelihood estimation method was utilized for testing hypotheses along with path coefficients at the pre-decided level of significance. The path (structural) model is presented in Fig 5.2. The summary of the results is presented in Table 5.5 presenting significance level, β-value, and t-values. At a value above 1.96, path coefficient is taken to be significant. As per the results H1($\beta = 0.494$, $p < 0.05$), H5 ($\beta = 0.193$, $p < 0.05$), H6 ($\beta = 0.261$, $p < 0.05$) and H7 ($\beta = 0.134$, $p < 0.05$) have a significant relationship and thus are accepted. On the other hand, H2 ($\beta = 0.088$, $p > 0.05$), H3 ($\beta = -0.049$, $p > 0.05$), and H4 ($\beta = 0.019$, $p > 0.05$) have insignificant relationship and hence not supported. The final model of the study is presented in Fig 5.3. Table 5.5 presents the outcome of hypothesis testing, where β coefficients represent relationship of influencing factor.

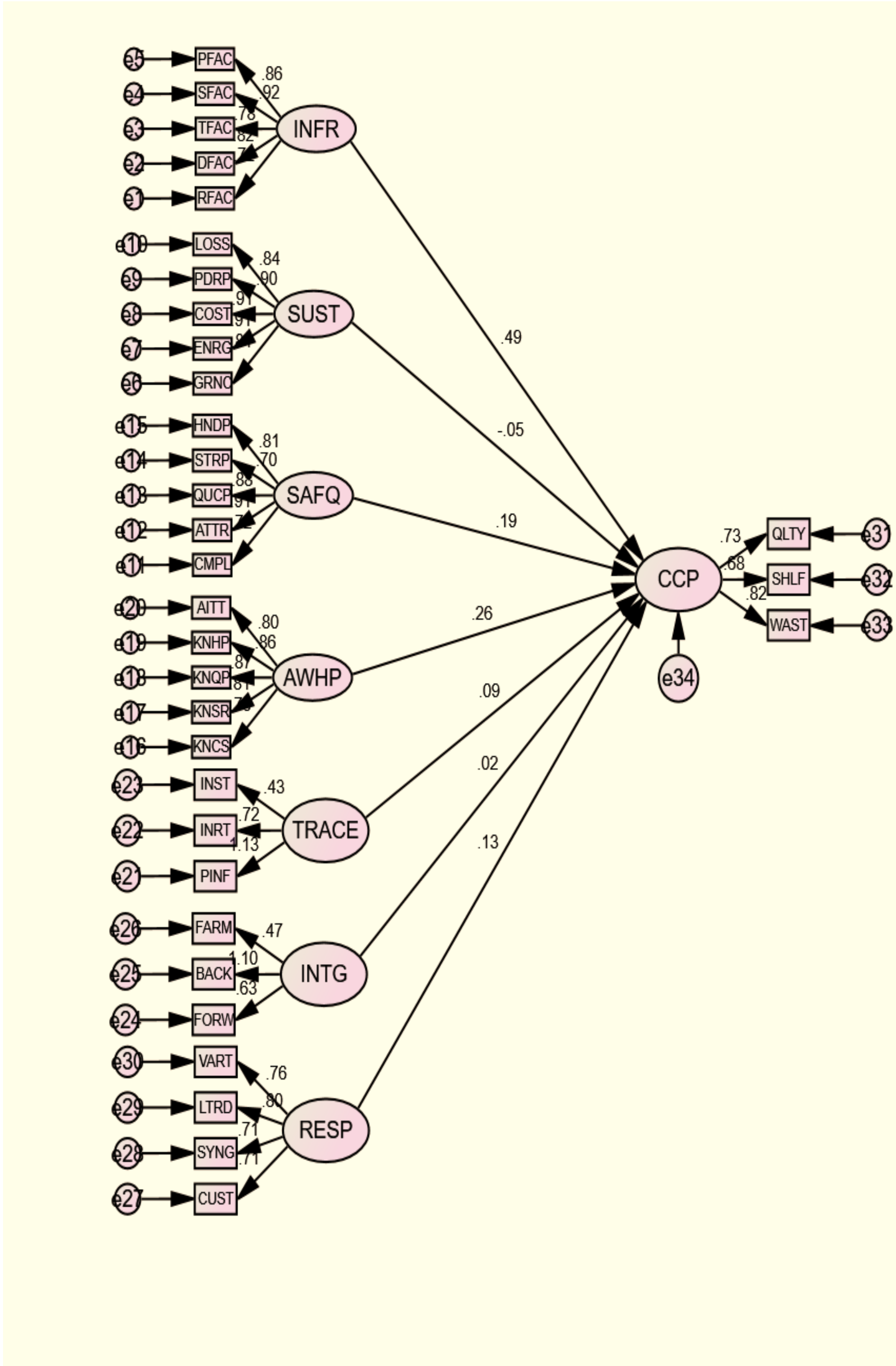


Fig 5.2 The Structural Model

Table 5.5. Summary of testing of hypothesis

Hypothesis	**Structural relationship**	**St. estimates (β)**	**Unst. estimates**	**S.E.**	**C.R.**	**P**	**Result**
H1	CCP← INFRA	0.494	0.360	0.052	6.877	***	Supported
H2	CCP← TRAC	0.088	0.029	0.016	1.787	0.074	Not Supported
H3	CCP← SUST	-0.049	-0.023	0.028	-0.833	0.405	Not Supported
H4	CCP← INTG	0.019	0.014	0.037	0.377	0.706	Not Supported
H5	CCP← SAFQ	0.193	0.117	0.037	3.157	0.002	Supported
H6	CCP← AWHP	0.261	0.198	0.048	4.168	***	Supported
H7	CCP← RESP	0.134	0.074	0.035	2.127	0.033	Supported

Notes: β , standardized beta coefficients SE, standard error; CR, critical ratio; *p < 0.05; **p < 0.01; ***p <0.001

5.4 INFLUENCE OF ISSUES ON COLD CHAIN PERFORMANCE: HYPOTHESES TESTING AND MODEL DEVELOPMENT

H1: *Resolving the issue of Infrastructure at various levels has significant influence on enhancing the performance of the cold supply chain.*

Among the seven relationships tested, the first relationship between the issue of infrastructure and cold chain performance was found to be statistically significant with path coefficient value of ($\beta = 0.494$, $p < 0.05$) and a t-value of 6.877 at 0.05 level of significance. Therefore, H1 is found to be statistically supported. It means resolving the issue of infrastructure has a significant positive impact on cold chain performance, so our first hypothesis is supported. Refer Table 5.5 and Fig 5.3.

H2: *Resolving the issue of Traceability at various levels has significant influence on enhancing the performance of the cold supply chain.*

The second relation between the issue of traceability and cold chain performance was viewed as not measurably critical with path coefficient value of ($\beta = 0.088$, $p > 0.05$) and a t-value of 1.788 at 0.05 level of significance. Therefore, H2 is found to be statistically not supported. Refer table 5.5 and Fig 5.3.

H3: *Resolving the issue of Sustainability at various levels has significant influence on enhancing the performance of the cold supply chain.*

The third relation between the issue of sustainability and cold chain performance was not found to be statistically significant with path coefficient value of ($\beta = -0.049$, $p > 0.05$) and a t-value of -0.833 at 0.05 level of significance. Therefore, H3 is found to be statistically not supported. Refer table 5.5 and Fig 5.3.

H4: *Resolving the issue of Integration at various levels has significant influence on enhancing the performance of the cold supply chain.*

The fourth relation too between the issue of integration and cold chain performance was not statistically significant with path coefficient value of ($\beta = 0.019$, $p > 0.05$) and a t-value of 0.377 at 0.05 level of significance. Therefore, H4 is also found to be statistically not supported. Refer table 5.5 and Fig 5.3.

H5: *Resolving the issue of Safety & Quality at various levels has significant influence on enhancing the performance of the cold supply chain.*

The fifth relation between safety & quality and cold chain performance is viewed as genuinely significant at ($\beta = 0.193$, $p < 0.05$) and a t-value of 3.157 at significance level of 0.05. The t-value of relationship found to be higher than the cut-off point of 1.96 (as indicated by Jermsittiparsert, 2019). Therefore, H5 is found to be statistically supported. Refer table 5.5 and Fig 5.3.

H6: *Resolving the issue of Awareness & Handling Practices at various levels has significant influence on enhancing the performance of the cold supply chain.*

Significant and positive relationship is depicted of hypothesis six also so the relationship between awareness & handling practices and cold chain performance is found to be influential at (β = 0.261, p < 0.05) and a t-value of 4.168 at 0.05 level of significance. Therefore, H6 is found to be statistically supported. Refer table 5.5 and Fig 5.3.

H7: *Resolving the issue of Responsiveness at various levels has significant influence on enhancing the performance of the cold supply chain.*

Finally, the relation between responsiveness and cold chain performance is also found to be significant (β = 0.134, p < 0.05) and t-value of 2.127 at 0.05 significance level thus supporting the hypothesis. Refer table 5.5 and Fig 5.3.

As the relationship between the variables (INFR!CCP, SAFQ!CCP, AWHP!CCP and RESP!CCP) is significant (p < 0.05) hence the estimates are reliable. The variables TRAC, SUST and INTG which are depicted to be not significantly related to cold chain performance which is an indicator of the extent of information coverage, sustainability and integration in the entire cold chain.

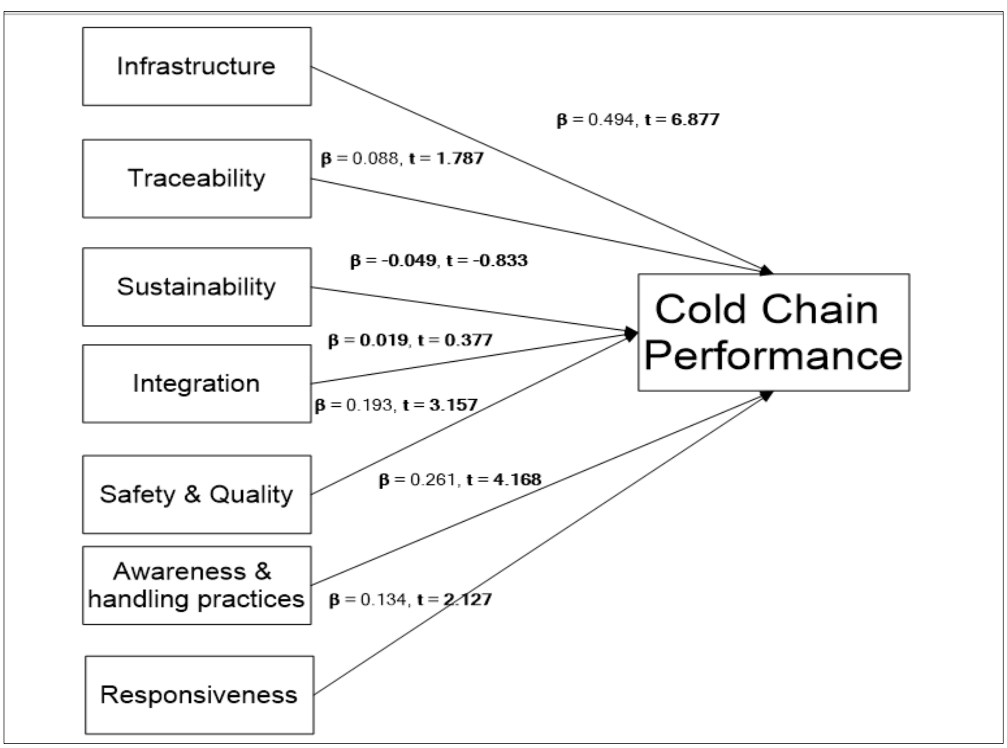


Fig 5.3 Hypothesized Model - Issues and Cold Chain Performance

5.5 AHP AND FAHP: RANKING OF ISSUES AND THEIR SUB-CATEGORIES

AHP is an MCDM technique which takes into consideration both the quantitative and qualitative aspects of the course of independent direction. The scale of relative importance and hierarchical structure of the issues and its sub-categories is presented in preceding chapters.

5.5.1 Measure of Consistency and Ranking using AHP

Pair-wise comparison was done by the experts for 7 main categories of issues by assigning Saaty scale for AHP. Normalized pairwise comparison matrix for the category of issues, is presented in Table 5.6. Random Index for 7 issues is 1.32(Ammarapala, 2018), the λmax is 7.248, CI is 0.041 and CR is 0.031. As the value of CR < 0.1, it portrays steady results.

Table 5.6. Normalized Pairwise comparison matrix of the main issues in CSC

	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
INFR	0.3944	0.4352	0.4456	0.3864	0.4082	0.3134	0.1892
SAFQ	0.1315	0.1451	0.1114	0.1932	0.1361	0.1791	0.1892
RESP	0.0986	0.1451	0.1114	0.0966	0.1361	0.1343	0.1892
AWHP	0.1972	0.1451	0.2228	0.1932	0.2041	0.2239	0.1892
TRAC	0.0657	0.0725	0.0557	0.0644	0.0680	0.0896	0.1351
SUST	0.0563	0.0363	0.0371	0.0386	0.0340	0.0448	0.0811
INTG	0.0563	0.0207	0.0159	0.0276	0.0136	0.0149	0.0270

Source: AHP Analysis

As given in step 3, the coefficient vector for criteria weights for the issues is determined and presented in Table 5.7.

Table 5.7. Criteria Weights and their Ranks

ISSUE	Weighted values	Rank
INFR	7.4102	**1**
SAFQ	7.2574	**4**
RESP	7.2949	**3**
AWHP	7.3411	**2**
TRAC	7.2110	**5**
SUST	7.1588	**6**
INTG	7.0684	**7**

Source: AHP analysis

From table given above, it is seen that the sequence of final ranks with application of AHP method is INFR>AWHP>RESP>SAFQ>TRAC>SUST>INTG.

5.5.2 Ranking using Fuzzy AHP

Pair-wise comparison was done by the experts for 7 main issues by considering the TFNs for Fuzzy AHP as presented in Table 5.8.

Table 5.8. Triangular Fuzzy Numbers of the main issues

	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
INFR	EI (1,1,1)	LI (2,3,4)	AI (3,4,5)	VLI (1,2,3)	VHI (5,6,7)	EHI (6,7,8)	EHI (6,7,8)
SAFQ	$(LI)^{-1}$ **(1/4,1/3,1/2)**	EI (1,1,1)	EI (1,1,1)	EI (1,1,1)	VLI (1,2,3)	AI (3,4,5)	EHI (6,7,8)
RESP	**$(AI)^{-1}$ (1/5,1/4,1/3)**	EI (1,1,1)	EI (1,1,1)	**$(VLI)^{-1}$ (1/3,1/2,1)**	VLI (1,2,3)	LI (2,3,4)	EHI (6,7,8)
AWHP	**$(VLI)^{-1}$ (1/3,1/2,1)**	EI (1,1,1)	VLI (1,2,3)	EI (1,1,1)	LI (2,3,4)	HI (4,5,6)	EHI (6,7,8)
TRAC	**$(VHI)^{-1}$ (1/7,1/6,1/5)**	**$(VLI)^{-1}$ (1/3,1/2,1)**	**$(VLI)^{-1}$ (1/3,1/2,1)**	**$(LI)^{-1}$ (1/4,1/3,1/2)**	EI (1,1,1)	VLI (1,2,3)	HI (4,5,6)
SUST	**$(EHI)^{-1}$ (1/8,1/7,1/6)**	**$(AI)^{-1}$ (1/5,1/4,1/3)**	**$(LI)^{-1}$ (1/4,1/3,1/2)**	**$(HI)^{-1}$ (1/6,1/5,1/4)**	**$(VLI)^{-1}$ (1/3,1/2,1)**	EI (1,1,1)	LI (2,3,4)
INTG	**$(EHI)^{-1}$ (1/8,1/7,1/6)**	**$(EHI)^{-1}$ (1/8,1/7,1/6)**	**$(EHI)^{-1}$ (1/8,1/7,1/6)**	**$(EHI)^{-1}$ (1/8,1/7,1/6)**	**$(HI)^{-1}$ (1/6,1/5,1/4)**	**$(LI)^{-1}$ (1/4,1/3,1/2)**	EI (1,1,1)

Source: FAHP Analysis

The steps given in the previous chapter have been applied to estimate the weighted score of the issues for Fuzzy AHP (refer Table 5.9). Fig 5.4 presents the relative weights for evaluation of issues considering analysis using DEMATEL, AHP and FAHP methods.

Table 5.9. Geometric Means of the Fuzzy Weights w1, w2 and w3

ISSUE	w_l	w_m	w_u	Defuzzification weights (M_i)	Normalized weights (N_i)	Rank
INFR	0.2230	0.3655	0.5719	0.3868	0.3585	**1**
SAFQ	0.1019	0.1566	0.2391	0.1659	0.1537	**3**
RESP	0.0796	0.1306	0.2185	0.1429	0.1325	**4**
AWHP	0.1222	0.2004	0.3303	0.2176	0.2017	**2**
TRAC	0.0455	0.0777	0.1449	0.0894	0.0828	**5**
SUST	0.0291	0.0461	0.0798	0.0517	0.0479	**6**
INTG	0.0159	0.0230	0.0356	0.0248	0.0230	**7**

Source: FAHP analysis

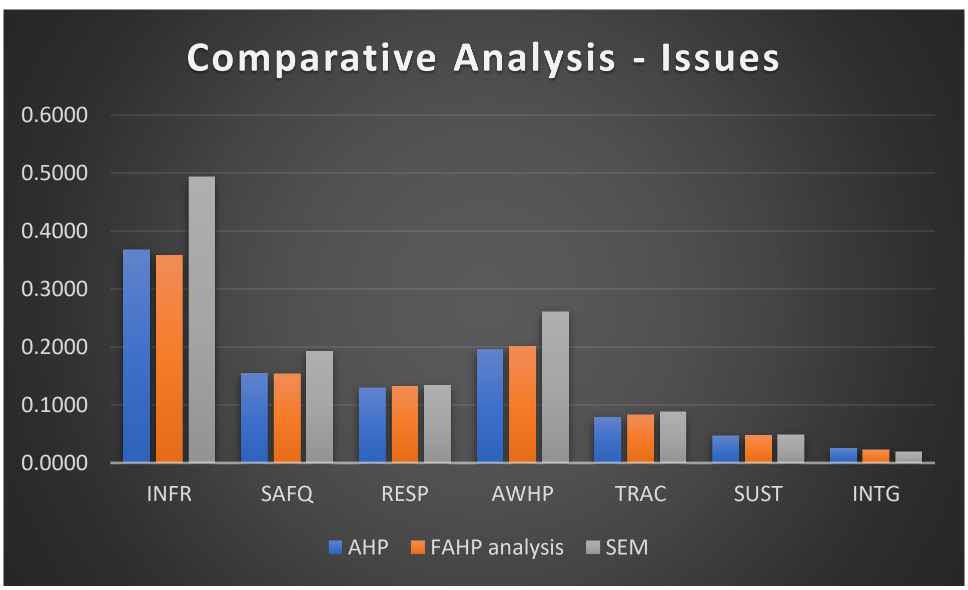


Fig 5.4 Comparative evaluation of issues

In view of the analysis, the sequence of final ranks with application of FAHP method is INFR>AWHP>SAFQ>RESP>TRAC>SUST>INTG.

5.5.3 Comparison of the rankings obtained from AHP and FAHP approaches

On prioritizing the issues in cold chain of frozen food products using AHP/FAHP approaches, a comparison in outcomes of two approaches have been presented in table 5.10 and Fig 5.4 (includes SEM also).

Table 5.10. Rank Comparison for AHP and FAHP

ISSUE	Rank for AHP	Rank for FAHP
INFR	1	1
SAFQ	4	3
RESP	3	4
AWHP	2	2
TRAC	5	5
SUST	6	6
INTG	7	7

Source: AHP and FAHP analysis

Spearman's correlation coefficient value is determined between the two rankings obtained from AHP method and FAHP method. A higher value indicates consistency of results i.e rankings in this case. Tables 5.11 and 5.12 present the Correlation value and the level at which the difference exists in the two methods.

Table 5.11. Rank Correlation with p-value

Sample 1	Sample 2	*N*	Correlation	*P*-value
RANK 1(AHP)	RANK 2 (FAHP)	7	.964	.000

Source: AHP and FAHP analysis

Table 5.12. Potential Issues in Sequence

Ranks	Issue
1	INFR
2	AWHP
3,4	SAFQ, RESP
4,3	SAFQ, RESP
5	TRAC
6	SUST
7	INTG

Source: AHP and FAHP analysis

5.5.4 Ranking of Sub-categories of the Issues

The ranking of the sub-categories of the Issues has been done at two levels: (i) within the construct they belong to ; and (ii) global ranking i.e considering all the sub-categories together. Table 5.13 represents these rankings for the seven identified issues.

Table 5.13 Ranking of sub-issues (Local and Global)

Specific issues	Weights	Rank	Sub-categories	Weights	Ranking	Global weights	Global ranking
INFR	0.3557	1	PFAC	0.2588	2	0.0920	2
			SFAC	0.3945	1	0.1403	1
			TFAC	0.1037	4	0.0369	10
			DFAC	0.1696	3	0.0603	5
			RFAC	0.0734	5	0.0261	14
SAFQ	0.1540	3	HNDP	0.2222	2	0.0342	11
			STRP	0.0889	5	0.0137	23
			QUCP	0.1985	3	0.0306	13
			ATTR	0.3913	1	0.0602	6
			CMPL	0.0991	4	0.0153	19
RESP	0.1326	4	VART	0.3279	2	0.0435	9
			LTRD	0.3650	1	0.0484	8
			CUST	0.1759	3	0.0233	15
			SYNG	0.1311	4	0.0174	17
AWHP	0.2019	2	AITT	0.0689	4	0.0139	22
			KNHP	0.3045	2	0.0615	4
			KNQP	0.4029	1	0.0814	3
			KNSR	0.1626	3	0.0328	12
			KNCS	0.0611	5	0.0123	24
TRAC	0.0837	5	INST	0.1147	3	0.0096	25
			INRT	0.2249	2	0.0188	16
			PINF	0.6605	1	0.0553	7
SUST	0.0486	6	LOSS	0.1375	3	0.0067	27
			PDRP	0.1344	4	0.0065	28
			COST	0.3470	1	0.0169	18
			ENRG	0.3123	2	0.0152	20
			GRNC	0.0688	5	0.0033	29
INTG	0.0237	7	FARM	0.0988	3	0.0023	30
			BACK	0.6044	1	0.0143	21
			FORW	0.2968	2	0.0070	26

5.6 DISCUSSION OF RESULTS

5.6.1 Discussion on Results of DEMATEL approach

Owing to the presence of issues, the cold chain management becomes a challenge especially in a developing country like India. According to the results of DEMATEL analysis, the most influential issue is “Lack of Infrastructure” and the least influential is “Lack of Sustainability”. Based on values attained through "D+R", the impact sequence of the issues is INFR>SAFQ>AWHP>TRAC>INTG>RESP>SUST. These identified issues have been categorised into “influencing group” and “influenced group” based on the sign of “D-R” values. Five issues, namely INFR, AWHP, TRAC, SUST, INTG belong to the “influencing group” and two issues, namely SAFQ and RESP belong to the “influenced group”.

Influencing Issues

The most influencing issue is ‘Lack of Infrastructure’ amongst the identified issues. Owing to the lack of infrastructural facilities, the firms are not able to achieve the desired cold chain performance. Firms need to invest in technological solutions to build up a better performing infrastructure. Next influential issue is the “Awareness and handling practices”. The cold chain stakeholders as well as the personnel working with the cold chain partners need to be given extensive training to create and sustain awareness and knowledge about the latest best practices and technological solutions that can benefit in many ways. The next important issue is the ‘Traceability’. The backward and forward traceability needs to be catered to by the firms involved in order to ensure safety, quality, responsiveness and sustainability. The fourth influential issue is the “Lack of Integration”. Once the cold chain network partners implement integration, both forward and backward, then a number of issues arising because of lack of integration will be resolved. The investment would be one-time but benefits that the firms accrue will be for many years to come. The fourth influencing issue is “Lack of Responsiveness”. This issue will be resolved once the previous issues are taken care of. The final influencing issue is the “Lack of Sustainability”. This is a very important issue that needs to be tackled. The benefits to the cold chain partners may not be direct but it will help the environment and the nation as a whole. Initiatives from the government can encourage these firms to consider sustainability in a major way.

Influenced Issues

The issues which are influenced by other issues fit in the influenced barrier category. The descending order of the influenced issue is SAFQ>RESP. The highest influenced issue is the “lack of safety and quality”. Safety & quality is influenced by the infrastructure, awareness and handling practices, traceability, integration and sustainability. The next influenced issue is “Lack of Responsiveness”. Responsiveness is an important aspect of cold chain as all firms work to achieve satisfaction of the customer and efficient responsiveness can help enhance customer satisfaction. Responsiveness can be increased with improved infrastructure, integration, traceability, awareness and handling practices. Fig 5.5 exhibits the calculated results of sum and difference of D, R plotted in a graph depicting the causal relationship among the issues for enhanced performance of cold chain.

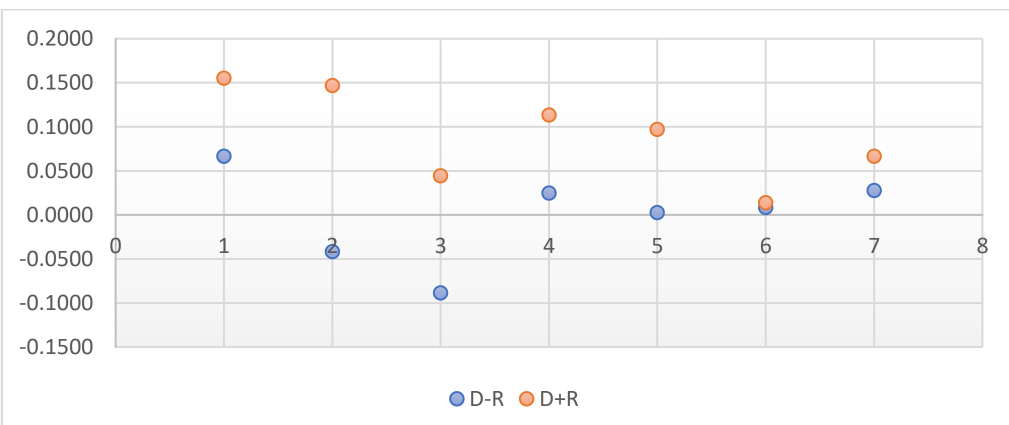


Fig 5.5. Cause and effect diagram of Issues

The seven issues identified and analysed do not exist as stand-alone issues but they influence the other issues as well. Hence, Fig 5.6 represents the influence of the issues on each other. This is achieved by estimating an average threshold value (alpha = 5.189) and thereby determining the effect of each of the issues on the other issues.

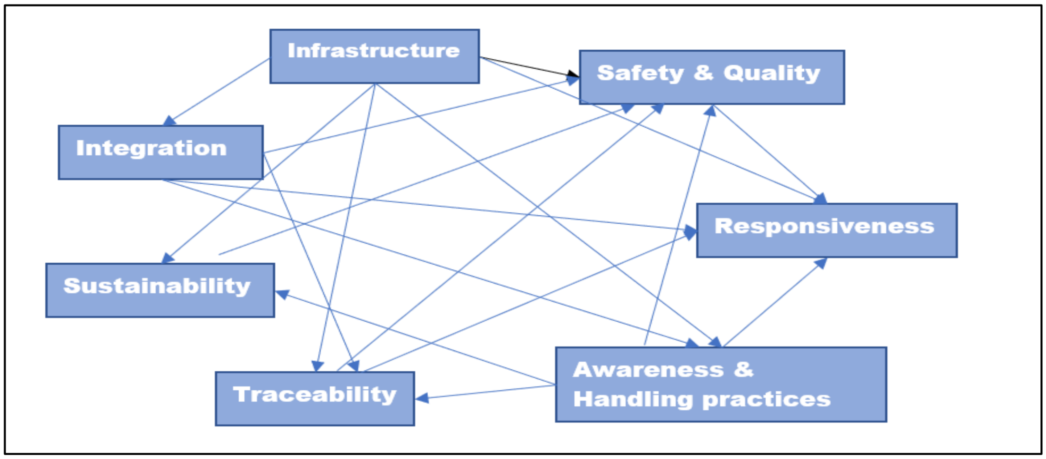


Fig 5.6 Inter-influence of the Issues

Thus, following can be derived: Infrastructure influences all other issues; Traceability influences responsiveness and safety & quality; Sustainability influences safety & quality; Integration influences safety & quality, traceability, responsiveness and awareness & handling practices; Safety & quality influences responsiveness; Awareness & handling practices influences safety & quality, responsiveness, traceability and sustainability; and Responsiveness influences none.

5.6.2 Discussion on the Issues in Cold Chain of Frozen food products

In this section, the various issues are discussed in terms of their ranking, ranking of the sub-issues comprising the issue and the influence of the issue over other issues.

<u>Infrastructure Issue</u>

Some of the recent studies that have focussed on infrastructural issues are: Theophilus *et al.* (2021); Bhatnagar, Vrat & Shankar (2019); Loisel *et al.* (2021); Khan (2020); Raut (2019); Han *et al.*(2021); Goedhals-Gerber & Khumalo (2020).

