

**A RISK MANAGEMENT FRAMEWORK FOR
CONSTRUCTION PROJECTS ALIGNED TO
ACTUALITIES**

RATNESH KUMAR



**DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI**

JULY 2020

©Indian Institute of Technology Delhi (IITD), New Delhi, 2020

**A RISK MANAGEMENT FRAMEWORK FOR
CONSTRUCTION PROJECTS ALIGNED TO
ACTUALITIES**

by

RATNESH KUMAR

Department of Civil Engineering

Submitted

In fulfillment of the requirements of the degree of Doctor of Philosophy

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

JULY 2020

Dedicated to

Didi,

Durva and Magda

CERTIFICATE

This is to certify that the thesis entitled “**A Risk Management Framework for Construction Projects Aligned to Actualities**”, being submitted by **Mr. Ratnesh Kumar** to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy** is a bonafide record of the research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the requisite standard, fulfilling the requirements for the degree of Doctor of Philosophy.

The contents of this thesis, in full or in parts, have not been submitted to any other University or Institute for the award of any degree or diploma.

Prof. Surya Prakash Singh
Department of Management Studies
Indian Institute of Technology Delhi
New Delhi, 110016
India

Prof. K. Chandrashekhhar Iyer
Department of Civil Engineering
Indian Institute of Technology Delhi
New Delhi, 110016
India

ACKNOWLEDGMENTS

I humbly express my sincere appreciation to everyone who helped me to reach this stage. I am also conscious that my words of acknowledgment would be inadequate in recognizing everyone's effort, however, I must mention a few.

I would like to extend my sincere gratitude to my guides, Prof. K. C. Iyer, Department of Civil Engineering, and Prof. S. P. Singh, Department of Management Studies, IIT Delhi for their constant support, guidance and cooperation at every stage of this research. Working under their supervision has been a highly educative and memorable experience.

I am thankful to my student research committee members, Prof. Rakesh Khosa and Dr. Uma Maheswari, Department of Civil Engineering; and Prof. S. S. Yadav, Department of Management Studies, IIT Delhi for providing their valuable inputs throughout my study. I also thank the two anonymous thesis examiners for their valuable feedback and suggestions.

I am also grateful to the members of the R&D Committee and other executives of NBCC (India) Ltd. for their full support during the Sponsored research project titled '*Identification, Evaluation and Strategic Management of Risks in Infrastructure Projects in India (RP02737)*'. I also acknowledge the support of the Industrial Research & Development Unit, IIT Delhi during this research project, which forms a significant part of this thesis.

I take this opportunity to extend my sincere thanks to other faculty members of IIT Delhi with whom I interacted occasionally. I also thank all the staff members of

the Department of Civil Engineering, IIT Delhi, especially Mr. Randheer Kumar Jha, Mr. Rajeev Aggarwal, and Mr. Jeet Ram for all possible help in administrative work.

I cannot forget to thank three esteemed researchers whose brief but timely suggestions helped in shaping my research - Prof. Ashwin Mahalingam (IIT Madras) for suggesting literature on case study research; Prof. Will Hughes (during ARCOM 2017 Conference) for emphasis on aligning the research to actualities and project data; and Prof. Pablo Ballesteros-Pérez (Editor, Construction Management and Economics) for handholding me through review and editorial process of my first journal paper. Some critical inputs about scarcity of project data also came from Mr. Craig Ferri, Managing Director at Palisade EMEA & Asia Pacific.

I thank my colleagues and friends, Neha Bhatia, Dr. Abhilasha Panwar, Padala Sreenivas, Yogita Mananbindal, Soumya Jain, Nivea Thomas, Aritra, Santu Kar, Ravindra, Shurti Sharma, Dr. Partha Sarthi, Dr. Satish, and Dr. Purva Muzumdar, with whom I have spent a lot of time. I am deeply grateful to Sparsh Johari who I always high jacked to discuss my doubts and proofread my manuscripts.

On the personal side, I extend my deepest gratitude to my parents, Lila Gupta and Om Prakash Gupta, for their quiet but constant support, encouragement and love. Last but most importantly, I owe lifelong debts to my pen pals Magdalena Mazur and Jaroslaw Mazur from Poland who have been my kindred souls over last three years. And there are two friends who I owe gratitude beyond words, for consoling, inspiring, and making me smile even in my toughest days - Saloni Jain and Durva Gupta.

Ratnesh Kumar

ABSTRACT

In the construction industry, changing legal environment and higher complexity of projects are exposing organizations and projects to higher risks. Simultaneously, there has been significant growth of literature on risk assessment tools and risk management frameworks. However, the industry shows low adoption of these tools and frameworks. A major reason for this low adoption is that the knowledge on risk management is largely founded on opinions of practitioners, without adequate attention to actual industry practices and factual project details. Such paradigm has created a gap between research and practice on risk management. This gap also has significant implications such as inability of risk models to provide cost implications of risks, and inability to provide prescriptive risk mitigation measures at project-level. Therefore, this thesis is set in the premise that existing knowledge on risk management needs to be augmented with research aligned to the actualities of construction projects to make research more useful. ‘Actualities of construction’ signifies observations grounded in industry practices and factual details instead of exclusive reliance on subjective opinions of practitioners.

