

**STUDY OF SELECT ISSUES IN ICT-ENABLED LEAN DAIRY
SUPPLY CHAIN**

UPENDRA KUMAR



**BHARTI SCHOOL OF TELECOMMUNICATION
TECHNOLOGY AND MANAGEMENT**

INDIAN INSTITUTE OF TECHNOLOGY DELHI

DECEMBER 2023

Indian Institute of Technology Delhi (IITD), New Delhi, 2023

Study of Select Issues in ICT-enabled Lean Dairy Supply Chain

by

UPENDRA KUMAR

Bharti School of Telecommunication Technology and Management

Submitted

In the fulfilment of the requirements for the degree of Doctor of Philosophy to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

DECEMBER 2023

This thesis is dedicated in the memory of my beloved father Late Shri Jagdish

Yadav

CERTIFICATE

This is to certify that the thesis entitled “**Study of Select Issues in ICT-enabled Lean Dairy Supply Chain**” being submitted by **Mr. Upendra Kumar** to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy (Ph.D.)**, is a record of bonafide 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 requisite standard required for 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.

(Prof. Ravi Shankar)

Research Supervisor

Department of Management Studies

Indian Institute of Technology Delhi

New Delhi- 110016

INDIA

ACKNOWLEDGEMENTS

I would like to begin by thanking the omnipotent God for giving me the necessary strength, patience, and endurance during my Ph.D. journey. Prior to anything else, I would like to express my deepest gratitude to my Ph.D. supervisor, Professor Ravi Shankar, for his continual supervision and follow-up, intensive scientific support, and inspiration during the whole of my doctoral studies. I will forever be thankful to him for the time and personal attention he has given me whenever I have needed it. Without his consistent assistance and unwavering support, the objective of this research would not have been attained. He has taught me not just technical competence, but also many other skills, like integrity, gratitude, influence, empathy, bravery, and respect.

I would like to extend my sincere thanks to the members of my Student Research Committee (SRC), comprising Professor P. Vigneswara Ilavarsan (Chairperson), Professor Arpan Kumar Kar (internal expert), and Professor Kumar Neeraj Jha (external expert) for giving valuable comments and insightful suggestions at various stages of this study.

I would like to thank my fellow research scholars and friends who have supported me in various ways during this journey. My sincere thanks to Dr. Veepan Kumar, Laxmi Gupta, Monica Shukla, Dr. Chandra Pal. Archana Roy, Ruchita, Dr. Tripti, Dr. Vinay Yadav, and Ujjwal Kumar.

I want to thank and show my sincere gratitude to my mother, Mrs. Chandramuni Yadav, and my brothers, Nemchand, Pushpendra Yadav, Anil Yadav, Sunil Yadav, and Ayush Yadav, for their continuous encouragement and support during my Ph.D. studies. I genuinely appreciate their love and unwavering support.

Upendra Kumar

Abstract

The dairy supply chain is an integral part of the global food system, with dairy products acting as a vital source of nutrition and income for millions of people throughout the globe. The worldwide dairy sector is valued at hundreds of billions of dollars and is expanding due to increased urbanization, rising income levels, and the expansion of the global middle class in many regions. Population growth, changing dietary patterns, and rising income levels in many countries are anticipated to continue to increase the demand for dairy products over the next few years.

In developing nations, the dairy business is expanding fast, creating new possibilities for dairy farmers, processors, retailers, and consumers. These nations are home to several of the world's greatest dairy-producing areas, and they are likely to play an increasingly significant role in satisfying future global demand for dairy products. In India, the dairy business is a significant economic contributor, employing and providing a livelihood for millions of people. The Indian dairy business is comprised of several small-scale farmers that produce milk for local use and sale to processors and merchants. India's dairy sector is one of the biggest in the world and is comprised of several small-scale farmers and cooperative dairies. The dairy supply chain in India is still in its infancy and faces several obstacles, including insufficient infrastructure, poor quality control, lack of suitable cold storage facilities, and lack of refrigerated transportation, among others, resulting in a considerable loss of dairy products.

