DEVELOPMENT OF RISK MANAGEMENT MODEL FOR CONSTRUCTION OF RAILWAY PROJECT IN INDIA

A thesis submitted to the

University of Petroleum and Energy studies

For the Award of
Doctor of Philosophy
in
Management

BY
Mr. Ravindra Shrivastava

June 2020

SUPERVISOR

Dr. Sumeet Gupta

Dr. Ankur Mittal

Dr. Brijendra K Saxena

UPES
UNIVERSITY WITH A PURPOSE

Department of Energy

School of Business

University of Petroleum and Energy Studies

Dehradun – 248007: Uttarakhand

DEVELOPMENT OF RISK MANAGEMENT MODEL FOR CONSTRUCTION OF RAILWAY PROJECT IN INDIA

A thesis submitted to the
University of Petroleum and Energy studies

For the Award of
Doctor of Philosophy
in
Management

BY

Mr. Ravindra Shrivastava

SAP ID 500028570

June 2020

Internal Supervisor

Dr. Sumeet Gupta, HOD- Department of General Management,

Senior Associate Professor,

School of Business (SoB), University of Petroleum and Energy Studies, Dehradun

Internal Co-Supervisor

Dr. Ankur Mittal, Department of General Management,

Associate Professor,

School of Business (SoB), University of Petroleum and Energy Studies, Dehradun

External Supervisor

Dr. Brijendra K. Saxena,

Retired Professor,

Tolani Maritime Institute, Pune

UPES
UNIVERSITY WITH A PURPOSE

Department of Energy
School of Business
University Of Petroleum and Energy Studies
Dehradun – 248007: Uttarakhand

JUNE-2020

DECLARATION

I declare that the thesis entitled "Development of risk management model for construction of railway project in India" has been prepared by me under the guidance of Dr. Sumeet Gupta, H.O.D. - Department of General Management, University of Petroleum and Energy Studies, Dehradun, Dr. Ankur Mittal, Department of General Management, University of Petroleum and Energy Studies, Dehradun and Dr. Brijendra K. Saxena, Retired Professor, Tolani Maritime Institute, Pune. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

Ravindra Shrivastava

02nd June 2020

UPES
UNIVERSITY WITH A PURPOSE

Great Place To Work® Certified MAR 2020–FEB 2021 INDIA

CERTIFICATE

I certify that Mr. Ravindra Shrivastava has prepared his thesis entitled “Development of risk management model for construction of railway project in India”, for the award of PhD degree of the University of Petroleum & Energy Studies, under my guidance. He has carried out the work at the Department of Infrastructure Management, University of Petroleum & Energy Studies.

Internal Guide
Dr. Sumeet Gupta
Department of General Management,
University of Petroleum and Energy Studies,
Dehradun **– 248007, Uttarakhand**
Date: 20th May 2020

External Guide
Dr. Brijendra K. Saxena,
Retired Professor,
Tolani Maritime Institute,
Pune
Date: 20th May 2020

CERTIFICATE

I certify that Mr. Ravindra Shrivastava has prepared his thesis entitled “Development of risk management model for construction of railway project in India”, for the award of PhD degree of the University of Petroleum & Energy Studies, under my guidance. He has carried out the work at the Department of Infrastructure Management, University of Petroleum & Energy Studies.

Internal Co-Guide
Dr. Ankur Mittal
Department of General Management,
University of Petroleum and Energy Studies,
Dehradun **– 248007, Uttarakhand**
Date: 20th May 2020