The goal of the research is to develop a Project-level Risk Management Framework (PRMF) that identifies, evaluates, and suggests mitigation measures for risks in construction projects. To achieve this goal, four project objectives of ‘risk identification’, ‘risk assessment’, ‘investigation of risk interdependence’, and ‘development of PRMF’ were defined.

To align the goal of the research with the actualities of construction projects, the research has undertaken inductive inquiries. In inductive inquiry, research methods are gradually guided by the observations from data. Various sources of factual project data and actual industry practices that could be used for risk management research were explored. Then, three research approaches were adopted—content analysis of claim documents to analyze risks from past projects, case study of ongoing projects to analyze risks in present projects, and opinion-survey among experts to analyze risks in anticipated future projects. Together, these three approaches provided a unique coverage on risks from past, present, and future projects as well as methodological diversity. For the first two objectives, viz. risk

identification and risk assessment, in all three research approaches were used in parallel. Subsequently, their findings were consolidated for analysis in the third and fourth objectives.

In the opinion survey approach, a questionnaire survey was done with 32 internal and 22 external risks to identify critical risks. The questionnaire measured ‘likelihood of occurrence’, and ‘degree of impact’ on four project objectives of Time, Cost, Scope, and Quality. Critical risks were shortlisted corresponding to ‘moderate likelihood and moderate impact’ resulting in 22 internal risks and 12 external risks. Relative priorities assigned by different stakeholders to four project objectives and trends of risk assessment under these project objectives were also analyzed revealing valuable insights.

The case study research covered in-depth investigation of risk management in nine ongoing projects located across India. For each project, a case study report was prepared by analyzing data from four sources; viz. project documents as primary source, interviews of site executives for undocumented information, site photographs as direct observations, and archival records. These nine case studies provided valuable observations and insights about risk management practices for formulating PRMF. A unique opportunity of two very similar case projects with different contractors helped in exploring the role of contractors in risk management at the project-level.

The content analysis research was conceptualized on the integration of literature on risk management and claim management, which revealed a causal relationship between risks and claims. Potential of this relationship was demonstrated by developing a Claim-based Risk Assessment Model (C-RAM) using techniques of content analysis over 28 settled arbitration case awards. Research findings revealed new parameters to quantify patterns of occurrences of risks, and their cost implications as fractions of contract sums.

Subsequently, the critical risks from the three research approaches were compared which revealed that critical risks from past, present, and anticipated future projects converge and exhibit perpetual nature. Further, interdependence among risks was analyzed using a second-round questionnaire on 21 consolidated critical risks using techniques of Cross Impact Matrix-Matrix Multiplication, and Interpretive Structural Modelling. These analyses provided a better understanding of driving,

dependent, and hierarchical structure of risks in a project. These observations were triangulated with the findings of case study and content analysis research to develop a ‘strategic plan for risk management in projects’.

Finally, the findings from all three approaches and existing literature were integrated to develop the PRMF and its three core components, viz. Risk Information Database, Risk register, and Risk Treatment Plan. Two additional components; viz. Vulnerability assessment and Heuristic model for scenario analysis of cash flow were developed to make PRMF comprehensive and more useful for the industry.

Apart from the PRMF, the research contributes three significant theories to the body of knowledge. *First*, an elevated understanding of the role of contractors in risk management highlights that contractors are decisive factors differentiating the success or failure of a project. Risks both to a project and its contractors, should be considered in risk management. *Second*, risk and claims have a causal relationship, and claims can be visualized as cost implications of unmitigated risks in a project. This relationship will encourage an integration of risk management and claim management. *Third*, critical risks in construction projects are perpetual in nature. Hence alongside criticality, interdependence among risks should also be considered for developing a risk management framework.

Overall, the thesis initiates a new paradigm in risk management research by demonstrating research methods aligning to the actualities of construction. It can be a milestone in bridging the gap between risk management research and practice.

Keywords: Case study, claim management, content analysis, contractor capability, cost implications of risks, risk assessment, risk interdependence, risk management, risk management framework, risk treatment plan.

सार

निर्माण उद्योग के विधिक माहौल में परिवर्तन तथा परियोजनाओं की उच्च जटिलता, परियोजनाओं तथा संगठनों के लिए अधिक जोखिम ला रही है। इसी दौरान जोखिम मूल्यांकन के उपकरणों और जोखिम प्रबंधन ढाँचे के अनुसंधान साहित्य की महत्वपूर्ण वृद्धि हुई है। तथापि, इन उपकरणों और ढाँचों का प्रयोग निर्माण उद्योग में काफी कम हुआ है। इस प्रवृत्ति का एक प्रमुख कारण यह है कि जोखिम प्रबंधन के अधिकतर ज्ञान का आधार काफी हद तक निर्माण उद्योग के पेशेवरों की व्यक्तिपरक राय पर आधारित है, और वास्तविक उद्योग पद्धतियों और परियोजनाओं संबंधी तथ्यात्मक विवरणों की ओर काफी कम ध्यान दिया गया है। इस तरह की प्रवृत्ति ने जोखिम प्रबंधन के अनुसंधान और अभ्यास के बीच एक दूरी बना दी है। इस दूरी के महत्वपूर्ण निहितार्थ हैं, जैसे कि— जोखिम मॉडल की जोखिम के लागत संबंधी अनुमान में अक्षमता, और प्रोजेक्ट—स्तर पर जोखिम कम करने के उपाय निर्धारित करने में असमर्थता। इसलिए इस शोध को इस प्रसंग पर निर्धारित किया गया है कि जोखिम प्रबंधन संबंधी वर्तमान ज्ञान को निर्माण की 'वास्तविकता के अनुरूप' ढालकर, अनुसंधान को और अधिक उपयोगी बनाने की आवश्यकता है। 'निर्माण की वास्तविकता' केवल विशेषज्ञों के व्यक्तिपरक मत पर निर्भर रहने के बजाय, उद्योग के तरीकों और तथ्यात्मक विवरणों पर आधारित अनुसंधान को दर्शाती है।

