

COLD-CHAIN MANAGEMENT FOR AGRO-BASED PERISHABLES

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COLD-CHAIN MANAGEMENT FOR AGRO-BASED PERISHABLES

by

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CERTIFICATE

The Thesis entitled **“Cold-Chain Management for Agro-Based Perishables”** being submitted by Mr. Aman Bhatnagar to the Indian Institute of Technology Delhi, for the award of the degree of Doctor of Philosophy (Ph.D.) is a record bona fide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has attained the standard required for a Ph.D. degree from the Indian Institute of Technology Delhi. The results presented in this thesis have not been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

India is one of the second largest producers of fruits and vegetables in the world and the second largest populated country after China producing 97.97 million tons of fruits and 183.17 million tons of vegetables. Agriculture is the source of livelihood for more than 0.20 billion people out of 1.35 billion population in India who are directly or indirectly involved in agriculture. However, when we talk about food loss it accounts for 6.70% to 15.88 % for fruits and 4.58% to 12.44% for vegetables, amounting to the total economic loss of Rs 441.43 billion. Cold-chain acts as a conduit for connecting farm-to-fork and is considered to be part of second green revolution, ensuring the food is delivered to every part of the country in its best form, maintaining its quality and nutrient value.

This study develops a Comprehensive Framework for the Management of an Integrated Cold-chain in India, by studying the end-to-end food value chain for a cold-chain industry, which is growing and exporting fresh fruits and vegetables across the states in India and abroad. The study uses Soft System Methodology to develop a framework for the management of integrated cold-chain development for perishable produce/products. Using, Soft System Methodology, it becomes apparent that implementation of a Smart IT Management System with integrated supply-demand planning with real time data analysis can provide better accessibility and reach to market.

The increase in production for perishables with the increase in population induces demand which requires adequate cold-chain facilities in terms of pack-houses, reefer transportations, cold storages etc. which may be utilized optimally with the present need. The study develops a Compatibility Matrix for safe storage and transportation of perishable produce/products. The clustering analytics approach was developed considering 43 different fruits and vegetables to enable safe storage and transportation based on similarity of their temperature, relative humidity, odour, and ethylene production. The results have identified seven groups in which these 43 fruits and vegetables can be grouped for safe transportation and distribution. The study also focusses on multi-commodity storage and hub and spoke model that are very much required for the development of cold-chain.

The study further analyses the storage requirements for agro-based perishables using production and distribution planning model. The study provides an opportunity for inter-state trade of commodities (potato in this case) to meet the growing demand and use the available cold storage infrastructure. It also provides insights about the complexities and hindrances faced during interstate transportation and government interventions taken to promote strong connect between

states. The study identifies the gap in storage infrastructure that needs to be filled seeing the growing production and demand scenario. Cost benefit analysis for building cold-chain infrastructure versus food wastage has also been discussed.

There is need for a holistic approach in terms of connecting farmers to market through development of cold-chain network and proper infrastructure development to ensure that the food is delivered to the consumers at right time, in right quantity and with minimal wastage and losses. Keeping this in mind, the study identifies, analyses and validates the Critical Success Factors (CSF) for Integrated Cold-chain Management. CSFs are identified through close interactive meetings and discussions with different stakeholders involved in food value chain. Further, a case study for surging prices in onion value chain is studied and important inferences are drawn using TISM learning.

The study further analyses the Impact of cold-chain on improving economic conditions of farmers. The study provides framework for the management of issues faced in an integrated cold-chain development through Literature Review Analytics and remedial solutions in terms of technologies, innovations, policy- framework etc. The study provides insights about the techno-financial analysis of movement of perishable produce from farm end to the customer end. It further briefs on the potential threats from new entrants, new substitute and bargaining power of buyers and suppliers through Porter Five Model.

The thesis concludes with the findings derived from the research, which could be helpful, specifically for the concerned authorities, policy makers, farmers, farmer producer organizations, industries, companies involved in cold-chain management and also in general for practitioners and academicians working in food & agriculture sector.

It also discusses about the various government interventions and policy decisions taken towards improving the economic conditions of the farmers. The thesis has come with valuable observations and insights for the managers to deal with the issue of cold-chain management. It has also provided the roadmap to the practitioners while dealing with the issues of cold-chain development and enables the decision makers to ensure food is delivered to the population in best state maintaining its quality & nutrient value, thereby improving the economic conditions of the farmers.

Keywords: Cold-chain management, perishable food products, food value chain, sustainability, clustering analytics for perishables, optimization model for storage and transportation, supply - demand planning, critical success factors, soft system methodology, improving economic conditions of farmers.