The problems generally encountered in the Indian dairy industry are lack of infrastructural facilities for collection, storage, transportation, processing, etc. Procurement problems include a lower number of procurement centers or sub-standardized procurement centers, a lower number of processing centers or a lack of technology at processing units, and sub-standardized

transportation that results in wastage and spoilage. All of these issues combine to create quality concerns for the consumer, resulting in customer dissatisfaction and disengagement.

In order to minimize the different kinds of waste in the system, we need to focus on lean philosophy and should try to develop an ICT-enabled lean dairy supply chain. For this, we required investment in cold storage, refrigerated transportation, processing facilities, ICT-enabled infrastructure, training and education of all stakeholders, etc. If we consider research work related to the lean dairy supply chain with aspect of India. There are very limited research work available that focuses on an ICT-enabled lean dairy supply chain to minimize the different kinds of waste in the dairy supply chain and improve the productivity of the system, which further leads to the excellent quality of dairy products, provides better customer satisfaction, and provides a competitive advantage to the company. There is a need for research that focuses on the lean philosophy to minimize the different types of waste in the dairy supply chain. So, in this research work, we are trying to fill this gap in the literature.

This study identified and addressed various research gaps based on a review of the available literature. To comprehend the available uncertainty and different kinds of waste in the dairy supply chain of India, we first developed the conceptual model of an ICT-enabled lean dairy supply chain by the help of “soft system methodology (SSM)”. The outcome of this objective helps us to understand the issues faced by the different stakeholders that restrict the effective operation of the dairy supply chain. This objective helped us to lay the foundation for our next objectives. In the second objective, we developed the hierarchical model for the critical success factors of the ICT-enabled lean dairy supply chain by using “total interpretive structural modelling (TISM).” This model provides the interrelationship among the critical success factors. With the help of this model, we can identify which critical success factor is more important compared to

others, which leads to better decision making. In the third objective, we ranked the critical success factors by using “fuzzy evidential reasoning approach (FERA).” In the fourth objective, we analyzed the different sets of variables such as “actor vs process” and “action vs performance” for ICT-enabled lean dairy supply chain by using the integrated methods of “SAPLAP (situation, actor, process, learning, action, and performance)” and “eIRP (efficient interpretative ranking process)”. In the fifth objective, we took the case study of an Indian dairy firm and studied their flow of dairy products from source to consumer end by using “value stream mapping (VSM).” This objective helped us to understand the different kinds of activity in the dairy supply chain, such as “value-added activity,” “non-value-added activity,” and “non-value-added but essential activity,” which leads to the reduction of lead time by removing “non-value activity” from the dairy supply chain.

This research work contributes to the existing literature on the ICT-enabled lean dairy supply chain, gives management implications to practitioners, gives suggestions to decision-makers in the dairy industry, and captures advances in the field. The thesis serves as a road map for practitioners working with dairy supply chain system challenges, allowing decisionmakers to develop a lean system, improve the quality of dairy products, improve customer satisfaction, and provide competitive advantages. The limitations of the study and suggestions for further research are discussed.

सार

डेयरी आपूर्ति श्रृंखला वैश्विक खाद्य प्रणाली का एक अभिन्न अंग है, जिसमें डेयरी उत्पाद दुनिया भर में लाखों लोगों के लिए पोषण और आय के महत्वपूर्ण स्रोत के रूप में कार्य करते हैं। दुनिया भर में डेयरी क्षेत्र सैकड़ों अरबों डॉलर का है और बढ़ते शहरीकरण, आय के बढ़ते स्तर और कई क्षेत्रों में वैश्विक मध्यम वर्ग के विस्तार के कारण इसका विस्तार हो रहा है। जनसंख्या वृद्धि, बदलते आहार पैटर्न और कई देशों में आय के बढ़ते स्तर से अगले कुछ वर्षों में डेयरी उत्पादों की मांग में वृद्धि जारी रहने का अनुमान है।