These studies have highlighted a specific aspect of infrastructural issues and therefore one reaches the conclusion that infrastructural issue is the most critical issue in the cold chain of frozen food products. Yuen (2017) and Osorio (2017) have also argued upon the significance of infrastructure for improved performance of cold chain and reduction of food losses and wastage. Under INFR, there are five sub-criteria which are ranked as SFAC>PFAC>DFAC>TFAC>RFAC, where SFAC is the most critical and ranked at first position and RFAC is least critical amongst. SFAC is the 'Storage facilities' and there are numerous studies (Yuen, 2017) which have emphasised on the criticality of having good storage facilities for the reduced food wastage and losses. PFAC is the 'processing facilities' and it is crucial that the manufacturing/processing facilities at the manufacturer/processor end are adequate and suitable for maintaining cold chain. DFAC is the 'distribution facilities' and is ranked at third position amongst the infrastructural issues being highly inadequate to meet the demands of a cold chain (Martikainen, 2014; Jedermann, 2014;Negi, 2015). The crux of TFAC i.e. 'transportation facilities' has been well-discussed upon by Chaudhari (2018), Sinha (2017), etc. but the transportation facilities are still inadequate considering the volume of refrigerated transportation expected for cold chain items as would be considered normal to fill dramatically in future. Ganesan (2009) and Su (2021) have highlighted in their study the significance of adequate facilities at the retail end thus indicating the importance of the fifth ranked infrastructural sub-criteria RFAC which is 'marketing/retail end facilities'. Though it is highly crucial, its rank at fifth position does indicate that the retail-end facilities (especially the organised retail) are adequately equipped with the infrastructural requirements for perishable products though there is scope for further improvement

The issue 'Lack of Infrastructure' has gathered first rank in both the AHP and Fuzzy AHP methods thus indicating the significance of the issue regarding CC's performance. According to the DEMATEL approach, the issue 'Lack of Infrastructure' has influence on all the other issues. It is having Cause relationship with the other issues. With the application of AHP, consistency ratio was estimated to be 0.025 which is less than 1 indicating steadiness of results. Thereafter, Fuzzy AHP was applied for a more precise ranking. Thus, it is clearly evident that storage facilities are the most critical sub-category of Infrastructure issue and the remaining in descending order are: PFAC>DFAC>TFAC>RFAC.

Awareness & Handling practices Issue

Going ahead with the ranking of Issues, Awareness & handling practices attained the second position in ranking and hence is the second most crucial issue after INFR issue. Under AWHP issue, there are five sub-criteria which are ranked as KNQP>KNHP>KNSR>AITT>KNCS where KNQP is ‘Knowledge of Quality parameters’ the most critical amongst the awareness and handling practices issue and the least critical is KNCS ‘Knowledge of Compliance standard’. KNHP which is ‘Knowledge of handling practices’ ranks at the second position while KNSR ‘Knowledge of safety requirements’ ranks at the third position. Fourth position is attained by AITT ‘Awareness of latest techniques and technology’.

The issue ‘Lack of Awareness & handling practices’ has gathered the next important rank in both the AHP and Fuzzy AHP methods. Awareness and handling practices are also very crucial with respect to the safety, quality of the food products. According to the DEMATEL approach, the issue influences the issues of ‘Lack of Responsiveness’, ‘Lack of Traceability’, ‘Lack of Sustainability’ and ‘Lack of Safety and Quality’ thus sharing a Cause relationship with the other issues. Thus, improving the awareness and handling practices will result in improvement of safety, quality, responsiveness, and sustainability too. With the application of AHP, consistency ratio was estimated to be 0.055 which is less than 1 indicating steadiness of results. Thereafter, Fuzzy AHP was applied for a more precise ranking. It is clearly apparent that knowledge of quality parameters is the most critical sub-category of Awareness & Handling practices issue and the remaining in descending order are: KNHP>KNSR>AITT>KNCS.

Safety & Quality Issue

The research concludes further that Safety and quality (SAFQ) is the third most critical issue which further consists of ‘handling practices’, ‘storage parameters’, ‘quality control parameters’, ‘attributes of the food maintained’ and ‘compliance to legislation’. Manzini in 2013 emphasized upon how safety and quality significantly influence all stakeholders including the society and environment in a direct or indirect manner. The five sub-criteria under SAFQ are ranked as ATTR>HNDP>QUCP>CMPL>STRP with ‘Attributes of the food product maintained during the entire chain’ is the most significant sub-criteria and ‘storage parameters’ is the least significant. In fact, Hong (2011) highlighted in his study that food safety and quality can be achieved, either through standards/certifications and regulations or through operations/production, logistics and storage processes and this together will help build customer confidence.

The issue ‘Lack of Safety & Quality’ has gathered the third rank in the Fuzzy AHP method while in the AHP method, it has gained fourth rank. According to the DEMATEL approach, the issue influences ‘Lack of Responsiveness’ and shares an effect relationship with the other issues. Thus, improving the other issues will result in improvement of safety and quality.

With the application of AHP, consistency ratio was estimated to be 0.065 which is less than 1 indicating steadiness of results. Thereafter, Fuzzy AHP was applied for a more precise ranking. It is clearly apparent that maintaining original attributes of the product is the most critical sub-category of safety and quality issue and the remaining in descending order are: HNDP>QUCP>CMPL>STRP.

Responsiveness Issue

Likewise, Responsiveness issue (RESP) is ranked at the fourth position being the fourth most significant issue. RESP has four sub-criteria which are in the sequence LTRD>VART>CUST>SYNG, where LTRD which is ‘Lead time reduction’ is the most significant and SYNG ‘Synergy with firms’ is the least. Sukati (2012) has highlighted how the organizations can accomplish competitive advantage through responsiveness of its supply network hence the focus on improving responsiveness is extremely important. Koops (2002) has also emphasized upon the significance of efficiency and responsiveness of a SC.

The issue 'Lack of Responsiveness' has gained the fourth important rank in the Fuzzy AHP method while in the AHP method, it has gained third rank. According to the DEMATEL approach, the issues does not cause any influence on other issues as it is influenced by presence of other issues thus sharing an effect relationship with the other issues. Thus, improving the other issues will result in improvement of responsiveness too as in the case of safety and quality. With the application of AHP, consistency ratio was estimated to be 0.079 which is less than 1 indicating steadiness of results. Thereafter, Fuzzy AHP was applied for a more precise ranking. It is clearly evident that lead time reduction is the most critical sub-category of responsiveness issue and the remaining in descending order are: VART>CUST>SYNG.

<u>Traceability Issue</u>

At the fifth critical position, comes the issue of traceability which has three sub-criteria under it: information about product at storage level; information about product at retail level; and extent of product information available in the sequence PINF>INRT>INST. Extent of product information available is the most critical while information at storage level is the least critical. Food traceability is an essential piece of arranged tasks of the operations in food and agrarian supply network (Bosona, 2013). Even, Manzini (2013) suggested a highly effective traceability system for effectively managing the food safety and quality risks and also promoting the development of effective CC management.

The issue 'Lack of Traceability' has fifth rank in both the AHP and Fuzzy AHP methods thus indicating the significance of the issue with respect to the performance of the cold chain. According to the DEMATEL approach, the issue causes influence upon the issues 'Lack of Responsiveness' and 'Lack of Safety & Quality' thus has a Cause relationship with the other issues. The dominant sub-categories of this issue are: information coverage at storage level; information coverage at retail level; and extent of information about the product. These sub-categories were identified through prior analysis done using structural equation modelling technique. With the application of AHP, consistency ratio was estimated to be 0.074 which is less than 1 indicating steadiness of results. Thereafter, Fuzzy AHP was applied for a more precise ranking. It is clearly evident that extent of information about the product is the most critical sub-category of Traceability issue and the remaining in descending order are: INRT>INST.

Sustainability Issue

The issue of sustainability gathered the sixth rank amongst the issues. It has five sub-criteria under it which are in the sequence COST>ENRG>LOSS>PDRP>GRNC where COST is ranked highest and GRNC i.e. 'Green CC practices' is ranked lowest. ENRG which is 'Energy consumption' is ranked at second position, followed by 'Losses and Wastage' and PDRP i.e. 'Product responsibility' at the fourth position. Attributable to the developing mindfulness and expanding worry for social, financial and natural effect on food creation and utilization, there is additional strain from social responsibility groups, consumer and what's more, agro-based associations and policymakers to foster practical SCs (Allaoui, 2017). Also, as re-iterated by Joshi (2020), a sustainable supply chain can help in waste reduction and increase in efficiency of the chain.

The issue 'Lack of Sustainability' has gained the sixth important rank in both AHP and Fuzzy AHP method. According to the DEMATEL approach, the issue influences the issue 'Lack of Safety & Quality' thus shares a cause relationship with the issue. The dominant sub-categories of this issue are: losses and wastage; product responsibility; cost; energy consumption; and green cold chain practices. With the application of AHP, consistency ratio was estimated to be 0.069 which is less than 1 indicating steadiness of results. Thereafter, Fuzzy AHP was applied for a more precise ranking. It is clearly evident that cost is the most critical sub-category of sustainability issue and the remaining in descending order are: ENRG>LOSS>PDRP>GRNC.

Integration Issue

And finally, the integration issue which is ranked at the seventh and last position. The issue consists of sub-criteria in the sequence: BACK>FORW>FARM. BACK i.e. 'backward integration' is the top ranked sub-criteria while 'linkage between farmer and firm' is the last sub-criteria. According to Pusporini (2020), a robust collaboration and integration is required between the government, main organisation and other chain partners to provide availability of efficient CC infrastructure and hence the need for desired level of interaction and sharing of information between the cold chain partners (Peng, 2020).

The issue 'Lack of Integration' has gained the seventh important rank in both AHP and Fuzzy AHP method. According to the DEMATEL approach, the issue influences the issues 'Lack of Safety & Quality', 'Lack of Traceability', 'Lack of Responsiveness', and 'Lack of Awareness & handling practices' thus sharing a cause relationship with the other issues. Thus, it is indicated that though this issue is ranked as least important however resolving this issue will have impact on the other issues too.

With the application of AHP, consistency ratio was estimated to be 0.074 which is less than 1 indicating steadiness of results. Thereafter, Fuzzy AHP was applied for a more precise ranking. It is clearly evident that backward integration is the most critical sub-category of integration issue and the remaining in descending order are: FORW>FARM.

5.7 SENSITIVITY ANALYSIS: ANALYZING THE ROBUSTNESS OF THE RANKINGS OF ISSUES

On the basis of analysis done using AHP and FAHP, the issue most important from the cold chain performance perspective is Infrastructure and the least important is Integration. The sequence of the issues in descending order of importance is INFR>AWHP>SAFQ(RESP)>RESP(SAFQ)>TRAC>SUST>INTG.

This study categorized seven key issues and out of these seven the highly prioritized barrier is the ‘Lack of Infrastructure (INFR). A slight fluctuation in weightage of highly ranked barrier can influence the rest of barriers (see Table 5.14). For addressing the fluctuations among variables this research applied sensitivity analysis. Therefore, highly prioritize barrier weightage can be changed from 0.3585 (INFR) to 0.3585*0.9, 0.3585*0.8…. 0.3585*0.1 with values taken to four decimal places (see Fig 5.7).

Table 5.14. Issues’ Sensitivity analysis with “INFR” issue weight changes from (0.3585*0.9 … 0.3585*0.1)

Issues	Normalized LITINF=0.3585	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
INFR	1	1	1	1	1	1	1	1	1	1
SAFQ	3	3	3	3	3	3	3	3	4	4
RESP	4	4	4	4	4	4	4	4	3	3
AWHP	2	2	2	2	2	2	2	2	2	2
TRAC	5	5	5	5	5	5	5	5	5	5
SUST	6	6	6	6	6	6	6	6	6	6
INTG	7	7	7	7	7	7	7	7	7	7

Source: Sensitivity Analysis

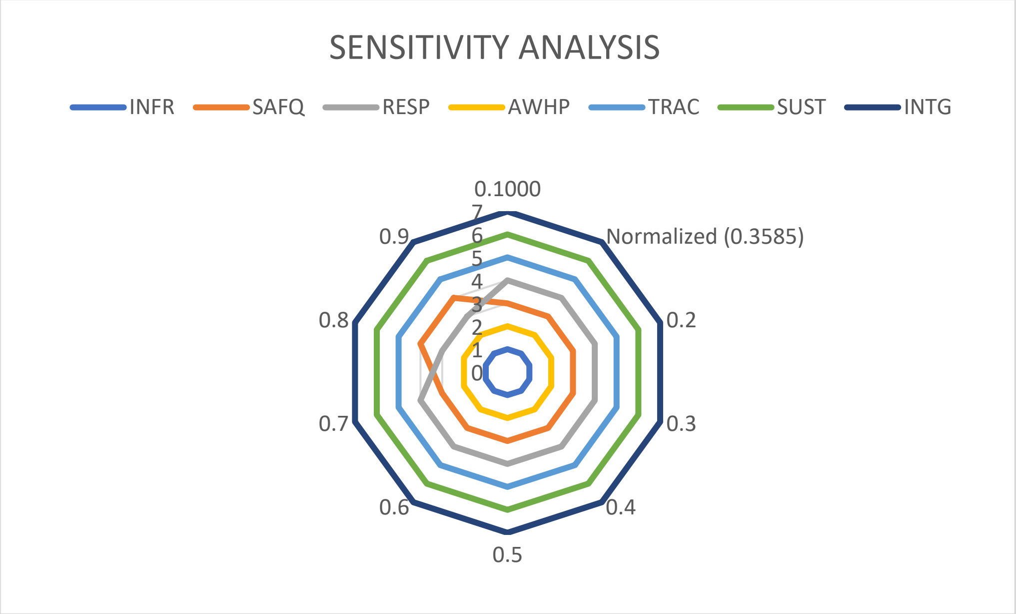


Fig. 5.7. Results of sensitivity analysis for issues

5.8 CHAPTER SUMMARY

This chapter presented arguments on the methodology and evaluated data obtained on categories and sub-categories of issues for the frozen food items' cold chain. To analyse issues, DEMATEL, Structural Equation Modelling, AHP and Fuzzy AHP techniques were employed. While SEM was used primarily for gaining an understanding of the causal relationship between the issues and the cold chain performance, testing of hypotheses and model development; DEMATEL was used to understand the inter-influence amongst the issues; and AHP/FAHP were used for prioritization of the issues and the sub-criteria. The results attained were presented clearly. The next chapter is based on suggestion of strategies and solutions to overcome the issues.

CHAPTER 6

SUGGESTION AND ASSESSMENT OF STRATEGIES & SOLUTIONS TO OVERCOME ISSUES

OVERVIEW

The previous chapter was based on the identification and analysis of issues. However, just identification of the issues is not sufficient. Hence, this chapter aims to present the strategies and solutions to overcome the issues that influence the performance of the cold chain of frozen food products. Ranking of the solutions on the basis of their usefulness towards resolving the issues and identification of the best solution and the worst solution has also been conducted. The methods Fuzzy TOPSIS and Best-Worst method have been used for conducting prioritization of the solutions.

6.1 INTRODUCTION

The change in the global economy can be represented well by the change in agricultural trade. While years ago, bulk commodities like cotton, grains, etc were the main products, today they have been replaced by the fresh, frozen and processed food products (Shister, 2004). For the Cold chain sector which is a growing industrial sector, safety, quality, sustainability are the top priorities to be addressed (Chen, 2020). According to a study by Gunaratne (2020), on the basis of literature survey, the strategies to enhance the efficiency of cold chain were - at operational level: preparing on specialized skill; legitimate information recording; plan opportune request satisfaction; - at center level - carrying out functional guidelines; stock administration and control; adjusting bundling components; arranging refrigerated armada; making mindfulness among ranchers/provider; booking preparing; lastly at vital level - securing quality authorizations; closeness to office area; putting resources into cold storage spaces; and contributing high level gear and vehicles. With increasing globalization and consumerism, cold chains have become highly complex. However, the cold chain of frozen food products is still at a very nascent stage in India and particularly so in Uttarakhand which is a newly formed state. The essential point of the cold chain is to hold the food quality back from decaying by enhancing the shelf life while also maintaining the quality of the food. However, an efficient and effective cold chain can result in minimization of losses and wastage in food products. Therefore, it is a vital prerequisite for the different accomplices in cold chain working in the country to guarantee great performance of the chain. Even then situation of CC is not in line with the global requirements and standards owing to the presence of various issues. Also, there is not enough literature available on FFP's CC which is the precise reason of the significance of the current research. Previous chapters presented a brief analysis of the issues present in the cold chain of frozen food products. But just analysis of the issues will not lead to any result and therefore the need to provide strategies and solutions to overcome the issues. The performance of the cold chain for frozen food products was measured using ascertained indicators. These indicators are proper storage of frozen food, texture restored, proper storage of frozen fruits & vegetables, quality maintained, moisture retained, nutrients retained, shelf life increased, freshness retained, spoilage and wastage minimized, and protected from bacteria.

After conducting an iterative search, exhaustive review of academic literature, white papers, company webpages, e-commerce websites, market research reports this thesis captures, analyses and compares solutions, both technology-based and non-technology based across the seven issues concerning improving the exhibition of cold chain of frozen food products. For the same reason, the present chapter is based on objective three as mentioned below:

<u>Objective 3</u>: To develop a model and suggest solutions to overcome issues finally leading to enhanced performance of cold chain.

This section presents the final model developed for improving cold chain performance of frozen food products and the solutions suggested for overcoming or resolving the issues. On the basis of the evaluation of issues and their analysis done in the previous chapter, fig 6.1 exhibits the final model.

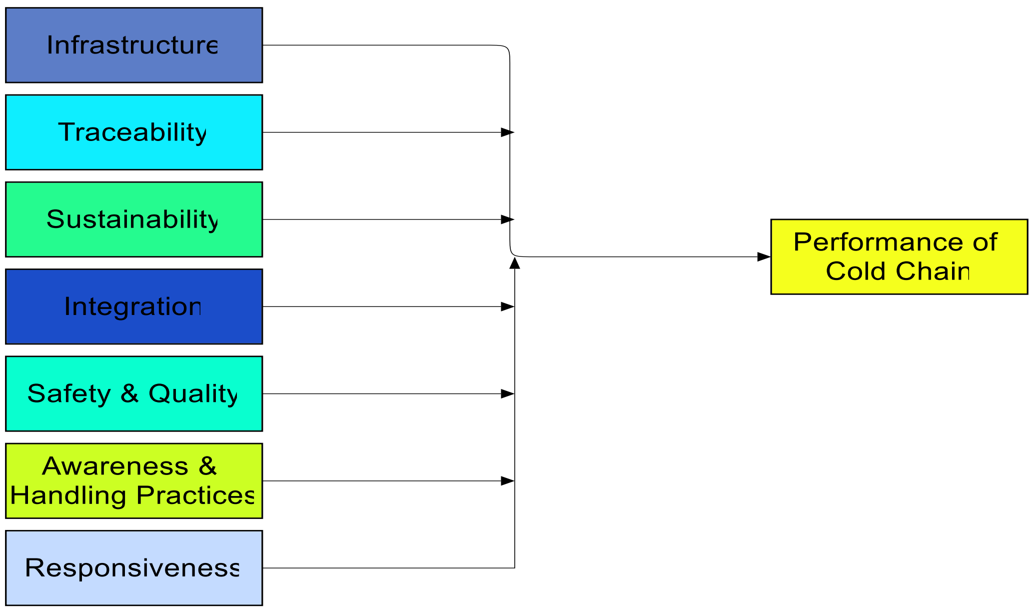


Fig 6.1 Final Model

6.2 INTERPRETATION OF THE MODEL

The model illustrates the issues which need to be resolved in order to overcome enhanced performance of cold chain ultimately leading to reduced losses and wastage. Presence of critical issues results in a number of performance related problems finally resulting in huge food losses and wastage.

It is clearly evident that lack of infrastructure, lack of traceability, lack of sustainability, lack of integration, lack of safety & quality, lack of awareness & handling practices and lack of responsiveness are the various issues having a significant impact on the cold chain performance. Issues related to infrastructure, safety & quality, awareness & handling practices, and responsiveness had a substantial influence on cold chain performance while lot of efforts are still required in areas of traceability, sustainability and integration.

6.3 IDENTIFICATION OF STRATEGIES AND SOLUTIONS TO OVERCOME ISSUES

From the previous chapters it is clearly evident that infrastructure, traceability, sustainability, integration, safety and quality, awareness and handling practices and responsiveness are the primary issues which needs to be dealt with extreme emphasis and focus by all the cold chain partners right from starting place to point of utilization.

This section portrays the solutions which need to be implemented at all the levels of a cold chain and by all the cold chain partners including farmers, manufacturers/processors, distributors, retailers and logistics. This will help enhance the performance of the cold chain, take the cold chain to a level which can help not only reduce losses and wastage in frozen food products but will also be able to exploit the premium position in food production that the nation holds globally.

6.3.1 Issue - 'Lack of Infrastructure'

Infrastructure is the most important issue that needs to be dealt with a huge emphasis as it requires substantial investment costs. However, these are one-time costs which shall reap continuous successive benefits. As per the study, the significant indicators are production/processing facilities, storage facilities, transportation facilities, distribution facility and retail-end facilities. Nonstop checking and control of temperature and other natural circumstances depending on the product is extremely important at all the important links of the cold chain. Raut (2019) in his study emphasized that infrastructure is the most important and influencing issue in the cold chain. Thus, it is an essential requirement to maintain these at creation/handling, capacity, transportation, dispersion and retail-end outlets. As per the field visits done, expert interviews and the survey conducted, though the required parameters are being maintained but it is insufficient and mostly done manually. In these facilities, the temperature and other required conditions are checked daily not many times each day, similar to two-three times each day by staff in the facility and records are maintained manually. There is a need for use of software solutions like RFID cold chain solutions which can allow the manufacturer/processor/distributor/retailer to capture the then-current conditions of the products whether they are in storage, in process, or in transit. This will help not only provide assurance of goods maintained, stored and transported in required conditions but will also ensure product monitoring and control from starting place to point of utilization. Wireless technologies coupled with RFID can be a powerful combination which can link all the ends in a cold chain. Manufacturers, distributors, retailers need to use logistic fleets equipped with modern technologies, namely digital electronic controls that are remotely monitorable, integrated temperature and other environmental condition management systems thus resulting in refrigeration units used for transportation that are not only highly efficient but also will help enhance food safety, reduce loss and wastage while improve profitability as well. The technology of RFID (radio frequency identification) is an amalgamation of hardware and software that works without user interference (Sheng, 2010).

Temperatures during loading/unloading and during door openings need to be monitored on real-time basis with the help of remote and wireless monitoring technologies. Proper distribution facilities can result in enhanced profitability for all the partners in the cold chain. Manpower in the cold chain works in harshest environment and therefore storages and warehouses need to be equipped with automated storage and retrieval systems. This will contribute in energy reduction as well as enhance productivity of manpower working in these harsh environments. Automated systems will also lead to reduction in errors in order-picking. Products need to remain in cold storages till they are delivered and without the cold chain getting broken. This can be made possible by the use of order selection processes built into the automated storage and retrieval systems and mobile racks as exhibited in Fig 6.2.

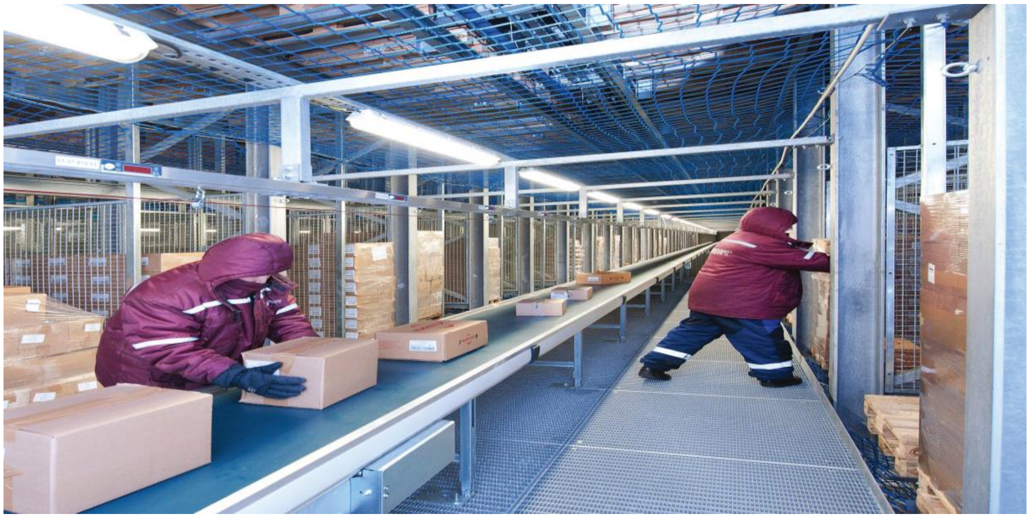


Fig 6.2 Automated Storage and Retrieval Systems

By using full automation systems, there will be considerable reduction in energy operating costs and also more storage can be accommodated in less refrigerated space. Firms can outsource their storages to specialized storage service providers. So, there is a need for more firms entering into specialized storages offering their services to the cold chain partners. With the help of mobile racks, access aisle can be used to move to the required location. This can lead to reduction in upfront costs along with exponential increase in profit margins. All transport vehicles carrying frozen food products and other such perishables must be equipped with cold-storage facilities that are customizable, supported by real-time recording and monitoring of the product temperature right through storage and distribution. Prior to selection of the appropriate packaging system, there is a need to understand properly the transportation logistics, the environment to which the shipment will get exposed to and the way shipments will be handled during the transit. Cold storage warehouses need to expand further from being used purely for storage to providing urbane value-added services. Compliance, data collection and analysis need to be automated for shipping and storage purposes.

However, real-time tracking of temperature for a food product requires technologies that can identify and record measurements but at the same time they should be able to justify the cost-benefit analysis criteria (adapted from Islam, 2021).

For packaging various materials can be used, some of them being foam sheeting in corrugated cases; inserts of expanded polystyrene which can be customized; no-sweat gel packs; condensed foam and foil; insulated packaging. Also, care can be taken to match packing as per the shipment location and timing. Smart packaging can be applied for extending the shelf-life, maintaining the freshness, safety, improved traceability and deliver quality information with the customers while the product movement takes place in the chain (Mackay, 2020). Intelligent packaging by making use of technologies like freshness indicator, RFID devices, time-temperature indicators, etc. can help monitor and track the settings of food product during storage and distribution activities (adapted from Chen, 2020).

With growing consumer demand for fresh F&V, the storage along with transport facilities need to be able to allow more temperature ranges to be able to exploit on the changing trends. Distributor networks need to be more alert, flexible and accessible. The future increase in demand for fresh and natural food will require the cold chain to possess the capability of managing even more temperature zones. Thus, there is need for cold chain partners to invest in temperature-management techniques along with increase in storage capacity. Infrared data transmitter will help identify the state of the shipment even with closed trailer and accordingly the information can be shared with the various parties involved. Implementation of Onboard telematics in the reefers or trailers can not only monitor the desired environmental conditions required to maintain or enhance the product life but will also help ensure that the food safety standards are complied with. Firms involved can use private extranets to connect with other cold chain partners. This will help improve visibility as well as enhance performance along the entire chain. Cold chain partners need a communications infrastructure through which they can not only feed sensor data (environmental status) but also makes sharing across the cold chain effective. Active reefers equipped with electronic data loggers or RFIDs, customized thermal profiles and pallet covers should be innovatively used. Fleets can be equipped with telematics technology providing temperature management, fuel management, and other applications for maintenance and for real-time monitoring and controlling of refrigerated transportation assets while also supporting two-way communication. The telematics integration utilizes global positioning systems, internet, sensors and wireless connections.

The cost of technology will be a one-time investment while value of information will give increasing benefits on a continuous basis. A fully-automated system when implemented can provide remote monitoring on continuous basis along with the necessary tools to comply with storage and temperature monitoring guidelines. A cost-effective tool for monitoring data related to temperature and time can make use of a combination of internet, RFID smart cards and RFID reader with barcode scanner integrated. The smart card can be placed within the reefer/container. The reader can scan the barcode and inscribes it to the memory of the smart card through wireless technology. Results regarding temperature recordings can be transmitted to the relevant chain partners with the help of internet. Freshness and quality of the product can be controlled based on the temperature history of the product. Thereafter, storage management can be optimized and thus the product safety and quality can be maintained and wastage reduced. It is important to ensure minimized perishable product loss during transportation (Bacon, 2015). Hence, intelligent food logistics is the requirement as per a study by Federmann (2017).

With increase in demand for cold storage and cold chain business in the country, the government as well as the industry need to make available more warehouses and distribution services equipped for cold chain along with guidelines to ensure high standards of logistics and storage.

6.3.2 Issue - 'Lack of Traceability'

As per the study, significant indicators are information coverage at storage level, information coverage at retailer level and extent of information provided about the product. There is need to use technology innovators that can track real time product location along with temperature from the product receipt generally used as proof of delivery. A shipment template can be created which clearly presents complete information related to the product, like its geographic origin, ingredients, method of processing, environmental conditions required for maintenance of shelf life, best before date, compliances, etc. As a result, at the point of receipt, the detailed personnel will be able to see the complete information and organise and sort out the product according to the procedural strategy like FIFO (first in first out), LIFO (last in first out), FILO (first in last out) etc. followed by the firm. RFID is an exceptionally valuable innovation in terms of following a wide range of items all through the cold chain. The radio frequency enabled devices can be put inside packages with the aim of recording temperature and desired other environmental conditions at scheduled intervals. This data can then be downloaded on a database accessible through the web. The data will have details of location and status of shipment as well. So, if a temperature violation is about to occur, action can be taken by the distributor or if the temperature violation has already occurred then the customer can be alerted and the package if already received by the customer can be replaced. This real-time exact monitoring and reporting will also help in providing evidence of the time and place when the breach happened and also send alerts in case of exceptional situation requiring any corrective action. Electronic data loggers can also be used for tracking and tracing. Another inexpensive and user-friendly device that can be used are thermostrip irreversible temperature indicating labels which maintain a relatively permanent record of span of temperatures. Colour changing labels can also be used where colour of the label changes indicating change in temperature or so. The time-temperature indicators (TTI) consisting of labels that change colour as shelf life reduces or if temperature abuse has occurred are another good alternative to use.

In a study Martinez-Sala (2009), after conducting a comparison of cost and benefits of various technologies, emphasised upon radio frequency identification (RFID) for automated traceability. While Qi *et al.* (2014) selected barcode technologies and wireless sensor networks for real-time product monitoring.