सार

भारत दुनिया में फलों और सब्जियों के दूसरे सबसे बड़े उत्पादकों में से एक है और चीन के बाद 97.97 मिलियन टन फल और 183.17 मिलियन टन सब्जियों का उत्पादन करने वाला दूसरा सबसे बड़ा आबादी वाला देश है। भारत में 1.35 बिलियन आबादी में से 0.20 बिलियन से अधिक लोगों के लिए कृषि आजीविका का स्रोत है जो प्रत्यक्ष या अप्रत्यक्ष रूप से कृषि में शामिल हैं। हालाँकि, जब हम खाद्य हानि के बारे में बात करते हैं तो यह फलों के लिए 6.70% से 15.88% और सब्जियों के लिए 4.58% से 12.44% तक होता है, जो कुल आर्थिक नुकसान 441.43 बिलियन रुपये है। कोल्ड-चेन खेत-से-कांटे को जोड़ने के लिए एक नाली के रूप में कार्य करता है और इसे दूसरी हरित क्रांति का हिस्सा माना जाता है, यह सुनिश्चित करता है कि भोजन को उसके सर्वोत्तम रूप में देश के हर हिस्से तक पहुंचाया जाए, इसकी गुणवत्ता और पोषक मूल्य बनाए रखा जाए।

यह अध्ययन भारत में एक एकीकृत कोल्ड-चेन के प्रबंधन के लिए एक व्यापक फ्रेमवर्क विकसित करता है, एक कोल्ड-चेन उद्योग के लिए एंड-टू-एंड फूड वैल्यू चेन का अध्ययन करके, जो भारत में राज्यों में ताजा फल और सब्जियों का विकास और निर्यात कर रहा है। और विदेश में। अध्ययन नाशपाती उत्पादन / उत्पादों के लिए एकीकृत कोल्ड-चेन विकास के प्रबंधन के लिए एक रूपरेखा विकसित करने के लिए सॉफ्ट सिस्टम मथोडोलॉजी का उपयोग करता है। सॉफ्ट सिस्टम मथोडोलॉजी का उपयोग करना, यह स्पष्ट हो जाता है कि वास्तविक समय डेटा विश्लेषण के साथ एकीकृत आपूर्ति-मांग की योजना के साथ एक स्मार्ट आईटी प्रबंधन प्रणाली का कार्यान्वयन बेहतर पहुंच प्रदान कर सकता है और बाजार तक पहुंच बना सकता है।

जनसंख्या में वृद्धि के साथ पेरीशैबल्स के उत्पादन में वृद्धि मांग को प्रेरित करती है जिसके लिए पैक-हाउस, रीफर ट्रांसपोर्टेशन, कोल्ड स्टोरेज इत्यादि के संदर्भ में पर्याप्त कोल्ड-चेन सुविधाओं की आवश्यकता होती है, जिसका वर्तमान आवश्यकता के साथ बेहतर उपयोग किया जा सकता है। अध्ययन में नाशपाती उत्पादन / उत्पादों के सुरक्षित भंडारण और परिवहन के लिए एक संगतता मैट्रिक्स विकसित किया गया है। क्लस्टरिंग एनालिटिक्स दृष्टिकोण को उनके तापमान, सापेक्ष आर्द्रता, गंध और एथिलीन उत्पादन की समानता के आधार पर सुरक्षित भंडारण और परिवहन को सक्षम करने के लिए 43 विभिन्न फलों और सब्जियों पर विचार करके विकसित किया गया था।

परिणामों ने सात समूहों की पहचान की है जिसमें इन 43 फलों और सब्जियों को सुरक्षित परिवहन और वितरण के लिए वर्गीकृत किया जा सकता है। अध्ययन बहु-वस्तु भंडारण और हब और स्पोक मॉडल पर ध्यान केंद्रित करता है जो कोल्ड-चेन के विकास के लिए बहुत आवश्यक हैं।

अध्ययन आगे उत्पादन और वितरण योजना मॉडल का उपयोग करते हुए कृषि-आधारित पेरिशबल्स के लिए भंडारण आवश्यकताओं का विश्लेषण करता है। अध्ययन बढ़ती मांग को पूरा करने और उपलब्ध कोल्ड स्टोरेज इंफ्रास्ट्रक्चर का उपयोग करने के लिए वस्तुओं (इस मामले में आलू) के अंतर-राज्य व्यापार के लिए एक अवसर प्रदान करता है। यह अंतरराज्यीय परिवहन और राज्यों के बीच मजबूत संपर्क को बढ़ावा देने के लिए उठाए गए सरकारी हस्तक्षेपों के दौरान आने वाली जटिलताओं और बाधाओं के बारे में भी जानकारी प्रदान करता है। अध्ययन में स्टोरेज इंफ्रास्ट्रक्चर की खाई की पहचान की गई है जो बढ़ते उत्पादन और मांग परिदृश्य को देखते हुए भरने की जरूरत है। कोल्ड-चेन इंफ्रास्ट्रक्चर बनाम फूड अपव्यय के निर्माण के लिए लागत लाभ विश्लेषण पर भी चर्चा की गई है।