विकासशील देशों में, डेयरी व्यवसाय तेजी से बढ़ रहा है, डेयरी किसानों, प्रोसेसर, खुदरा विक्रेताओं और उपभोक्ताओं के लिए नई संभावनाएं पैदा कर रहा है। ये देश दुनिया के कई सबसे बड़े डेयरी उत्पादक क्षेत्रों का घर हैं, और वे डेयरी उत्पादों के लिए भविष्य की वैश्विक मांग को पूरा करने में तेजी से महत्वपूर्ण भूमिका निभाने की संभावना रखते हैं। भारत में, डेयरी व्यवसाय एक महत्वपूर्ण आर्थिक योगदानकर्ता है, जो लाखों लोगों को रोजगार देता है और आजीविका प्रदान करता है। भारतीय डेयरी व्यवसाय में कई छोटे किसान शामिल हैं जो स्थानीय उपयोग और प्रोसेसर और व्यापारियों को बिक्री के लिए दूध का उत्पादन करते हैं। भारत का डेयरी क्षेत्र दुनिया में सबसे बड़ा है और इसमें कई छोटे पैमाने के किसान और सहकारी डेयरी शामिल हैं। भारत में डेयरी आपूर्ति श्रृंखला अभी भी अपनी प्रारंभिक अवस्था में है और कई बाधाओं का सामना कर रही है, जिसमें अपर्याप्त बुनियादी ढांचा, खराब गुणवत्ता नियंत्रण, उपयुक्त कोल्ड स्टोरेज सुविधाओं की कमी, और प्रशीतित परिवहन की कमी शामिल है, जिसके परिणामस्वरूप डेयरी उत्पादों का काफी नुकसान होता है।

भारतीय डेयरी उद्योग में आम तौर पर जिन समस्याओं का सामना करना पड़ता है, वे संग्रह, भंडारण, परिवहन और प्रसंस्करण आदि के लिए बुनियादी सुविधाओं की कमी हैं। खरीद की समस्याओं में खरीद

केंद्रों की कम संख्या या उप-मानकीकृत खरीद केंद्र, प्रसंस्करण केंद्रों की कम संख्या या प्रसंस्करण इकाइयों में प्रौद्योगिकी की कमी और उप-मानकीकृत परिवहन शामिल हैं जिसके परिणामस्वरूप बर्बादी और खराब हो जाती है। ये सभी मुद्दे उपभोक्ता के लिए गुणवत्ता की चिंता पैदा करने के लिए गठबंधन करते हैं, जिसके परिणामस्वरूप ग्राहक नाखुश और असंतुष्ट होते हैं।

सिस्टम में विभिन्न प्रकार के कचरे को कम करने के लिए हमें लीन दर्शन पर ध्यान देने की आवश्यकता है और आईसीटी-सक्षम लीन डेयरी आपूर्ति श्रृंखला विकसित करने का प्रयास करना चाहिए। इसके लिए हमें कोल्ड स्टोरेज, रेफ्रिजरेटेड ट्रांसपोर्टेशन, प्रोसेसिंग सुविधाओं, आईसीटी-सक्षम इंफ्रास्ट्रक्चर, सभी हितधारकों के प्रशिक्षण और शिक्षा आदि में निवेश की आवश्यकता थी। अगर हम भारत के लीन डेयरी आपूर्ति श्रृंखला पहलू से संबंधित शोध कार्य पर विचार करें। बहुत सीमित अनुसंधान कार्य उपलब्ध हैं जो डेयरी आपूर्ति श्रृंखला से विभिन्न प्रकार के कचरे को कम करने और सिस्टम की उत्पादकता में सुधार करने के लिए आईसीटी-सक्षम लीन डेयरी आपूर्ति श्रृंखला पर केंद्रित हैं। जो आगे डेयरी उत्पादों की उत्कृष्ट गुणवत्ता की ओर ले जाता है, बेहतर ग्राहक संतुष्टि प्रदान करता है, और कंपनी को प्रतिस्पर्धात्मक लाभ प्रदान करता है। डेयरी आपूर्ति श्रृंखला से विभिन्न प्रकार के कचरे को कम करने के लिए शोध की आवश्यकता है जो लीन दर्शन पर केंद्रित है। अतः इस शोध कार्य में हम साहित्य में इस कमी को पूरा करने का प्रयास कर रहे हैं।