ABSTRACT

The overrun of the projects in terms of time and cost are considered to be one of the major concern of Indian railway project. Any overrun would result in tremendous losses for the nation, such losses can be caused by the project's risk and uncertainty and poor risk management in projects. Overrun is a common phenomenon, affecting nearly all railway projects. The limited effort has been made, however, to limit the occurrence of overrun, this research tries to identify the significant risk factor causing the time & cost overrun and developed risk management model for railway projects in India. This research is compiled in nine chapters. **Chapter one** sets the briefs on background of the study. It highlights the background and significance of Infrastructure for economic development and problem faced by the infrastructure projects across the globe. The chapter highlights the significance of transport sector in India and its necessity for economic development of a country. The chapter further narrow down to railway transport infrastructure in India, development of indian railways in terms passenger & freight traffic growth, route length development, capacity addition of BG, MG & NG, capital expenditure and past investment trends. It also emphasizes on the overrun trend of Indian Railways which is an acute problem of railway infrastructure development. Then, it emphasizes on the role of risk management in mitigating the overruns and need for improvement in the process. **Chapter two** sets the literature review and theoretical background for the research. A two-part analysis of the literature conducted to critically understand the business problem. The first part is a review related with key terms and their technical significance such as project management and project risk management etc., in construction management; whilst the second part is focuses on the comprehensive literature relevant to Project Risk management into the different theme such as construction project management, project risk management in global scenario, tools and techniques used for risk modelling in construction projects, risk attributes and categories and project risk management in Indian scenario, railway project in India and management of public infrastructure projects.

Thematic literature review done to find research gap, business problem from the problem statement, research problem, research questions and three research objectives. **Chapter three** covers details on research method adapted in the study. The research methodology for objective 01 uses the confirmatory factor analysis, the objective 02 uses the Expected Value Method and objective 03 uses the Expected Value Method and Earned Value Method. **Chapter four** explains the research work conducted to achieve the objective one i.e. identification of significant risk factors causing the overruns of railway projects in India. Chapter discusses the sampling sufficiency, reliability of scale statistics, and data collection for variables taken from literature review related to overruns of railway projects. It further discusses results and findings for Objective one which is in the form of extracted risk factors by using Confirmatory Factor analysis. **Chapter five** explains the research work conducted to achieve the objective no two i.e.to identify the exposure of the risk on project activities. The expected value method have used to achieve objective number two. The Activity and risk factor relation have established and survey conducted to identify the likelihood of occurrence, Impact and weightages of the risk on the activities. The monte-carlo simulation performed to understand the severity of risk factors on various activities. The outcome of the objective two is in the form of Composite Likelihood factor and Composite Impact Factor for all the risk factors on an activity and severity of risk factor on individual activity. The Chapter six explains the research work conducted to achieve the objective no three i.e. to to develop the risk management model in terms of relationship between project risk and project performance. The Expected Value Method and Earned Value Method have used for model development. Outcome of the model is in the form of Quantified effect of risk on the project in terms of cost and time. **Chapter seven** compiles and lists all conclusions and suggestions. **Chapter eight** mentions significance of study in International arena and contribution to literature. **Chapter nine** highlights the future scope and limitation of the study.

ACKNOWLEDGEMENT

The work presented in this thesis would not have been possible without my close association with many people. I take this opportunity to extend my sincere gratitude and appreciation to all those who made this PhD thesis possible.

First and foremost, I would like to extend my sincere gratitude to my research guide, Dr. Sumeet Gupta, for introducing me to this exciting field of management research and for his dedicated help, advice, inspiration, encouragement and continuous support, throughout my PhD research. I could not have imagined having a better advisor and mentor for my PhD study. Also, I would like to thank my external guide and co-guide: Dr B K Saxena, and Dr Ankur Mittal for their insightful comments and encouragement, but also for the hard question which incented me to widen my research from various perspectives.

Special thanks to Dr Githa S Heggde, Dean, School of Business (SoB), UPES, for giving the encouragement and sharing insightful suggestions, Dr Tarun Dhingra- Associate Dean, School of Business (SOB), UPES for his review and guidance from time to time, Dr Joji Rao - School of Business (SoB), UPES for his suggestion during research, Centre of Continued Education, UPES, Dehradun, Library of NICMAR, IIM Indore and UPES for permitting access to various journals and books during my research work.

My special word of thanks to Dr Mangesh Korgaonkar - Director-General, National Institute of Construction Management and Research (NICMAR) for his continuous support, guidance, cooperation, encouragement and for facilitating all the requirements, going out of his way. I am also grateful to Dr Rajesh Goyal, Dean, NICMAR Delhi campus and faculty colleagues at NICMAR for their continuous support during this journey.