कोल्ड-चेन नेटवर्क और उचित बुनियादी ढांचे के विकास के माध्यम से किसानों को बाजार से जोड़ने के संदर्भ में समग्र दृष्टिकोण की आवश्यकता है ताकि यह सुनिश्चित किया जा सके कि भोजन सही समय पर, सही मात्रा में और कम से कम अपव्यय और नुकसान के साथ उपभोक्ताओं तक पहुंचाया जाए। इसे ध्यान में रखते हुए, अध्ययन एकीकृत शीत-श्रृंखला प्रबंधन के लिए महत्वपूर्ण सफलता कारक (CSF) की पहचान, विश्लेषण और सत्यापन करता है। CSF की पहचान करीबी इंटरैक्टिव मीटिंग्स के माध्यम से की जाती है और खाद्य मूल्य श्रृंखला में शामिल विभिन्न हितधारकों के साथ चर्चा की जाती है। इसके अलावा, प्याज मूल्य श्रृंखला में कीमतों में वृद्धि के लिए एक केस स्टडी का अध्ययन किया जाता है और महत्वपूर्ण निष्कर्षों को टीआईएसएम सीखने का उपयोग करके तैयार किया जाता है।

अध्ययन में किसानों की आर्थिक स्थिति में सुधार पर कोल्ड-चेन के प्रभाव का विश्लेषण किया गया है। अध्ययन साहित्य समीक्षा विश्लेषिकी और प्रौद्योगिकियों, नवाचारों, नीति-रूपरेखा आदि के संदर्भ में एकीकृत समाधान के माध्यम से एक एकीकृत कोल्ड-चेन विकास में सामना करने वाले मुद्दों के प्रबंधन के लिए रूपरेखा प्रदान करता है। अध्ययन में गड़बड़ी के आंदोलन के तकनीकी-

वित्तीय विश्लेषण के बारे में जानकारी प्रदान की गई है। खेत के अंत से ग्राहक के अंत तक उत्पादन। यह पोर्टर फाइव मॉडल के माध्यम से खरीदारों और आपूर्तिकर्ताओं के नए प्रवेशकों, नए स्थानापन्न और सौदेबाजी की शक्ति से संभावित खतरों पर आगे जानकारी देता है।

थीसिस शोध से प्राप्त निष्कर्षों के साथ समाप्त होती है, जो विशेष रूप से संबंधित अधिकारियों, नीति निर्माताओं, किसानों, किसान उत्पादक संगठनों, उद्योगों, शीत-श्रृंखला प्रबंधन में शामिल कंपनियों और सामान्य तौर पर काम करने वाले चिकित्सकों और शिक्षाविदों के लिए भी उपयोगी हो सकती है। खाद्य और कृषि क्षेत्र।

इसमें किसानों की आर्थिक स्थितियों में सुधार की दिशा में उठाए गए विभिन्न सरकारी हस्तक्षेपों और नीतिगत फैसलों के बारे में भी चर्चा की गई है। थीसिस प्रबंधकों द्वारा कोल्ड-चेन प्रबंधन के मुद्दे से निपटने के लिए मूल्यवान टिप्पणियों और अंतर्दृष्टि के साथ आया है। इसने कोल्ड-चेन विकास के मुद्दों से निपटने के लिए चिकित्सकों को रोडमैप भी प्रदान किया है और निर्णय निर्माताओं को यह सुनिश्चित करने में सक्षम बनाता है कि भोजन को उनकी गुणवत्ता और पोषक मूल्य को बनाए रखने के लिए सबसे अच्छी स्थिति में आबादी तक पहुंचाया जाए, जिससे किसानों की आर्थिक स्थिति में सुधार हो सके ।

कीवर्ड: कोल्ड-चेन प्रबंधन, खराब खाद्य उत्पाद, खाद्य मूल्य श्रृंखला, स्थिरता, पेरिहाबल्स के लिए क्लस्टरिंग एनालिटिक्स, भंडारण और परिवहन के लिए अनुकूलन मॉडल, आपूर्ति-योजना योजना, महत्वपूर्ण सफलता कारक, सॉफ्ट सिस्टम कार्यप्रणाली, किसानों की आर्थिक स्थिति में सुधार।