इस अध्ययन ने उपलब्ध साहित्य की समीक्षा के आधार पर विभिन्न शोध अंतरालों की पहचान की और उन्हें संबोधित किया। भारत की डेयरी आपूर्ति श्रृंखला में उपलब्ध अनिश्चितता और विभिन्न प्रकार के कचरे को समझने के लिए, सबसे पहले "सॉफ्ट सिस्टम मेथडोलॉजी (एसएसएम)" की मदद से आईसीटी-सक्षम लीन डेयरी आपूर्ति श्रृंखला का वैचारिक मॉडल विकसित किया। इस उद्देश्य के परिणाम हमें विभिन्न हितधारकों के सामने आने वाले मुद्दों को समझने में मदद करते हैं, जो डेयरी आपूर्ति श्रृंखला के प्रभावी संचालन को प्रतिबंधित करते हैं। इस उद्देश्य ने हमें अपने अगले उद्देश्यों के लिए आधार तैयार करने में मदद

की। दूसरे उद्देश्य में हमने "टोटल इंटरप्रिटिव स्ट्रक्चरल मॉडलिंग (टी आई एस एम)" का उपयोग करके आईसीटी-सक्षम लीन डेयरी आपूर्ति श्रृंखला के महत्वपूर्ण सफलता कारकों के लिए पदानुक्रमित मॉडल विकसित किया। यह मॉडल महत्वपूर्ण सफलता कारकों के बीच अंतर्संबंध प्रदान करता है। इस मॉडल की मदद से हम यह पहचान सकते हैं कि दूसरों की तुलना में कौन सा महत्वपूर्ण सफलता कारक अधिक महत्वपूर्ण है, जो बेहतर निर्णय लेने की ओर ले जाता है। तीसरे उद्देश्य में हमने "फ़ज़ी एविडेंसियल रीजनिंग एप्रोच (फेरा)" का उपयोग करके महत्वपूर्ण सफलता कारकों को रैंक किया। चौथे उद्देश्य में हमने आईसीटी-सक्षम लीन डेयरी आपूर्ति श्रृंखला के लिए "एसएपीएलएपी (स्थिति, अभिनेता, प्रक्रिया, सीखने, क्रिया, और प्रदर्शन)" और "ईआईआरपी (कुशल व्याख्यात्मक रैंकिंग प्रक्रिया)" की एकीकृत पद्धति का उपयोग करके "अभिनेता बनाम प्रक्रिया" और "कार्य बनाम प्रदर्शन" जैसे चर के विभिन्न सेट का विश्लेषण किया। पांचवें उद्देश्य में हमने एक भारतीय डेयरी फर्म का केस स्टडी लिया और "वैल्यू स्ट्रीम मैपिंग (वीएसएम)" का उपयोग करके स्रोत से लेकर उपभोक्ता तक उनके डेयरी उत्पाद के प्रवाह का अध्ययन किया। इस उद्देश्य ने हमें डेयरी आपूर्ति श्रृंखला में विभिन्न प्रकार की गतिविधि जैसे "मूल्य वर्धित गतिविधि", "गैर-मूल्य वर्धित गतिविधि", और "गैर-मूल्य वर्धित लेकिन आवश्यक गतिविधि" को समझने में मदद की। जिससे डेयरी आपूर्ति श्रृंखला से "गैर-मूल्य गतिविधि" को हटाकर लीड टाइम में कमी आती है।