My entire thesis is dedicated to my late mother, who wished to see this study completed. She formed part of my vision and taught me good things that really matter in life. Her true love and support have always been my strength. Her patience and sacrifice will remain my inspiration throughout my life. She has taught me another aspect of life, that, goodness can never be defied and good human beings can never be denied. I owe a lot of gratitude to her for always being there for me. Also, my heartfelt regard goes to my father and grandmother for their love and moral support.

I owe my deepest gratitude towards my wife, Mrs Ruchi, for her eternal support and understanding of my goals and aspirations. Her true love and support have always been my strength. Her patience and sacrifice will remain my inspiration throughout my life. Without her help, I would not have been able to complete much of what I have done and become who I am. I am thankful to my daughter Ms Aanya for giving me happiness during the last three and a half year of my studies.

I would like to extend my sincere gratitude to my elder cousin brother Mr Manish Shrivastava for his encouragement and continuous support, throughout my PhD research. I am grateful to my younger brothers Mr Mayank and Mr Chandan, who have provided me through moral and emotional support in my life. I am also thankful to all my other family members and friends who have supported me along the way.

CONTENTS

LIST OF SYMBOLS

$	US Dollars
Bn	billion
$\sqrt[n]{}$	n^{th} root
%	Percentage
Rs.	Indian Rupees
INR	Indian Rupees
₹	Indian Rupees
*	Multiplication
/	Division
>, <	Greater than, less than
=	Equal to
+, -	Addition, Subtraction
∑	Summation
β	Beta coefficient

LIST OF ABBREVIATIONS

GDP	Gross Domestic Product
PMI	Project Management Institute
KPMG	Klynveld Peat Marwick Goerdeler
LPR	Length of paved roads
PGNP	Per-capita Gross National Product
IR	Indian Railways
RVNL	Rail Vikas Nigam Limited
PMC	Project Management Consultant
BG	Broad Gauge
MG	Meter Gauge
NG	Narrow Gauge
GC	Gauge Conversion
DFC	Dedicated Freight Corridors
CAPEX	Capital Expenditure
OPEX	Operational Expenditure
MOSPI	Ministry of Statistics and Programme Implementation
FICCI	Federation of Indian Chambers of Commerce and Industry
CAG	Comptroller General Audit
CMIE	Centre for Monitoring Indian Economy
RM	Risk Management
PRM	Project Risk Management
EVA	Earned Value Assessment
EV	Earned Value
TCPI	To Complete Performance Index
BAC	Budget at Completion
AC	Actual Cost
PV	Planned Value
BCWS	Budget Cost of Work Scheduled
BCWP	Budget Cost of Work Performed
ACWP	Actual Cost of Work Performed
CPI	Cost Performance Indicator
SPI	Schedule Performance Indicator
CFA	Confirmatory Factor Analysis
PCA	Principle Component Analysis
CLF	Composite Likelihood Factor
CIF	Composite Impact Factor
EVM	Expected Value Method

LIST OF ABBREVIATIONS

RC	Risk Cost
RT	Risk Time
BTE	Budgeted Time Estimate
BCE	Budgeted Cost Estimate
CC	Corrective Cost
CT	Corrective Time
WD	Work Done
CPI_B	Cost Performance Indicator (Base Cost based)
BCm	Budgeted Cost (Monthly)
CPI_R	Cost Performance Indicator (Risk based)
ECWP	Expected Cost of Work Performed
PCD_B	Project Completion Date (Baseline based)
PCD_R	Project Completion Date (Risk based)
PCD_U	Project Completion Date (Monthly updates)
KMO	Kaiser-Meyer-Olkin Measure
PCA	Principal Component Analysis
EFA	Exploratory Factor Analysis
PMC	Project Management Consultants