As per Mercier *et al.* (2017), a dynamic shelf-life assessment system can be very useful in reduction of losses and wastage and safe consumption. Based on the past recordings of temperature and time, shelf life of the item can be reassessed thus ensuring quality of the product. It can actually help reduce wastage by nearly 80%.

A traceability system which can effectively report on the movement and location of product can help in minimizing health and economic consequences of risk of an outbreak of a disease. Traceability to a great extent relies on real-time monitoring and/or record-keeping. Internet-of-Things(IoT) can be very effective and precise for such monitoring and recording purposes right from 'farm' to 'fork'. It will enable the devices to be connected to internet, permit changing of set points while also perform diagnostics when required. This can lead to reduced wastage and spoilage along with improved cold chain visibility. At all the links of the cold chain, the previous source along with the product details should be documented properly and the information passed downstream such that the last link must contain complete information right from the point of origin. Any breaks in the link should be also indicated using the trace forward and trace backward method. RFIDs and blockchain technology can be effectively used for the purpose. At the transaction level, the cold chain management systems will give real-time information regarding shipments and at the cold chain level, a dashboard can give information regarding the performance of the cold chain and the partner involved. Economies that are fast growing, like India, with increasing new demands regarding visibility that is real-time to know where their product is and the time of arrival without damage or loss, information technology is required to be implemented throughout CC. Software solutions enabling cold chain partners to know as well as monitor the security along with environmental status of their products irrespective of their location. The customers can be notified through product intelligence and exception alerts and this real-time intelligence will help the involved manpower to respond appropriately and prevent losses. With the use of technology that is existing today, it will be possible to monitor and act on any challenge in the shipment right from point of start to point of finish. Integration of wi-fi tags with the logistics software will help track paths of products in real time through web-browsers. Web application with the reporting and analytics capabilities will help enhance visibility while in transit also improve the operational efficiency of the refrigerated transport thus leading to improvement in the chain execution.

As per the FSMA(Food Safety Modernization Act) passed in 2011 requiring traceability of the item across the whole SC, recalling product in case of any contamination or health hazard becomes easier as complete tracking helps to isolate the point where it occurred.

An adequately integrated system incorporating traceability into it can help enhance process control as well as detect effect and its cause in case a product does not conform to desired standards. As per Regattieri (2007), the traceability systems can help optimise the use of raw material by improvement of operations planning. Integration of traceability with SCM processes determined to oversee and further developing business processes using traceability data (Wang, 2006). As per a study by Ruiz-Garcia (2010), integrating information across the chain into a standardized traceability system right from place of creation to the place of utilization represents an effective way to enhance food safety and quality as well as achieve customer confidence.

6.3.3 Issue - 'Lack of Sustainability'

As per the study, significant indicators are losses & wastage, product responsibility, cost, energy consumption and green cold chain practices. Sustainability of cold chain can be effectively achieved through application of technologies which have the capabilities of identification and tracking; logistics management (Yang, 2017);

manage fluctuations in temperature, humidity, etc. and help take decisions for shelf-life management of food products (Gunaratne, 2020).

Firms need to invest in energy reduction equipment like solar panels, LED lighting, dock doors and racking. The responsibilities of manufacturers/processor for tackling the issue of sustainability does not actually end with the offer of item but there needs to be a certain level of accountability with respect to the influence on the environment and so initiatives need to be taken for implementation of shelf-life management and waste management programs (Du Pisani, 2006). However, considering the cold chain network which is so complex today, not just the manufacturers/processors but all the cold chain partners must have HACCP/ISO 9001 or a relevant accreditation to ensure product safety, delivery of products following the required temperature and other environmental parameters throughout the cold chain as well as to streamline any inefficiencies on the management part. A solar energy management system can be effectively deployed in refrigeration along with a software that has the capability to monitor real-time usage of energy. This will help understand energy usage patterns, impacts of using the equipment and also make changes to streamline usage peaks for the entire day.

There is need of more temperature-controlled logistics solutions operating multi-modal while combining the economies of rail, sea with the flexibility of roadways containers. This will ensure reduction in carbon footprints and greening of cold chain. Use of recycled resin or renewable materials in packaging needs to be increased and all cold chain partners must collaboratively have extended sustainability goals by aiming to have zero waste entering the landfills even from the consumer end. Firms can even start with programs in order to create the ability of recycling the packaging material. Carbon emissions can also be reduced by densely packaging products for distribution. Polypropylene packages that are lightweight and airless are a sustainable option for packaging. RFID with wireless communication links can not only just identify but also help defend against threats that may be biological, chemical or even radioactive. As per study by Sundmaeker

(2010), Internet of Things can be significantly used in wastage reduction and improving sustainable performance.

When the reefers or containers reach the dock, the point of loading and/or unloading, use of networks to automatically collect temperature data without the need of unloading and checking each container, will help not just reduce costs but also increase efficiency. Cost-effective and environment-conscious transportation should be a high concern area in the relevant decisions for all the partners in the cold chain. Technological solutions offering sustainability traits like recyclability, reusability or renewability to be implemented. Shippers can be made insulated using biodegradable material like cornstarch-based material. Biofuel can be a good alternative for non-renewable sources for energy production.

Table 6.3 presents solutions to overcome the issue of sustainability. According to a study by Wu (2019), use of solar electricity for pre-cooling could lessen the ecological effect by 55 g CO_2-eq/kg of natural product (or 8.5%) while holding the natural product quality. Stakeholders together should convert a traditional cold chain to green cold chain by adopting Green Procurement, Green Manufacturing, Green Distribution, and Green Logistics (reverse logistics) in order to reduce energy consumption and eliminate waste in the form of gaseous emission, chemicals or solids across the entire cold chain (adapted from Jermsittiparsert, 2019). Biofuel is considered as a good alternative to eliminate or reduce the waste material including energy, chemical, emission or solid waste throughout supply chain

6.3.4 Issue - 'Lack of Integration'

As per the study, significant indicators are linkage between farmer and firm, backward integration and forward integration. The cold chain capabilities need to be enhanced by integrating its systems at various points like warehouse management systems, processing systems, sales and distribution systems such that customers can have not only have access to their orders but also complete history of the product right from point of creation till it reaches them. Partnerships and alliances need to be developed between cold chain stakeholder firms. This will deliver a platform for the cold chain industry to share knowledge about trends, opportunities, best practices and development. Aligned with being future-ready, if the cold chain industry is to be strengthened then it becomes imperative that each link is connected to the other link of the chain so that the knowledge-sharing happens throughout the chain. Customers can be best served collectively when the resources along with knowledge are combined and shared. Partners in cold chain need to synergistically adopt a learning strategy where they accept, understand existing knowledge and develop new knowledge and knowledge-sharing procedures to make partnering work. This will promote cost-reduction, innovation and also achieve competitive advantage. Cold chain partners should collaborate together and create a platform for integrated procurement and logistics. For this, it is imperative to integrate the onboard system with a complete refrigerated container management system. Such a system will help increase return on investment as well as further developed execution of the strategies and the whole chain. The 360^{o} -view data provided by these integrated systems will improve visibility, increase safety, reduce wastage and losses as well as enhance customer satisfaction. Systems enabling reliable flow of information can give firms an oversight into their cold chain. Determination of status in a collaborative manner, detection of equipment tampering, providing link with external networks can be achieved through wireless connectivity. Collaborative forecasting with the help of technology that provides accurate, timely and complete information to all the partners can help related firms accrue higher earnings for the firm. Synchronisation amongst the chain partners will increase cold chain visibility and help maintain collaborative relationships (Wei, 2011); reduce risks; better quality and output; and better infrastructure in handling perishable products (Gunaratne, 2020).

All organizations engaged in the cold network should have the information on cold chain integrated across the network along with packaging, distribution and intervention abilities and then implementing these effectively. A platform that procures data from multiple monitoring systems including sensors and provides interpretation of temperature, energy consumption and other environmental attributes in real time is highly needed. It will provide comprehensive visibility of cold chain on any integrated device. Application of e-business model will help the partners establish a better relationship and also sustain competitive advantage. There are various technologies and technological solutions, such as blockchain, IoT, cloud, etc.) available for use to improve and implement integrated cold chain which in the future is going to require such a transformation to an intelligent, digital, effective and sustainable cold chain network (Han, 2021).

6.3.5 Issue - 'Lack of Safety & Quality'

As per the study, significant indicators are handling practices, storage practices, quality control practices, food attributes and required environmental conditions maintained and compliance to standards for assurance of safety and quality. Facilities should be guaranteed through certifications for food handling and quality. To ensure quality of products, real-time data regarding the location and temperature is a must and a requirement by the producers and retailers. The information such as 'use by', 'best before', etc. has already become norm but it does not offer much data on the situation with the food item and so it is important that shelf-life determination is dynamic and available to the customer (Poyatos-Racionero, 2018).

RFID labels should be utilized to screen the nature of the item, as it can give readings on the existing shelf life based on temperature and other environmental conditions that the product has been through. This will ensure that the product is not only of the required quality but also ensure that it is consumed while it is safe thereby reducing wastage or causing any health concerns. Use of technological devices and solutions is one significant measure for tackling the safety issue of food as well as preventing wastage and losses of foods (Vilarino, 2017). Today, use of technologies to guarantee food safety and quality has become a compelling requirement.

Information systems need to be implemented which based on input data can gauge the leftover timeframe of realistic usability of the transient item. This will help in taking decisions regarding the fast movement of the product for consumption before it expires or is unsafe. With expansion into new geographic regions, it becomes a necessity to keep products compliant and safe during the long journeys. A freeze indicator, in the form of a colour label or any such technology, which gives the level of freezing along with the assurance that no speedy freezing has occurred will be very useful in gauging the safety and quality of the frozen food. It could register time as well as temperature while also indicating the degradation of the product. This can be used for the entire lot. Such enhanced information services will help in chain execution as well as guarantee nature of item to the chain accomplices. For increasing safety and quality of the product by preventing exposure to dust, wind or precipitation, the trailer doors, at the time of loading/unloading, can open inside the facility with even the seal be broken by the staff inside rather than the driver of the trailer. This will also help maintain the integrity of the cold chain which can further be improved by separation of the de-palletizing and de-boxing areas from the processing room.

6.3.6 Issue - 'Lack of Awareness & Handling Practices'

As per the study, significant indicators are awareness about latest techniques & technology, knowledge of handling practices, knowledge of quality parameters, knowledge of safety requirements and knowledge of compliance standards. The staff working at the various points of the cold chain must be trained well considering severities of handling and storing CC items. Most of the cold chain partners, especially the farmers and the distributors do not have the ideal skill and assets expected to deal with their item delivery. The drivers of the refrigerated containers should be trained not only for temperature monitoring but also need to be aware about impact of speeding, hard braking, idling, etc. for improved performance. Regulations requiring proofs throughout the cold chain with respect to desired environmental conditions maintained need to be followed strictly and accordingly manpower needs to be specially trained to handle the perishables. There is an absolute need to increase the awareness of the various stakeholder with respect to safety and quality issues (Mercier, 2017). Consumers too need to be educated to improve their awareness regarding quality deterioration and the risks associated while encouraging them to use techniques like temperature monitoring, use of insulated bags, etc.

Firms need to leverage the best practices in packaging, product processing, transportation that are existing and these need to be applied to the care of frozen food products. As cold chain industry partners, the needs of the respective customers are served in the best manner when the knowledge and resources are combined to aid the best practices and that is where lies the strength of the cold chain.

6.3.7 Issue - 'Lack of Responsiveness'

As per the study, significant indicators are catering to varieties in products, lead time reduction, synergy with firm supplied to, and customer-centric in terms of response time and customer complaints. A hotline can be launched to indicate the food wastage and the point at which it is occurring. This will help both the producers and the distributors to point out the links at which the wastage occurs and they can together with retailers work to tackle those hotspots. Cold chain partners can use extranets for better agility and quick responsiveness to their partners both upstream and downstream. The trailer data needs to be integrated with back-office so as to lead to significant increase in responsiveness and chain partner satisfaction ultimately contributing to the consumer satisfaction.

6.4 CATEGORIZATION OF SOLUTIONS INTO IT AND NON-IT

With the intention of overcoming the issues and reducing their negative influence on the cold chain performance, nine IT solutions and twenty non-IT solutions are advocated in the research. Though implementation of these solutions is not an easy task however, the decision-makers can implement the solutions based on the priority level. Therefore, for the ease and convenience of decision-makers and policy makers, the solutions have been categorized into two categories: IT solutions and Non-IT solutions and both the categories have been separately prioritized. The prioritization has been done using two methods: Best-Worst which contrasts the arrangements as regards Best arrangement and the Worst arrangement and the FTOPSIS method which prioritizes based on the closeness coefficient value.

Based on literature review as well as the expert inputs, seven issues and 30 sub-categories of issues were ascertained along with 9 IT solutions and 20 non-IT solutions to help overcome the identified issues. The study consulted 30 experts with experience above 10 years in the relevant field. The solutions identified have been presented in Table 6.1 for IT solutions and Table 6.2 for Non-IT solutions. The initially identified 12 IT solutions were combined and reduced to nine solutions.

6.4.1 IT Solutions

Selection of right technologies can result in enhanced cold chain performance through improved infrastructure, traceability, safety and quality, responsiveness, sustainability, integration, awareness & handling practices. The use of information technology needs to be promoted and encouraged to solve various issues of the manufacturers, distributors and farmers (Kumar, 2017). The government bodies should take initiatives in promoting IT solutions for the cold chain industry.

Table 6.1 Solutions (IT) to overcome Issues in CC of frozen food products

Solution Description	Solution Code	References
Automation of Data collection, storage, retrieval, shipment, analysis & compliance	SIT1	Chen (2014); Wu (2020); Kim (2014); Expert Inputs
Wireless real-time & remote monitoring and reporting using technologies like RFID, etc and sensors	SIT2	Grunow (2013); Haan (2013); Expert Inputs
Use of electronic data loggers/time temperature indicators, digital electronic control, onboard telematics technology and other such devices for monitoring of temperature	SIT3	Joshi (2011); Taoukis (2016); Expert Inputs
Temperature-controlled logistics software solutions along with integrated refrigerated container management system with back-office	SIT4	Flynn (2010); Chaudhuri (2018); Ruiz-Garcia (2010); Expert Inputs
Traceability software system using technologies like IoT, Blockchain, etc	SIT5	Farooq (2016); Dabbene (2014); Expert Inputs
Product intelligence & exception alerts using technology and software to inform about shelf life, expiry date, freezing indicator, etc	SIT6	Bruckner (2012); Joshi (2011); Expert Inputs
Creation of platform for integrated procurement, processing, warehouse management, logistics, sales and distribution system using communications infrastructure like intranets, extranets, etc	SIT7	Sabir & Irfan (2014); Flynn (2010); Expert Inputs
Use of Web applications and adoption of e-business model	SIT8	Kumar (2013); Zhang (2018); Expert Inputs
Online and simulated training using technology	SIT9	Sukati (2012); Gligor (2018); Expert Inputs

6.4.2 Non-IT Solutions

Table 6.2 Solutions (Non-IT) to overcome Issues in CC of frozen food products

Solution Description	Solution Code	References
Specialized cold storage services provided by govt.(public) or industry(private) on lease	SNIT13	Aravindaraj (2020); Yahia (2009); Expert Inputs
Use of energy reduction equipment like solar panels, solar energy management system, LED lighting, dock doors and racking	SNIT14	Adekomaya (2016); Shashi (2018); Expert Inputs
Accreditations & certifications for processing, storage, logistics and retail along with strict following of regulations required for frozen food handling	SNIT15	Ali (2018); Cerchione (2018); Expert Inputs

Use of bio-degradable material for packaging, etc	SNIT16	Cerchione (2018); Han (2021); Expert Inputs
Partnerships and alliances to be built for sharing of knowledge and resources	SNIT17	Salin (2003); Lan (2012); Expert Inputs
Collaborative forecasting, sustainability goals and joint learning strategies	SNIT18	Pramatari (2007); Li (2017); Expert inputs
Extensive training for all CC stakeholders	SNIT19	Mallik (2011); Tsironi (2015); Expert inputs
Extensive training for all manpower working in CC facilities at different links of a CC	SNIT20	Mallik (2011); Tsironi (2015); Expert inputs
Contract farming to be encouraged through govt initiatives	SNIT21	Gulati (2008); Kirsten (2002); Expert inputs
More customer awareness needed for packaging(prefer bio-degradable than fancy ones) and handling of frozen food	SNIT22	Tsang (2017); Joshi (2009); Expert inputs
Launch of hotline	SNIT23	Expert Inputs
More initiatives required by Govt. for providing tools and machines to farmers, finance at lower level, mandi level, crop disease tackling, cold storages and reefers for transportation of fruits and vegetables to destination	SNIT24	Aravindaraj (2020); Singla (2016); Dandage (2017); Expert inputs
Application of best practices prevalent in frozen food industry	SNIT25	Shabani (2012); Bremer (2018); Expert inputs
Distribution infrastructure to be improved along with increase in number of distributors required	SNIT26	Milić (2015); Surange (2013); Expert inputs
Proper waste processing required that can be used for producing alternate energy. Govt. initiative required for that	SNIT27	Expert Inputs
Cold storage - maintenance and power backup to be improved, provided by industry or govt.	SNIT28	Maheshwar (2006); Joshi (2009); Expert inputs
Companies approach farmers directly and give prices equivalent to that of mandi	SNIT29	Expert inputs
Awareness and training provided to farmers regarding use of cold storages, reefers and new ways of farming, etc	SNIT30	Gautam (2017); Noor (2011); Expert inputs
More emphasis to be paid on exports for reducing wastage as production is more than demand	SNIT31	Wilkinson (2008); Ch (2010); Dandage (2017); Expert inputs
Emphasis on Ethical approach	SNIT32	Kumar (2020); Mani (2016)

6.5 PRIORITIZATION OF THE SOLUTIONS TO OVERCOME CC ISSUES

The prioritization of the arrangements proposed to mitigate the issues of cold chain is conducted by applying a combination of BWM & FTOPSIS method. The solutions are divided into two sets: IT solutions and Non-IT solutions. This has been done for ease of comparison and understanding of the solutions for the purpose of implementation by the decision-makers and firm owners. IT solutions are coded as SIT(number) and Non-IT solutions are coded as SNIT(number). Both FTOPSIS and BWM methods are used for prioritizing solutions as while FOTPSIS helps arrive at the distance of solutions from the ideal solution and then prioritize accordingly, Best-Worst Method helps conduct a comparison of the solutions taking both the best solution as well as the worst solution. Thus, these techniques are used for the study as they give results that are consistent and fit for the analysis for this study. Fuzzy environment used in the study lends suitability of integrated decision-support system (Prakash, 2016).

6.5.1 BEST-WORST METHOD

To decide the usefulness of solutions, researchers collected comparison data required for the Best-Worst method from thirty experts who were stakeholders in the cold chain being manufacturer/processor, retailer, farmer and IT specialist. Then based on their inputs, weights were determined by applying the BWM method. Thereafter, the global weights for each solution were estimated. Since the Non-IT solutions are 20 in number, as per the requirements of BWM method the solutions were grouped into four clusters named as: Organizational, Environmental, Infrastructural and Miscellaneous considering that each cluster has more than two sub-criteria. Organisational criteria are eight; Environmental has three; Infrastructure has four; and Miscellaneous has five sub-criteria.

The consistency ratio for all the solutions (main and sub-criteria) are close to zero falling in the range 0.06-0.09, which depicts high reliability of the resultant data. It is evident from the analysis that SIT1 ‘Automation of data collection storage, retrieval, shipment, analysis & compliance’ is the most preferred solutions (weight = 0.2344). Amongst non-IT solutions the ones under Organizational sub-criteria are the most preferred (weight = 0.4545) consisting of sub-solutions: partnership and alliances, collaborative forecasting, training for stakeholders, training for manpower, application of best practices, approaching farmers, emphasis on exports and emphasis on ethical approach.

Identifying the best solution preference over all solutions

An average was taken of the expert inputs on the best criterion’s preference over all other criteria, using 1 to 9 measurement scale. Table 6.3 depicts the preference of the best solution i.e. SIT1 ‘Automation of Data collection, storage, retrieval, shipment, analysis & compliance’ the most preferred IT solution to the other IT solutions while Table 6.4 depicts the preference of the Organizational category of Non-IT solutions over the other categories.

Table 6.3: Best solution preference over other solutions (IT solutions)

Best to others	SIT1	SIT2	SIT3	SIT4	SIT5	SIT6	SIT7	SIT8	SIT9
SIT1	1	5	1	2	4	4	6	3	7

Table 6.4: Best solution preference over other solutions (Main Categories of Non-IT solutions)

Best to Others	Organizational	Environmental	Infrastructural	Miscellaneous
Organizational	1	4	2	3

Identifying the remaining solutions’ preference over the worst solution

An average was taken of the expert inputs on the penchant of all solutions over the least important solution, using 1 to 9 measurement scale. In this step the remaining solutions are rated according to their preference over the worst solution. So, Table 6.5 depicts the preference of all other IT solutions over SIT9 ‘Online and simulated training using technology’, the least preferred solution and Table 6.6 showcases the preference of all other categories of Non-IT solutions over the Environmental category, the least preferred category of Non-IT solutions.

Table 6.5: Preference of all solutions over the Worst solution (IT solutions)

Others to the Worst	**SIT9**
SIT1	7
SIT2	5
SIT3	6
SIT4	7
SIT5	4
SIT6	7
SIT7	3
SIT8	6
SIT9	1

Table 6.6: Preference of all solutions over the Worst solution (Main categories of Non-IT solutions)

Others to the Worst	**Environmental**
Organizational	4
Environmental	1
Infrastructural	4
Miscellaneous	3

Finding the Optimal Weights of Solutions

In this step, the optimal weights of the criteria are calculated, by solving the BWM optimization model using the BWM Solver in Excel (Rezaei, 2016) as shown in table 6.7 and Fig 6.3 for the IT solutions. It also indicates the average consistency ratio (Ksi*) which should be a value between 0 and 1As reflected in the table, the value is 0.07 and thus the comparisons are profoundly steady and dependable.

Table 6.7: Results of BWM: criteria weights (IT solutions)

Criteria	**Weights**
SIT1	0.2344
SIT2	0.0625
SIT3	0.2121
SIT4	0.1563
SIT5	0.0781
SIT6	0.0781
SIT7	0.0521
SIT8	0.1042
SIT9	0.0223
Ksi*	**0.0781**

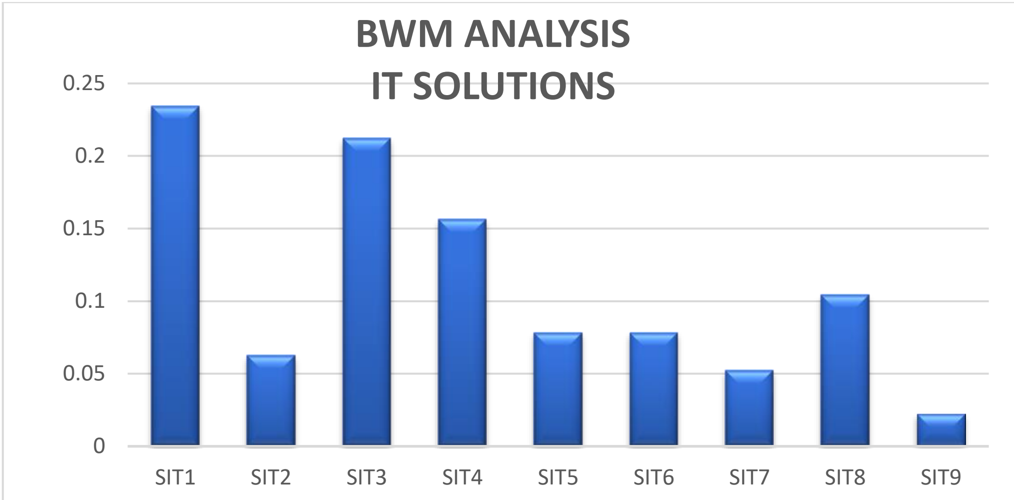


Fig 6.3. Relative importance of IT solutions (BWM analysis)

The optimal weights of the four categories: Organizational, Environmental, Infrastructural and Miscellaneous along with their sub-criteria is exhibited through Table 6.8 and Fig 6.4. The global weight of each sub-criteria is also determined by calculating the product of sub-criteria's local weight and that of its parent criteria. The result is found to exhibit consistency and reliability (Ksi* $= 0.0909$).

Table 6.8: Results of BWM: criteria weights (Main categories of Non-IT solutions)

Criteria	Criteria Weights	Sub-criteria	Local weights of sub-criteria	Global weight of sub-criteria
Organizational	0.4545	SNIT17	0.2406	0.1299
		SNIT18	0.2661	0.1406
		SNIT19	0.1093	0.0577
		SNIT20	0.0656	0.0346
		SNIT25	0.1640	0.0866
		SNIT29	0.0469	0.0248
		SNIT31	0.0820	0.0433
		SNIT32	0.0255	0.0134
Environmental	0.0909	SNIT14	0.6875	0.0519
		SNIT16	0.1875	0.0141
		SNIT27	0.125	0.0094
Infrastructural	0.2727	SNIT13	0.3803	0.0860
		SNIT23	0.0563	0.0127
		SNIT26	0.2394	0.0542
		SNIT28	0.3239	0.0733

Miscellaneous	0.1818	SNIT15	0.2459	0.0417
		SNIT21	0.1639	0.0278
		SNIT22	0.0738	0.0125
		SNIT24	0.3934	0.0668
		SNIT30	0.1230	0.0209
Ksi*	0.0909			

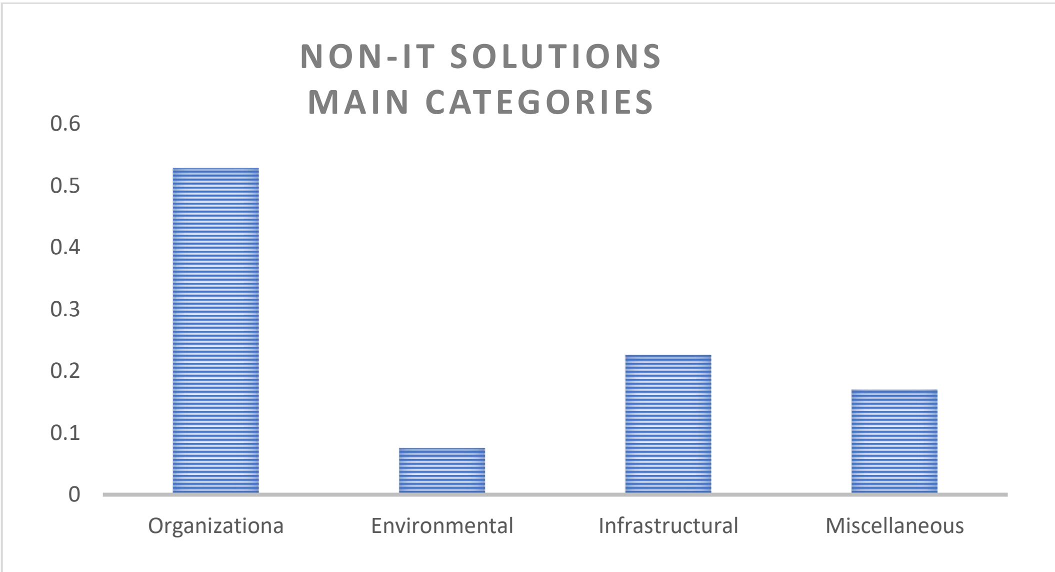


Fig 6.4. Relative importance of main categories of Non-IT solutions (BWM analysis)

6.5.2 Fuzzy TOPSIS Method

The assessment scale of relative influence used for constructing the fuzzy matrix is presented in Chapter 3 (Rezaei, 2016). Table 6.9 presents the score matrix for IT solutions while Table 6.13 presents the score matrix for Non-IT solutions. The fuzzy scores determined for the IT and Non-IT solutions are exhibited in Tables 6.10, 6.14 respectively. The weighted decision matrix after application of normalized fuzzy logic is depicted in Table 6.11 for IT solutions and 6.15 for Non-IT solutions. Thereafter, Ideal solution is determined using fuzzy positive and negative vectors and ascertaining the distance of every arrangement from both the positive and negative vectors to show up at the closeness coefficient value. It is on the basis of this value then the ranking is determined and IT solutions presented in Table 6.12 while Non-IT solutions displayed by Table 6.16.