इस अनुसंधान का लक्ष्य परियोजना स्तर के लिए एक ऐसे जोखिम प्रबंधन ढाँचा (पी.आर.एम.एफ.) को विकसित करना है, जो निर्माण परियोजनाओं में जोखिमों के मूल्यांकन, अनुमान, और समन के लिए सुझाव दे सके। इस लक्ष्य को हासिल करने के लिए चार अनुसंधान उद्देश्यों को परिभाषित किया गया— जोखिम पहचान, जोखिम मूल्यांकन, जोखिम के आपसी संबंधों का विश्लेषण, और 'पी.आर.एम.एफ.' का विकास।

अनुसंधान के लक्ष्य को निर्माण परियोजनाओं की वास्तविकता के अनुरूप ढालने के लिए यह अनुसंधान आगमनात्मक जांच पर आधारित है। आगमनात्मक जांच में अनुसंधान विधियों को क्रमशः आंकड़ों के प्रेक्षण द्वारा निर्देशित किया जाता है। जोखिम प्रबंधन अनुसंधान में इस्तेमाल की जा सकने वाली परियोजना के तथ्यात्मक आंकड़ों और वास्तविक उद्योग पद्धतियों के विभिन्न स्रोतों का पता लगाया गया। इसके बाद तीन सम्मिलित अनुसंधान पद्धतियों को अपनाया गया। जैसे कि— भूतकालिक परियोजनाओं के जोखिमों का विश्लेषण करने के लिए दावा (claim) दस्तावेजों का विषयवस्तु विश्लेषण (content analysis), वर्तमान परियोजनाओं में जोखिमों का विश्लेषण करने के लिए चल रही परियोजनाओं के मामले का अध्ययन (case study), और विशेषज्ञों के बीच भावी

परियोजनाओं में जोखिमों का विश्लेषण करने के लिए राय सर्वेक्षण। इन तीन तरीकों से भूत, वर्तमान और भविष्य की परियोजनाओं से जोखिमों की जानकारी का एक अभूतपूर्व संगम प्राप्त हुआ, और इसके साथ ही पद्धतिगत विविधता भी प्राप्त हुई। पहले दो उद्देश्य में शामिल जोखिम पहचान और जोखिम मूल्यांकन के लिए तीनों अनुसंधान दृष्टिकोणों को समानान्तर रूप से प्रयोग किया गया। बाद में, उनके निष्कर्षों को तीसरे तथा चौथे उद्देश्यों में विश्लेषण के लिए समेकित किया गया।

विशेषज्ञों के मत सर्वेक्षण दृष्टिकोण में महत्वपूर्ण जोखिमों की पहचान के लिए 32 आंतरिक और 22 बाह्य जोखिमों के साथ प्रश्नावली सर्वेक्षण किया गया। प्रश्नावली में जोखिम के 'घटित होने की संभावना' तथा परियोजनाओं के चार उद्देश्य— समय, लागत, कार्यव्याप्ति, और गुणवत्ता के आधार पर 'जोखिम के प्रभाव' को मापा गया। 'मध्यम संभावना और मध्यम प्रभाव' के समकक्ष महत्वपूर्ण जोखिमों को चुना गया, जिसके परिणामस्वरूप 22 आंतरिक और 12 बाह्य जोखिमों को गंभीर पाया गया। इन परियोजना उद्देश्यों के अंतर्गत विभिन्न हितधारकों द्वारा प्रदत्त सापेक्ष प्राथमिकताओं और जोखिम मूल्यांकन के रुझानों का तुलनात्मक विश्लेषण किया गया। इससे कुछ मूल्यवान अंतर्दृष्टि प्रकट हुई।

केस अध्ययन में भारत भर में स्थित नौ परियोजनाओं के जोखिम प्रबंधन की गहन जांच के अनुसंधान को शामिल किया गया। प्रत्येक परियोजना के लिए चार स्रोतों से आंकड़ों का विश्लेषण करके नौ केस स्टडी रिपोर्ट तैयार की गई। इन स्रोतों में परियोजना दस्तावेज को प्राथमिक स्रोत के रूप में, अन्य जानकारी के लिए निर्माणस्थल के कार्यपालकों से साक्षात्कार, प्रत्यक्ष निरीक्षण के रूप में निर्माणस्थल के फोटोग्राफ, और सार्वजनिक अभिलेख को सम्मिलित किया गया। इन नौ केसों के अध्ययनों से 'पी.आर.एम.एफ.' तैयार करने के लिए जोखिम प्रबंधन प्रथाओं के बारे में मूल्यवान टिप्पणियां और अंतर्दृष्टि प्राप्त हुई। इन केस स्टडी में, दो ऐसे केस स्टडी थे जिनमें ठेकेदारों की भिन्नता को छोड़ कर अन्य सभी विशेषताएं समान थीं। दो केस परियोजनाओं के इतने अधिक समानता के विशेष अवसर से परियोजना-स्तर पर जोखिम प्रबंधन में ठेकेदारों की भूमिका की खोज में मदद मिली।