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LIST OF ABBREVIATIONS

\$	Dollar
%	Percentage
AHP	Analytic Hierarchy Process
APEDA	Agricultural & Processed Food Products Export Development Authority
APMC	Agricultural produce market committee
ASSOCHAM	Associated Chambers of Commerce and Industry of India
BOM	Bill of Material
CAPEX	Capital Expenditure
CATWOE	Customers – Actors – Transformation process – World view – Owners – Environmental constraints.
CFC	Chlorofluorocarbons
CfPFP	Cold-chain for perishable food products
CICEM	Cold Item Cost and Emission Model
CIPHET	Central Institute of Post-Harvest Engineering and Technology
CLU	change in land use
CO ₂	Carbon dioxide
CSF	Critical Success Factor
CTCT	Cape Town Container Terminal
EBITA	Earnings before interest, taxes, and amortization
ECB	External Commercial Borrowing
ES	Expert Systems
FLASP	Facility Layout Support Program
FMEA	failure-mode and effect-analysis
FPO	Farmer Producer Organization
FSSAI	Food Safety and Standards Authority of India
GDP	Gross Development Product
GDP	Gross Development Product
GJ	Gujarat
GoI	Government of India
GPRS	General Packet Radio Service
GPS	Global Positioning System
GST	Goods and Service Tax
GT	Group Technology
GTH	Graph-Theoretic Approach
HACCP	Hazard analysis and critical control points
HCFC	Hydrochlorofluorocarbons
HP	Himachal Pradesh
HR	Haryana
ICAR	The Indian Council of Agricultural Research
IDASM	Integrated Data Analysis and Stimulation Model
INR	Indian Rupees
ISM	Interpretive Structural Modelling
IT	Information Technology
J&K	Jammu and Kashmir
Kgs	Kilograms
KM	Knowledge Management
L	Liters
LAYSPLIT	Layout Split

LP Method	Linear Programming Method
MAFCO	Maharashtra Agro and Fruit Processing Corporation
MGARCH	Multivariate Autoregressive conditional heteroskedasticity
MICMAC	Matrices Impacts Croises Multiplication Appliquer Classement
MIDH	Mission for Integrated Development of Horticulture
M-Kisan	Mobile Kisan
MNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MNREGA	The Mahatma Gandhi National Rural Employment Guarantee Act
MoA & FW	Ministry of Agriculture & Farmers Welfare
MOFPI	Ministry of Food Processing & Industries
MPG	Machine Part Grouping
MPUs	Mango Processing Units
MT	Metric Ton
NABCONS	NABARD Consultancy Services
NCAER	National Council of Applied Economic Research
NCCD	National Centre for Cold-chain Development
NCDC	National Cooperative Development Corporation
NE	North-East
NEH	Nawaz–Enscore–Ham
NHB	National Horticulture Board
NMFP	Nagaland Forest Management Project
Nos.	Numbers
NPD	New Product Development
NSEL	National Stock Exchange Limited
NSSO	National Sample Survey Office Statistics
O ₂	Oxygen
O ₃	Ozone
°C	Degree Celsius
ODS	Ozone-depleting substances
ODS	Ozone-depleting substances
OEMs	Original Equipment Manufacturer
OM	Operation Management
OPEX	Operational Expenditure
PAT	Profit After Tax
PHC	Pre-Harvest Contractors
PIB	Press Information Bureau
PJ	Punjab
PnL	Profit & Loss
POS	Probability of Superiority
PPP	Public Private Partnerships
Qtl	Quintal
R&D	Research and Development
R, I, F, E, H, V, N	R-Room cool, I-Top iced cooling, F-Forced air cooling, E-Evaporative forced air cooling, H-Hydro-cooling, V-Vacuum cooling, N-No pre-cooling
RD	Root Definition
Reefer	Refrigerated
RFID	Radio-frequency identification
RH	Relative Humidity
RJ	Rajasthan
RKVY	Rashtriya Krishi Vikas Yojna

ROI	Return on Investment
Rs	Rupees
SEM	Structural Equation Modelling
SHG	Self Help Group
SMS	Short Message Service
SPSS	Statistical Package for the Social Sciences
SRC	Search Result Clustering
SSIM	Structural Self Interaction Matrix
SSM	Soft System Methodology
SSM	Soft System Methodology
TISM	Total Interpretive Structural Modelling
TOPSIS	The Technique for Order of Preference by Similarity to Ideal Solution
UK	Uttarakhand
UP	Uttar Pradesh
USA	United States of America
USD	United States Dollar
USDA	United States Department of Agriculture
UT	Union Territory
VAM	Vogel Approximation Method
VCA	Value Chain Analysis
VOC	Voice of Customers
VT/CA	Village Trader/Commission Agent
WALC	Weighted Average Linkage Clustering
WB	West Bengal