Table 6.9 Score matrix for the IT solutions

	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
SIT1	VH	VH	VH	AV	VH	H	VH
SIT2	VH	VH	VH	L	H	L	VH
SIT3	VH	VH	VH	AV	VH	AV	VH
SIT4	VH	VH	VH	AV	VH	L	VH
SIT5	VH	VH	AV	L	VH	AV	H
SIT6	AV	VH	H	AV	H	H	AV
SIT7	VH	AV	VH	L	VH	H	VH
SIT8	H	AV	H	L	H	AV	VH
SIT9	H	VH	AV	VH	AV	AV	VL

Table 6.10 Fuzzy score matrix for the IT solutions

	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
SIT1	(7,9,9)	(7,9,9)	(7,9,9)	(3,5,7)	(7,9,9)	(5,7,9)	(7,9,9)
SIT2	(7,9,9)	(7,9,9)	(7,9,9)	(1,3,5)	(5,7,9)	(1,3,5)	(7,9,9)
SIT3	(7,9,9)	(7,9,9)	(7,9,9)	(3,5,7)	(7,9,9)	(3,5,7)	(7,9,9)
SIT4	(7,9,9)	(7,9,9)	(7,9,9)	(3,5,7)	(7,9,9)	(1,3,5)	(7,9,9)
SIT5	(7,9,9)	(7,9,9)	(3,5,7)	(1,3,5)	(7,9,9)	(3,5,7)	(5,7,9)
SIT6	(3,5,7)	(7,9,9)	(5,7,9)	(3,5,7)	(5,7,9)	(5,7,9)	(3,5,7)
SIT7	(7,9,9)	(3,5,7)	(7,9,9)	(1,3,5)	(7,9,9)	(5,7,9)	(7,9,9)
SIT8	(5,7,9)	(3,5,7)	(5,7,9)	(1,3,5)	(5,7,9)	(3,5,7)	(7,9,9)
SIT9	(5,7,9)	(7,9,9)	(3,5,7)	(7,9,9)	(3,5,7)	(3,5,7)	(1,1,3)

Table 6.11 Weighted normalized fuzzy decision matrix for IT solutions

Soln. Code/ Issue	**INFR**	**SAFQ**	**RESP**	**AWHP**	**TRAC**	**SUST**	**INTG**
SIT1	(5.39,9,9)	(5.39,9,9)	(5.39,9,9)	(1.65,3.85,6.93)	(5.39,9,9)	(2.75,5.39,9)	(3.85,7,9)
SIT2	(5.39,9,9)	(5.39,9,9)	(5.39,9,9)	(0.55,2.31,4.95)	(3.85,6.93,9)	(0.55,2.31,4.95)	(3.85,7,9)
SIT3	(5.39,9,9)	(5.39,9,9)	(5.39,9,9)	(1.65,3.85,6.93)	(5.39,9,9)	(1.65,3.85,6.93)	(3.85,7,9)
SIT4	(5.39,9,9)	(5.39,9,9)	(5.39,9,9)	(1.65,3.85,6.93)	(5.39,9,9)	(0.55,2.31,4.95)	(3.85,7,9)
SIT5	(5.39,9,9)	(5.39,9,9)	(2.31,4.95,6.93)	(0.55,2.31,4.95)	(5.39,9,9)	(1.65,3.85,6.93)	(2.75,5.39,9)
SIT6	(2.31,4.95,6.93)	(5.39,9,9)	(3.85,6.93,9)	(1.65,3.85,6.93)	(3.85,6.93,9)	(2.75,5.39,9)	(1.65,3.85,6.93)
SIT7	(5.39,9,9)	(2.31,4.95,6.93)	(5.39,9,9)	(0.55,2.31,4.95)	(5.39,9,9)	(2.75,5.39,9)	(3.85,7,9)
SIT8	(3.85,6.93,9)	(2.31,4.95,6.93)	(3.85,6.93,9)	(0.55,2.31,4.95)	(3.85,6.93,9)	(1.65,3.85,6.93)	(3.85,7,9)
SIT9	(3.85,6.93,9)	(5.39,9,9)	(2.31,4.95,6.93)	(3.85,7,9)	(2.31,4.95,6.93)	(1.65,3.85,6.93)	(0.55,0.77,2.97)

Table 6.12 Ranking for IT solutions

Soln. Code	di*	di-	Closeness coefficient	Rank
SIT1	2.5197	22.8236	0.90	1
SIT2	8.7434	16.7481	0.66	5
SIT3	4.1391	21.2045	0.84	2
SIT4	5.7202	19.6232	0.77	3
SIT5	9.9698	15.6616	0.61	6
SIT6	11.1901	14.6738	0.57	7
SIT7	7.2248	18.0708	0.71	4
SIT8	13.3128	12.5705	0.49	8
SIT9	14.8078	10.6838	0.42	9

Table 6.13 Score matrix for the Non-IT solutions

	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
SNIT13	5	9	5	5	7	9	5
SNIT14	5	3	3	7	1	9	1
SNIT15	9	9	5	9	7	9	5
SNIT16	5	5	1	5	1	9	1
SNIT17	9	9	9	7	9	9	9
SNIT18	7	7	9	3	7	9	5
SNIT19	7	9	9	7	7	7	5
SNIT20	1	9	5	9	5	9	3
SNIT21	3	7	7	3	5	9	3
SNIT22	1	7	5	3	3	5	1
SNIT23	5	5	7	5	5	5	7
SNIT24	9	9	9	9	7	9	5
SNIT25	9	9	9	9	9	9	9
SNIT26	7	9	7	5	5	9	7
SNIT27	3	1	1	5	1	9	1
SNIT28	7	9	5	7	5	7	3
SNIT29	5	7	5	1	3	7	3
SNIT30	3	7	1	3	1	7	1
SNIT31	5	5	3	5	5	7	3
SNIT32	3	7	3	9	5	7	1

Table 6.14 Fuzzy score matrix for the Non-IT solutions

	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
SNIT13	(3,5,7)	(7,9,9)	(3,5,7)	(3,5,7)	(5,7,9)	(7,9,9)	(3,5,7)
SNIT14	(3,5,7)	(1,3,5)	(1,3,5)	(5,7,9)	(1,1,3)	(7,9,9)	(1,1,3)
SNIT15	(7,9,9)	(7,9,9)	(3,5,7)	(7,9,9)	(5,7,9)	(7,9,9)	(3,5,7)
SNIT16	(3,5,7)	(3,5,7)	(1,1,3)	(3,5,7)	(1,1,3)	(7,9,9)	(1,1,3)
SNIT17	(7,9,9)	(7,9,9)	(7,9,9)	(5,7,9)	(7,9,9)	(7,9,9)	(7,9,9)
SNIT18	(5,7,9)	(5,7,9)	(7,9,9)	(1,3,5)	(5,7,9)	(7,9,9)	(3,5,7)
SNIT19	(5,7,9)	(7,9,9)	(7,9,9)	(5,7,9)	(5,7,9)	(5,7,9)	(3,5,7)
SNIT20	(1,1,3)	(7,9,9)	(3,5,7)	(7,9,9)	(3,5,7)	(7,9,9)	(1,3,5)
SNIT21	(1,3,5)	(5,7,9)	(5,7,9)	(1,3,5)	(3,5,7)	(7,9,9)	(1,3,5)
SNIT22	(1,1,3)	(5,7,9)	(3,5,7)	(1,3,5)	(1,3,5)	(3,5,7)	(1,1,3)
SNIT23	(3,5,7)	(3,5,7)	(5,7,9)	(3,5,7)	(3,5,7)	(3,5,7)	(5,7,9)

SNIT24	(7,9,9)	(7,9,9)	(7,9,9)	(7,9,9)	(5,7,9)	(7,9,9)	(3,5,7)
SNIT25	(7,9,9)	(7,9,9)	(7,9,9)	(7,9,9)	(7,9,9)	(7,9,9)	(7,9,9)
SNIT26	(5,7,9)	(7,9,9)	(5,7,9)	(3,5,7)	(3,5,7)	(7,9,9)	(5,7,9)
SNIT27	(1,3,5)	(1,1,3)	(1,1,3)	(3,5,7)	(1,1,3)	(7,9,9)	(1,1,3)
SNIT28	(5,7,9)	(7,9,9)	(3,5,7)	(5,7,9)	(3,5,7)	(5,7,9)	(1,3,5)
SNIT29	(3,5,7)	(5,7,9)	(3,5,7)	(1,1,3)	(1,3,5)	(7,9,9)	(1,3,5)
SNIT30	(1,3,5)	(7,9,9)	(1,1,3)	(1,3,5)	(1,1,3)	(5,7,9)	(1,1,3)
SNIT31	(3,5,7)	(3,5,7)	(1,3,5)	(3,5,7)	(3,5,7)	(5,7,9)	(1,3,5)
SNIT32	(1,3,5)	(7,9,9)	(1,3,5)	(7,9,9)	(3,5,7)	(5,7,9)	(1,1,3)

Table 6.15 Weighted normalized fuzzy decision matrix for Non-IT solutions

S. Code / Issue	**INFR**	**SAFQ**	**RESP**	**AWHP**	**TRAC**	**SUST**	**INTG**
SNIT13	(2.31,4.95,6.93)	(5.39,9,9)	(2.31,4.95,6.93)	(1.65,3.85,6.93)	(3.85,6.93,9)	(3.85,7,9)	(1.65,3.85,6.93)
SNIT14	(2.31,4.95,6.93)	(.77,2.97,4.95)	(.77,2.97,4.95)	(2.75,5.39,9)	(.77,.99,2.97)	(3.85,7,9)	(.55,.77,2.97)
SNIT15	(5.39,9,9)	(5.39,9,9)	(2.31,4.95,6.93)	(3.85,7,9)	(3.85,6.93,9)	(3.85,7,9)	(1.65,3.85,6.93)
SNIT16	(2.31,4.95,6.93)	(2.31,4.95,6.93)	(.77,.99,2.97)	(1.65,3.85,6.93)	(.77,.99,2.97)	(3.85,7,9)	(.55,.77,2.97)
SNIT17	(5.39,9,9)	(5.39,9,9)	(5.39,9,9)	(2.75,5.39,9)	(5.39,9,9)	(3.85,7,9)	(3.85,7,9)
SNIT18	(3.85,6.93,9)	(3.85,6.93,9)	(5.39,9,9)	(0.55,2.31,4.95)	(3.85,6.93,9)	(3.85,7,9)	(1.65,3.85,6.93)
SNIT19	(3.85,6.93,9)	(5.39,9,9)	(5.39,9,9)	(2.75,5.39,9)	(3.85,6.93,9)	(2.75,5.39,9)	(1.65,3.85,6.93)
SNIT20	(.77,.99,2.97)	(5.39,9,9)	(2.31,4.95,6.93)	(3.85,7,9)	(2.31,4.95,6.93)	(3.85,7,9)	(.55,2.31,4.95)
SNIT21	(.77,2.97,4.95)	(3.85,6.93,9)	(3.85,6.93,9)	(0.55,2.31,4.95)	(2.31,4.95,6.93)	(3.85,7,9)	(.55,2.31,4.95)
SNIT22	(.77,.99,2.97)	(3.85,6.93,9)	(2.31,4.95,6.93)	(0.55,2.31,4.95)	(.77,2.97,4.95)	(1.65,3.85,6.93)	(.55,.77,2.97)
SNIT23	(2.31,4.95,6.93)	(2.31,4.95,6.93)	(3.85,6.93,9)	(1.65,3.85,6.93)	(2.31,4.95,6.93)	(1.65,3.85,6.93)	(2.75,5.39,9)
SNIT24	(5.39,9,9)	(5.39,9,9)	(5.39,9,9)	(3.85,7,9)	(3.85,6.93,9)	(3.85,7,9)	(1.65,3.85,6.93)
SNIT25	(5.39,9,9)	(5.39,9,9)	(5.39,9,9)	(3.85,7,9)	(5.39,9,9)	(3.85,7,9)	(3.85,7,9)
SNIT26	(3.85,6.93,9)	(5.39,9,9)	(3.85,6.93,9)	(1.65,3.85,6.93)	(2.31,4.95,6.93)	(3.85,7,9)	(2.75,5.39,9)
SNIT27	(.77,2.97,4.95)	(.77,2.97,4.95)	(.77,2.97,4.95)	(1.65,3.85,6.93)	(.77,.99,2.97)	(3.85,7,9)	(.55,.77,2.97)
SNIT28	(3.85,6.93,9)	(5.39,9,9)	(2.31,4.95,6.93)	(2.75,5.39,9)	(2.31,4.95,6.93)	(2.75,5.39,9)	(.55,2.31,4.95)
SNIT29	(2.31,4.95,6.93)	(3.85,6.93,9)	(2.31,4.95,6.93)	(.55,.77,2.97)	(.77,2.97,4.95)	(3.85,7,9)	(.55,2.31,4.95)
SNIT30	(.77,2.97,4.95)	(5.39,9,9)	(.77,.99,2.97)	(0.55,2.31,4.95)	(.77,.99,2.97)	(2.75,5.39,9)	(.55,.77,2.97)
SNIT31	(2.31,4.95,6.93)	(2.31,4.95,6.93)	(.77,2.97,4.95)	(1.65,3.85,6.93)	(2.31,4.95,6.93)	(2.75,5.39,9)	(.55,2.31,4.95)
SNIT32	(.77,2.97,4.95)	(5.39,9,9)	(.77,2.97,4.95)	(3.85,7,9)	(2.31,4.95,6.93)	(2.75,5.39,9)	(.55,.77,2.97)

Table 6.16 Ranking for Non-IT solutions

Solution Code	**di***	**di-**	**Closeness coefficient**	**Rank**
SNIT13	12.8719	25.3274	0.6630	8
SNIT14	25.9672	12.0558	0.3171	16
SNIT15	7.1807	30.7385	0.8106	4
SNIT16	26.9658	10.6834	0.2838	17
SNIT17	1.1258	36.5326	0.9701	2
SNIT18	11.0418	27.4299	0.7130	7
SNIT19	7.7504	30.8950	0.7994	5
SNIT20	16.7697	21.0009	0.5560	10
SNIT21	19.2274	19.3090	0.5011	12
SNIT22	27.9339	10.1407	0.2663	18
SNIT23	17.1691	21.2833	0.5535	11
SNIT24	4.0093	33.7587	0.8938	3

SNIT25	0.0000	37.3227	1.0000	1
SNIT26	9.7961	28.7752	0.7460	6
SNIT27	29.1599	8.7183	0.2302	20
SNIT28	14.1373	24.5107	0.6342	9
SNIT29	22.2120	16.0138	0.4189	15
SNIT30	28.2524	9.6544	0.2547	19
SNIT31	22.1833	16.2012	0.4221	14
SNIT32	19.5937	18.5323	0.4861	13

6.6 SENSITIVITY ANALYSIS OF THE PRIORITIZED SOLUTIONS

Utilization of Sensitivity Analysis is finished to look at the consistency and trustworthiness of the applied structure. By making changes to the weight of a specific criteria, variation can be seen in the final ranking of the alternatives (Vishwakarma, 2019; Yadav, Garg & Luthra, 2021). To attain this, nine iterations have been conducted as depicted in Table 6.17 and 6.18. The value of the solution possessing maximum weight is substituted while the other solutions' weight remains the same. Thereafter ranks are considered for all the solutions. The sensitivity analysis result is graphically represented in Fig 6.17 for IT solutions and Fig 6.18 for Non-IT solutions. The final results of the sensitivity analysis indicate that SIT1 (IT solution) has maximum value in the nine iterations while in non-IT solutions SNIT25 has the maximum value. Most of the rank values remain the same except for changes in the SIT8 and SIT9 in the 8th run and SIT2,SIT5, SIT8,SIT9 in the 9th run for IT solutions and SNIT20,SNIT23 in the 8th and 9th run. It thus suggests that the approach used is reliable.

Sensitivity Analysis of IT solutions

The highly prioritized solution weightage was changed from 0.1509 (SIT1) to 0.1509*0.9, 0.1509*0.8…….0.1509*0.1 (refer Table 6.17 and Fig 6.5). The final results of the sensitivity analysis thereby indicate that SIT1 has highest rank in the nine iterations, followed by SIT3, SIT4 and ranked last is SIT9.

Table 6.17 Results of Sensitivity Analysis (IT Solutions)

	0.1000	Normalized (0.1509)	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
SIT1	1	1	1	1	1	1	1	1	1	1
SIT2	5	5	5	5	5	5	5	5	5	6
SIT3	2	2	2	2	2	2	2	2	2	2
SIT4	3	3	3	3	3	3	3	3	3	3
SIT5	6	6	6	6	6	6	6	6	6	5
SIT6	7	7	7	7	7	7	7	7	7	7
SIT7	4	4	4	4	4	4	4	4	4	4
SIT8	8	8	8	8	8	8	8	8	9	8
SIT9	9	9	9	9	9	9	9	9	8	9

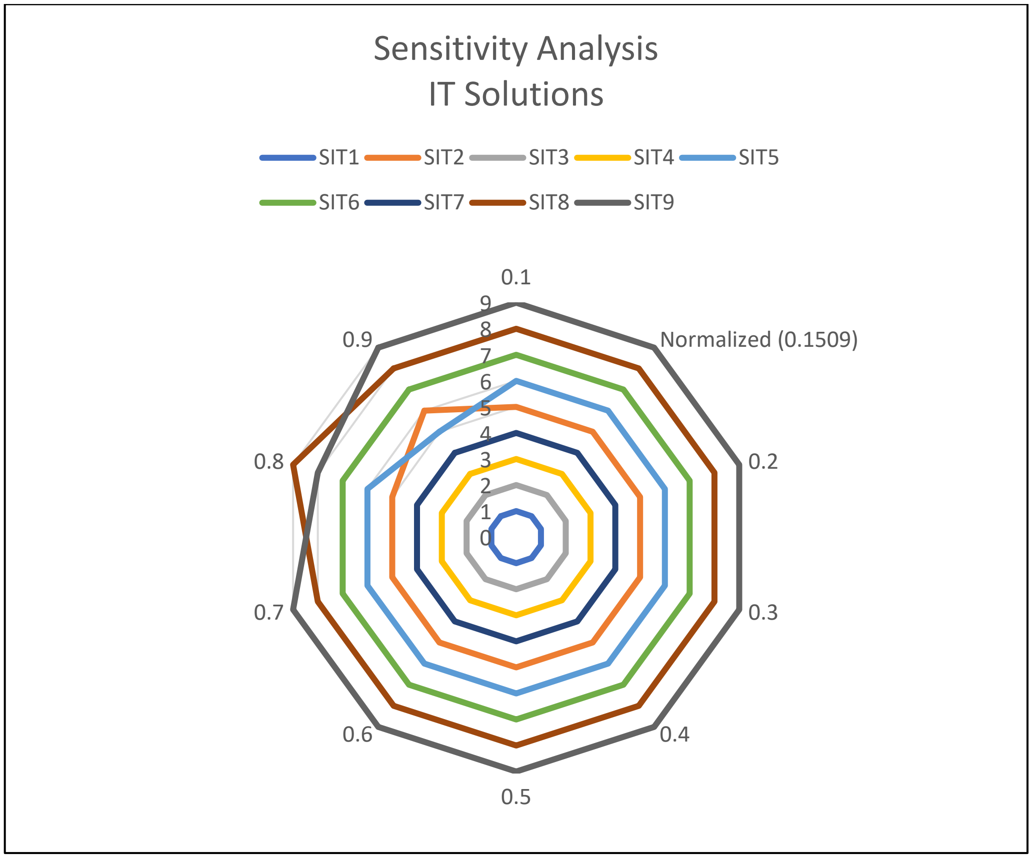


Fig 6.5 Results of Sensitivity Analysis (IT Solutions)

Sensitivity analysis of Non-IT solutions

The highly prioritized solution weightage was changed from 0.0868 (SNIT25) to 0.0868*0.9, 0.0868*0.8…….0.0868*0.1 (refer Table 6.18 and Fig 6.6). The final results of the sensitivity analysis thereby indicate that SNIT25 has highest rank in the nine iterations, followed by SNIT17, SNIT24 and ranked last is SNIT27.

Table 6.18 Results of Sensitivity Analysis (Non-IT Solutions)

	0.1000	Normalized (0.0868)	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
SNIT13	8	8	8	8	8	8	8	8	8	8
SNIT14	16	16	16	16	16	16	16	16	16	16
SNIT15	4	4	4	4	4	4	4	4	4	4
SNIT16	17	17	17	17	17	17	17	17	17	17
SNIT17	2	2	2	2	2	2	2	2	2	2
SNIT18	7	7	7	7	7	7	7	7	7	7
SNIT19	5	5	5	5	5	5	5	5	5	5
SNIT20	10	10	10	10	10	10	10	10	11	11
SNIT21	12	12	12	12	12	12	12	12	12	12
SNIT22	18	18	18	18	18	18	18	18	18	18
SNIT23	11	11	11	11	11	11	11	11	10	10
SNIT24	3	3	3	3	3	3	3	3	3	3
SNIT25	1	1	1	1	1	1	1	1	1	1
SNIT26	6	6	6	6	6	6	6	6	6	6
SNIT27	20	20	20	20	20	20	20	20	20	20
SNIT28	9	9	9	9	9	9	9	9	9	9
SNIT29	15	15	15	15	15	15	15	15	15	15
SNIT30	19	19	19	19	19	19	19	19	19	19
SNIT31	14	14	14	14	14	14	14	14	14	14
SNIT32	13	13	13	13	13	13	13	13	13	13

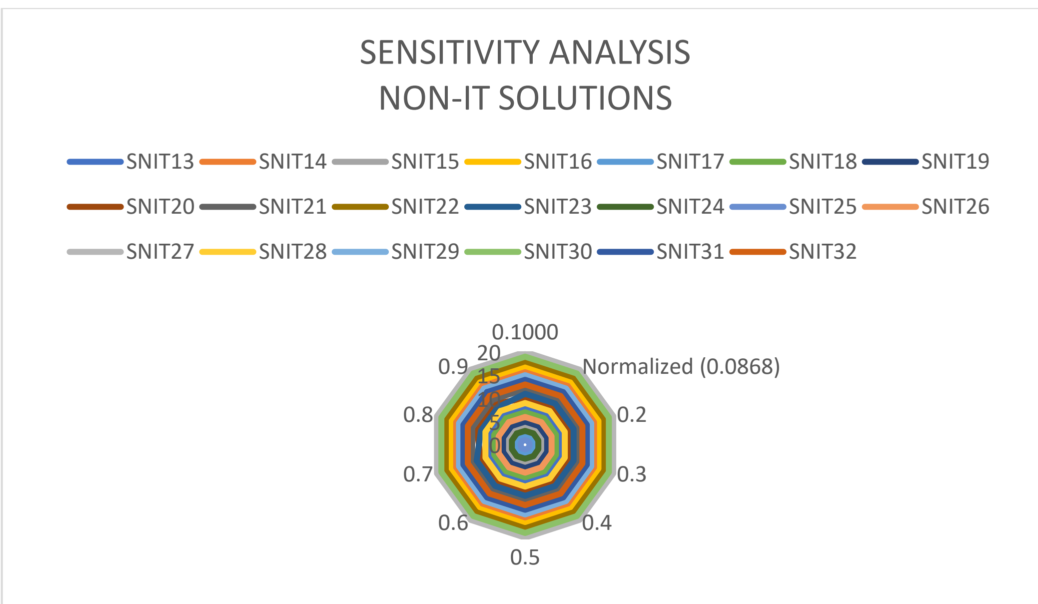


Fig 6.6 Results of Sensitivity Analysis (Non-IT Solutions)

6.7 DISCUSSION ON SUGGESTED SOLUTIONS TO OVERCOME ISSUES

The strategies and solutions suggested and prioritized need to be implemented at all the levels of a cold chain and by all the cold chain partners including farmers, manufacturers/processors, distributors, retailers and logistics. This will help enhance the performance of the cold chain, take the cold chain to a level which can help not only reduce losses and wastage in frozen food products but will also be able to exploit the premium position in food production that the nation holds globally. With the intention of overcoming the issues and reducing their negative influence on the cold chain performance, nine IT solutions and twenty non-IT solutions are advocated in the research. Though implementation of these solutions is not an easy task however, the decision-makers can implement the solutions based on the priority level. Therefore, for the ease and convenience of decision-makers and policy makers, the solutions have been categorized into two categories: IT solutions and Non-IT solutions and both the categories have been separately prioritized. The prioritization has been done using two methods: Best-Worst which compares the solutions as for the Best and Worst solutions and the FTOPSIS method which prioritizes based on the closeness coefficient value. Thus, BWM method indicates that SIT1 i.e. 'Automation of Data collection, storage, retrieval, shipment, analysis & compliance' is the most preferred IT solution while 'Online and simulated training using technology' is the least preferred. Similarly, under non-IT solution category, the sub-category 'Organizational' solutions are the most preferred and the 'Environmental' are the least preferred. Applying FTOPSIS, 'Application of best practices prevalent' is the most preferred non-IT solution while 'Proper waste processing required' is the least preferred solution. Ranking of the IT solutions is in the sequence SIT1>SIT3>SIT4>SIT7>SIT2>SIT5>SIT6>SIT8>SIT9 and ranking of the non-IT solutions is in the sequence SNIT25>SNIT17>SNIT24>SNIT15>SNIT19>SNIT26>SNIT18>SNIT13>SNIT28>SNIT20>SNIT23>SNIT21>SNIT32>SNIT31>SNIT29>SNIT14>SNIT16>SNIT22>SNIT30>SNIT27. The significance of implementation and execution of these solutions is imperative to achieve enhanced CC performance as well as reduce losses and wastage of food. Thus, with the help of the integrated approach, the priority list of IT and non-IT solutions is determined. Sensitivity analysis was also conducted, both for IT solutions and non-IT solutions to determine the reliability and robustness of the result thus proposed.

The players involved in the cold chain should implement these solutions and strategies based on their prioritization for overcoming the issues identified above. The importance of the strategy SIT1-SIT9 can be understood by the role that information technology plays in enhancing the infrastructural facilities, safety and quality, traceability and responsiveness. In fact, the issue of 'lack of integration' can be subjugated exclusively with the assistance of innovative technology. Even the attributes of products like remaining shelf life can be easily intimated by implementing solution SIT6.

The importance of non-IT solutions like SNIT24 'more initiatives required by government' and SNIT 15 'accreditations and certifications' can help resolve issues of sustainability, traceability, safety and quality as well as awareness and handling practices. SNIT13 'Specialised cold storage services' and SNIT 28 'cold storage maintenance and power backup' along with SNIT26 'Distribution infrastructure' can be very effective in resolving infrastructural issues not only at the processor or logistics end but even at the distributor and final retail end also especially for the small-size retailers. SNIT17 'partnerships and alliances' and SNIT18 'collaborative forecasting, etc' can be very effective in promoting integration amongst the cold chain players for sharing knowledge and resources. SNIT19, SNIT20, SNIT22, SNIT30 can contribute significantly in raising the level of awareness and handling practices. Specific solutions are also suggested for overcoming the issues as given below:

Lack of Infrastructure To overcome infrastructural related issues, implementation of technological devices and solutions like 'Wireless real-time monitoring', 'Use of temperature monitoring devices', 'Temperature-controlled logistics software solutions' and other non-IT solutions like 'More initiatives by the government', 'Specialised cold storages', 'Improvement in distribution infrastructure', etc can be very effective.

Lack of Awareness & handling practices IT solutions like 'Online and simulated training using technology' and non-IT solutions like 'Extensive training' both for the stakeholders and the working manpower, 'Awareness and training to farmers' will assume a significant part in overcoming the issue of awareness and handling practices. A high amount of losses in food products is the result of improper handling, unsatisfactory training for manpower in the cold chain and of course shortage of appropriate facilities (Ndraha, 2018) therefore as recommended by Sainathan (2018), training the personnel will help improve the cold chain performance.

Lack of Safety & Quality In order to tackle this issue and its sub-criteria, IT solutions like 'Product intelligence & exception alerts using technology and software', 'Online and simulated training' and non-IT solutions like 'Accreditations and certifications', 'Extensive training' can contribute effectively. In fact, implementation of most of the solutions will contribute in a certain manner directly or indirectly.

Lack of Responsiveness implementing solutions like 'Creation of platform for integrated procurement, processing, warehouse management, logistics, sales and distribution system', 'Use of Web applications and adoption of e-business model', 'Partnerships and alliances',' Collaborative forecasting, sustainability goals and joint learning strategies', 'more customer awareness' can efficiently and successfully tackle the issue of responsiveness.

Lack of Traceability The solutions which can help overcome this issue to a major extent are 'Automation of Data collection, storage, retrieval, shipment, analysis &

compliance’, ‘Traceability software system using technologies like IoT, Blockchain, etc’, ‘Partnerships and alliances’ along with ‘Emphasis on ethical approach’.

Lack of Sustainability To enhance sustainability of the chain solutions like ‘Use of energy reduction equipment like solar panels, solar energy management system, LED lighting, dock doors and racking’, ‘Product intelligence & exception alerts using technology and software’, ‘Use of bio-degradable material for packaging, etc’, ‘Proper waste processing’ along with ‘Accreditations and Certifications’ will be very effective.

Lack of Integration The solutions which can help effectively tackle this issue are: ‘Creation of platform for integrated procurement, processing, warehouse management, logistics, sales and distribution system using communications infrastructure like intranets, extranets, etc’, ‘Partnerships and alliances to be built for sharing of knowledge and resources’, ‘Collaborative forecasting, sustainability goals and joint learning strategies’ and many other solutions also can contribute significantly.

Overcoming or resolving the issues identified in the study, the performance of the cold chain of frozen food products can be enhanced. Fig 6.8 exhibits the fact that information technology plays a significant role in overcoming various issues and their sub-categories. Performance of a cold chain can be improved by considering these primary indicators to produce better results by reducing wastage and losses, while also delivering products that are safe and of quality to the customer. All this will ultimately lead to increased adoption of frozen food products by the consumer and profitability for the cold chain partners.

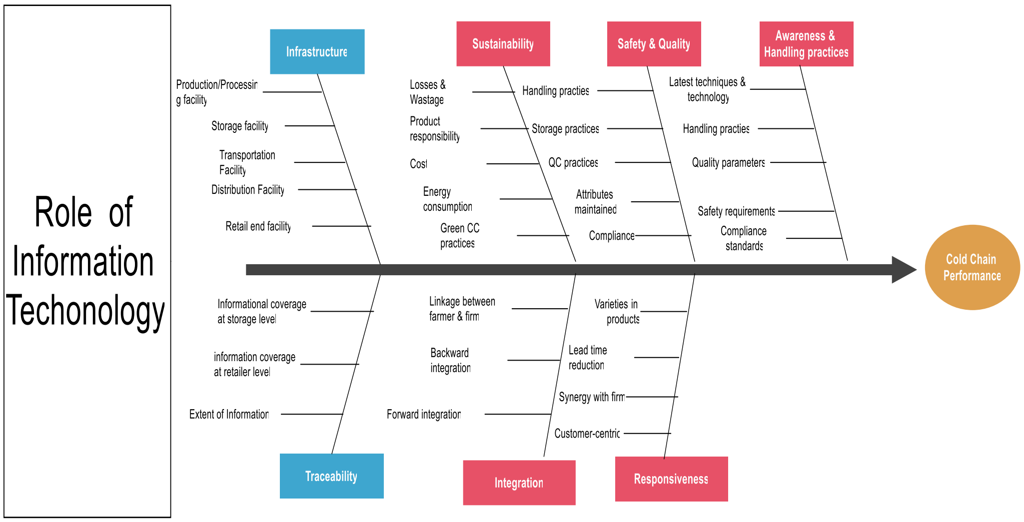


Figure 6.7 Role of information technology in improving cold chain performance of frozen food products

6.8 CHAPTER SUMMARY

Strategic solutions and the significance of technological innovation in conquering issues in the cold chain of frozen food products are discussed in current chapter. The suggestive solutions have been identified and prioritisation conducted using Best-Worst method and FTOPSIS. For analysing the consistency and reliability of the ranking outcomes obtained for the IT solutions as well as Non-IT solutions, sensitivity analysis was considered. The next chapter presents conclusion for the complete study as well as offers the way for future exploration.