विषयवस्तु विश्लेषण (content analysis) अनुसंधान की अवधारणा, जोखिम प्रबंधन और दावा प्रबंधन के साहित्य के एकीकरण पर आधारित है। इस अनुसंधान से जोखिमों और दावों के बीच एक कारणवश संबंध उजागर हुआ। इस रिश्ते की संभावना को दर्शाने के लिए 28 तय आर्बिट्रेशन केस अवार्ड्स की विषयवस्तु विश्लेषण का उपयोग करते हुए एक दावा-आधारित जोखिम मूल्यांकन मॉडल (C-RAM) विकसित किया गया। अनुसंधान निष्कर्षों से जोखिमों की घटनाओं की

गणना के लिए नए मापदंड प्राप्त हुए। इसके अतिरिक्त, (C-RAM) मॉडल ने जोखिम घटनाओं के प्रभाव की लागत के मूल्यांकन को संविदा राशियों के अंश के रूप में प्रस्तुत किया।

इसके उपरान्त, तीन अनुसंधान दृष्टीकोणों के महत्वपूर्ण जोखिमों की तुलना की गई, जिससे पता चला कि भूत, वर्तमान, और भविष्य की परियोजनाओं से प्राप्त गंभीर जोखिमों में काफी समानता है। इससे जोखिमों की शाश्वत प्रकृति का भी अनावरण हुआ। इसके अलावा, जोखिमों के बीच अन्योन्य निर्भरता का विश्लेषण 21 समेकित महत्वपूर्ण जोखिमों का उपयोग करते हुए किया गया। इसके लिए क्रॉस-इम्पैक्ट मैट्रिक्स गुणन (CIM-MICMAC) और इंटरप्रेटिव स्ट्रक्चरल मॉडलिंग (Interpretive structural modelling) की तकनीकों का प्रयोग किया गया। इन विश्लेषणों से परियोजना जोखिमों के संचालन, निर्भरता, तथा सोपानबद्धता की उन्नत समझ प्राप्त हुई। इन निरीक्षणों को केस स्टडी तथा विषयवस्तु विश्लेषण अनुसंधानों के निष्कर्षों के साथ समेकित कर 'परियोजनाओं में जोखिम प्रबंधन के लिए कार्यनीतिक योजना' का विकास किया गया।

तत्पश्चात, सभी तीन दृष्टीकोणों और वर्तमान अनुसंधान साहित्य के निष्कर्षों का एकीकरण करके, पी.आर.एम.एफ. तथा इसके तीन मुख्य घटक— जोखिम सूचना डेटाबेस, जोखिम रजिस्टर, तथा जोखिम उपचार योजना, को विकसित किया गया। यहाँ दो अतिरिक्त घटक— भेद्यता मूल्यांकन (vulnerability assessment), और नकदी प्रवाह (cash flow) के परिदृश्य विश्लेषण के लिए ह्यूरिस्टिक माडल को भी विकसित किया गया। इन विकसित मॉडलों से निर्माण उद्योग में पी.आर.एम.एफ. का व्यापक उपयोग होने का मार्ग प्रशस्त हुआ।

पी.आर.एम.एफ. के अतिरिक्त यह शोध प्रबंध ज्ञान की मुख्य धारा में तीन महत्वपूर्ण सिद्धांतों का योगदान देता है। पहला, जोखिम प्रबंधन में ठेकेदारों की भूमिका के महत्व पर इस बात का प्रकाश डाला गया है कि, ठेकेदार की क्षमता पर परियोजना की सफलता या विफलता निर्भर करती है। परियोजना और इसके ठेकेदार दोनों के लिए जोखिम प्रबंधन पर विचार किया जाना चाहिए। दूसरा, जोखिम एवं दावों के बीच कारणवश संबंध है। परियोजना में दावों को अनिमित जोखिमों के प्रभाव के निहितार्थ लागत के रूप में देखा जा सकता है। इस कारणवश संबंध से जोखिम प्रबंधन और दावा प्रबंधन के साहित्य के एकीकरण को बढ़ावा मिलेगा। तीसरा, निर्माण परियोजनाओं के गंभीर जोखिम वास्तव में शाश्वत प्रकृति प्रदर्शित करते हैं। इसलिए जोखिम प्रबंधन ढांचा विकसित करने के लिए जोखिमों की गंभीरता के साथ, उनके बीच परस्पर निर्भरता पर भी विचार किया जाना चाहिए।

कुल मिलाकर, यह शोध प्रबंध, जोखिम प्रबंधन में एक नया प्रतिमान आरंभ करता है और अनुसंधान विधियों को निर्माण की वास्तविकता में ढालने की कोशिश करता है। जोखिम प्रबंधन अनुसंधान और व्यवहार के बीच अंतर को पाटने में यह शोध प्रबंध एक मील का पत्थर साबित होगा।