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 01

INTRODUCTION

1.1. INFRASTRUCTURE (BACKGROUND AND SIGNIFICANCE)

The economic growth of a country is reflected and typically evaluated by its infrastructure status. Additionally, a built state of infrastructure by attracting capital investment would promote economic growth. The physical infrastructure that includes transportation, water, electricity and communication fosters the development of a society, which inturns improve the quality of life. Therefore, speed of developing infrastructure and the efficiency of infrastructure services are vital to ensuring that the country can maintain a healthy rate of economic growth. The World Bank reports that a 10 % rise in infrastructure assets raises GDP directly by up to 1 % (Calderón et al., 2015). Furthermore, in both a growing and matured economy, the infrastructure has a vital role to play, sector produces jobs that foster global prosperity, which provides alternatives to the issues of social and energy challenges. The construction industry has broad partnerships with other firms or allied businesses; its impact on economy is vast and devastating compare to direct contribution by the construction activities. While most other industries have undergone tremendous change over the last few decades and have reaped the benefits of the process and product innovation, the construction sector has been uncertain about fully embracing the latest technology opportunities; as a result, consider to be more labour intensive compared to other industries. According to the latest report (PMI & KPMG, 2019), India is the world's 4th-largest economy, and the Infrastructure constraints are a key concern for the lack of GDP and economic development as compared with India's development capacity. In recent years, the exponential development of the Indian economy has brought a tremendous pressure on physical infrastructures

(Nataraj, 2014). In the report (PMI & KPMG, 2012 & 2019), at the centre, large budgets were allocated in every Five Year Plan for infrastructure development. However, over the last few years, the country has often failed to achieve these targets, these projects faced with scheduling constraints and cost overruns.

In particular, the same pattern witnessed globally; large development projects have a tradition of issues such as funding, overruns and procurement. Beckers *et al.* (2013) suggested that the majority of overruns could be foreseen and avoided. Most of the issues found derive from a lack of adequate, forward-looking risk management. The losses due to project risk-management for today's large-scale project pipeline approaching $1.5 trillion in the next five years, not even to mention economic growth damages and reputational and social implications (Beckers *et al.*, 2013). Large projects suffer under risk management at all the levels from the inception to operations. The structuring and execution of major infrastructure projects is highly complex; the long-term nature of these projects involves a plan that adequately reflects the risk the project will pose over the life cycles.

Planned / Actual

Example	Budget vs actual € billion	Delays and start-up problems	Incorrect capacity and revenue plans	Total value lost vs plan € billion
Eurotunnel	7.5 / 15.0	▪ 6-month delay ▪ 18 months of unreliable service after opening	▪ Overestimated market-share gain in freight and passengers by 200%	~7.5
High-speed rail Frankfurt-Cologne	4.5 / 6.0	▪ 1-year delay of construction ▪ Legal and technical issues	▪ Unforeseen capped government funding	~1.5
Betuwe Line NL (cargo rail)	2.3 / >5.0	▪ 1.5-year[1] delay of construction ▪ Technology choices still not finalized	▪ Annual revenue shortfall of €20 million	~3.0
Kuala Lumpur Airport	2.0 / 3.5	▪ Initial issues with connectivity to downtown area ▪ Complaints about facility hygiene levels	▪ Handles only ~60% of current capacity ▪ Losing market share to Singapore	~1.5

Fig. 1.1: Overruns in few mega-project across the world

(Source - Beckers *et al*. 2013)

Infrastructure projects frequently include a wide range of various players joining the project with specific roles, commitments, risk management expertise, risk-bearing capabilities and sometimes conflicting interests. A more comprehensive risk management strategy would tackle critical concerns impacting all stakeholders, and if applied over the infrastructure project life cycle, the infrastructure project's performance would be dramatically improved.