यह शोध कार्य आईसीटी-सक्षम लीन डेयरी आपूर्ति श्रृंखला पर मौजूदा साहित्य में योगदान देता है और प्रबंधन के निहितार्थ प्रदान करता है व्यवसायियों और डेयरी उद्योग में निर्णय लेने वाले को सुझाव देता है और क्षेत्र में प्रगति हासिल करता है। थीसिस डेयरी आपूर्ति श्रृंखला प्रणाली की कठिनाइयों से निपटने वाले निर्णय निर्माताओं के लिए एक रोड मैप प्रदान करती है, जो निर्णयकर्ताओं को एक लीन प्रणाली स्थापित करने, डेयरी उत्पाद की गुणवत्ता बढ़ाने, ग्राहकों की खुशी बढ़ाने और प्रतिस्पर्धी लाभ देने में सक्षम बनाती है। अध्ययन की सीमाओं और आगे के शोध के लिए सुझावों पर चर्चा की गई है।

TABLE OF CONTENTS

	Page
CERTIFICATE.....	v
ACKNOWLEDGEMENT.....	vi
ABSTRACT.....	vii
TABLE OF CONTENTS.....	xiii
LIST OF FIGURES.....	xxii
LIST OF TABLES.....	xxiv
LIST OF ABBREVIATIONS.....	xxvi
CHAPTER 1: INTRODUCTION.....	1
1.1 Introduction.....	1
1.2 Research motivation.....	3
1.3 Concept of supply chain.....	4
1.4 Dairy supply chain.....	5
1.5 Problems and challenges in Indian dairy industry.....	9
1.6 Research gaps identified from literature review.....	10
1.7 Research questions.....	11
1.8 Research objectives.....	12
1.9 Research methodology.....	12

1.10	Organization of the thesis.....	15
1.11	Chapter summary.....	16
CHAPTER 2: LITERATURE REVIEWS.....		17
2.1	Introduction.....	17
2.2	Systematic literature review (SLR) analysis of dairy supply chain.....	18
2.2.1	Collection of the research articles.....	18
2.2.2	Refinement of the selected research articles.....	19
2.2.3	Descriptive analysis for bibliographic details.....	20
2.2.4	Selection of categories.....	20
2.2.5	Categorical analysis of the selected articles.....	20
2.2.6	Results and conclusions.....	21
2.3	Findings based on descriptive analysis of dairy supply chain.....	21
2.3.1	Year-wise publication trends of dairy supply chain articles.....	21
2.3.2	Journal wise distribution of research papers.....	22
2.3.3	Author wise distribution of research articles.....	23
2.3.4	Country wise distribution of research articles.....	24
2.4	Review of literature for dairy supply chain and lean supply chain.....	25
2.4.1	Review of literature related for dairy supply chain.....	25

2.4.2 Review of literature for lean supply chain.....	31
2.4.3 Review of literature related for ICT-enabled lean dairy supply chain.....	37
2.5 Research gaps.....	39
2.6 Chapter summary.....	40
CHAPTER 3: CONCEPTUAL MODELING OF ICT-ENABLED LEAN DAIRY SUPPLY CHAIN: SOFT SYSTEM METHODOLOGY.....	42
3.1 Introduction.....	42
3.2 Soft system methodology (SSM).....	45
3.3 Major issues in dairy supply chain.....	47
3.3.1 Lack of cold storage facility.....	48
3.3.2 Lack of refrigerated transportation system.....	48
3.3.3 Lack of ICT Infrastructure.....	48
3.3.4 Lack of autonomous system.....	49
3.3.5 Lack of quality management capability.....	49
3.3.6 Lack of skilled workers.....	50
3.4 Application of SSM for dairy supply chain: Indian perspective.....	50
3.4.1 Developing symptoms map.....	51
3.4.2 Problem situation expressed.....	52
3.4.3 Developing root definition.....	55

3.4.4 CATWOE formulation.....	55
3.4.5 Development of conceptual model.....	58
3.4.6 Development of the final implementable model.....	62
3.5 Discussion and managerial implications.....	63
3.5.1 Contribution for literature.....	63
3.5.2 Implications for practice.....	65
3.6 Chapter summary.....	65

CHAPTER 4: HIERARCHICAL MODELING OF CRITICAL SUCCESS FACTORS OF THE ICT-ENABLED LEAN DAIRY SUPPLY CHAIN: AN INTEGRATED APPROACH OF EFA AND TISM.....68