बीजशब्द— केस अध्ययन (case study) , दावा प्रबंधन (claim management), विषयवस्तु विश्लेषण (content analysis) ठेकेदार क्षमता (contractor capability), जोखिम का निहितार्थ लागत, जोखिम मूल्यांकन, जोखिम प्रबंधन, जोखिम प्रबंधन ढांचा, जोखिम प्रबंधन योजना।

TABLE OF CONTENTS

CERTIFICATE	i
ACKNOWLEDGMENTS	ii
ABSTRACT	iv
TABLE OF CONTENTS	vii
LIST OF FIGURES	xiii
LIST OF TABLES	xvi
LIST OF ABBREVIATIONS	xviii
CHAPTER 1 INTRODUCTION	1
1.1 INCREASING RISKS IN CONSTRUCTION INDUSTRY	1
1.2 RESEARCH PROBLEM.....	3
1.2.1 State of the Art on Risk Management.....	3
1.2.2 Research Gaps.....	5
1.3 RESEARCH OBJECTIVES AND SCOPE	7
1.4 RESEARCH METHODS.....	9
1.4.1 Alignment with Actualities of Construction	9
1.4.2 Risk Identification (Objective 1)	12
1.4.3 Risk Assessment (Objective 2).....	12
1.4.4 Risk Interdependence (Objective 3).....	14
1.4.5 Risk Management Framework (RMF) (Objective 4).....	14
1.5 ORGANIZATION OF THIS THESIS.....	15
CHAPTER 2 LITERATURE REVIEW	17
2.1 INTRODUCTION.....	17
2.2 OVERVIEW OF RISK MANAGEMENT LITERATURE.....	18
2.2.1 Ontological and Epistemological Perspectives on Risk Management.....	18
2.2.2 Clarifying Some Risk-related Terms	21
2.3 RISK IDENTIFICATION.....	23
2.4 RISK ASSESSMENT THROUGH OPINION SURVEY APPROACH.....	27
2.4.1 Risk Ranking.....	28
2.4.2 Risk Relationship.....	34
2.4.3 Statistical Techniques for Risk Assessment	38

2.4.4	Other Risk Assessment Techniques.....	40
2.5	RISK ASSESSMENT USING PROJECT DATA	42
2.6	CRITICAL REVIEW OF RISK ASSESSMENT TECHNIQUES	44
2.7	RISK MITIGATION.....	47
2.7.1	Risk Response Plan.....	47
2.7.2	Risk Allocation	48
2.7.3	Risk Register.....	51
2.7.4	Project Contingency.....	52
2.8	RISK MANAGEMENT FRAMEWORK.....	55
2.9	ALLIED TOPICS IN RISK MANAGEMENT	58
2.9.1	Role of Contractors in Risk Management.....	58
2.9.2	Project System Vulnerability.....	59
2.9.3	Claim Management.....	60
2.10	CONCLUDING REMARKS	62
CHAPTER 3 OPINION SURVEY APPROACH FOR RISK ASSESSMENT... 64		
3.1	INTRODUCTION.....	64
3.2	DATA COLLECTION THROUGH QUESTIONNAIRE SURVEY	64
3.2.1	Questionnaire Development.....	64
3.2.2	Data Collection and Sample Characteristics.....	66
3.3	DATA ANALYSIS	68
3.3.1	Prioritization of Project Objectives.....	68
3.3.2	Risk Assessment.	70
3.4	RESULTS AND DISCUSSION	72
3.4.1	Likelihood of Occurrence of Risks	72
3.4.2	Severity of Risks	75
3.4.3	Criticality of Risks	80
3.5	CONCLUDING REMARKS	83
CHAPTER 4 CASE STUDY OF ONGOING PROJECTS FOR RISK IDENTIFICATION AND ASSESSMENT* 85		
4.1	INTRODUCTION.....	85
4.2	RESEARCH METHOD FOR CASE STUDY	85
4.2.1	Research Design.....	85
4.2.2	Case Study Reports	87
4.2.3	Risk Assessment Across Case Projects.....	90

4.3	EXAMPLES OF CASE STUDY	90
4.3.1	Salient Features of Nine Case Projects	90
4.3.2	Chennai Project (P).....	92
4.3.3	Coimbatore Project (Q).....	96
4.4	ROLE OF CONTRACTORS IN RISK MANAGEMENT.....	98
4.4.1	Research Method for Comparative Analysis of Two Similar Projects.....	99
4.4.2	Comparative Analysis of P and Q.....	99
4.4.3	Theory Building: Role of Contractor Capability in Project Risk Management.....	108
4.5	HIGHLIGHTS OF REMAINING CASE STUDIES	111
4.5.1	NBCC Square Kolkata (West Bengal, Appendix D-3).....	111
4.5.2	NTPC Power Plant Project Bongaigaon (Assam, Appendix D-4).....	112
4.5.3	Singerani Power Plant Project (Telangana, Appendix D-5).....	113
4.5.4	IIT Roorkee Project (Uttarakhand, Appendix D-6).....	113
4.5.5	VNIT Nagpur (Maharashtra, Appendix D-7)	114
4.5.6	PMGSY Agartala (Tripura, Appendix D-8)	115
4.5.7	TFCCM Varanasi (Utter Pradesh, Appendix D-9)	116
4.6	RISK ASSESSMENT ACROSS CASE PROJECTS	117
4.7	ROBUSTNESS AND GENERALIZATION.....	121
4.8	CONCLUDING REMARKS	122
CHAPTER 5 CONTENT ANALYSIS OF CLAIM DOCUMENTS FOR RISK IDENTIFICATION AND ASSESSMENT*		125
5.1	INTRODUCTION.....	125
5.2	CONTENT ANALYSIS METHODS IN CM LITERATURE	126
5.3	RESEARCH METHOD ADOPTED IN THIS CHAPTER.....	128
5.4	THEORY DEVELOPMENT: RELATION BETWEEN RISK AND CLAIM	129
5.4.1	Conceptual Framework to Compare Risk and Claim	129
5.4.2	Overlap between Processes of RM and CM	131
5.4.3	Common Characteristics of Risk and Claim.....	133
5.4.4	Similarity in Identification of ‘Risks’ and ‘Sources-of-claims’	136
5.4.5	Causal Relationship between Risks and Claims	138
5.5	MODEL DEVELOPMENT: C-RAM.....	141
5.5.1	Document Selection and Preparation.....	141
5.5.2	Framework for Content Analysis of Claim Documents	143
5.5.3	Analysis of Extracted Data	146