1.2. TRANSPORT SECTOR IN INDIA

Transport infrastructure plays a crucial part in a country's economic growth, and is considered to be one nation's lifeline; Good physical connectivity is essential to economic growth in urban and rural areas of a country. Laxmanan (2011) discusses transport infrastructure's more comprehensive economic benefits from the observed role of rail, roads and waterways in urban growth. The report illustrates a close link between transport infrastructure and economic development by taking into account the various factors such as market expansion, export gains, technological shifts, spatial agglomeration processes and investment processes and the commercialization of new technology in urban clusters (made possible by transport improvements). Queiroz *et al.*, 1992 researched to recognize the effect of road infrastructure on the growth of the economy; the author surveyed ninety-eight (98) countries. Figure 1.2 shows a clear correlation emerged between the Length of paved roads (LPR) and per-capita GNP (PGNP). It indicates that the more physical infrastructure a country has, the higher the economic stability and vice versa and similar relation hold good for other types of infrastructure. There is extensive literature available which indicate how transport infrastructure has contributed to the speed and efficiency of the development of a nation. And it also presents the strong correlation between the investments in transport infrastructure and its positive economic and social effect in terms of the efficiency gains to a variety of macro and microeconomic parameters, social benefits, poverty reduction, regional connectivity etc. (Nadiri and Mamuneas (1996), Queiroz *et al.*, 1992, Kessides (1993), Grigoriou (2007), Laxmanan and Anderson (2007), Fasoranti, (2012), etc.

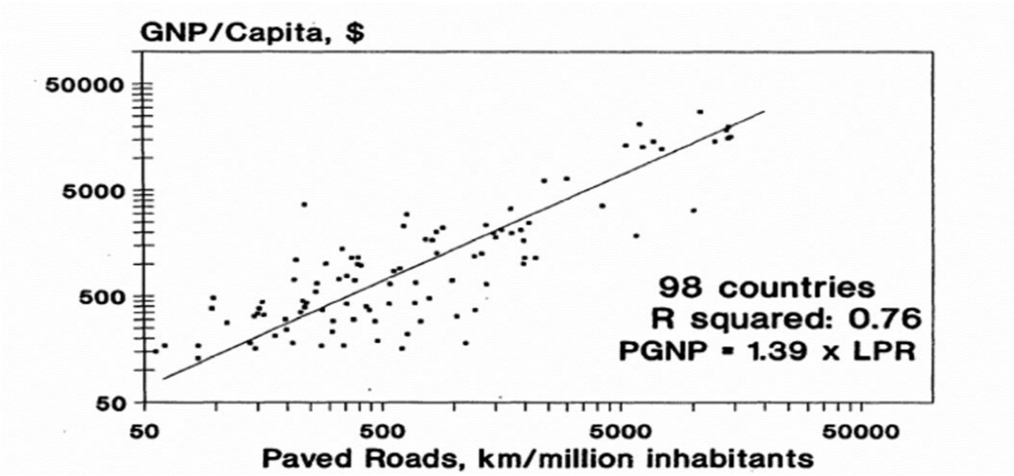


Fig. 1.2: Relation between per capita GNP and paved road density (Source - circa 1988)

1.3. RAILWAY INFRASTRUCTURE IN INDIA

The Indian economy has shown a real GDP average economic growth of 6.84% in the last eight years and expected to grow by 5.9 per cent in 2019-20. Considering the past and future trend of the GDP growth, In the future too, demand for transport services is projected to rise at a faster pace. Despite the development of the alternative mode of transportation, the Indian railway remains the key player in India's transport and Logistic sector. It performs two critical roles by supporting the crucial social and economic task of transporting Freight and passengers across its vast network. It also shows the essential social job of connecting far-flung places at an affordable cost, which, in turn, create externalities.

Table 1.1 - Passenger and Traffic Freight Growth in Indian Railways

(Source - By author using CMIE data)

Year	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Freight Traffic (Tonnes)	504,210.0	522,230.0	542,690.0	581,400.0	626,180.0	682,400.0	744,600.0	804,110.0	836,610.0	892,220.0	926,430.0	975,160.0	1,014,150.0	1,058,810.0	1,101,090.0	1,108,620.0	1,110,950.0	1,162,640.0
Passenger traffic (Million Units)	4,839.80	5,169.30	5,048.20	5,202.90	5,475.50	5,832.40	6,333.70	6,536.40	7,046.90	7,382.80	7,809.10	8,224.40	8,420.70	8,397.10	8,224.10	8,101.00	8,116.00	8,285.80