CHAPTER 7

RECOMMENDATION, CONCLUSION AND FUTURE RESEARCH

Overview

This part presents an exhaustive summary of the exploration directed in this proposal. The primary outcomes and inferences have been presented in detail. The chapter also exhibits the contributions of the study to the literature along with suggestive solutions deliberated from the findings of this study. Arguments regarding impediments of the review and the future scope are additionally highlighted.

7.1 INTRODUCTION

The general aim of this exploration was to attain insights on the issues prevailing in the CC of FFP, their impact on performance of cold chain, the prioritisation of the issues and the sub-issues, prioritisation of the solutions including both IT and Non-IT solutions and suggesting solutions for identified issues. By the application of Structural Equation Modelling, an MADM method, the formulated hypotheses were tested and a final model is developed that exhibits the relation between the issues and the CC performance. The focus was on the CC players operating in the Uttarakhand region of India.

The cold chain today has turned into a basic piece of the food business today without which it is not possible to meet the supply and demand both nationally and globally. However, the presence of various issues in the country have not only affected the performance of the cold chain but also have led to huge losses and wastage in the agricultural produce and its derived products. This truly is a cause of concern for the various stakeholders involved in the cold chain as it is acting as an impediment in the growth and economic benefits that could have been otherwise attained.

Owing to the dearth of pertinent literature and expert knowledge in the state, there were many challenges faced in understanding the current status and nature of the cold chain of frozen food products. India being a developing country and Uttarakhand being a state which is also in a developing stage as well as the cold chain itself being in a nascent stage, there are not many studies done on the CC of FF items in context with Uttarakhand in India. Based on the little literature that is available and the interviews conducted, it could be deliberated that the cold chains are suffering from various issues present that are seriously affecting its performance. Hence, the existing literature and meetings with the cold chain stakeholders contributed in the recognition of a set of classifications and sub-classifications of issues which were analysed using Structural equation modelling technique. Simply identification and analysis of issues is not sufficient, and so suggestive solutions and use of information technology to overcome the issues and enhance the cold chain performance has been presented in chapter six.

It was learnt from literature that even though India ranks second in F&V, only 60% of the agricultural produce is used with maximum wastage in fruits and vegetables, contribution to world food exports is negligible. Identifying the need to improve the CC sector, this research has been conducted as an attempt to find solution for the same.

7.2 RESEARCH OBJECTIVES AND RESEARCH HYPOTHESES

7.2.1 Research Objectives

Key questions for the cold chain of frozen food products were designed on the basis of gap analysis conducted based on review of literature and practitioners in this field. These were regarding the ongoing status of the chain, the issues affecting the performance of the CC and resolution of these issues by implementation of suggested solutions. These were covered by the following research objectives:

1. To understand the CSC of FFP with special reference to the state of Uttarakhand in India and to identify the issues existing in the cold chain of the frozen food products.
2. To analyse identified issues in the cold chain of frozen food products w.r.t their influence on cold chain performance
3. To develop a model and suggest solutions to overcome issues finally leading to enhanced performance of cold chain.

7.2.2 Research Hypotheses

In this research study, model has been developed for understanding the influence of the issues identified in the study on the performance of the cold chain for frozen food products. In addition to this, the following hypotheses have been formulated and tested:

H1: Resolving the issue of Infrastructure at various levels has significant influence on enhancing the performance of the cold supply chain.

H2: Resolving the issue of Traceability at various levels has significant influence on enhancing the performance of the cold supply chain.

H3: Resolving the issue of Sustainability at various levels has significant influence on enhancing the performance of the cold supply chain.

H4: Resolving the issue of Integration at various levels has significant influence on enhancing the performance of the cold supply chain.

H5: Resolving the issue of Safety & Quality at various levels has significant influence on enhancing the performance of the cold supply chain.

H6: Resolving the issue of Awareness & Handling Practices at various levels has significant influence on enhancing the performance of the cold supply chain.

H7: Resolving the issue of Responsiveness at various levels has significant influence on enhancing the performance of the cold supply chain.

7.3 DATA BASE AND RESEARCH METHODOLOGY

7.3.1 Sample Size and Sampling technique

Determining the sample size was quite tricky. As a general rule, there should be least five-fold the number of perceptions as the quantity of independent factors to be analyzed.

As prior to conducting factor analysis, there were 63 independent variables, hence sample size was estimated to be 5*63=315. Also, since SEM is the main technique employed for hypotheses testing and model development, 315 was considered as a good sample size as it met the requirements of SEM technique.

The level of confidence was decided to be 95% and hence level of significance was 0.05 (i.e. 5% chances of error occurrence).

The sampling technique was chosen to be purposive sampling to ensure correctness of response as responses were to be collected only from individuals having sufficient knowledge and experience of working in the cold chain sector.

7.3.2 Research Process

It is significant for an effective research to carry out activities that are properly sequenced. The current research therefore considers the following steps:

1. **Problem Definition**: Information was collected from various primary and secondary sources to arrive at the research problem. Basis the gaps in literature and the discussions with CC stakeholders, it became apparent that Cold chain is at an

early stage in the country. However, there is huge scope for growth as well as improvement in this sector. Agri-production is good but then there is also huge wastage and losses. Hence, it was decided to focus upon the CC for frozen food products.

2. **Literature Survey**: Knowledge related to various theories and concepts was gained by studying the previous research including research papers, articles, newsletters, government annual reports, and market research reports. An in-depth review of these was carried out for a deeper and effective understanding of the challenges and issues present in the sector under study.

3. **Questionnaire**: A questionnaire was designed and redesigned in view of the contributions from research studies and meeting with academicians and the CC players. 5-point Likert scale was utilized for gathering reactions from various players involved in the cold chain. Pilot study was also conducted after which questionnaire was further improvised. Later, a full survey was conducted for the purpose of the study.

4. **Organizations and Respondents Selected**: For the purpose of conducting research, the unit of analysis consisted of the various players in the cold chain operating in different regions of the Uttarakhand state of India. The respondents were selected based on the list referred on the government websites and through a general search on internet. In most of the cases, a telephone call was made or mail was sent to gain prior permission and on their willingness, personal visit was made to obtain better insights on the research problem. Most of the respondents in the firms visited were the owners or the senior store managers. Responses from the IT companies and the quality bodies were collected primarily by mail only.

5. **Data Analysis**: The technique of factor analysis using Maximum likelihood estimation with Varimax rotation was used for classification of factors affecting performance of the cold chain. Structural model was developed for the purpose of testing the hypotheses by application of the SEM method. The method was also used for the development of the final model. SEM was used as it can deal with

latent constructs measured by indicators and also perform multiple regression analysis. The technique of DEMATEL, AHP and Fuzzy AHP was applied to obtain a complete picture of the criticality of the issues w.r.t. CC performance. Thereafter, Fuzzy TOPSIS and BWM methods were applied for the prioritisation of the solutions in terms of their preference / usefulness to help overcome the issues.

6. **Non-response Bias**: The common method biasness test was conducted by applying Harman's biasness test through SPSS to check if there is any biasness in the responses. As per the results, no biasness existed in the responses.

7. **Scale development and Testing**: While conducting the research, unidimensionality, reliability and validity were given adequate consideration. Unidimensionality refers to the scale measuring a single trait and can be assessed with the help of scree plots and Eigen values (>1.0) and also by the factor loadings of the items. Reliability measures the consistency between the measures of a variable. It can be tested for internal consistency through composite reliability and cronbach alpha and composite reliability. Validity refers to the extent to which the measures accurately represent the construct. Validity can be tested for discriminant and convergent validity. After testing all measures, the desired requirements of unidimensionality, reliability and validity were met in the current study.

7.4 FINDINGS OF THE STUDY

The present status of the CC in Uttarakhand, India was examined based on the primary and secondary source of data collection.

7.4.1 Findings from the Cold chain players

Following are the findings of the study based on primary source of data being visits, observation and discussion with the CC stakeholders in relation to the present state of cold chain of frozen food products in Uttarakhand, India:

General:

- Supply of Frozen food actually increased during COVID times
- Nutrients are preserved for frozen for a period of 12-20 months provided the temperature and other desired conditions are maintained.
- There are no cold storage service providers, owned by government or private firms in UK. Each CC partner have their own cold storages. Hence there are no cold storages provided on lease like in certain other states of India, some being UP, Gujarat, Maharashtra, etc.
- The use of Information technology is minimum, only to the extent of using it for billing purpose or stock management.
- Integration is conspicuous by its absence.
- With regard to the ranking in terms of importance and effect on cold chain performance, most of the respondents gave a ranking of 4 (More Effect) or 5 (Most Effect) to all the parameters - Infrastructure, traceability, sustainability, integration, safety and quality, awareness & handling practices and responsiveness. Thus, it is indicated that according to all the cold chain players irrespective of their position in the cold chain, all the above issues are extremely important for enhanced performance and reduction of wastage and losses.

Frozen food manufacturers/ processors:

- In Uttarakhand, maximum frozen food manufacturers/processors are located in the Rudrapur-Udham Singh Nagar belt.
- Generally, manpower sourcing is through a Contractor and the training of the manpower is given by the Contractor only who takes care of their training too.
- Most of the frozen food manufacturers/processors operating in Uttarakhand deal with Frozen peas (90%) owing to the huge demand from other states of the country. Other vegetables used as frozen are mix vegetables, carrots,

cauliflower, beans, and sweet corn, bitter gourd, bottle gourd, lady finger, etc. A few are using automated machines for processing of the vegetables.

- Most of the frozen food manufacturers/processors used manual, thermometry devices for monitoring and controlling of temperature for their cold storages. Only one or two reported using electronic data loggers and time temperature indicators. For packaging purposes, most of the firms were following packaging norms and using standardized material for packaging their products.
- In most of the facilities, cold chain facility was less than 10,000 sq. ft. The electricity consumption is anywhere between Rs. 80,000 to 15 lakhs or per month depending upon the capacity of the plant. Solar panel is used by very few firms.
- Considering Covid-19 having struck in 2019, even then nearly all the respondents reported anywhere between 10 -20% increase in supply of frozen food products along with 10% increase in annual turnover.
- Most of the complaints are related to handling practices.
- Temperature monitoring was generally through thermometry devices, in very few cases electronic data loggers were used and checking of temperature was manual. No software was used for the purpose or for traceability purpose.
- Required some government initiatives or training so that the waste produced can be used for bio-gas or alternate energy.

Distributors/private agents:

- At the local mandi, very few wholesalers have cold storage and there is no power backup for the cold storage. According to them, in case of no light the product stays fine till one day provided the door to cold storage is not opened. There is also no service provided for the cold storages by the companies to check if the cold storage is functioning properly.

- According to the wholesalers in the local mandis, wastage in fresh fruits and vegetable is around 2-4% daily (monthly wastage is around 10-15%) while for frozen food it is minimum. Electricity consumption cost is around 10000/- per month with frozen foods while without frozen it is around 2000/- per month. Around 0.5% wastage is because of mishandling, damaged or expiry date over.

Farmers:

- Generally, time taken to transport crop from the place of harvesting, village to the mandi is less than 2 hours. The charge for transportation is packet-wise, for eg. Rs. 20/packet.
- No access to cold storages or reefers.
- Farmers are not educated and are not aware of the benefits of using cold storage. Though when discussed with them, they agreed that it will help reduce wastage considerably.
- Farmers do not have knowledge and awareness regarding better techniques of farming or putting it to better use. Though machines like tillers, harrows are used by some of the farmers
- The calculation of profitability is based on the land cost especially when farmers lease land as per crop requirement and the produce of the crop on that piece of land. For ex, say cost of 1 bigha is Rs 20000, considering Rs. 2000 per quintal of crop, 1 bigha may help produce 3 quintals. So, for one bigha of land used for crop produce, farmer will get Rs. 60000/-. And after deducting inputs costs of material, equipment, labour, etc. will be the profitability earned (the example given is just for illustration).
- Though a few farmers indicated usage of latest machines and equipment for farming however, usage of information technology was not indicated anywhere. Better machines are required for ploughing, etc. as it is ploughing

is time-consuming. Finance is a hurdle in the acquisition of such machines and equipment.

- Crop wastage many a times is as much as 70%.
- Companies can approach the farmers directly and offer the price similar to the one offered by the mandis.

Logistics:

- Use of reefers for transportation of cold chain products is minimum. Generally, reefers used for transportation of milk, etc. or pharmaceutical products. Apart from that, there are hardly any reefers used. Most of the logistics firms did not own reefers. Food products are often transported along with pharmaceutical products.
- Freight cost, fuel cost and manpower cost of reefers is high as compared to normal vehicles. Like as per the inputs by a logistic company, freight cost from Dehradun to Delhi for a 20ft size normal vehicle is around 15000 while for a reefer it is 22000. While transportation cost with a normal vehicle is 11000 while with a refrigerated vehicle it is around 18000. The air-conditioning in a refrigerated vehicle remains on even if the vehicle is off. Remote Monitoring of location of the vehicle is possible with the use of GPS systems fitted in the vehicles. The wages of drivers for normal vehicles is 500/day while for a refrigerated vehicle it is 1000/day.
- In many cases, products are transported in thermocol bags using normal vehicles.

Retailers:

- Frozen food is around 10-40% of the total food items stocked depending upon the type of retailer.
- Purchase is through distributors only. No purchases are made directly from farmers.

- There is no technology used for monitoring temperatures. After the goods are stocked in the refrigerators, manual temperature monitoring is done.
- Reference to traceability is negligible.
- Electricity consumption cost for the entire retail outlet with refrigerator storage being around 15-20% of the total size could be in the range of 20000 - 50000 per month (depending upon the size of retail outlet) as the refrigerators run 24 hours.
- Transportation of frozen food is generally done through a normal vehicle with the products packed in thermocol bags.
- Lack of distributors for frozen food products for supplying to retail in spite of presence of demand.
- Short briefing to the manpower is generally given at time of induction.

7.4.2 Findings from the Analysis of Data

Given below are findings in light of the analysis of information directed in this review:

- The issue 'Lack of Infrastructure', 'Lack of Safety & Quality', 'Lack of Awareness & handling practices' and 'Lack of Responsiveness' were found to have critical impact on CC performance. The issues 'Lack of Traceability', 'Lack of Sustainability' and 'Lack of Integration' were not found to significantly influence the performance primarily owing to the fact that the presence of these was either negligible or not to the extent it should have been. Like for Sustainability, though most of the firms were ISO 22000 or FSSAI or HALAL certified but even then major efforts towards enhancing sustainability were not being exercised. There were hardly any green cold chain practices being implemented, wastage was huge, energy consumption was huge and so on. Traceability was only exercised with respect to the information displayed on the packaging of the product but apart from that there forward/backward traceability was manual with no records maintained. Use of technology was negligible hence integration was conspicuous by its absence.

- Ranking of the main issues (as per FAHP) was determined to be in the following sequence: **INFR>AWHP>SAFQ>RESP>TRAC>SUST>INTG i.e.** based on the importance with respect to performance, Infrastructure was ranked first, Awareness & handling practices was at 2nd position, Safety & Quality was ranked third, Responsiveness was ranked at 4th position, Traceability was at 5th position, Sustainability at second last position and Integration was ranked least important.
- The ranking of the sub-categories of each issue was as follows (in descending order):
  - Infrastructure sub-issues : Storage facilities (SFAC) > Processing facilities (PFAC) > Distribution facilities (DFAC) > Transportation facilities (TFAC) > Retail facilities (RFAC) . Retail facilities ranked least also is an indication of the fact that presently retail has a better infrastructure as compared to other facilities.
  - Awareness & Handling practices sub-issues**:** Knowledge of Quality parameters (KNQP) > Knowledge of Handling practices (KNHP) > Knowledge of Safety requirements (KNSR) > Awareness of latest techniques & technology (AITT) > Knowledge of Compliance standards (KNCS)
  - Safety & Quality, sub-issues: Attributes information (ATTR) > Handling practices (HNDP) > Quality control parameters (QUCP) > Compliances followed (CMPL) > Storage practices (STRP)
  - Responsiveness sub-issues: Lead time reduction (LTRD) > Variety in products (VART) > Customer-centric (CUST) > Synergy with firms in cold chain (SYNG).

    - Traceability sub-issues: Extent of product information (PINF) > Information at Retail level (INRT) > Information at Storage level (INST)
    - Sustainability sub-issues: Cost (COST) > Energy consumption (ENRG) > Losses and wastage (LOSS) > Product responsibility (PDRP) > Green cold chain practices (GRNC)
    - Integration sub-issues: Backward integration (BACK) > Forward traceability (FORW) > Linkage between farmer and firm (FARM)
- The influence of an issue over other issues is as follows (based on DEMATEL analysis):
    - Infrastructure has influence upon all other issues
    - Traceability has influence upon responsiveness and safety & quality
    - Sustainability has influence upon safety & quality
    - Integration has influence upon safety & quality, traceability, responsiveness and awareness & handling practices
    - Safety & quality has influence upon responsiveness
    - Awareness & handling practices has influence upon safety & quality, responsiveness, traceability and sustainability
    - Responsiveness influences none
- There were 9 IT solutions and 20 Non-IT solutions identified to overcome issues in the CC of FFPs. They were ranked as follows (based on FTOPSIS):
    - IT Solutions were ranked as : ‘Automation of Data collection, storage, retrieval, shipment, analysis & compliance’ (SIT1) was ranked at first position; ‘Use of electronic data loggers/time temperature indicators, digital electronic control, onboard telematics technology and other such devices for monitoring of temperature’ (SIT3) was ranked at 2nd position; ‘Temperature-controlled logistics software solutions along with integrated refrigerated container management system with back-office’ (SIT4) was at 3rd position followed by ‘Creation of platform for integrated

procurement, processing, warehouse management, logistics, sales and distribution system using communications infrastructure like intranets, extranets, etc' (SIT7) at the fourth position; 'Wireless real-time & remote monitoring and reporting using technologies like RFID, IOT, etc. and sensors' (SIT2) was ranked at the 5th position; 'Traceability software system using technologies like IoT, Blockchain, etc' (SIT5) was at 6th position; 'Product intelligence & exception alerts using technology and software to inform about shelf life, expiry date, freezing indicator, etc' (SIT6) was found to be at 7th position; followed by 'Use of Web applications and adoption of e-business model' (SIT8); and finally ranked as least preferred / useful was 'Online and simulated training using technology' (SIT9).

- Non-IT solutions were ranked as: 'Application of best practices prevalent in frozen food industry' (SNIT25) was ranked at first position; 'Partnerships and alliances to be built for sharing of knowledge and resources' (SNIT17) is at second position; 'More initiatives required by Govt. for providing tools and machines to farmers, finance at lower level, mandi level, crop disease tackling, cold storages and reefers for transportation of fruits and vegetables to destination' (SNIT24) is at 3rd position; 'Accreditations & certifications for processing, storage, logistics and retail along with strict following of regulations required for frozen food handling' (SNIT15) is ranked at 4th position followed by 'Extensive training for all CC stakeholders' (SNIT19) at the fifth position; 'Distribution infrastructure to be improved along with increase in number of distributors required' (SNIT26) is ranked at sixth position; 'Collaborative forecasting, sustainability goals and joint learning strategies' (SNIT18) ranked at seventh position; 'Specialized cold storage services provided by govt.(public) or industry(private) on lease' (SNIT13) is at eighth position; 'Cold storage - maintenance and power backup to be improved, provided by industry or govt.' (SNIT28) is at ninth position; 'Extensive training for all manpower working in CC facilities at different links of a CC' (SNIT20) is ranked at 10th position; 'Launch of hotline' (SNIT23) is at 11th position; 'Contract farming to be encouraged through govt initiatives' (SNIT21) is at 12th position followed by 'Emphasis on Ethical approach' (SNIT32) at the 13th position; 'More emphasis to be paid on exports for reducing wastage as production is more than demand' (SNIT31) is ranked at the 14th position; 'Companies approach farmers directly and give prices equivalent to that of mandi' (SNIT29) is ranked at 15th position; followed by 'Use of energy reduction equipment like solar panels, solar energy management system, LED lighting, dock doors and racking' (SNIT14) is ranked at 16th position; 'Use of bio-degradable material for packaging, etc' (SNIT16) is at 17th position; 'More customer awareness needed for packaging(prefer bio-degradable than fancy ones) and handling of frozen food' (SNIT22) is ranked at 18th position; followed by 'Awareness and training provided to farmers regarding use of cold storages, reefers and new ways of farming, etc' (SNIT30) at the 19th position; and the least ranked as preferred/useful is 'Proper waste processing required that can be used for producing alternate energy. Govt. initiative required for that'.

7.5 RECOMMENDATION

7.5.1 Recommendation for the CC players

As this study has focussed on different stakeholders in the cold chain of frozen food products, the recommendation for each stakeholder is as follows:

Farmer

- Organic methods of farming and minimized/nil usage of chemicals to be used extensively for enhanced sustainability and safety and quality of produce
- More initiatives from the government to provide machines like tillers, ploughs, harrows, tractors, etc; seeds of good quality, medicines for the crop protection; and other such equipment at subsidised prices.
- Reefers should be made available to them for transportation of the fruits and vegetables. This will reduce the immediate post-harvest wastage and losses. Also, facility of cold storages should be provided to the farmers by the government or privately-owned cold storages.
- More financial support provided at lower level i.e. at mandi level and farmer level
- Initiatives by the government / firms are needed to create awareness and educate the farmer with respect to seed quality and crop maintenance, latest techniques of farming, better practices of farming, technology use, etc. A center may be opened for the purpose.
- Awareness needed for the benefits and requirements of Contract farming

Frozen Food manufacturer/processor

- Exert efforts for reducing energy consumption and enhance sustainability in their operations too.
- Buying from farmers directly will help maintain the produce quality, however, price offered to the farmers need to be similar to that offered by

the mandis. this would encourage production as per demand and less wastage.

- Integration needs to be implemented with the assistance of innovative technology to make the whole cold chain an integrated cold chain
- Extensive use of IT by implementing the solutions suggested is required.
- Being the big players amongst other cold chain stakeholders, they need to take initiative in making the cold chain sector an organised one as well as for increasing demand for the frozen products.
- Can provide their cold storages on lease to farmers, and other players.

Logistics Service provider

- Use of better technology to track changes in temperature and other environmental conditions while the product is in movement or transit
- More emphasis needs to be given on ethical approach to ensure safety of the product transported
- Proper training needs to be provided to drivers and all the manpower involved in loading and unloading of the products.

Distributors

- Cold storage at the distributors end must be equipped with power backup and appropriate maintenance for enhanced safety and quality of product.
- Government support required at mandi level for providing finance as well as machines/equipment to reduce wastage of food.
- Separate cold storage required for storage of the produce not sold rather than using simple refrigerators. Here again there need be at least one cold storage provided at the mandi level which can be utilized by the various wholesalers.

- Compliances need to be followed strictly and put on the packaging also as presently it is a practice to put the compliance followed on the bill only.

Retailer

- Just like the frozen food firm, retailers too need to exert special efforts to make the cold chain integrated.
- Use of reefers need to be encouraged for transportation of products from the supplier to the outlet.
- Regular maintenance of cold storage required and stocking of products to be as per the compatibility of temperature and other requirements.
- Exert efforts to increase customer demand for frozen food products
- Need to encourage integration, traceability and sustainability by the application of relevant practices and implementation of technology.

7.5.2 Recommendation based on Analysis of Data

General

- Need for more infrastructural investment by the government or private players. For instance, in terms of building cold storages in the state which can be leased out to other parties. Presently, cold storages are owned by the firms using it but there is a huge need for more cold storage service providers who can offer their cold storages on lease to the other players of the cold chain right from farmers to retailers.
- Though, green supply chain practices are talked about a lot but in reality these are not being followed. There need to be more government regulations or motivational schemes for encouraging firms to inculcate sustainability in their products, operations and practices.

- Awareness amongst consumers is presently limited to: list of ingredients, best before date, and chemical content but as they become more and more aware they would demand exhaustive product information. So, firms need to be pro-active and have systems implemented to store and further transmit complete information about the product.
- Also, the firms are presently using technology only for billing purposes or for stock-taking. They need to integrate upstream and downstream for agility, flexibility, responsiveness of the chain. Integration will bring in many more benefits in the coming future.

Suggestion of Solutions to overcome/mitigate issues

As the study emphasises upon resolving issues with the help of solutions suggested in the study, hence below specific solutions have been suggested for the various identified issues. Though most of these solutions will work towards resolving more than one issues directly or indirectly, however for clarity in understanding and speedy resolution of prevailing issues, following solutions can be implemented:

- To overcome or mitigate the negative influence of ‘Lack of Infrastructure’ on CC performance, ‘Use of electronic data loggers/time temperature indicators, digital electronic control, onboard telematics technology and other such devices for monitoring of temperature’; ‘Temperature-controlled logistics software solutions along with integrated refrigerated container management system with back-office’; ‘Wireless real-time & remote monitoring and reporting using technologies like RFID, IOT, etc. and sensors’; ‘More initiatives required by Govt. for providing tools and machines to farmers, finance at lower level, mandi level, crop disease tackling, cold storages and reefers for transportation of fruits and vegetables to destination’; Distribution infrastructure to be improved along with increase in number of distributors required’

‘Specialized cold storage services provided by govt.(public) or industry(private) on lease’ can be implemented based on the priority ranking given in the study.

- To overcome or resolve the issue of ‘Lack of Awareness & handling practices’ the following solutions can be implemented: ‘Online and simulated training using technology’; ‘Application of best practices prevalent in frozen food industry’; ‘Extensive training for all CC stakeholders’; ‘Extensive training for all manpower working in CC facilities at different links of a CC’; ‘More customer awareness needed for packaging(prefer bio-degradable than fancy ones) and handling of frozen food’; and ‘Awareness and training provided to farmers regarding use of cold storages, reefers and new ways of farming, etc’.
- For improving the issue of ‘Lack of Safety & Quality’, following solutions can be useful: ‘Product intelligence & exception alerts using technology and software to inform about shelf life, expiry date, freezing indicator, etc’; ‘Application of best practices prevalent in frozen food industry’; ‘Extensive training for all CC stakeholders’; ‘Accreditations & certifications for processing, storage, logistics and retail along with strict following of regulations required for frozen food handling’; ‘Extensive training for all CC stakeholders’; ‘Extensive training for all manpower working in CC facilities at different links of a CC’; ‘Emphasis on Ethical approach’; and ‘More customer awareness needed for packaging(prefer bio-degradable than fancy ones) and handling of frozen food’.
- ‘Lack of Responsiveness’ can directly affect consumer loyalty and satisfaction and hence the solutions that can improve it are: ‘Automation of Data collection, storage, retrieval, shipment, analysis & compliance’; ‘Creation of platform for integrated procurement, processing, warehouse management, logistics, sales

and distribution system using communications infrastructure like intranets, extranets, etc'; 'Traceability software system using technologies like IoT, Blockchain, etc '; 'Use of Web applications and adoption of e-business model'; 'Partnerships and alliances to be built for sharing of knowledge and resources'; 'Collaborative forecasting, sustainability goals and joint learning strategies'; 'Launch of hotline '; 'More customer awareness needed for packaging(prefer bio-degradable than fancy ones) and handling of frozen food'.

- The solutions that need to be applied for improved traceability are: 'Automation of Data collection, storage, retrieval, shipment, analysis & compliance'; 'Creation of platform for integrated procurement, processing, warehouse management, logistics, sales and distribution system using communications infrastructure like intranets, extranets, etc'; 'Traceability software system using technologies like IoT, Blockchain, etc'; 'Wireless real-time & remote monitoring and reporting using technologies like RFID, IOT, etc. and sensors'; 'Partnerships and alliances to be built for sharing of knowledge and resources'; and 'Emphasis on Ethical approach'.
- For enhanced Sustainability, following solutions can be implemented: 'Automation of Data collection, storage, retrieval, shipment, analysis & compliance '; 'Traceability software system using technologies like IoT, Blockchain, etc'; 'Product intelligence & exception alerts using technology and software to inform about shelf life, expiry date, freezing indicator, etc'; 'Accreditations & certifications for processing, storage, logistics and retail along with strict following of regulations required for frozen food handling'; 'Collaborative forecasting, sustainability goals and joint learning strategies'; 'Contract farming to be encouraged through govt initiatives '; 'More emphasis to be paid on exports for reducing

wastage as production is more than demand‘; ‘Use of energy reduction equipment like solar panels, solar energy management system, LED lighting, dock doors and racking’; ‘Use of bio-degradable material for packaging, etc’; and ‘Proper waste processing required that can be used for producing alternate energy. Govt. initiative required for that’.

- For an integrated cold chain, following solutions need to be implemented: ‘Creation of platform for integrated procurement, processing, warehouse management, logistics, sales and distribution system using communications infrastructure like intranets, extranets, etc’; ‘Use of Web applications and adoption of e-business model’; ‘Partnerships and alliances to be built for sharing of knowledge and resources’; ‘Collaborative forecasting, sustainability goals and joint learning strategies’.

7.6 CONCLUSION

This exploration was utilized to concentrate on the issues and difficulties present in the cold chain of frozen food items in Uttarakhand. For the study, several frozen food organizations, transportation firms, growers, distributors and retailers were focused on to acquire a comprehension of the difficulties looked in the cold chain. Various cold chain stakeholders were thus identified and responses were collected from them to understand the level of issue existence in the prevalent cold chain. The research leads to suggest various solutions including use of information technology which can immensely benefit the cold chain partners as well as enhance the cold chain performance of frozen food products.