5.6	RESULTS.....	147
5.7	DISCUSSION	147
5.7.1	Quantification of Occurrences of Risks.....	152
5.7.2	Quantification of Cost Implications due to Risks.....	156
5.8	CONCLUDING REMARKS	157
CHAPTER 6 INTERDEPENDENCE AMONG CRITICAL RISKS		160
6.1	INTRODUCTION.....	160
6.2	COMPARISON OF CRITICAL RISKS FROM THREE APPROACHES.....	161
6.3	RESEARCH METHOD FOR RISK RELATIONSHIP	162
6.3.1	Removal of Redundant Relationship Among Critical risks.....	162
6.3.2	Questionnaire Survey for Direct Relationships among Risks.....	167
6.3.3	Tools Used for Analyzing Risk Interdependence	170
6.4	MICMAC ANALYSIS	170
6.4.1	Identification of Indirect Relationships	170
6.4.2	Driving and Dependence Power of Risks	174
6.5	HIERARCHICAL STRUCTURE OF CRITICAL RISKS.....	181
6.5.1	Reachability Matrix	181
6.5.2	ISM Diagraph for Hierarchical Structure of Risks	184
6.5.3	Strategic Plan for Risk Management in Projects	188
6.6	CONCLUDING REMARKS	191
CHAPTER 7 RISK MANAGEMENT FRAMEWORK FOR CONSTRUCTION PROJECTS*		193
7.1	INTRODUCTION.....	193
7.2	SCOPE OF RISK MANAGEMENT IN PROJECT MANAGEMENT	194
7.3	RESEARCH METHOD FOR DEVELOPING PRMF	194
7.4	COMPONENTS OF PRMF	196
7.4.1	Risk Information Database (RID).....	196
7.4.2	Risk Register	198
7.5	RISK TREATMENT PLAN	201
7.6	PROJECT-LEVEL RISK MANAGEMENT FRAMEWORK (PRMF).....	212
7.6.1	Risk Management Framework in Risk Standards.....	212
7.6.2	Formulation of PRMF	214
7.6.3	Discussion on Four Phases of PRMF.....	215
7.6.4	Validation of PRMF.....	220

7.7	CONCLUDING REMARKS	221
CHAPTER 8	SUMMARY AND CONCLUSION	222
8.1	SUMMARY	222
8.2	CONCLUSIONS	225
8.3	RESEARCH HIGHLIGHTS AND RECOMMENDATIONS	227
8.3.1	Unique Coverage of Data Collection	227
8.3.2	Contribution to the Body of Knowledge.....	229
8.3.3	Contribution to the Industry and Society	230
8.4	LIMITATIONS AND THE WAY FORWARD	231
8.5	RESEARCH PUBLICATIONS	233
REFERENCES	234	

APPENDIX TABLE

APPENDIX B-1 Description of 54 risks identified from literature	250
APPENDIX B-2 Comparison of Criticality Indices used in literature	256
APPENDIX C-1 Questionnaire to assess likelihood and impact of risks.....	258
APPENDIX D-1 Case study of Chennai project, Tamilnadu	264
APPENDIX D-2 Case study of Coimbatore project, Tamilnadu.....	276
APPENDIX D-3 Case study of NBCC Square project, West Bengal	285
APPENDIX D-4 Case study of NTPC Bongaigaon project, Assam	298
APPENDIX D-5 Case study of Singereni Power Plant project, Telangana	316
APPENDIX D-6 Case study of IIT Roorkee project, Uttarakhand	330
APPENDIX D-7 Case study of VNIT Nagpur project, Maharashtra	350
APPENDIX C-8 Case study of PMGSY Agartala Rural Road project, Tripura	362
APPENDIX D-9 Case study of TFCCM Varanasi project, Utter Pradesh	374
APPENDIX D-10 Direct risk relationship in Chennai and Coimbatore projects	383
APPENDIX E-1 Ontological and epistemological perspectives of claims.....	386
APPENDIX E-2 Comparison of ‘risks’ and ‘sources of claims’	388
APPENDIX E-3 List of arbitration case awards covered in content analysis	399
APPENDIX F-1 Comparison of critical risks from the three research approaches.....	400
APPENDIX F-2 Questionnaire to identify direct relationship among risks.....	403
APPENDIX G-1 Letter from NBCC for validation and acceptance of PRMF	406
APPENDIX G-2 Vulnerability assessment of contract clauses	407