4.1 Introduction.....	68
4.2 Identification of critical success factors.....	73
4.3 Research methodology & framework.....	77
4.3.1 Framework of the present research.....	77
4.3.2 Identification of success factors for ICT-enabled lean dairy supply chain...	77
4.3.3 Methodology.....	77
4.3.3.1 Exploratory factor analysis.....	78
4.3.3.2 Formation of questionnaires.....	78
4.3.3.3 Administration and supervision of questionnaire.....	78

4.3.3.4 Total interpretive structural modelling.....	79
4.4 Exploratory factor analysis.....	82
4.5 Modelling CSFs of ICT-enabled lean DSC.....	84
4.5.1 Validation of the TISM.....	90
4.5.2 Classification of CSFs using the MICMAC algorithm.....	95
4.6 Result and discussion.....	96
4.6.1 Exploratory factor analysis results.....	96
4.6.2 Total interpretive structural modelling results.....	97
4.6.3 MICMAC analysis results.....	98
4.7 Managerial implications.....	99
4.8 Chapter summary.....	100
CHAPTER 5: RANKING OF THE CRITICAL SUCCESS FACTORS OF ICT-ENABLED LEAN DAIRY SUPPLY CHAIN: FUZZY EVIDENTIAL REASONING APPROACH.....	101
5.1 Introduction.....	101
5.2 Role of economic, operational, and social criteria in an ICT-enabled lean dairy supply chain for the evidential reasoning approach.....	105
5.2.1 Role of economic criterion in ICT-enabled lean dairy supply chain.....	106
5.2.2 Role of operational criterion in ICT-enabled lean dairy supply chain.....	106
5.2.3 Role of social criterion in ICT-enabled lean dairy supply chain.....	108

5.3 Methodology.....	108
5.3.1 Identify the CSFs for ICT-enabled lean dairy supply chain.....	110
5.3.2 Implement the fuzzy analytical hierarchy process.....	112
5.3.2.1 Procedure for FAHP algorithm.....	112
5.3.2.2 Formulate the fuzzy pair-wise comparison matrix.....	113
5.3.3 Application of fuzzy belief degree to measure the effectiveness of CSFs...115	
5.3.3.1 Application of the belief degrees.....	115
5.3.3.2 Linguistics variables for CSFs.....	116
5.3.4 Implementation of evidential reasoning algorithm.....	118
5.3.5 Determining the crisp value of the ICT-enabled lean dairy supply chain using the expected utility approach.....	122
5.4 Application of the proposed algorithm.....	123
5.4.1 Identifying CSFs of ICT-enabled lean dairy supply chain.....	124
5.4.2 Implementation of fuzzy analytical hierarchy process.....	128
5.4.3 Linguistics variables and belief degrees.....	130
5.4.4 Evidential reasoning algorithm.....	130
5.4.5 Expected utility approach.....	133
5.4.6 Results and discussion.....	133
5.4.7 Sensitivity Analysis.....	141
5.5 Managerial implications.....	143

5.6 Chapter summary.....	145
CHAPTER 6: AN ANALYSIS OF DIFFERENT SETS OF VARIABLES IN THE ICT-ENABLED LEAN DAIRY SUPPLY CHAIN IN INDIA BY USING THE SAP-LAP AND E-IRP APPROACH.....	146
6.1 Introduction.....	146
6.2 Research methodology.....	151
6.2.1 SAPLAP methodology.....	154
6.2.2 Efficient – interpretive ranking process.....	155
6.2.3 Steps for integrating SAPLAP and eIRP approach.....	157
6.3 Application of the proposed methodology.....	157
6.4 Discussion of the results.....	160
6.4.1 Actor with respect to processes.....	160
6.4.2 Action with respect to performances.....	163
6.5 Theoretical implications.....	166
6.6 Managerial implications and insights.....	167
6.7 Chapter summary.....	168
CHAPTER 7: APPLICATION OF VALUE STREAM MAPPING FOR LEAN OPERATION: A CASE STUDY OF AN INDIAN DAIRY FIRM.....	170