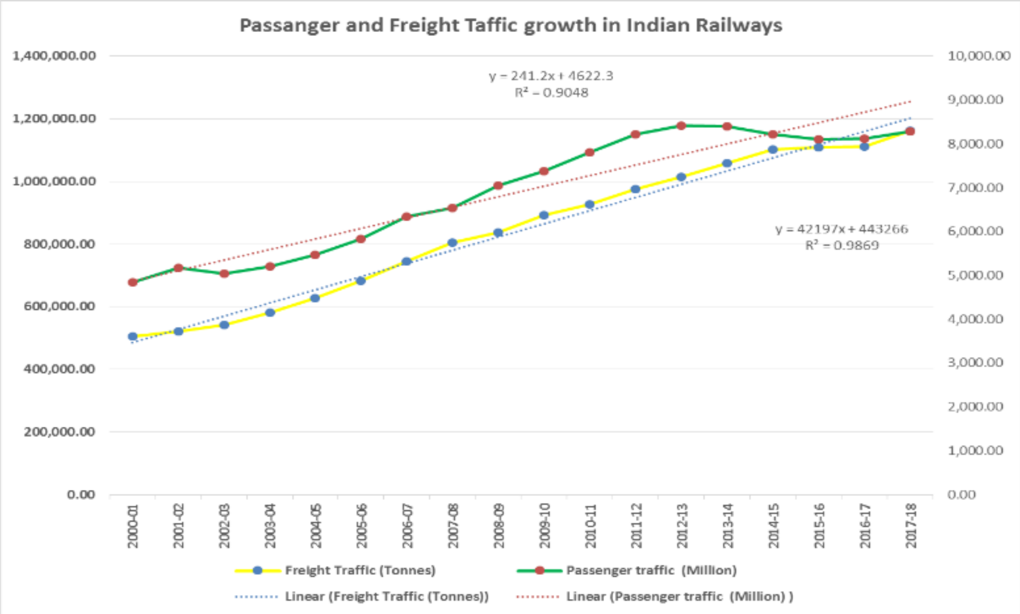


Fig. 1.3: Passenger and Freight Traffic growth of Indian Railways

(Source - By author using CMIE data)

The past data on the passenger (Millions) and freight traffic (Tones) of Indian railways are represented below in figure no 1.3 and table no. 1.1 which shows the pattern of continuous growth of the railway sector in the past. The Freight was a significant element in the rail net profit, as this segment accounted for more than two-thirds of overall sales. Nevertheless, over the last 60-70 years, the carrier has lost its modal share, especially to the road sector. Freight transport by road often obstructs traffic and toxic pollutants that are more troublesome to the city as a whole.

In the past eighteen years, passenger traffic has grown significantly from 4839.8 million in the year 2000-01 to 8257.8 million in the year 2017-18 with an average growth of 3% per annum and total growth of 71%. The freight traffic has grown significantly from 504,210 Tones in the year 2000-01 to 11,62,640 Tones in the year 2017-18 with an average increase of 5 % per annum and total growth of 131% in the past eighteen years.

The revenue from passenger and freight traffic has shown significant growth in the past twenty years; the passenger revenue has grown from Rs. 1,05,150 Million in the year 2000-01 to Rs. 6,10,000 Million in the year 2020-21 with an average growth of 9% per annum and total growth of 131%.

Table 1.2: Passenger and Freight Traffic revenue of Indian Railways *(Source - By author using CMIE data)*

Year	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Freight Traffic (Million Rs.)	233,051.00	248,454.00	265,048.20	276,179.60	307,784.00	362,869.70	417,165.00	474,349.00	534,334.20	585,016.80	628,447.20	695,475.90	852,625.80	939,056.30	1,057,913.40	1,092,076.50	1,043,385.40	1,170,554.00	1,274,327.20	1,347,330.00	1,470,000.00
Passenger earnings (Million Rs.)	105,150.70	111,964.50	125,754.40	132,983.30	141,125.40	151,260.00	172,245.60	198,441.70	219,313.20	234,881.70	257,926.30	282,464.30	313,228.40	365,322.50	421,896.10	442,832.60	462,804.60	486,431.40	510,666.50	560,000.00	610,000.00

The freight revenue has grown from Rs. 2,33,051 Million in the year 2000-01 to Rs. 14,70,000 Million in the year 2020-21 to an estimated annual rise of 10 per cent and total growth of 531%.