LIST OF FIGURES

Figure 1-1 Motivation for the research	8
Figure 1-2 Overall research methodology adopted in the thesis.....	11
Figure 2-1 Outline of literature review on risk management.....	18
Figure 2-2 Level of detailing in risk identification.....	24
Figure 2-3 Phenomenon of risk relationships	35
Figure 4-1 First stage- research methodology for preparation of case study reports.....	86
Figure 4-2 Second stage- research methodology for analysis of case study reports	87
Figure 4-3 Overview of Chennai Project (P), [Legend for timeline: % progress, delays in months; m-million].....	94
Figure 4-4 Hierarchy of risks in Chennai project (P) shown using influence line diagram	95
Figure 4-5 Overview of Coimbatore project (Q) [Legend for timeline: % progress, delays in months; m-million].....	97
Figure 4-6 Hierarchy of risks in Coimbatore project (Q) shown using influence line diagram	98
Figure 5-1 Proposed method for content analysis research	128
Figure 5-2 Conceptual framework to examine relationship between risks and claims ..	130
Figure 5-3 Similarities in concepts of risks and claims	135
Figure 5-4 Causal relationship between risks and claims.....	139
Figure 5-5 Framework for content analysis of arbitration award documents.....	145
Figure 6-1 Comparison of 15 most critical internal risks from three approaches (*external risks)	163
Figure 6-2 [M]: CIM of risks, '1' denotes a risk along the column had direct impact on risks along the row; Dr – Driving power of risks.	169
Figure 6-3 [M] ² : CIM of direct relationship raised to power of 2 (blanks cells contain 0, values in red correspond to newly identified second order indirect relationship)	171
Figure 6-4 [M] ³ : CIM of direct relationship raised to power of 3 (blanks cells contain 0, values in red correspond to newly identified third order indirect relationship).....	171
Figure 6-5 [M] ⁴ : CIM of direct relationship raised to the power of 4 (blanks cells contain 0, no new and higher-order indirect relations are identified).....	172

Figure 6-6 Indirect relationship between R5-R10 first appears in [M]3 (i.e. 3rd order relationship); Value of element (5, 10) in [M]3 = 3 (i.e. three paths of R5→ R17→ R4 → R10, R5→ R3→ R4 → R10 and R5→ R3→ R9 → R10).....	173
Figure 6-7 Matrix showing direct and indirect relationships among risks	173
Figure 6-8 Direct influence/Dependence map of 21 critical risks corresponding to [M] (LIPSOR®-EPITA-MICMAC). (Risk ID with suffix ‘e’ and ‘i’ corresponds to external and internal risks respectively.)	177
Figure 6-9 Lower Triangular Matrix for ISM.....	185
Figure 6-10 ISM Diagram: Hierarchical structure of critical risks in projects	186
Figure 6-11 Strategic plan for risk management in projects.....	190
Figure 7-1 Research method for developing PRMF (*Iyer and Kumar 2016).....	195
Figure 7-2 List of documents covered in Risk Information Database (RID)	197
Figure 7-3 Relationships between the risk management principles, framework and process (IS/ISO 31000:2009, p. iii)	213
Figure 7-4 Project-level Risk Management Framework (PRMF)	216
Figure 8-1 Project locations covered under data collection.....	228
Figure 1. Water logging at site, pipe head breaking activity without PPEs.....	294
Figure 2. Sheet piling (Not in BOQ, Scope variation risks)	295
Figure 3. Labour colony (Prone to fire, poor ventilations, Safety and health hazards risks).....	295
Figure 4. No safety barricading along excavation pit (steep slope, 8-9 m depth)	295
Figure 5. Walkways and ramps without hand rails or protection (depth >2 m)	295
Figure 6 No physical isolation of electrical generators (cable passing through water logging).....	296
Figure 7. Nonstandard distribution board panel	296
Figure 8. Workers without PPE (no Safety helmet, no shoes and others PPEs).....	296
Figure 9. Workers without fall protections, PPEs (at height 10-12 m from).....	297
Figure 10 Absence of proper approach for workers to access site	297
Figure 2 Water logging at work front, poor drainage (Weather risk).....	313
Figure 3 Water logging at work front, poor drainage (Weather risk).....	313
Figure 4 Workers without PPEs such as Safety Shoes, Safety Jacket, Safety Gloves (Safety risks).....	313
Figure 8 Electrical DB not isolated (Safety risk).....	315
Figure 1: IDTC 1 and 2, the lack of approach roads can be easily noticed.	328

Figure 3. Passenger lift was only option to reach the platform of Chimney. Photo taken at the height of 275 m. Space constraints can be easily seen. 329