7.1 Introduction.....	170
7.2 Value stream map.....	174
7.3 Research methodology.....	181
7.4 Result and discussion.....	187
7.4.1 Data collection and analysis.....	188
7.4.2 Creation of the current state map.....	189
7.4.3 Future state improvement suggested.....	189
7.4.4 Creation of a future state map.....	190
7.4.5 Comparative assessment of each process’s current and future states.....	191
7.4.6 Reduction of lead time.....	192
7.5 Managerial implication.....	193
7.6 Chapter summary.....	194
CHAPTER 8: RESEARCH SUMMARY AND CONCLUSIONS.....	195
8.1 Introduction.....	195
8.2 Summary of research findings.....	199
8.3 Significant research contributions.....	205
8.3.1 Theoretical implications of the research.....	205
8.3.2 Managerial implications of the research.....	207

8.4 Limitations of the research.....	208
8.5 Future scope of the research.....	209
REFERENCES.....	210
APPENDIX.....	244
APPENDIX A Cover letter to participants about the research study.....	244
APPENDIX B Interpretive matrix for TISM.....	245
APPENDIX C Questionnaire design for FERA model.....	248
APPENDIX D Dominance relation for efficient-interpretive ranking process for ICT-enabled lean dairy supply chain.....	252

LIST OF FIGURES

Figure	Title	Page
Figure 1.1:	Research design.....	14
Figure 2.1:	Publishing trend in the area of dairy supply chain.....	21
Figure 3.1:	Checklands’s seven stage overview of the SSM.....	46
Figure 3.2:	Flowchart for adopting SSM.....	51
Figure 3.3:	Dairy supply chain in India with dairy product, information, and cash flow.....	53
Figure 3.4:	Symptom map.....	53
Figure 3.5:	Rich picture.....	54
Figure 3.6:	Alternative root definitions.....	60
Figure 3.7:	Conceptual model.....	61
Figure 3.8:	Final implementable model.....	63
Figure 4.1:	The proposed study flow in above diagram.....	81
Figure 4.2	TISM for critical success factors for ICT-enabled lean dairy supply chain.....	89
Figure 4.3	TISM for critical success factors of ICT-enabled lean dairy supply chain.....	94
Figure 4.4:	MICMAC analysis.....	96
Figure 5.1:	Flow diagram for prioritization of the CSFs.....	111
Figure 5.2:	The triplet (l, m, u) represents the lowest, middle, and upper weights of triangular fuzzy numbers.....	116

Figure 5.3: Triangular fuzzy members for five linguistics variables such as very high (VH), high (H), medium (M), low (L), and very low (VL).....	117
Figure 5.4: Framework of various category, critical success factors, and criteria.....	125
Figure 5.5: Example of turning TFNs into five non-normalized linguistics variables.....	133
Figure 5.6: The overall ranking of sixteen critical success factor of ICT-enabled lean dairy supply chain.....	137
Figure 5.7: Pie-chart representation for the normalized percentage value of sixteen CSFs.....	140
Figure 5.8: 3D representation for sensitivity analysis of output model of sixteen CSFs.....	142
Figure 5.9: 2D representation for sensitivity analysis of output model of sixteen CSFs.....	142
Figure 5.10: Radar chart for sensitivity analysis of output model of sixteen CSFs.....	143
Figure 6.1: Integration of SAPLAP and eIRP method.....	153
Figure 6.2: The process flow for integrating SAPLAP and eIRP to prioritise actors and actions in the lean dairy supply chain.....	159
Figure 7.1: Diagram of DSC in India.....	173
Figure 7.2: Flow chart of methodology.....	182
Figure 7.3: Current state map (CSM) of dairy supply chain.....	185
Figure 7.4: Future state map (FSM) of dairy supply chain.....	186