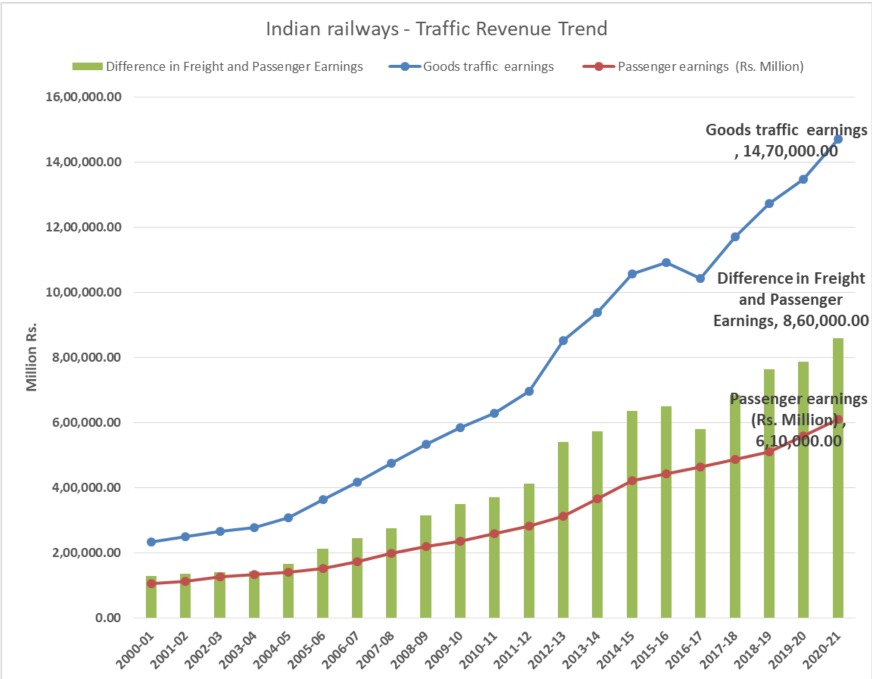


Fig. 1.4: Past trend of Passenger & Freight traffic revenue *(Source - By author using CMIE data)*

Figure 1.4 depicts the steep increase of the freight revenue compare to passenger revenue, the reason for the slow growth of passenger revenue may be the subsidy offered by the government to passenger. However, the traffic growth of passenger and freight traffic is 3 % and 5 % respectively. The IR passenger segment has been making losses due to its unviable fare structure. Indian Railways freight segment is a profit-making one, accounting for almost three-fourth of total earnings. However, the share of railroads in the country's total freight traffic is only about 31 per cent, with the sector losing out to the road sector. Based on the past growth trend of GDP and traffic of railway, the demand of the railway infrastructure will continue to grow and in the future, increased railway network resources would be required to satisfy the demand for potential GDP and traffic growth.

Railway tracks play a crucial role in stimulating the country's economic growth, facilitating smooth transport and creating revenues. The IR network is congested and overused, leading to slower train speeds and potential revenue losses. To overcome these shortcomings, IR focuses on building new lines, doubling existing ones and upgrading narrow gauge to broad gauge.