The reason for this study was to research the connection between infrastructure, traceability, sustainability, safety & quality, awareness & handling practices, integration, responsiveness and cold chain performance. The results indicated statistical significance for the constructs related to the issues of infrastructure, safety and quality, awareness and handling practices and responsiveness while it indicated that lot of efforts are still required to build traceability, sustainability and integration in the cold chain of frozen food products in the Uttarakhand region. Resolving or overcoming the issues will help improve the performance of the cold chain. Further in the study, the strategies and solutions including the use of information technology were recommended to subjugate the issues present in the cold network.

With shifting shopping patterns, changing psychologies and, shortage of time owing to hectic lifestyles with more disposable income being available are surely going to lead to higher demand for frozen food products (Goel, 2020). Hence, it becomes imperative that sincere efforts are put by firms and all the stakeholders in the influencing factors. The firm owners, managers and decision-makers need to admit the benefits of implementing the solutions to overcome the issues or reduce the influence of issues on the frozen food CC's performance.

India as a nation is an agriculture-dominant nation and considering the status it holds globally with respect to fruit and vegetable production, there is a huge scope for it to economically grow exponentially if it can take advantage of the available technology to help overcome these issues and not just enhance performance of the cold chain network but also contribute towards development in the food area for the state and country. Without an efficient and robust infrastructure, complete traceability, sustainable practices and products, integrated network, products with high safety and quality, excellent awareness and handling practices and responsiveness, the cold chain players will not be able to achieve the benefits and profitability that is actually possible unless the solutions are implemented effectively to resolve these issues. Integration, traceability and sustainability are dominant issues requiring serious consideration as there is hardly any efforts being put to ensure the mitigation of these issues. If the firms and service providers involved want to sustain for future, then resolving these issues becomes extremely important.

Considering that the cold chain sector is growing with the increase in globalised economy, changes in consumer preferences, it is a gigantic challenge for the CC partners for their ability to sustain. The presence of issues in CC prompts decreased benefits, expanded wastage and losses. Hence, there is an urgent need to eliminate or mitigate the influence of these issues on the cold chain and its performance. However, in a developing nation like India which is gripped with numerous challenges, implementation and execution of the strategies is not easy. It therefore becomes important to prioritize the solutions so that the cold chain players can decide which solution(s) to first consider for implementation.

This study offers a robust model exhibiting the issues and their relation to cold chain performance. First, the issues were identified and categorized into seven categories. Then inputs regarding the issues' linguistic grading were gathered from the experts. The indicators through which the issues could be measured were identified and there were in all 63 sub-categories which were reduced to 33 sub-categories by applying exploratory factor analysis and confirmatory factor analysis. For the dependent latent construct, cold chain performance the observed indicators were reduced from ten to three. Thereafter, SEM technique was applied to analyse the influence on the cold chain performance as well as arrive at a good-fit model. Then, the solutions using information technology and without the use of IT were suggested to overcome the issues or reduce their impact on the performance. This study prioritizes the 29 solutions using MCDM techniques for implementation which can significantly help the policy makers and decision-makers to overcome these issues. Hence, an integrated approach involving fuzzy AHP-TOPSIS and BWM is employed for ranking of the issues and the solutions.

The infrastructural issue was found to be the most critical issue. Finally, sensitivity analysis is conducted to study the variations in the decision with changes in the weights of the issues and considers the biasness or uncertainty in experts' inputs.

Prioritizing solutions will help cold chain players and decision-makers to overcome or reduce the impact of issues. Thus, to subjugate the influence of these issues, various solutions have been advocated in this study by reviewing the literature, and referring research reports and articles. All this is adequate to prove the viability and validity of this research. Hence, it is recommended that in order to make cold chain of frozen food products efficient and effective, strategists and decision-makers must implement the solutions recommended in this study. The cold chain players themselves have agreed that the solutions are effective to counter the issues. But more government intervention and support is required. Else, in such a competitive scenario, it will become increasingly difficult for the cold chain players to sustain in future.

7.7 MANAGERIAL AND STRATEGIC IMPLICATIONS

The results of the present study hold prominent practical implications, especially for partners and stakeholders in the frozen food cold chain sector. The experts in the sector have agreed upon the presence of the issues and their influence on the cold chain performance. Such findings thereupon give an opportunity to the cold chain partners to understand the present status of these issues. The segregation of issues into categories and sub-categories will help all the cold chain stakeholders to comprehend the nature of the issues and the way these issues influence the business. The results derived can help the cold chain players to distinguish these issues so as to focus and overcome them. The various stakeholders and players in the cold network add to dynamics connected with their firm, the supply chain or the entire supply network or maybe even the cold chain sector depending upon the type of stakeholder like government, service provider, retailer, etc. This study is meant for all the stakeholders of the cold chain sector and hence will benefit all in effective decision-making. Hence, it will be highly correct to mention that the study has significant practical implications for the different cold chain players.

Seven issues and 30 sub-categories of issues prevalent in the CSC have been identified which were approved by the experts along with the usefulness and preference of solutions for resolving the issues. The results from the study will also help in comprehending the criticality of the issues and thereby prioritize the issues to focus upon. The issues have been assessed using SEM, structural equation modelling method, which is the most appropriate technique to analyse the collected data. The analysis concludes that Infrastructure (INFR), Safety & Quality (SAFQ), Awareness & handling practices (AWHP) and Responsiveness (RESP) as significant in terms of their influence on the cold chain performance. Traceability (TRACE), Sustainability (SUST) and Integration (INTG) have been shown to be not prominently affecting however, this is primarily because efforts are not being put towards these issues hence the result. As already discussed, FAHP method is used for the assessment of the issues where the issue ‘Infrastructure’ is the most prominent followed by ‘Awareness and handling practices. Issue ‘Safety and Quality’ stands at the third position, ‘Responsiveness’ at the fourth position, followed by ‘Traceability’ at the fifth position. At last, ‘Sustainability’ issue is at the sixth position and ‘Integration’ gets the seventh position in the ranking of issues. Post analysis of issues, the study acknowledges and prioritizes 29 strategies and solutions, with nine IT solutions and twenty non-IT solutions so that the cold chain players could benefit by implementing them to either overcome the issues or reduce the negative impact of those issues.

The solutions are ranked by applying Fuzzy TOPSIS and BWM method. Implementing the solutions considering the prioritization done can help them achieve efficient and effective cold chain as well as sustain in the sector. As per the analysis, ‘Automation of Data collection, storage, retrieval, shipment, analysis & compliance’ was the highest prioritized followed by ‘Use of temperature monitoring devices’ and the solution ‘Online and simulated training using technology’ was ranked the lowest amongst IT solutions. As far as Non-IT solutions are concerned, ‘Application of best practices’ is concluded to be ranked highest amongst non-IT solutions; and ‘Emphasis on ethical approach’ was ranked the lowest. These rankings give the roadmap for further development of the cold chain. Thus, the issues can be checked and monitored by the management personnel in the organisation by application of the solutions appropriately. However, it is not necessary that all the issues and the solutions have to be implemented at one go. It depends upon the decision-maker to prioritize them and implement those solutions which will lead to better results in cold chain performance or help sustain profitability.

Developing nations like India must exert serious and sincere efforts to reduce food losses in its perishable product category. The study is of benefit to the food sector for reduction of losses and wastage. Firms in the frozen food sector need ensure that the food quality is able to meet the consumer's requirements of freshness and safety (Charlebois, 2021). Managers and professionals involved in the cold chain may not be able to focus on all issues. But they need to emphasise on crucial issues as per their firm or cold chain and then later extend it to other issues. The study will therefore help decision-makers to take decisions by gaining in-depth understanding and clarity on significant issues and sub-categories of these issues. The study thus encourages practitioners of the developing economies to take initiatives and implement efficient and effective systems in the frozen food cold chain. It will help different partners in figuring out the current status of the chain and working towards enhancement. The firm owners, policymakers, decision-makers must try to apply the solutions as per the criticality of the issue present in their cold chain. The suggestive solutions given in this study will help the cold chain partners mitigate the impact of issues on the performance.

To make it easier for the players to understand which solution to apply for resolving the relevant issue, the study has recommended solutions according to the criticality of the category of issue prevalent. The study will also help the various stakeholders understand how these different issues interact with one another and how they are related to one another. Thus, this research serves as a comprehensive guide for the cold chain players to distinguish the issues and relieve them with suitable solutions. This way the huge amount of losses and wastage can be reduced as well as the huge agricultural produce of the state and nation can be utilized within the country or even exported to other nations.

Thus, it is very clear that the cold chain partner firms need to put significant efforts and investments in the areas of traceability, sustainability and integration to have prominent impact on the cold chain performance. These efforts will not only help in reduction of food losses and wastage but will help in enhancing the usage of agricultural produce and not just meet demand in the country but also increase the export to other countries.

The issues present in the cold chain are affecting the functional, monetary, social and sustainable execution of the CC, and the business as well as it is bringing about food misfortunes and wastage. The categorisation of issues will help the cold chain partners to comprehend the nature of the issues and their influence on their firm performance. The study therefore applied fuzzy AHP to prioritize the issues along with prioritization of their sub-categories. However, a plain understanding of the issues is not sufficient as it will not benefit in overcoming the issues and resolving them. But with the ranking of the solutions, segregated into IT and Non-IT solutions, by the application of both BWM and FTOPSIS methods, the firms involved in the cold chain can truly benefit.

The presence of these issues is creating hindrances to smooth operations of CC. The categorisation of issues into seven categories and then their further sub-division into sub-categories will make the comprehension of the problems and the areas of their occurrence and their influence on the entire network easy. But simply dividing them into categories and sub-categories will not help resolve the issues. Hence, it was important to prioritize these issues and their sub-criteria based on their critical impact by using Fuzzy analytic hierarchy process. This will make it easier for the decision-makers to understand the issues better and how they impact the cold chain. In addition to the prioritization of issues, the study also has discerned 29 strategies and solutions which were then ranked by the application of Fuzzy TOPSIS. Also, Best-Worst method was applied to get more clarity on how the best or worst solution interacts with the others. This will help the various players in the cold chain to comprehend the solutions and strategies that are required to be implemented or executed on priority basis to resolve the critical issues. Therefore, this study uniquely helps to identify issues and then subjugate the issues with appropriate solutions, both IT and Non-IT solutions. The robustness of the framework and reliability of the ranking results were checked by performing Sensitivity analysis. Huge food losses and wastage are being experienced by the nation affecting the economy and so with proper implementation of the solutions, the wastage and losses can be reduced considerably. Therefore, this study has implications for the manufacturers/processor, logistics, distributors, farmers, retailers and ultimately the consumer. All these partners need to work in a teamed-up way to guarantee decreased food wastage and losses and enhanced cold chain network performance. Hence, this study holds dominant implications in cold chain domain for all the cold chain stakeholders in understanding the issues, their influence on the entire network and the nation’s economy along with suggestion of solutions to resolve the issues or reduce their impact considerably and thus contribute towards the sustainable development of the business as well as the nation.

7.8 THEORETICAL IMPLICATIONS AND CONTRIBUTION OF THIS RESEARCH

An exhaustive analysis of prevailing literature and expert interviews, this study has identified seven categories and 30 sub-categories of issues that impact the CC of frozen food items. The study presents a distinctive and innovative methodological and analytical approach for assessing issues in the cold chain of frozen food and suggesting solutions to overcome the issues and mitigate their influence on the cold chain performance. After studying the existing literature, it was apprehended that no review has been led to examine the issues in the CC of frozen items in Uttarakhand. Actually, this research is first of its kind which has impressed upon the seven categories of issues which are: Infrastructure, Traceability, Sustainability, Integration, Safety & Quality, Awareness & Handling practices, and Responsiveness. The selection of the primary issues was done in view of a careful survey of writing and expert interviews. The review was an all-inclusive integrated approach as compared to certain other studies conducted. The categories and sub-categories of the issues have covered various relevant aspects. The integrated approach of SEM/DEMATEL/FAHP/FTOPSIS/BWM model-based approach has been applied first-time on these issues in Uttarakhand, India.

The recognition of the issues into appropriate categories and sub-categories arrangement, which has not been done previously, will lead to clarification of many doubts. The cold chain players will be able to either build upon more on the issues to enhance performance multi-fold or will try to reduce their impact on the performance. In fact, one of the cold chain partners, a frozen food processor also commented on the theoretical implications of this research as "*This study is unique in that it highlights all the major issues existing in the cold chain of frozen food. Also, the suggestion of solutions will certainly give insights to the stakeholders on implementing them for not only an improved cold chain but also in reduction in food losses and wastage*".

Besides, rather than simply emphasizing upon the issues, this study also suggested solutions to resolve them thus leading to completion. Overall, this study is a sincere attempt to highlight the issues in the cold chain of frozen food towards loss and wastage reduction which is a grave concern for the nation as a whole. The research contributes significantly by establishing a model to identify categories and sub-categories of issues, to analyse their influence on the cold chain performance and to suggest solutions to overcome them. Thus, it significantly adds to the prevailing literature. This study has contributed importantly also as it considers a synergistic view of the issues existing in the cold chain of frozen food sector which no earlier study has done. Therefore, by considering frozen food sector of a developing and economically growing nation like India, the present research augments to the literature.

The study comprehends the criticality of the issues and thereby prioritize the issues and their sub-categories to focus upon using using SEM/FAHP/DEMATEL methods. The study also identifies, assesses and prioritizes solutions using Fuzzy TOPSIS & BWM method to overcome the issues or mitigate the negative impact of issues. The integrated framework can be applied by stakeholders to evaluate the issues and subjugate them through implementation of relevant solutions and strategies. This framework thus applied with an objective to identify and evaluate issues in CSC of Frozen food products and thereafter identify and rank solutions to overcome them would be exclusive and has not been conducted earlier for CSC in Uttarakhand, India. Also, the study extends the application of Knowledge-based view, TBL, Stakeholder theory & Network perspective to cold chain of frozen food products.

7.9 LIMITATIONS OF THE STUDY

Finally, although the study has reached its aim and got evidences to support the research hypotheses, there were some inescapable limitations which are listed below: were remembered for this review. Thus, the example was chosen

- First, because of the COVID-19 scenario and the time limit this research was led as it were in Uttarakhand region in India hence only the firms operating in the region were considered for this research work. Thus, the sample was chosen for the frozen food industry in Uttarakhand only. The ratio of respondents including farmers, producers/processors, logistics, distributors, and retailers may not be representative of the actual population size.
- The responses from cold chain partners other than farmers were collected from the urban areas dominant with respect to cold chain presence. Responses from the farmers were collected from rural areas. Since Uttarakhand does not have the presence of many IT companies dealing with software for agro-products, therefore responses from IT companies were collected from the urban metro cities. Responses from the quality agencies were collected from the inspectors and other professionals visiting government offices in Uttarakhand.
- Since, these respondents were scattered across the region, hence own means of transport was used which was more expensive and time consuming.

- The survey was conducted in Uttarakhand, which comes under the North Hill Zone. The results would vary based on the agricultural area, urban or rural area and the cultural differences when compared to other regions in the country or other countries.
- The farmers, logistics service providers, distributors and private agents have very little knowledge of the concept of cold chain network. Especially related to issues like traceability, sustainability, etc. both awareness and knowledge was just the minimum required. Also, various sub-categories of the issues in the survey questionnaire had to be explained to them in detail. This procedure was therefore extremely time-consuming but helped in collecting accurate and appropriate responses.
- Majority of the respondents like farmers, distributors, private agents, and logistics service providers were not appropriately educated and did not understand English. Hence, the questionnaire was also framed in Hindi language to make them understand it easily thus avoiding any inaccurate understanding/responses.
- The study has only focussed upon frozen food products. There are very few literatures available with respect to this study. Therefore, more time was spent on understanding the present cold chain system and the various issues prevalent in the industry. Thus, there is need for more writings on cold chain of frozen food items.
- SEM method works best with a 200 to 300 sample size and consequently a bigger sample size was not considered. However, with another technique application a larger sample size can be taken.
- Suggestive solutions were simply recommended and techniques like FTOPSIS and BWM were applied to rank the solutions in terms of their preference/usefulness for overcoming the issues. However, an experimental study comparing the pre- and post- implementation of solutions can be conducted to understand the benefits and the extent to which a solution can help resolve the issues.

7.10 SCOPE FOR FUTURE RESEARCH

The outcomes and impediments of this exploration would be a decent beginning stage for investigating future necessities of implementing other solutions and IT in the cold chain network of frozen food sector. Further studies can use other methods and techniques for analysing and ranking the issues. Therefore, to generalize the result the research will have involved and be replicated for different other regions in the country. . Also, the study has only focussed upon frozen food products. In future, there will be a need to imitate this review to check whether its discoveries turn out as expected for different locales in the nation as well as applied to different items in the chain. Also, comparison can be carried out between cold chain system of different regions of the country or between countries. Also, various other methods like case-based reasoning, experimentation, decision tree analysis can be applied. Future research in this direction can consider other approaches like ANP, PROMETHEE, TISM, etc. The practical implementation of information technology can be tried as far as advantageous to the CC performance. National competitiveness of the agro-industry will enhance with the application of information technology. The measurement of cold chain performance index will help provide a distinct paradigm to the cold chain industry and can be considered in future research.

7.11 CHAPTER SUMMARY

This research was used to study the issues and challenges present in the cold chain of frozen food products in Uttarakhand. For the study, several frozen food organizations, planned operations specialist co-ops, farmers, wholesalers and retailers were targeting to gain an understanding of the challenges faced in the cold chain. Various cold chain stakeholders were identified and responses were collected from them to understand the level of issue existence in the predominant chain. The exploration leads to suggest various solutions including use of information technology which can immensely benefit the cold chain partners as well as enhance the cold chain performance of frozen food products. This chapter also presented how the developed model and solutions suggested can be utilized and implemented by the various chain partners in the frozen food sector. Additionally, this part likewise explained over the impediments and future extent of this concentrate in the area of cold network.

Once the issues were identified, the survey questionnaire was framed with the aim of collecting responses from the various cold chain partners and other stakeholders. The cold chain partners are farmers, producers/processors, logistics service providers, distributors and retailers. The other stakeholders were IT companies and quality agencies. The reason for including IT companies to understand the resolvability of the issues with the help of technology. The questionnaire was divided into three sections including demographic profile, status of existing cold chain and scope of presence of determinants.

The responses were collected from Uttarakhand region. Frozen food companies were randomly selected covering prominent parts of the Uttarakhand region. Farmers and distributors were also selected based on inputs from the vegetable mandis. Retailers were targeted in different regions of Uttarakhand to understand the issues till the final point of the cold chain. IT companies and 2 quality agencies were selected. The responses were collected from IT companies and quality bodies also for carrying out a wholistic investigation.

The information was gathered for the period 2011 to 2021 for various parameters to understand their growth position. Data was analysed to understand the responses and the current status of presence of issues in the cold at various levels of the framework. To examine the presence of issues, three hypotheses were formulated with respect to the identified constructs. Reliability test (Cronbach α) was performed for all constructs. Structural equation modelling along with EFA & CFA was employed for validation of constructs and for identification of relationship among constructs. Different model-fitting indices were utilized to test the integrity of-fit for the model. The results showed that cold chain performance is negatively influenced by the presence of the issues. Settling or conquering the issues will assist with working on the CC performance. The results indicated statistical significance for the constructs related to the issues of infrastructure, safety and quality, awareness and handling practices and responsiveness. While it was indicated that still lot of efforts are required to build traceability, sustainability and integration in the cold chain of frozen food products in the Uttarakhand region. Further in the study, the solutions including use of information technology were suggested in order to overcome the issues present in the cold chain.

CHAPTER VIII

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APPENDICES

Appendix A

Theme Supply Chain Management (SCM)

No.	Details	Objective of the Study	Methodology	Finding	Inference	Gap
1	Ganesan (2009)	1. Examine ways 3 late patterns - worldwide obtaining rehearses, multichannel courses to market, and relationship-based development — are changing the retail scene and prompting an assortment of execution upgrades as to mark picture, notoriety, deals and benefits, development, and relationship 2. Feature central questions for these patterns.	Based on Literature, Propositions arrived at	1. Retailer's image picture can be upgraded by offering stock delivered in a socially mindful way. 2. Nature of the item might influence shopper mentalities and buy conduct. 4. There will be more straightforward admittance to shopper by the SC accomplices when retailers' experiential and creative drives affect execution	1.Retailers should amend SC structures, methodologies, what's more, the executives practices to adjust to the changing climate	Propositions can be experimentally attempted and endorsed.
2	Chandra (2019)	To recognize the KPIs of vaccine SC, and measure their effect on immunization SC perf. improvement	1. Field visits were done and KPIs concerning four component of the fair scorecard (BSC), for	Essential Indicators maximumly influencing immunizer SC execution are: 1.Enhancement in agent work satisfaction2.Enhanceme nt in proficient antibody	1.The three execution markers ought to be given needs to further develop conveyance execution 2.Better antibody SC& Logistics	1.More Focus given on worker fulfilment and not much spotlight is given on the nature of antibody. 2.

			example monetary, client, inward interaction and learning and development have been distinguished and approved 2. Effect of inside cycle and learning and development perf. pointers on the antibody SC execution improvement assessed.	SC administrators and pioneers 3.Improvement in arranging and coordination in the SC	frameworks are vital for powerful and effective conveyance of antibodies	It tends to be applied to food items while thinking about different boundaries
3	Kumar (2017)	Means to further develop the SC perf. of sugar industry with the execution of IT applications by overseeing different recognized issues at obtainment and sugar creation level	1. The issues were distinguished based on LR and master board. 2.The field review was directed for checking the pertinence of the issues. 3.Regression was utilized to examine the information.	1. SC execution marks of sugar industry are decidedly related with the execution of IT applications. 2.Role of IT at obtainment and sugar creation level will help in further developing the SC execution of sugar industry in India.	1.IT application in the SC system of sugar industry will help in improving the surplus of the SC and bring transparency among the SC partners. 2. Help foster a favorable business environment in the sugar industry. 3.Measurement of SC perf. index provides a different worldview to the sugar business furthermore, work on the exhibition of the sugar	1.A comparative review should be possible for Frozen food industry

					enterprises in India.	
4	Kadwa (2013)	1.Sugarcane SC is portrayed as an in general extensive agri-present day framework that means to make, gather, transport and cycle sugarcane from the field to the plant. 2.Discuss factors which cause peculiarities in sugarcane SCs and the techniques executed for development6.5.	1.Development of model and its usage in organizations	1. In the sugarcane SC, properties that cause quality abnormalities were: anomaly, gathering methodologies, endless arrangements and the consume harvest to-crush delay2. Methodologies used to further develop the sugarcane framework incorporate an improvement processing season model, sugar installment frameworks, storing, a day to day rateable conveyance framework, vehicle booking and revamped gather plans	1.Sugarcane quality and stream consistency are the two properties created and checked on as wellsprings of SC irregularities. 2.These properties fundamentally decline consistency across the inventory network, as well as abatement sugar supply.	1.Inconsistencies in SC of frozen food industry can be examined and broke down
5	Lavastre (2014)	To create and approve an instrument to gauge Innovative Supply Chain Practices (ISCP) in SCM. 2.Consists of three autonomous estimation scales: ISCP sending conditions and Setting; association's development limit; and ISCP execution.	1.Exploratory and confirmatory research 2.Test and validation of research model 3.Factor analysis	.Innovation is a vital wellspring of significant worth creation and intensity 2.An association might have aptitude in advancement of cycles also,/or rehearses with minimal specialized insight in item advancement.	.The improvement of a limit with regards to hierarchical development, and the circumstances and setting of arrangement, are basic to the presentation of an ISCP.	1.The review should be possible for the retail area which is exceptionally imaginative in its relations between strategies accomplices, producers and merchants
6	Gurumurthy (2013)	1.To fill in the exploration hole by dissecting the commitments of academicians and professionals tending to	1.Based on LR, taxonomy was proposed and trends were observed	1. The vast majority of the SC issues are contemplated concerning car industry. 2. 10% papers center around SC of agri and different areas.	1.Field of SCM is advancing exceptionally quick with changes in innovation,	1. The connection point between various accomplices in a SC can

		different SC issues according to an Indian viewpoint		3. Not very many location answers for SCM issues.	economy and business standards	be examined. 2. Figure out the job of information and innovation inside SC. 3. The job of IT in business capabilities inside SCM ought to be investigated. 4. Supportability ought to be investigated in SCM
7	Dhande (2012)	1.To Study the SC of sugar industry and recognize the serious issues in SC of sugar industry	LR	1. Factors influencing supply of Sugarcane are :environment, absence of specialized information, sugarcane creation, political elements, recuperation rate 2. Serious issues in SC of sugar ventures are: Cane creation; Transportation; Warehousing; Govt approaches and different issues like fumble, absence of coordination, absence of current techno.	1. In the sugar business, SCM is evolving w.r.t. market environment. 2.GIS and GPS are utilized broadly in area, site determination, land use arranging, climate science, transportation framework.	Can be applied to frozen food industry as well
8	Wang (2010)	1. Examine limits of present SCOR examination and give a Method for mapping of gaps, issue prioritization, and business process alteration in	Action case study research	1.SCM expects a segment in influencing monetarily in how business processes are made due .2.SCM effects costs of stock holding, stock movement, and gathering processes.	1.SCM impacts monetary way of behaving by the way business processes are made due.	1. A multi-disciplinary methodology might be taken on in future review to additionally dissect the directing

		SC setting. 2.It consolidates BPR and SCM disciplines.		3.Achieving reasonability of SCM not simply relies upon process tuning, yet what's more JIT correspondence and bearing through the engaging impacts as perf. assessment and IS		impacts of the distinguished factors 2. Multi-disciplinary examination is additionally expected to test the proposed methods and dynamic bases in business settings in various ventures and areas. 3.Other boundaries and constraints to SCM execution and ways of defeating should be recognized.
9	Burch (2005)	1. To talk about how changing examples of interest for food wares and the new job grocery store own brands are playing can be viewed to be responsible for the change in power connections between the assembling and the retailing	Literature Review	1.Own brand items not just contend on the foundations of both cost and quality, yet additionally overwhelm underway of various new food varieties items described by accommodation, newness, and oddity.	1.Changes focused upon the development of store own brands and the predominance of these lines in a scope of new food items, signal a significant change in the connections between processors, retailers and buyers, 2.It is	1.Empirical analysis required to be done

		Areas			suggestive of a more extensive change in the whole SC.	
10	Fernie (2003)	1. Look at factors that effect upon costs in the basic food thing SC 2.Detail how vehicle use and energy proficiency can be managed through a development of pragmatic measures.	Survey based	There was low normal weigarzuht use of vehicles in the overview. 2. Roughly 22% of all excursions were run vacant, 3. A lot of this inactive/void time can be credited to keeping an 'overabundance' ability to meet pinnacle streams over everyday, week by week and occasional cycles. 4.In essential activities, vehicles were commonly pre-load approximately 3 hours before despatch. 5.The most normal reason for delay, was unscheduled stand by at the conveyance point.	1. Endeavours to further develop vehicle usage will be likely to clashing tensions of speedy reaction recharging and gridlock	1.Factors other than cost reserve funds can likewise be considered for proficiency of SC
11	Gaucher (2003)	1.A displaying approach in view of two correlative models has been created to recreate the preparation and activity of factory supply all through the season. 2.The first model looks at week by week and all out sugar creation for a season. 3.The second model spotlights on the recreation of strategic chains,	1.Model based reproduction. 2.Briefly audits hypothetical structures utilized in chain examination 2. Proposes a displaying way to deal with stream of material between firms.	1.The key model, in light of a worked upon image of the whole SC region, evaluates the effect of partners' specialized connection points on all out sugar creation. 2.The calculated model permits appraisal of the attainability of vital situations as far as undertaking limits and everyday administration of stick streams. 3.Combining SC and spending plan recreations gives an extensive perspective on the outcomes that can be	1.Stakeholders cooperation and SC effectiveness will profit from such a choice help approach.	1.Can be applied to frozen food industry as well

		and empowers the effects of innovative and underlying changes on day to day reap and move abilities to be evaluated.		anticipated from key changes.		
12	Gardas (2019)	.Analyse PIs utilizing an ISM approach. 2.Classify the critical PIs of GSCM in horticultural SC. 2.Identify most huge PIs.	1. The PIs of GSCM were distinguished through a writing review and assessments of field specialists. 2. The distinguished 14 PIs were demonstrated by applying an ISM approach to recognize PIs having high compelling power.	14 recognized PIs were: Green plan; Knowledge and preparing, Orgn. and env. mgmt., Green buying, ,Competitive tension, Green manufacturing, Regulatory strain, brand picture and portion of the overall industry , ., Cooperation with clients and providers for joint activity Collaborative cold stockpiles and green transportation, Economic perf , Operational perf., Env. perf, Reverse planned operations. 2. Three PIs, in particular, natural mgmt.., administrative tension and serious strain are huge PIs having high driving power. 3. Financial perf. also, Brand and portion of the overall industry pay the most un-powerful job.	1.Agro-industry produces critical natural, social and monetary effects. 2.Perf. of the current SC must be upgraded. 2.Increased proficiency of the food SC will satisfy the rising food interest and cause less harm to the climate. 3.Managers from the food business and agribusiness can answer in a superior manner to the evolving buyer's requests by expanding the supportability of cycle and items	1.Same model can be applied to other sectors too.
13	Turi (2014)	1.Point out the main difficulties and propose total pointers to evaluate the exhibition of the food SC by taking into account monetary,	1.LR 2.Ten PIs recognized were : Number of laborers arranged; Management levels with	1. The Perfect Order Percentage and Validity Period in Transport are among the main PIs for the food business. 2. A high wonderful request rate implies the SC is adaptable and figures out how to deal	1.The food industry assumes a critical part in guaranteeing sound create. of customers, feasible financial development and more	1.The competitiveness of the FSC can be studied and analysed empirically.

		social and natural turn of events.	express environment commitments; number of progress thoughts by delegates; Reverse composed factors; Reduce energy use; CO2 releases/Pallet ; Transport costs/Pallet; Perfect solicitation rate; Number of green things; Total authenticity period in transport	with all items by following both legitimate prerequisites and explicit industry norms. 3. The Total Validity Period in Transport is one more corresponding pointer which shows the organization's ability to give items on time 4. Edges acquired by conveying the item faster to the hold decreases its gamble getting died.	consideration regarding ecological issues. 2.Proposed markers can be applied to individual connections of the food SC and to the whole chain 3. The comprehension will assist organizations with fostering a more cutthroat position and fortify the FSC	
14	Brockhaus (2013)	1.Focus on fostering a superior comprehension of: "how do organizations include other individuals from their inventory network into their manageability endeavors?"	1.LR & interviews 3.Empirical analysis.	1.Lack of SC incorporation recognized. 2.To foster a more cooperative execution upheld by elaborate gatherings.	1.To foster a more cooperative execution that can be upheld by every one of the elaborate gatherings.	1.Sustainable efforts can be tested in frozen food SC as well
15	Deshmukh (2012)	.Examined various issues, challenges of Indian sugar industry investigated years. 2.Discusses inbound SC issues of Indian sugar industry and	Case Study	Focused on connection between sugarcane cultivators and mill operators at a specific mgmt.. level. 3Limit gathering to pulverizing time to get the most extreme conceivable sugar	1.Develop connection point between the sugar business and the ranchers to accomplish the above said objective	1.Can be applied to frozen food industry as well

		cultivated the design for SC illustrating.		recovery to enhance the profitability.		