LIST OF TABLES

Table	Title	Page
Table 2.1:	Top twenty journal of publishing literature on dairy supply chain.....	22
Table 2.2	Authors wise distribution of the research papers.....	23
Table 2.3	Country-wise distribution of dairy supply chain research articles.....	24
Table 3.1:	Dairy supply chain issues.....	57
Table 3.2:	CATWOE analysis for dairy supply chain of India.....	58
Table 4.1:	Critical success factor for lean dairy supply chain.....	74
Table 4.2:	EFA for 18 critical success factors.....	83
Table 4.3:	EFA for 16 critical success factors.....	84
Table 4.4:	Final reachability matrix.....	86
Table 4.5:	Partitioning the matrix of reachability.....	87
Table 4.6	Results of the hypothesis testing of CSFs of ICT-enabled lean DSC.....	91
Table 5.1:	Definition of the linguistic variable used for prioritizing the CSFs.....	113
Table 5.2:	Value of RI versus matrix order.....	115
Table 5.3:	Linguistic terms with fuzzy values and notations.....	118
Table 5.4:	CSFs for ICT-enabled lean dairy supply chain and its explanation.....	126
Table 5.5:	Expert’s Opinion linguistics variables used for ranking of CSFs.....	131
Table 5.6:	Average of expert’s opinion and belief degrees.....	132
Table 5.7:	Normalized TFNs for third CSF.....	133

Table 5.8: Calculation of assessment value of a CSF.....	135
Table 5.9: Individual ranking of each CSF under various criteria.....	136
Table 5.10: The overall ranking of CSFs and their normalized value.....	139
Table 6.1: Identification of different set of variables of ICT-enabled lean dairy supply chain.....	150
Table 6.2: Development of CIM for actors with respect to process.....	161
Table 6.3: Development of interpretive matrix for actors with respect to processes.....	161
Table 6.4: Dominance relation analysis of actors with respect to processes.....	162
Table 6.5: Dominance matrix ranking of actors with respect to processes.....	163
Table 6.6: Development of CIM of action with respect to performance.....	164
Table 6.7: Development of interpretive matrix for actions with respect to performance.....	165
Table 6.8: Dominance relation analysis of actions with respect to performance.....	165
Table 6.9: Prioritization of action based on DI value.....	166
Table 7.1: Parameter comparisons between the current and future state map.....	190
Table 7.2: Time associated with pasteurizer tank, separator tank, and filling tank.....	191
Table 7.3: Time associated with the waiting time activity at cold storage room.....	192
Table 8.1 Mapping of research questions and objectives to research method.....	198

LIST OF ABBREVIATIONS

BNA	Best non fuzzy assessment
CATWOE	Customer actor transformation worldview owner environment
CSFs	Critical success factors
CSM	Current state map
DSC	Dairy supply chain
DM	decision making
eIRP	Efficient Interpretative Ranking Process
EDI	Electronic data interchange
ERP	Enterprise resource planning
ERA	Evidential reasoning approach
EUT	Expected utility theory
FAHP	Fuzzy analytical hierarchy process
FAO	Food and agriculture organization
FERA	Fuzzy evidential reasoning approach
FSC	Food supply chain
FSM	Future state map
FST	Fuzzy set theory

GPS	Global positioning system
ICT	Information, communication, and technology
IDS	Intelligent decision system
IoT	Internet of things
LM	Lean manufacturing
LSC	Lean supply chain
MCDM	Multi-criteria decision making
MICMAC	Matrice d'impacts croisés multiplication appliquée à un classement
MRP	Material resource planning
NVA	Non-value-added
NVAE	Non-value-added but essential
RFID	Radio frequency identification device
SAPLAP	Situation, actor, process, learning, action, performance
SPSS	Statistical package for social sciences
SCM	Supply chain management
SCs	Supply chains
SCVSM	Supply chain value stream mapping
SEM	Structural equation modelling

SM	System map
SME	Small and medium-sized enterprises
SSM	Soft system methodology
TFNs	Triangular fuzzy numbers
TOPSIS	Order preference by similarity to ideal solution
TISM	Total interpretive structural modelling
VA	value added
VSM	Value stream mapping