LIST OF TABLES

Table 2-1 Various ontological and epistemological perspective in risk management literature	19
Table 2-2 Risks identified from literature (*new risks from this research).....	26
Table 2-3 Research trends in studies on risk assessment and ranking.....	29
Table 2-4 Trends in statistical technique-based research in risk management.....	39
Table 2-5 Research Trends in case studies in risk management.....	43
Table 3-1 Macro characteristics of respondents in the survey.....	67
Table 3-2 Micro characteristics of respondents in the survey	67
Table 3-3 Distribution of respondents for prioritization of four project objectives	68
Table 3-4 Weighted Priorities (WP) of four project objectives.....	69
Table 3-5 Internal risks arranged in descending order of FI.....	73
Table 3-6 External risks arranged in descending order of FI.....	74
Table 3-7 Severity Index (SI in %) of internal risks (IR) for Time, Cost, Scope, and Quality.....	76
Table 3-8 Severity Index (SI in %) of external risks for Time, Cost, Scope, and Quality.....	77
Table 3-9 Comparison of SI values (in %) for internal risks (IR) and external risks (ER).....	77
Table 3-10 Spearman's rank correlation coefficients for SI of internal risks (SPSS output).....	78
Table 3-11 Spearman's rank correlation coefficients for SI of external risks (SPSS output).....	78
Table 3-12 Range of Criticality Index (CI) expressed in percentage (%)	80
Table 3-13 Weighted Average Criticality Index (WACI) of internal risks	81
Table 3-14 Weighted Criticality Index (WCI) of external risks calculated with Weighted Average Severity Index (WASI).....	82
Table 4-1 Salient features of nine ongoing case projects	91
Table 4-2 Comparison of salient features of Chennai project and Coimbatore project..	100
Table 4-3 Summary of identified risks from project P and Q, comparison of occurrences and status of risks in April 2016	104
Table 4-4 Comparison of capabilities of the contractor organizations (approximate values).....	107

Table 4-5 Summary of internal risks (IR) assessed across nine projects through case study approach	118
Table 4-6 Summary of external risks (ER) assessed across nine projects through case study approach	120
Table 5-1 Contents from literature shows claims are visualized as consequences of risks	132
Table 5-2 Similarity between texts describing 'Risks' and 'Sources-of-claims'	136
Table 5-3 Quantified similarity between texts for 'Risks' and 'Sources-of-Claims' for various issues (for details see Appendix E-2).....	138
Table 5-4 Template of database on risk-related information from claim documents.....	144
Table 5-5 Risks identified and assessed by the proposed model from 24 Arbitration cases (see Legend).	148
Table 5-6 Cost implications due to risks; Values in % of respective contract sums (see Legend)	150
Table 6-1 Consolidated list of risks for analysis of interdependence among risks.....	164
Table 6-2 Consolidated list of risks for analysis of interdependence among risks.....	166
Table 6-3 Level portioning from reachability matrix, 1 st Iteration.....	182
Table 6-4 Level portioning from reachability matrix, 2 nd Iteration	182
Table 6-5 Level portioning from reachability matrix, 3 rd Iteration	183
Table 6-6 Level portioning from reachability matrix, 4 th Iteration.....	183
Table 6-7 Level portioning from reachability matrix, 5 th Iteration.....	183
Table 6-8 Level portioning from reachability matrix, 6 th Iteration.....	184
Table 7-1 Template for risk register (pre-construction stage)	199
Table 7-2 Template for risk register (construction stage).....	200
Table 7-3 Risk Treatment Plan (RTP) for critical risks.....	201

LIST OF ABBREVIATIONS

AHP	Analytical Hierarchical Process
BOQ	Bill of Quantities
C-RAM	Claim-based Risk Assessment Model (proposed)
CI	Criticality Index
CIM	Cross Impact Matrix
CM	Claim Management
CPWD	Central Public Works Department of India
DPR	Detailed Project Report
DSR 2007	Delhi Schedule of Rates published by the government of India in 2007
EOT	Extension of Time
ER	External Risks
FI	Frequency Index
FST	Fuzzy Set Theory
GCC	General Conditions of Contract
GDP	Gross Domestic Product
IC	Insurance Company
ILD	Influence Line Diagram
INR, ₹	Indian National Rupee (Rs.)
IR	Internal Risks
ISM	Interpretive Structural Modelling
ISO	International Organization for Standardization
MCS	Monte Carlo Simulation
M&A	Architectural firm engaged as the designer and technical consultant
MICMAC	Cross Impact Matrix – Matrix Multiplication, Cross-Impact Matrix – Multiplication Applied to Classification
NBCC	NBCC (India) Ltd.
NIT	Notice Inviting Tender
P	Chennai project, case project located in Chennai
PC1, PC2, PC3, PC4, PC5, PC6 and PC7	Contractor organizations engaged in Chennai project.

PIA	Project Implementing Agency, turnkey contractor, NBCC
P-I	Probability-Impact rating
PMBOK	Project Management Body of Knowledge
PMGSY	Prime Minister Rural Road Program (Pradhan Mantri Gramin Sarad Yojana).
PMC	Project Management Consultant
PPP	Public-Private-Partnership
PRMF	Project-level Risk Management Framework (proposed in this thesis).
PRMP	Project Risk Management Plan
Q	Coimbatore project, Case project located in Coimbatore
QC	Contractor organization engaged in Coimbatore project
RID	Risk Information Database
RII	Relative Importance Index
RM	Risk Management
RMF	Risk Management Framework
RTP	Risk Treatment Plan
SEM	Structural Equation Modelling
SI	Severity Index
WACI	Weighted Average Criticality Index
WASI	Weighted Average Severity Index
WP	Weighted Average Severity Index
WSI	Weighted Severity Index