Appendix B

Cold Supply Chain

No.	Details	Objective of the Study	Methodology	Finding	Inference	Gap
1	Bhatnagar (2019)	1.Determine similarity gatherings of various F&V that can be put away and shipped together in light of their prerequisites for temperature, relative moistness, smell and ethylene creation. 2. Talk about Pre-cooling to set up the ware for resulting transportation and safe stockpiling.	1. Groups shaped for putting away F&V together 2. An agglomerative various leveled bunching calculation is utilized to fabricate a group progressive system 3. Further dissected utilizing K-implies bunching 4. The outcomes got are contrasted and accessible information of collection F&V.	1. Seven similarity groups of various F&V have been distinguished for safe capacity and transportation thinking about key parts of temperature, relative mugginess, smell and ethylene creation/responsiveness.	1.Temperature, stickiness, smell and ethylene responsiveness are significant boundaries for thought for capacity and transportation of perishables. 2.Will assistance the retailer in putting away the F&V according to the groups demonstrated in this examination. 3.Will assist with decreasing food wastage. 4 Facilitate orgn.. to deal with their calculated exercises to acquire upper hand.	1.The review considers new F&V. 2.The review can be applied to frozen food and handled food sources too.
2	Bremer (2018)	1. Propose reference model for CCs that coordinates different crucial Viewpoints: **regulatory**	1.Follows object-situated displaying approach. 2.Reference model's	1.Conceptual components combined from LR are moved into static view (object model). 2.Reference model's powerful properties	1.Suggests a first draft of an item situated reference model for cold chains. 2.Focus is on the classes, which	1. Contextual analyses in various virus chains can be created. 2.Need for planning CC

		framework, infrastructure, technical equipment, information technology and operational processes.	unique properties addressing the business interaction view are framed.	addressing the business cycle view are illustrated.	have been indicated along four areas: item, administrative system and guidelines, data innovation, and framework and gear.	IS coordinating all data streams.
3	Ali (2018)	1.Bridge the examination hole by fostering a model, in light of wide observational proof, of the exchange between CC Logistic dangers, flexibility and firm execution in PPSCs.	1.Mixed strategy approach is utilized with subjective information from interviews what's more, quantitative information from a study across the SC. 2.The examination is outlined by possibility hypothesis what's more, asset based hypothesis. 3.EFA, CFA, Cronbach are utilized for dependability testing and SEM displaying	1. Four critical risks were identified: Temperature Breakdown; Substandard bundling; Natural fiasco; Deterioration of item quality because of conveyance delays 2. Six substantial and elusive assets utilized by the organizations to fabricate flexibility were recognized as multi-sourcing; business certifications, a quality management system, public–private collaboration and globalised operations, multi-skilled workforce	1.CC Logistic dangers including temperature breakdowns, unacceptable bundling, normal catastrophes and quality disintegration, adversely affect a company's execution in PPSCs.	1. Exploration could be duplicated in different nations/ventures. 2.Empirically test the directing effect of firm size on the connection among hazard and firm execution.
4	Kumar (2016)	1.Study issues that help highlight poor SC policies leading to weak links in the chain	1.Case Study based 2.qualitative analysis	1.It is significant for the organization to plan their methodologies in synchronization with the methodologies and goals of their outsider arrangement suppliers so	1.To guarantee more noteworthy proficiency and adequacy across the CC exercises, each component of the conveyance	1. Different players of CC can likewise be thought of. 2. Explicit variables prompting

				both the individuals benefit commonly.	network shapes a significant connection. 2.Third party planned operations players and the C&F specialists can assume the part of catalysers in improving and smoothening the movement pattern of CC.	conflicts and obstacles among the different chain individuals can be recognized
5	Bag (2016)	1.Identify essential boundaries, decide progressive and context-oriented connections between factors impacting green CC practices in India.	1.ISM utilized. 2.Dependence and driving force of factors are arranged utilizing MICMAC investigation. 3.Barriers of green CCM:(1) High capital expenses of sustainable ventures, (2) Outdated innovation, (3) Poor CC organization, (4) Lack of gifted labor, (5) Poor cold stockpiling Infrastructure, (6) CC disinfection with synthetic substances, (7) Lack of	1. High Capital expenses of sustainable tasks, Outdated innovation, and Lack of gifted labor have frail drive and reliance power. 2. Unfortunate CC organization, CC sanitization with synthetics, Lack of converse strategies, Lack of IS foundation, Non-recyclable bundling have feeble drive power serious areas of strength for however power. 3. Unfortunate cold stockpiling Infrastructure and absence of government support serious areas of strength for have power yet feeble reliance power.	1.CC framework and support of government are main drivers of green CC.	1. SEM can be employed for testing legitimacy of model

			opposite coordinated factors, (8) Lack of IS foundation, (9) Lack of government backing, and (10) Non-recyclable bundling.			
6	Yakum (2015)	1. Led to assess the accessibility and working of CC gear as well as information	1.Observation utilized. 2.Cross-sectional review including multistage testing.	1. Enormous quantities of the overall prosperity workplaces didn't store inoculation suitably. 2.Improper limit was for the most part a direct result of presence of food in the vaccination cooler, 3.vaccines not kept at the right compartment, deficient air course, and nonattendance of icepacks in the fridges. 4. Just 37.3% of the wellbeing specialist knew the right term where antibodies ought to be put away in the wellbeing offices.	11.Potential elements responsible to be liable for low level of data and practices consolidate lacking/ no planning, coming up short on/no oversight, nonattendance of the SOP for neutralizer limit. 2.Availability of CC is acceptable. 3.The status of CC checking didn't meet proposal rules. 4. Need to prepare staff in CC observing.	1.Empirical analysis required to be done
7	Sharma (2015)	1.Consider every one of the critical elements that have suggestions on the adequacy of CC	1.Extensive LR. 2. Inter relations are drawn in view of basic examination of each element and its suggestions	1.CC with higher probabilistic worth will have better working viability.	1. Improvement endeavours made on the generally significant variables will greatly affect by and large adequacy of the	1. Concentrate on the significance of the variable according to the product. 2.Compariso n devices like AHP and

			on cool chain.			DEA can be utilized to focus on the recorded variables.
8	Martikainen (2014)	1.Iintroduces interaction of building potential plans of action for a strategic specialist co-op working in a neighbourhood FSC.	.The strategic assistance needs of various members in territorial food supply chains are broke down	1.Need for calculated administrations, dispersion and transportation administrations was communicated by all gatherings in the nearby food production network.	1. Need to foster a scattered neighborhood established pecking order and to make new business open doors and advancements successfully, in close co-activity with the little and miniature size chain administrators,	1.Empirical validation can be done. 2. Can be applied to other industries as well.
9	Joshi (2011)	1.Develop a benchmarking structure that assesses the CC exhibition, uncovers its assets and shortcomings lastly recognizes and focuses on expected other options for constant improvement	1.A Delphi-AHP-TOPSIS based system has partitioned the entire benchmarking into three phases. 2.First stage is Delphi strategy, where distinguishing proof, combination and prioritization of key execution factors and sub-factors are finished and an original	.With the proposed Delphi-AHP-TOPSIS system administrators can undoubtedly comprehend the current qualities and shortcomings of their organizations when contrasted with market pioneers. 2.They can distinguish the great practices from the market chief and can benchmark them for working on the shortcomings. 3.Can further examine the adequacy of the potential improvement open doors according to the ongoing functional necessities and techniques of the organization	1.A organization shouldn't simply duplicate the practices learnt from the contenders, it can adjust and go past the learning and utilize inventive means to make what is the most important according to its functional technique and subsequently create serious advantage.	1.Empirical validation can be done. 2.Can be applied to other industries as well.

			steady estimation scale is created. 3.Ssecond stage is AHP based CC execution assessment of a chose organization against its rivals, to notice cold chain execution of person factors and sub-factors, as well as generally speaking execution file. 3.Third stage is TOPSIS-based appraisal of potential choices for the consistent performance			
10	Bogataj (2005)	Fathom the effects of specific irritates in a SC, in its creation/ dispersal, on the trustworthiness of transient product in such structures and moreover grasp the legitimate control which keeps the thing on the	Model-based	1.Perturbations can show up on the various phases of a cold chain.	1.Visibility and proper control is needed.	1.Can be applied to frozen food industry as well

		normal level of significant worth and sum at the last transport. 2.These investigations are particularly vital to guarantee the steadiness of CC in CCM.				
11	Boland (2016)	1.Examine the difficulties of carrying out manageability in a huge association. 2.Discuss the advancement of corporate maintainability ideas, portray various methodologies that huge associations can take in seeking after supportability drives.	LR and Case study based	1.All partner bunches assume part in manageability. 2.Supplier sets of rules were a significant methodology coordinating both first- and fourth-party systems. 3.Company's manageability program incorporates exercises searching externally in its SC and exercises searching internally to turn out to be more productive in its assembling, operations, and dissemination exercises	1.Stakeholder hypothesis gives a central connect to understanding maintainability to the extent that the viewpoints of non-the board gatherings, who have a stake in the organization, should be remembered for the executives choices.	1.Empirical analysis based. 2.Sustainability performance can be analysed for FF sector
12	Xiao (2017)	1. Foster a quality and wellbeing discernibility framework coordinated with WSN and speedy reaction (QR) code (SMS-CQ) for sea-going items	1. Examined temperature variances of amphibian items in CC coordinated factors that is carried out and assessed in a real CC. 2. Review and field stud.	1.WSN innovation empowers an ongoing temperature-detected information procurement without network framework. 2.QR code empowers CC supervisors, laborers and purchasers to dominate the wellbeing and nature of the amphibian items in CC operations. 3.Integrated framework could naturally understand the ongoing	1. WSN development engages modified Affirmation of consistent temperature getting, far-off transmission and checking	1.Could be applied to frozen food industry

				information observing, and dynamic data request.		
13	Jedermann (2014)	Bases on advances, models and applications to separate changes the thing time frame of convenience, and to plan moderate chain cycles and composed factors as needs be to reveal and forestall imperceptible or dormant misfortunes in thing quality and for state-of-the-art matching between the additional timeframe of convenience and the ordinary vehicle range	Case study based	1.Waste decrease can be accomplished by utilizing appropriate SCM frameworks and checking time span of usability	1.Waste decrease can be accomplished by utilizing legitimate SCM frameworks and observing timeframe of realistic usability	1.Can be empirically tested

Appendix C

Cold Supply Chain for Frozen Food

No.	Details	Objective of the Study	Methodology	Finding	Inference	Gap
1	Cerchione (2018)	1.Provide a survey zeroed in on FCCM to feature research holes and characterize proper exploration inquiries for future examination.	1.LR 2.Develop a conceptual framework for food CC performance.	1. FCC foundation influences esteem expansion. 2. FCC coordination influences esteem expansion.3.	1.Four areas of examination featured are: factors causing wasteful FCCP, FCC maintainability issues, key measurements for FCCP	1. Approve theory. 2. SEM approach can be applied to fortify proposed structure

				Partner interest influences value expansion. 4. Food CC infra influences accomplices performance 5. FCC integration affects partners perf. 6. Partners interest influences accomplices perf. 7. FCC infra decidedly influences FCC perf. 8. Partner interest decidedly influences FCC execution. 9. FCC joining decidedly influences FCC execution. 10. value expansion emphatically influences FCC execution. 11. Partners performance positively affects FCC performance	estimation and major FCCP improvement draws near	
2	Osorio (2017)	1.Understand job that admittance to normalized information, in-store CC practices,	1.Stratified arbitrary examining; 2.Dependent variable- size of disturbance; Independent variable - Access to information,	1. A company's admittance to satisfactory normalized	1.Last connection in the SC, the retailer is significant.	1. More unambiguous information practices ought to be

		what's more, their impact on honesty of in-store CCs. 2.Develop a model to survey the effect of information in forestalling in-store cold chain disturbances, present the idea of dormant disappointment (i.e., a nonidentified disappointment that takes into consideration the unforeseen decay of items in front of their lapse date), and utilize an information based point of view to conceptualize what disturbances in the CC mean for the wellbeing and nature of food sold at retailers	Handling rehearses, Combinative ability; Control factors - Socio monetary status of neighbourhood of retailer, size of store, contenders 3.SEM model utilizing Partial least squares was utilized.	information, addressed by the company's participation in a store chain, adversely influences the probability of an in-store cold chain interruption. 2. The better a company's item dealing with rehearses, addressed by the temperature varieties across tests of a similar item at a similar retailer, the lower the probability of instore CC interruptions. 3. Admittance to information emphatically influences the in-store CC dealing with practices of a food retailer.	2. There is connection between sanitation and the business climate.	contemplated, including satisfactory components for sharing the information expected to protect the nature of items as they travel along the CC. 3. Also, intuitive impacts among information and other taking care of training related data. ought to be analyzed. 4.External legitimacy of these outcomes ought to be tried in different enterprises in which short-lived items are famous.
3	Derens-Bertheau (2015)	1.Presents the consequences of a CC field concentrate on in France 2.Enable us to have a genuine image of the CC since temperature checking was done	1. Aftereffects of Survey from prior writing audit taken. 2. Field tests led. 3. Measurable examination performed	1.The most delicate connections are transportation after buy and especially stockpiling in a family fridge. 2.Preservation	1.Most delicate connections are transportation after buy and especially stockpiling in a family fridge. 2.Preservation	1.Study was done for chilled foods in France. Similarly, it could be done for frozen food in India

		in a way not noticeable to administrators and buyers.		of items at home is as yet hazardous	of items at home is as yet hazardous.	
4	Manzini (2013)	1.Presents a general and calculated system for the evaluation of FSC what's more, planned operations of food items in concurrence with a multidisciplinary and coordinated view. 2.Target of the proposed consolidated method for managing SC plan and the mgmt.. is the concurrent control of huge worth. thriving, common sense and assignments capacity of food things and cycles along the entire FSC.	Case Study based			
5	Mahajan (2013)	1.Analyse a case investigation of assembling cycle and SC of frozen corn and to investigate its status of SC execution.	1.Case review strategy is chosen to concentrate on handled food area's SC execution as far as frozen corn producing also, its SC. 2.A circumstance entertainer process (SAP), learning-activity execution (LAP) model has been applied to examine the contextual investigation	1.Major difficulties are mindfulness creation, instructing and preparing of channel individuals particularly (3PL) or carriers, merchants and retailers to keep up with temperature for frozen corn transportation and its stockpiling 2.Frozen corn wastages or harms can be disposed of or decreased	1.Indian CCs are at the incipient stage. 2.Demand for frozen handled food will undoubtedly increment many folds in India.	1. Can be applied to other processed food as well.

				3. One of the restrictions of CCM is that chain individuals for their pitiful increases switch-off the CC supplies like virus rooms, profound freezes, dope vans cooling frameworks to save power costs or diesel for a couple of hours. 4. Another impediment, there is dependably lack of frozen extra room. 5. compelling coordination of the frozen CSC is the best to wipe out squanders. 6.Modern innovations ought to be used for successful execution of its coordinated CCM in lengthy run		
6	Chaowarut (2009)	1.Proposes a two-stage structure to assess the propriety of a clever reasonable model for	1.Identify the KPIs by LR on existing perf. and model in SC writing.	1. Client point of view assumes the significant part for the frozen	1.Customer point of view assumes the main part for FF industry.	The framework can be tested with data

		inventory network execution estimation in frozen food area.	2.Calculate the load for each KPI by utilizing AHP system and show the connection between each KPI through Balanced Scorecard (BSC).	food businesses than some other viewpoints follow by the presentation estimation. 2. Exercises worried about client are exceptionally basic in the businesses and need the main improvement to increment perf. in SCM. 3. Client point of view goes before the Financial point of view the most predominant one from the outline of item cost and Profit. 4. Client point of view most significant wrt grumbling, food handling, and return of venture,	2.PIs like "item wellbeing" assumes a decisively significant part.	
7	Rathore (2010)	1. Draw the consideration of the user towards the possibility that exists in the FF business in India	Review and Conceptual framework	Agreeable exertion concerning different associates like public-private alliance, cartels and cooperatives can fundamentally help in building	1.There is dearth of infrastructure	1.Empirical validation can be done. 2.Can be applied to other industries as well.

				serious areas of strength for a that would add to the GDP, make business, help in developing things and advantage assistants.		
8	Vrat (2018)	1. Examine existing writing on pain point connected with practical sustainable CC for PFP.	1.LR analytics, including network and bibliometric analytics is used. 2. Different exploration articles were ordered into three subjects, for example (a) Sustainable transportation of transitory items (b) Strategies to incorporate supportability in cool chain and (c) Adverse natural effect of refrigerated compartments.	1.Many regions in CC for transient items are not enough tended to in spite of a dire requirement for rehearsing world. Practical cargo transportation (SFT) and cold-chain for transient food items are the two most unmistakable regions where examination is hugely developing	Practical cargo transportation (SFT) and cold-chain for transitory food items are the two most unmistakable regions where exploration is immensely developing	1. The job of trend setting innovations should be contemplated to guarantee the nature of transitory items during transportation. 2. Investigate the effect of creating and connecting data sets for reinforcing of data. in horticultural area. 4. Following of the transient items inside compartments, where the controlled temperature is kept up with to decrease wastage of food is required. 5. Additionally the joining of various

						cutting-edge innovations and their ideal use is required. 6. The need to investigate numerous ways of conveying items to different shoppers before the finish of timeframe of realistic usability is required.
9	Aung (2014)	1.Present far reaching data about recognizability with respect to somewhere safe and quality in the food store network.	LR	1.Traceability will arise as another list of value and a reason for exchange what's in store.	1.Customer interest for continuous data. about items they purchase and eat will likewise develop and it will be one of the serious benefits of food industry showcasing	1.Empirical validation required
10	Mercier (2017)	1.Field investigations on time-temperature conditions at each basic phase of the CC are looked into to survey the present status of business CCs. 2.Precooling, ground activities during transportation, stockpiling during show at	1. Field concentrates on directed on estimation of temperature of chilled food items along the CC are explored, with each step from precooling limit in home coolers pondered. 2. Current productivity of CC in keeping up with	1.Four key stages or activities addressing the points of failure in CC as far as temperature control were distinguished: Precooling; Storage and Transportation and capacity by	1.Weaknesses in CC distinguished: heterogeneous precooling, ground tasks during transportation, show at retail, capacity in homegrown fridges, the changeability	1. Endeavours ought to be made to consolidate information on time-temperature conditions along current business CCs for precise financial, social, and

		retail and in homegrown coolers, business taking care of practices are recognized and talked about as the significant shortcomings in present day CC. 3.Improvement in productivity accomplished through the estimation, examination, and the executives of time-temperature conditions is assessed, alongside the going with specialized and functional difficulties deferring the execution of such techniques	temperature of transient food is laid out, and shortcomings that should be adjusted for better food quality and wellbeing are recognized. 3. Potential administration frameworks to work on the CC in light of estimation of short-lived food temperature are examined, and challenges connected with the execution of such frameworks recognized.	clients; Ground activity during transportation; Showcasing at Retail outlet	of temperature inside shipments, and industry dealing with rehearses. 2.Challenges for the business execution of the board frameworks in light of time-temperature estimation featured, also, applicable planned research were proposed.	natural estimates. 2. Completely refrigerated SC from ranch to fork is required. 3. Give a reasonable evaluation of the province of CC in creating nations, and the information that is procured ought to be applied to bringing issues to light of the quality and dangers related with unfortunate temperature control and to supporting the advancement of similarly proficient and economical CCs
11	Rong (2011)	1. Coordinate food quality in dynamic on creation and conveyance in a FSC. 2. Give a procedure to show degradation of quality so that it tends to be integrated and used for production and distribution planning.	1. Strategy to show food quality debasement to such an extent that it very well may be incorporated and applied in distribution/production planning.	1. Both quality basics of the retailers and the scope of the shipments impact the temperature levels. 2. Shipments to retailers with additional	Quality necessities of retailers and length of shipments affect temperature levels	1.The model can be applied to other food sector industries. 2.The study can be applied to multiple products.

				unmistakable necessities happen at lower temperatures than those to retailers with lower basics. 3. Shipments to retailers which require longer transportation time are finished at lower temperatures than to those retailers which require less transportation time. 3. The extension in transportation temperature ought to be reimbursed by a development in the underlying item nature of the item.		

Appendix D

Issues in CSC

No	Details	Objective of the Study	Methodology	Finding	Inference	Gap
1	Negi (2015)	1.Discuss the SC of F&V area in India and make sense of the issues which are influencing it. 2.Suggest comparing alleviation systems to conquer distinguished	1.Descriptive Research; 2.Literature review	1. CC Facilities; Fragmented SC; Cost of Packaging Material; Linkages and Fuse between the associates; Taxation Issue; Infrastructure Facilities; Cost of Packaging Material; Innovation and Techniques; Farmer's Knowledge and Awareness; Quality and Safety principles;	1.There is inappropri ate SCM, absence of CC infra. Food Processin g units which are prompting greatest shortcomi	1.Factors recognized may additionally be observationally tried and approved on the F&V SC of various states. 2. A comparable observational review might

		issues and difficulties.		Handling and Value Addition; Supply Chain shortcoming; Farmers pay; Supply chain misfortunes and wastage of new produce; Transportation offices; Demand and market data and so on are the elements which is serious difficulties for F&V area and are influencing the general development of the agrarian improvement of India.	ngs and coming about to misfortunes and wastage of F&V. 2.Entire SC of F&V is weighed down with the issue of post-gather misfortunes and wastages because of long and divided chain, reliance on go-betweens, unfortunate street framework, wasteful Mandi framework, deficient CC foundation offices, significant expense of bundling, low quality of conveyance, failure	additionally be done for the SC of different related area like food handling unit, refreshments industry, CC industry and furthermore in F&V items.

					point in SC. 3.Highly wasteful SC and CC foundation is the critical obstacle in the method of fast improvement of agribusiness region in India	
2	Singh (2016)	1.Address CC manageability issues. 2.Understand the explanations for the reception of economical CC practices. 3. Recognize food provider choice rules 4. Recognize current maintainability ecological issues. 5.Understand how SCCM adds an incentive for firms and clients 6. Recognize viable CC practices and the dynamic capacities expected to	1.Extensive LR, Expert meetings, 2.Descriptive Statistics utilized. 3CC builds figured out. 4Validated proposed structure with observational investigation of the Indian food industry. 5. Ten SCCM builds have been distinguished to be specific: explanations for the reception of manageability, food provider determination rules, env. mindfulness,	1.Specifically in India: I) natural issues and social obligation are not generally so significant as other provider determination standards 2.In India purchasers center more around individual and prompt advantages as opposed to longer enduring benefits 3.Government generally urges organizations to take on maintainability in their tasks, yet in genuine work on, preparing programs that give direction as far as manageability are less thorough in contrast with the genuine necessity	1.Sustainability could significantly affect CC perf. 2.Consumers are likewise not exceptionally mindful of the advantages of low fossil fuel byproduct levels. 3.Training projects could build the productivity of functional	1. The proposed model structure can be applied to the frozen food industry to quantify its ways to deal with maintainability. 2. SEM could be utilized to test the connections between the manageability builds created.

		accomplish maintainability? 7. Distinguish best pointers for estimating supportable CC perf. 8. Decide significant obstacles to and benefits from manageable CC?	adding esteem through manageable CC,sustainable CC classifications, reasonable CC practices, economical CC unique exercises, maintainable CC PIs, feasible CC obstacles, what's more, practical CC recompenses.		staff, cut squander furthermore, make the economy less subject to carbon.	
3	Srivastava (2013)	1.Focus on the accompanying: (I) Examining the ongoing green functional practices in firms and SCs; (ii) Studying significant viewpoints in green activities and SCs; (iii) Identifying green functional issues in a portion of these viewpoints; (iv) Impacts of Green SCM on perfor. (v) To propose measures for greening activities and SCs	1.LR and interviews and field visits; 2. Longitudinal case studies	1 Firms can acquire upper hand by overseeing biological factors. 2. Client stresses over agreeable commitment ought to be facilitated with various components of critical while directing suppliers and undertaking laborers. 3. Viable methodologies for information sharing inside and across the businesses should be created.	1. Four significant between hierarchical powers driving green SCM exercises in India. are government, suppliers, clients and contenders.	1. Recognizing labor force ability holes and preparing needs appraisal on green practices and cycles is required 2. The connection between parts of green inventory network practices and parts of green inventory network execution should be considered. 3. Studies might be done to measure execution of effective firms that have

						carried out GSCM. 4. Examination might be done for assessing and estimating the level of greenness.
4	Ndraha (2018)	.Review temperature maltreatment in food CCs that work in various nations, as well as CC arrangements zeroed in on food quality and security.	Content Analysis on Literature Review	1. In many nations, temperature misuse was accounted for. 2. A portion of the food business administrators had lacking information on cool chain uprightness. 3. Temperature maltreatment in retail cooler cases bureau was profoundly articulated in the late spring, specific for items situated on the top retires thus, remaining timeframe of realistic usability was diminished. 4. Temperature control issues during the capacity of refrigerated food at the retailer normally happens because of absence of consistence with the temperature details for refrigerated food, unfortunate arrangement of the cool storerooms , and disproportionate temperature flow for an extensive variety of food on the racks. 5.During vehicle, temperature deviations were related with the places of items and bundles in the holder	1. Temperature the executives in chilled food items was the primary focal point of examination, 2.The most researched food classifications were meat, dairy, fish, natural product, and vegetable items; 2) Most temperature misuse detailed is in the CC of created nations, while substantially less is realized about the	1. Little thought has been given to frozen F&V 2. Followed temperature data should be unified and imparted to SC accomplices. 3. There is a requirement for coordinated research considering food squander, energy use, temperature management& the executives of cold food dissemination frameworks. 3.More exploration be committed to quality and security of refrigerated food, energy use and an unnatural weather conditions change impact, and level of food waste, as

					circumstance in agricultural nations; 3) Recent innovation applied in temperature checking gives a critical commitment to food CC 4) Food waste might be decreased with a superior temperature the executives in FCC.	well as surveying the capability and practicality of CCs.

Appendix E

SC Performance

No.	Details	Objective of the Study	Methodology	Finding	Inference	Gap
1	Najmi (2013)	1.Focus on the SC draws near, procedures used to work with execution and assessment rules that were focused harder.	Literature Review	1. Most well known strategy took on in SC execution assessment writing are DEA and AHP. 2. Most well-known rule considered by the creators for assessing entire SC are cost/finance, client, adaptability, imaginativeness,	. A SC model can be made of different methodologies, procedures, rules	1.Can be replicated for frozen food supply chain

				inside processes, dependability, responsiveness, productivity, asset, yield, time, quality, resource the executives.	and measurements as indicated by SC technique.	
2	Machado (2016)	2Present a speculative framework for execution assessment of SC quality organization. 2.Considers six areas of incorporation between quality administration and SCM env.: authority, determined improvement and advancement, acceptability, accomplice commitment and obligation, data., and mgmt. and vital plng	Literature Survey and Model proposed	1.SCQM reconciliation can be surveyed by nine execution estimations: Relationship Strength, Joint improvement exercises, Supplier's and client's contribution in item advancement, Suppliers and clients activities, Collaboration and trust, Information Asymmetry, IS use, Strategic empowering agents use, and Top administration commitment	1.The review expands the comprehension of the reconciliation of SCQM, introducing a proposition for a bunch of execution estimations	1. Can provide a comprehensive basis for future studies in the area of SC quality management integration
4	Gunasekaran (2004)	1.Develop a structure for better comprehension of SCM execution estimation and measurements	1.Survey based with empirical analysis done	1.Supplier, Order planning measures, strategic planning, , Delivery and production measurements were the metrics used for measuring SC performance. 2. The value that a customer attaches to the product is of high importance. 3. Client inquiry time was exceptionally significant underscoring the nature of client assistance. 4. Provider conveyance execution is generally	1.Effort focussed on cautiously overseeing SC created monetary advantages for taking part firms. 2.Effective SCM	1.Additional examination and drives are required for evaluating perf. of SC. 2.Parameters can be distinguished for FF industry too.

				significant for provider assessment measurements. 5. Level of imperfections was the most significant.	assists with winning clients and further develop client care.	
5	Arzu Akyuz (2010)	1. Give a basic LR on SC execution estimation. 2.Reveal essential exploration techniques/approaches followed, trouble spots and prerequisites for the exhibition the executives of the new SC time.	LR	1The estimations used for assessing execution should have the choice to get the focal point of progressive execution worked with on affiliation procedure and objectives; Reflect a congruity among financial and non-money related measures; Relate to key, vital and utilitarian levels of route and control; Be identical to other execution gauges used by near affiliations; and serve the necessities of people from all levels	1. Perf. estimation in the new stockpile time is as yet an open area of examination	1. Recognized need of additional examination is with respect to structure advancement, experimental exploration and reception of execution estimation frameworks for the necessities of the new time, to incorporate the improvement of organization, joint effort, dexterity, adaptability, data efficiency and business greatness measurements
6	Shepherd (2010)	1.Provide a scientific classification of execution estimates followed by a basic assessment of	LR	1. Issue of how to incorporate execution estimation frameworks with HRM and present-day fabricating rehearses like TQM, BPR, JIT, or new data advancements has not been enough tended to.	1.A number of significant issues definitely stand out, including: the	1.For perf. estimation frameworks, the review centers mostly around the Operations Management

		estimation frameworks intended to assess the presentation of supply chains		2.There have been not many observational investigations of the elements influencing the achievement or disappointment of endeavours to execute execution estimation frameworks.	elements influencing the fruitful execution of execution estimation frameworks for SCs; and the issue of their continuous support.	writing. 2.Non financial proportions of inventiveness and consumer loyalty ought to likewise be tended to.
7	Hausman (2004)	1. Depict different SC perf. measures that are unequivocally intended to help and screen Supply Chain Performance. 2.Improvements across the SC tended to	Conceptual	1. Supply Chains need to perform on three key angles: • Organization • Assets • Speed 2.Service interfaces with the ability to anticipate, get and fulfil customer interest with customized items and on-time conveyance; 3.Assets include anything with business esteem, essentially stock and money; and 4.Speed incorporates measurements which are time-related - they track responsiveness and speed of execution.	1.Internet is a key empowering influence of both SC execution upgrades. 2.Awareness that Perf. ought to be for complete SC, not their singular specialty unit, estimated by end client.	.Carrying out cross-adventure estimations will be basic in enabling top organization to search for and screen consistent store network execution upgrades
8	Su (2008)	1.Studies the effect of key client conduct on inventory network execution.	1.Foster a framework m to concentrate on purchaser behaviour in SCs.	1.Decentralized SC with a discount value agreement might perform stringently better compared to a unified SC;	1.Decentralized SCs, can commit to purchasers in	1.How the introduction of client lead affects the impulses for embracing

			2.Investigate effect of key buyer conduct on SC perf. Decide ways of bettering oversee SC.	2. a portion of the agreements can't designate benefits randomly between inventory network individuals in view of key client conduct.	a roundabout way.	these useful techniques can be investigated2. This framework can be applied in various locales as well.
9	Mor (2018)	1. Investigate the KPIs that act as a choice help device in the event of dairy SC rehearses and to dissect their cooperations with regards to Indian dairy industry area. 2. Benchmarking the SC rehearses through an ISM-based model and grouping the PIs by utilizing MICMAC investigation.	1.ISM procedure is utilized to dissect the collaborations among PIs and to propose an underlying model.	1. 11 PIs identified were: Effective product marketing, Brand mgmt and featured products Effective quality mgmt., Supplier relationship mgmt., on time delivery of products, Traceability systems, Milk wastage mgmt. , Effective CC infrastructure Responsiveness in shipment accuracy, IT enabled support system better order-fill rate and Support for technological innovations and Production operations mgmt. 2. Effective IT, brand management, responsiveness in shipment and accuracy and a control over wastages as the key PIs in the dairy industry sector. 3. The effective traceability systems, cold chain infrastructure, quality management and the support for technological innovations are the next major PIs.	1.Understanding of various PIs and their reliance to acquire an upper hand over contenders. 2. Firms in milk handling area in India need critical improvement in the IS, wastages the executives and responsiveness in delivery precision followed by the powerful detectability framework.	1.Hypothesis testing might be completed to see how postulations PIs are connected with SC perf. measures in dairy industry. 2.This technique might be summed up by executing it on the other short-lived food handling businesses

10	Sukati (2012)	1.Explore the relationship between SCM strategy and chain management practices on supply chain performance	1.The data were analysed using mean, standard deviation and correlation between independent and dependent variables. 2.The analyses involved statistical methods such as reliability and validity tests and multiple	1.Strategic supplier partnership, customer relationship & information sharing are important determinant of SC performance. 2. No significant correlation between SC strategy and SC performance. 3. There is weak relationship between SCM strategy and SC performance. 4. There is a weak relationship between SCM strategy & customer responsiveness. 5. There is significant relationship SCM practices & SC integration. 6. There is significant correlation between SCM practices & SC flexibility	1. Solid indicators of production network execution are key provider organizations; ,customer relationship and information sharing. 2.SCM practices have a significant relationship with SC performance 3.SCM strategy is a weak predictor of SCM performance.	The study can be carried out for CSC.

Appendix F

Suggestion of Solutions

No.	Details	Objective of the Study	Methodology	Finding	Inference	Gap
1	Parthasarathy (2017)	1. Present a pilot test directed	Field test based	1. Use of CCM in Indian SC conditions has illustrated	1.The system when taken on into their interaction	1.Study could be stretched out to additional

		utilizing a cloud based remote checking framework to follow inner temperature, mugginess and encompassing light of CC compartments with programmed alarms to separate bosses.		benefits of ongoing persistent following, geo and age labeling, programmed identification and making aware of bosses of fixed and versatile holders found.	could guarantee their products are saved and conveyed securely to their clients	different locales. 2.Monitoring additionally relies upon the mindfulness and readiness of the staff utilizing the framework also, clients
2	Comes (2018)	1.Analyse how far innovation and data empower, work with or support the preparation and execution of choices in philanthropic immunization cold chains for inoculation crusades.	Based on Review of Literature and Reports	1.Technological improvements are brought to beat blocks: robots to overcome confined accessibility, and sun fuelled coolers to beat the shortfall of strong power systems. 2. Usage of checking and worldwide situating systems and information the board structures.	1.Three key areas of exploration that are basic for progressing fruitful CCM: arranging and carrying out CC under states of vulnerability; the job of data in carrying out CC in the field; and adapting to choice irreversibility at the preparation and execution stage.	1.Several key issues should be additionally explored to accomplish responsive SCs
3	Chaudhuri (2018)	1. Recognize various types of data that can be accumulated and researched by experts across the infection chain 2.ICT establishment	1.Content investigation based LR was utilized to make an outline of information catch, innovations utilized for assortment and	1. Need to comprehend how constant checking of conditions like temperature, moistness, and vibration can be meant help ongoing appraisal of value, assurance of genuine	1.Most of the papers explored are connected with new F&V and zeroed in on the circulation stage.	1. Scope for future examination to comprehend information catch and use it for decision making for circulation as well as across

		expected to engage data get and the best strategy to involve the data for dynamic in cool chain arranged tasks.	sharing of information, and dynamic that can be upheld by the information, across the virus chain what's more, for various kinds of short-lived food items.	excess timeframe of realistic usability of items and utilization of those for dynamic in chilly chains. 2. Firms across CC need to take on proper advances fit to the particular settings to catch information across the CC. 3. Investigation of such information over longer periods can likewise uncover examples of item disintegration under various transportation conditions, which can prompt upgrading the transportation organization to limit quality misfortune.		the virus fasten from present gather on handling, dispersion and retail. 2. More work should be possible on how information caught can be actually utilized for dynamic in chilly chains. 3. Distinguish all important boundaries to catch item condition as well as exchange information across the virus chain processes.
4	Badia-Melis (2018)	1. Frame key difficulties affecting advanced CC applications. 2.Outlines the most recent patterns in innovative work and presents innovation arrangement used to address these challenges	Literature Review	1.Emphasizes meaning of an inventive Internet-of-Things approach, RFID progressions and WSN can interconnect the data and those things, and make them accessible in informational indexes accomplice equipment and programming	1.A capacity to execute a total CC can introduce critical time and cost putting something aside for business organizations and furthermore have a positive cultural effect through lessening worldwide food squander.	1.Can be applied for other sectors as well

5	Bigaj (2017)	1 Present the idea of observing of cycles acted in a CSC	1.The research was conducted in Polish companies along-with LR. 2. The outcomes were utilized to choose conditions impacting the intricacy of the examination of productivity of coordinated operations processes.	1. In excess of a portion of the organizations lead productivity examination of planned operations processes. 2.Most of organizations utilize just the overall examination of the productivity of the business and just partially utilize the intricate investigation of person operations processes.	1. The level of the utilization of the examination of proficiency of strategies processes is unacceptable	1.Contribution of Only portable innovation was thought of. 2.Impact of Other advancements additionally should be examined
6	Tian (2016)	1. Focus on the use and improvement by utilization of RFID and blockchain development. 2.Analyse the benefits and detriments of utilizing RFID and blockchain innovation in building the agri-food SC recognizability framework.	Literature Review and framework suggested.	1.Agri-food SC discernibility framework is laid out, in view of RFID and blockchain innovation. 2.realizes the observing, following and detectability the executives for the quality and security of the agri-food "from homestead to fork	1.IT can understand the detectability with confided in data in the whole agri-FSC, which would really ensure the sanitation, by social affair, moving what's more, sharing the true information of agri-food underway, handling, warehousing, conveyance and selling joins.	1.In future examinations, blockchain innovation can be concentrated on 2.If application cost can be fundamentally diminished, RFTD innovation will be more generally utilized in the planned operations industry.
7	Luo (2016)	1.Discuss the issues connected with coordination of advances	1.By coordinating IOT and following advancements, a smart global	1.Wireless sensors situated in cool stockpiles or refrigerated trucks can gather and send	Remote sensors situated in chilly stockpiles or	1.Efficiency of the system can be tested .

		utilized in CC for observing transient products. 2. Propose an adroit worldwide situating structure for CC by consolidating IoT and following advances to accomplish viable and quick live checking of merchandise in the virus chain at the most minimal expense and with the biggest organization limit and least complex conventions.	positioning framework, intended to accomplish viable and quick live observing of merchandise in the virus chain at the most minimal expense and with the biggest organization limit and easiest conventions.	live information rapidly and proficiently. 2.Users can undoubtedly check merchandise moved in CCs. 3.System can save verifiable information for requests.	refrigerated trucks can gather and send live information rapidly and proficiently	
8	Gogou (2015)	1.Develop Cold Chain Database (CCD) as an online instrument that could essentially add to the assurance of the points of failure of the CC for a critical number of food items	1.A online stage was planned and a product instrument was created; and field tests were led	Database developed	1.CC Database improvement can be used for concluding disappointment focuses in a CC	1.Can be applied to frozen food industry.
9	Hendrik (2013)	1.Present consequences of a subjective contextual	1.Interviews; 2.Case study	1. WSN requires satisfaction of	1. WSN can additionally foster cycle quality and	1. Occupation of outcasts or alliances to achieve a

		investigation of the continuous reception of WSN in a pharma CC to forestall damage of high worth consignments. 2.Benefits and obstructions that influence the reception cycle are recognized.		different errands and obligations by SC members. 2.Trust between SC entertainers is significant for the reception of WSN. 3.Organizational culture significantly affects how WSN are seen.	decrease waste in CC 2.Careful thought ought to be paid to managing the different interconnected factors that could maintain or hinder gathering	sensible and prevalent grade constant observing arrangements be considered. 2.Benefits and influences on reception of advancements that can affect trust and eagerness should be explored.
10	Kumar (2013)	1.Find out the empowering agents of e-Applications in the Indian agri-food production network	1. Empowering agents distinguished utilizing auxiliary sources. 2. Normal relationship was created among these empowering influences utilizing ISM exhibiting reliance and driving power	1.It is vital that agribusiness area of India involves IT for most extreme advantage. 2.Enabler 'constantly diminishing expense of equipment' was found to have most extreme driving power.	1.The use of IT is astoundingly accommodating to at last help the overall population, which is unfathomable aside from if cultivating area of India includes it for most outrageous benefit.	1.The study and such a methodology can be applied to the frozen food industry too
11	Chen (2014)	1 (RSCCS) .A Refined Smart Cold Chain System was anticipated in which the semi-aloof labels are supplanted with the aloof labels to decrease the expense. 2.For accessibility	Implementation based, experiment	1. Most significant advantage of RSCCS is to supplant semi-aloof labels with uninvolved labels and decrease cost of SCCS. 3. It will likewise altogether decrease the correspondence, handling and stockpiling heap of	1.The 2G-RFID-Sys enjoys benefits and further guarantees the accuracy of the framework execution. 2.Not just the food maker can guarantee the food newness yet in addition	1.The benefits need to be empirically validated

		and versatility, another kind of RFID application named 2G-RFID-Sys is applied to our plan		the backend framework by trying not to get to the standard information base without fail.	the shopper can securely buy the items through RSCCS without getting to the backend framework.	

Appendix G

Underpinning theories and Data analysis techniques

S.No.	Author(s)	Keywords	Methodology	Objective
1.	Chandra (2019)	Balanced scorecard, Analytic hierarchy process, Immunization, Two-way assessment, Vaccine supply chain	DEMATEL approach	To identify the KPIs of vaccine SC, and measure their impact on vaccine SC performance improvement
2.	Lavastre (2014)	Innovation, Supply Chain, Performance	Exploratory and Confirmatory factor analysis	To create and approve an instrument to gauge Innovative Supply Chain Practices (ISCP) in SCM.
3	Bhatnagar (2019)	Bunch innovation, CCM, Cold-capacity, Compatibility grid, Multi-standards grouping for perishables, Storage boundaries	Agglomerative hierarchical clustering algorithm	Decide similarity gatherings of various leafy foods (F&V) that can be put away and shipped together in view of their prerequisites for temperature, relative mugginess, scent and ethylene creation.
4	Bremer (2018)	CC; SCM; Modelling	Object-oriented modeling approach.	Draft a reference model specific to the cold chain.
5	Loisel (2021)	Food squander ; ML; Temperature expectation Food security ; CC break	Machine learning methods	Different definitions and hardships related with the revelation of cold chain breaks are presented and analyzed.
6	Khan (2018)	Cold Chain; Cold Chain Management; Barriers; temperature Controlled Logistics, Perishable Products	DEMATEL	Identifies the barriers for effective management of cold chain and evaluate the interrelationship among them
7	Muzylyov (2020)	Cargo; trucks; merchandise; production network; business; basis;	Regression Analysis	To plan a technique for the normal inventory network decision of short-lived cargoes.

		course; costs; quality; transport overhauling; transportation; model		
8	Su (2021)	Online retailer; customer loyalty cold chain; pandemic; psychological Distress; physical distribution	EFA and SEM	Joins the speculations of seen worth and influence as data, taking virus chain coordinated operations administrations, illustration to talk about impact of PDS quality (PDSQ) of online retail cool chain
9	Han (2021)	Fresh agricultural products; Cold chain; Food safety; Digital development; Energy conservation; China	Review	Discusses active research areas, gaps in the existing state of research, and future research challenges for CCL
10	Chen (2020)	Flexible electronics, food safety, food waste, printing technologies, smart packaging, supply chain management, sustainability	Review	Integrate conceptual frameworks and technological applications and focuses on how innovative smart packaging solutions are beneficial to the overall quality and safety of food supply by enhancing product traceability and reducing the amount of food loss and waste.
11	Jermsittiparsert (2019)	Practices - Green SC, TQM; electronic sector	SMART-PLS and SEM	Examines the impact of green supply chain practices on sustainability of performance of electronic industry of Thailand.
12	Vivaldi (2020)	CC; RFID; Ionic fluid; Temperature sensor; Shipment control; Perishable products	Experimental	To identify the passing of a temperature boundary (8 °C) during the delivery of clinical items.
13	Giannakourou (2020)	CC; Monte Carlo; Frozen food sources; Variability; Shelf life illustrating; Uncertainty; Joint sureness extends	Stochastic calculation is executed, through a twofold Monte Carlo	To gauge the active boundaries of both essential and optional models
14	Gardas (2019)	Decision making; Modelling; Performance management; Supply chain management	ISM	Analyse 14 drivers or performance indicators (PIs) of GSCM in the agro-sector.
15	Ali (2018)	Australia, Resilience, Logistics, Cold chain, Risks, Mixed method, Perishable products	Mixed method approach	To bridge the current research gap by developing a model, based on broad empirical evidence, of the interplay between CCLRs, resilience and firm

				performance (FP) in perishable product supply chains (PPSCs).
16	Wang (2018)	Location-routing Problem; Carbon emission; Hybrid genetic algorithm; Cold chain logistics	A hybrid genetic algorithm with heuristic rule	Give a low-carbon and ecological security perspective, in light of the qualities of transitory items, and joins with the general improvement thought of cold chain coordinated operations.
17	Mangla (2018)	Agri-food; store network; Sustainable drives; DEMATEL; India; Enablers; ISM-MICMAC; Fuzzy	Combined ISM - Fuzzy DEMATEL based framework.	Analyze the key enablers in implementing sustainable initiatives for Agri-Food Supply Chains (A-FSCs).
18	Mor (2018)	Execution estimation, Supply chain, Benchmarking, Technological development, Choice emotionally supportive networks	ISM & MICMAC analysis	To investigate the key presentation pointers (PIs) that act as a choice help device in the event of dairy store network rehearses and to break down their collaborations with regards to Indian dairy industry area.
19	Ndraha (2018)	Temperature abuses, perishable products, food safety, food quality, food waste	LR	Review temperature abuse in food cold chains that operate in different countries, as well as cold chain solutions focused on food quality and safety
20	Comes (2018)	Cold chain, Humanitarian, innovation, Information the executives, Irreversible choices, Uncertainty. Immunization crusade	Review	To examine how far innovation and data empower, work with or support the preparation and execution choices in compassionate immunization cold chains for inoculation crusades.
21	Chaudhuri (2018)	framework; coordinated factors ;content investigation based writing survey; information examination; Cold chain	LR	To recognize the various kinds of data that can be accumulated and analyzed by specialists across the cold chain, the ICT establishment expected to engage data catch and how to involve the data for dynamic in cool chain facilitated tasks
22	Gallo (2017)	Cold chain; food distribution; energy; logistics; transport;	Mixed integer linear programming model	Propose a mixed integer linear programming model to minimize the total energy consumption associated with

		optimization; Silk Road		the cold operations experienced by perishable products.
23	Carson (2018)	Cold chain; Refrigerated transport	Review	The immense evaluation subject related with the cool chain in New Zealand is focussed around impelling chilling and freezing processes for time period of comfort augmentation.
24	Arora (2022)	FF; India; Unhealthy. Consumer perception; Consumer Adoption; convenience	Binary logistic regression and chi-square	Analyse the influence of identified factors on frozen food product adoption and understand the level of consumer adoption towards frozen food products.
25	Osorio (2017)	Argentina, cold chain, food safety, food security, in-store logistics, retailing, service failure, urban environment	SEM	Seek to understand the role that access to standardized knowledge, in-store cold chain practices, and the interaction of those two have on the integrity of in-store cold chains.
26	Titlo (2019)	Cold chain, Performance measurement, AHP, Export and Longan fruit	AHP	Discussed the factor affecting the performance such as Quality and safety, Traceability, Cost, and Responsiveness
27	Salimi (2018)	Small Medium enterprise; Research and Development perf.; Best-Worst Method; Research and Development measures	AHP-TOPSIS	To measure R & D performance taking into account the different levels of importance of R & D measures, using a multi-criteria decision-making method called Best Worst Method (BWM) to identify the weights (importance) of R & D measures and measure the R & D performance of 50 high-tech SMEs in the Netherlands using the data gathered in a survey among SMEs and from R & D experts
28	Blome (2013)	Knowledge transfer Supply chain flexibility Product complexity Supply complexity	KBV	Investigate the influence of internal and external knowledge transfer activities on supply chain flexibility.
29	Cheng (2009)	SC, Semiconductor, AHP, FDM, FAHP, FMCDM.	FAHP	To recognize basic elements connected with the wafer provider determination. It likewise has turned into

				another subject by how to provoke current place of semiconductor industry and their wafer provider in Taiwan.
30	Khan (2018)	Cold Chain; Cold Chain Management; Barriers; Temperature Controlled Logistics, Perishable Products	DEMATEL	Identify the barriers for effective management of cold chain and evaluate the interrelationship among them.
31	Shoar (2019)	Risk collaborations; Risk reaction choice; FTOPSIS; Project RM; Fuzzy set	FTOPSIS	Presents a structure for settling a response reaction activity determination issue by considering: 1) the effect of chance occasions on the undertaking goals, 2) the connections between risk occasions, 3) the executives rules and inclinations.
32	Osorio (2017)	Argentina, cold chain, food safety, food security, in-store logistics, retailing, service failure, urban environment	KBV & SEM	To understand the role that access to standardized knowledge, in-store cold chain practices, and the interaction of those two have on the integrity of in-store cold chains.
33	Shashi (2016)	Food industry, cold supply chain, sustainability, production, supply chain practices	Stakeholder theory	To mention CC sustainability issues
34	Ahi (2015)	Sustainability Supply chain Triple bottom line Probabilistic model Multidimensional Performance assessment	TBL	To better understand how the factors affect the sustainability performance of supply chains
35	Lazzarini (2001)	Cooperative strategy, SC, Value chain, Interdependence, Network	Network analysis theory	Introduces the concept of netchain analysis

Appendix H - Section of Questionnaire (used for Main analysis)

SECTION III: Performance of Cold Chain

1. Presence of following determinants influencing the performance of Cold chain:
Please rate as per given below:

1- Strongly Disagree; 2- Disagree; 3 – Neutral; 4- Agree; 5- Strongly Agree

Determinants influencing CC Performance	**Checking Agreement**				
	1	2	3	4	5
1.Proper Storage of frozen food					
2.Restore texture					
3.Proper storage of frozen fruits & veg					
4.Quality maintained					
5.Moisture retained					
6.Nutrients retained					
7.Shelf life increased					
8.Freshness retained					
9.Spoilage and wastage minimized					
10.Protected from bacteria					

Section IV: Scope of Presence of Determinants w.r.t. their Current Status in the Cold Chain

1. Please rate the presence of the determinants on a scale of 1 to 5 in terms of their current status

Extremely Poor/Not present - 1;Poor - 2; Average - 3; Good - 4; Extremely Good - 5

Presence of Determinants affecting performance of Cold Chain	**Checking Agreement**				
	1	**2**	**3**	**4**	**5**
1. Production/Processing facilities					
2. Storage facilities					
3. Loading/Unloading facilities					
4. Transportation facilities					
5. Packaging facilities					
6. Distribution facilities					
7.Marketing/Retail end facilities					
8. Access to Information about Geographic Origin					

9. Access to Information about Ingredients					
10.Access to Information about Method of Processing					
11.Access to Information about Compliance to Legislation					
12. Access to Information about Best Before date					
13. Access to Information about Environmental conditions					
14. Information coverage about product at farmers level					
15. Information coverage about product at packaging level					
16. Information coverage about product at storage level					
17. Information coverage about product at wholesaler level					
18. Information coverage about product at retailer level					
19. Information coverage about Associated costs					
20. Extent of information provided about ingredients					
21. Losses & wastage					
22. Following of Human Rights					
23. Consideration of Product responsibility					
24. Consideration of Social welfare					
25.Cost					
26. Resource usage					
27. Use of Automation					
28. Energy consumption					
29. Carbon footprints					
30.Consideration for Storage compatibility					
31. Vehicle insulation					
32. Usage of Alternate sources of energy					
33. Adverse environment impact					
34. Green CC practices					
35. Complying to Certification					
36. Use of Organic production methods					
37.Backward integration					
38.Forward integration					
39.Linkage between firm and government					
40.Linkage between farmer/producer and firm					
41.Linkage between firm and distribution channels					
42.Linkage between firm and marketing					
43.Handling practices					

44.Storage practices					
45.Processing practices					
46.Distribution practices					
47.Quality Control practices					
48.Access to Information related to traceability to all CC partners					
49.**F**ood attributes like Taste, Flavour, Weight, Nutrition, Shelf life & required environmental conditions maintained					
50.Reduction of Chemical content					
51.Compliance to Standards for assurance of safety & quality					
52.Real-time monitoring using IT					
53.Awareness about latest techniques & technology					
54.Knowledge of handling practices					
55.Knowledge of quality parameters					
56.Knowledge of safety requirements					
57.Knowledge of compliance standards					
58.Knowledge of environmental sustainability					
59.Knowledge about traceability requirements					
60.Catering to varieties in Products					
61.Lead time reduction					
62.Synergy with firm we supply to					
63.Customer-centric in terms of response times and customer complaints					

Appendix I (only few have been given)

Questionnaire for Expert Inputs

[I] For Main Issues (AHP analysis)

Please rate the following in terms of relative importance on the following scale: Equal Importance - EI; Very Low importance - VLI; Low importance - LI; Average importance - AI; High importance - HI; Very High importance - VHI; and Extremely High importance - EHI. For example, if INFR has High importance as compared to AWHP then put HI in the row of INFR and column of AWHP

	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
INFR				HI			
SAFQ							
RESP							
AWHP							
TRAC							
SUST							
INTG							

[II] For DEMATEL analysis

Please rate the following in terms of influence of one criterion on the other as per the following scale: No Influence - 0; Low influence - 1; Medium influence - 2; High influence - 3; Very High influence - 4 respectively

	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
INFR				HI			
SAFQ							
RESP							
AWHP							
TRAC							
SUST							

INTG							

[III] FOR BWM ANALYSIS

a) IT solutions

Select the best and worst solution . Thereafter compare the best to other solutions given the following appropriate scale: Very low - 1; Low - 2; Average - 3; High - 4 and Very High - 5

Select the Best	Solution Code of best soln.

Select the Worst	Solution Code of worst soln.

Best to Others	SIT1	SIT2	SIT3	SIT4	SIT5	SIT6	SIT7	SIT8	SIT9

Others to the Worst	Worst solution
SIT1	
SIT2	
SIT3	
SIT4	
SIT5	
SIT6	
SIT7	
SIT8	
SIT9	

[IV] For FTOPSIS SOLUTIONS

Please give an appropriate rating on the basis of usefulness of the solution for the corresponding Issue as per the following scale: 1 - Very Low; 3 - Low; 5 - Average; 7 - High; and 9 - Very High

a) IT SOLUTIONS

S CODE	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
SIT1							
SIT2							
…….							
SIT9							

b) Non-IT solutions

S CODE	INFR	SAFQ	RESP	AWHP	TRAC	SUST	INTG
SNIT13							
SNIT14							
…….							
SNIT32							

Appendix J Common Method Bias Test

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.765	25.044	25.044	7.973	22.779	22.779
2	4.306	12.303	37.346			
3	2.941	8.403	45.750			
4	2.210	6.314	52.064			
5	2.089	5.969	58.033			
6	1.921	5.489	63.521			
7	1.762	5.035	68.556			
8	1.116	3.187	71.743			
9	.849	2.427	74.170			
10	.806	2.303	76.473			
11	.751	2.145	78.618			

12	.682	1.948	80.566			
13	.564	1.611	82.177			
14	.536	1.532	83.710			
15	.488	1.394	85.104			
16	.462	1.319	86.424			
17	.433	1.236	87.660			
18	.403	1.152	88.813			
19	.372	1.062	89.874			
20	.360	1.029	90.903			
21	.355	1.014	91.917			
22	.316	.903	92.820			
23	.307	.877	93.697			
24	.267	.762	94.459			
25	.258	.737	95.196			
26	.234	.668	95.864			
27	.231	.659	96.522			
28	.222	.634	97.156			
29	.203	.581	97.737			
30	.188	.536	98.273			
31	.142	.404	98.678			
32	.135	.385	99.063			
33	.118	.336	99.399			
34	.113	.322	99.720			
35	.098	.280	100.000			

Extraction Method: Maximum Likelihood.

RESEARCH PUBLICATIONS

Journals

1. Arora, M., Kumar, R., Anand N. (2022), "Analysis of Frozen Food Adoption by Consumer in Uttarakhand, a State of India: An Inferential Statistics Approach", International Journal of Value Chain Management, (2022), Vol 13, No. 1, pp. 88-111, doi 10.1504/IJVCM.2022.122164 ISSN online 1741-5365

2. Arora, M., Kumar, R. "Issues and Challenges in the Cold Chain of Frozen Food in India: A Review", Korea Review of International Studies (Accepted for Publication)

3. Arora, M., Kumar, R. "Identification of Issues in the Cold Chain of Frozen Food in India: A Review", Int. J. of Logistics Economics and Globalisation (Accepted for Publication)

Conferences

1. Arora, M., Panda, B P. (2018) "IT-enabled Traceability for Effective Cold Chain Management", 5th Agro Supply Chain Conference, School of Business University of Petroleum and Energy Studies, Dehradun
2. Jha, M., Arora, M. (2017) "Impact of Demonetization in India on Ecommerce payment methods" , 5th International Conference on Management of Infrastructure, COMES University of Petroleum and Energy Studies, Dehradun

BRIEF BACKGROUND

Name: Madhu Arora

Qualification:

- Pursuing Ph.D. at School of Business, UPES, Dehradun – India
- Masters of Personnel Management from Pune University, Pune - India
- Masters of Business Administration (Operations) from Indira Gandhi National Open University, Delhi - India
- Bachelor of Science (Physics, Chemistry, Maths) from Delhi University, Delhi - India

Work Experience:

- ‘Assistant Professor’ at Department of Management, Uttaranchal University, Dehradun from Jan 2017 to March 2022.
- Prior Experience of around 14 years (full time) and 11 years (Visiting)

PLAGIARISM REPORT

ORIGINALITY REPORT

7%	5%	3%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Deepak Bangwal, Prakash Tiwari. "Workplace environment, employee satisfaction and intent to stay", International Journal of Contemporary Hospitality Management, 2019 Publication	<1%
2	core.ac.uk Internet Source	<1%
3	www.emeraldinsight.com Internet Source	<1%
4	onlinelibrary.wiley.com Internet Source	<1%
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6	www.tandfonline.com Internet Source	<1%
7	Shahbaz Khan, Mohd Imran Khan, Abid Haleem. "Towards Effective Management of Cold Chain: A DEMATEL Approach", IOP	<1%