Table 1.3: Route length development of Indian Railways

	Year	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Route length (KM)	Total (KM)	63,028	63,140	63,122	63,221	63,465	63,332	63,327	63,273	64,015	63,974	64,460	64,600	65,436	65,808	66,030	66,687	67,368	68,443
	Single line	47,018	47,016	46,904	46,940	46,800	46,435	45,961	45,536	45,843	45,368	45,237	45,232	45,593	45,819	45,397	45,450	45,347	45,480
	Double/ multiple line	16,010	16,124	16,218	16,281	16,665	16,897	17,366	17,737	18,172	18,606	19,223	19,368	19,843	19,989	20,633	21,237	22,021	22,963

India has a vast network of railway route with a total route length of 68,443 km spread across the geography. Over the years, Indian railway has made significant progress in strengthening its track and route length.

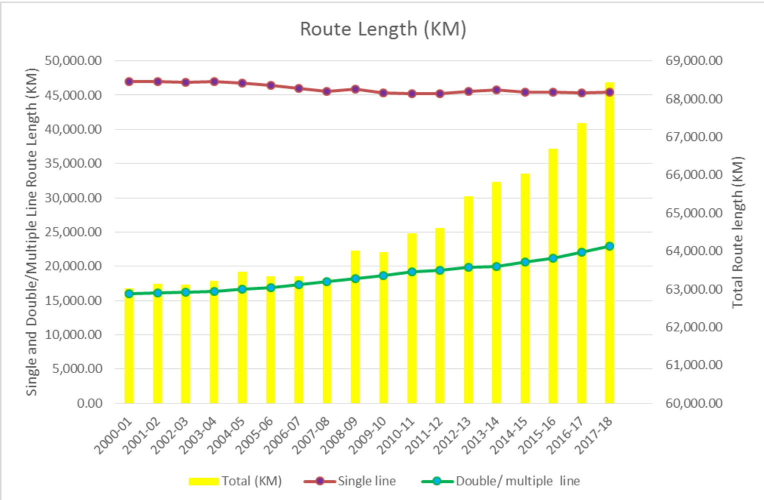
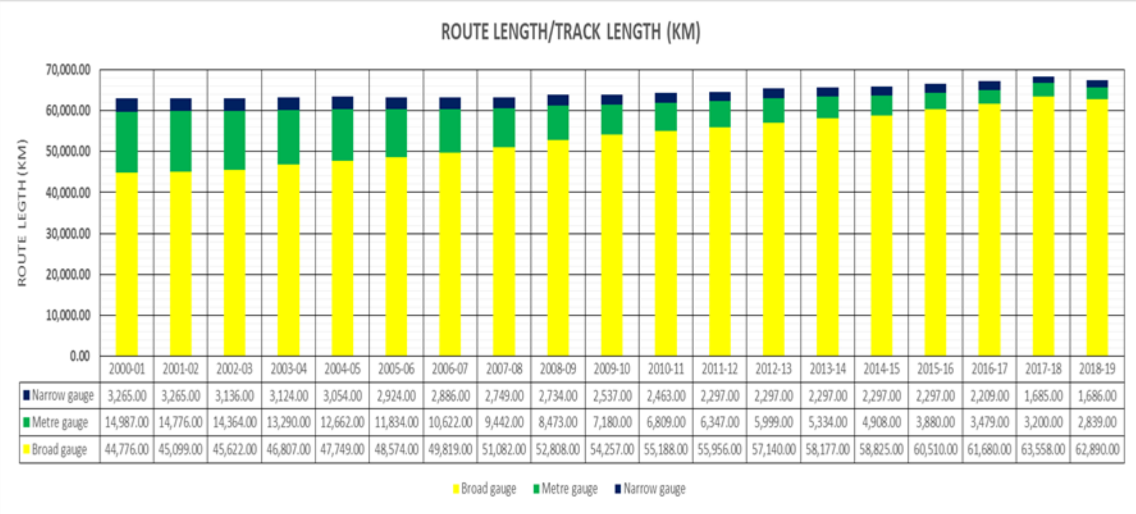


Fig. 1.5: Route Length (km) development of Indian railways

The route length has increased from 63,028 km from in 2000-01 to 68,443 km in 2017-18. Table 1.3 and figure 1.5 depicts the trend of the change in the capacity of route length of Indian railways in the past eighteen years, the year-year growth reveals an inverted U shaped trend and peaking at 2015 to 2018.

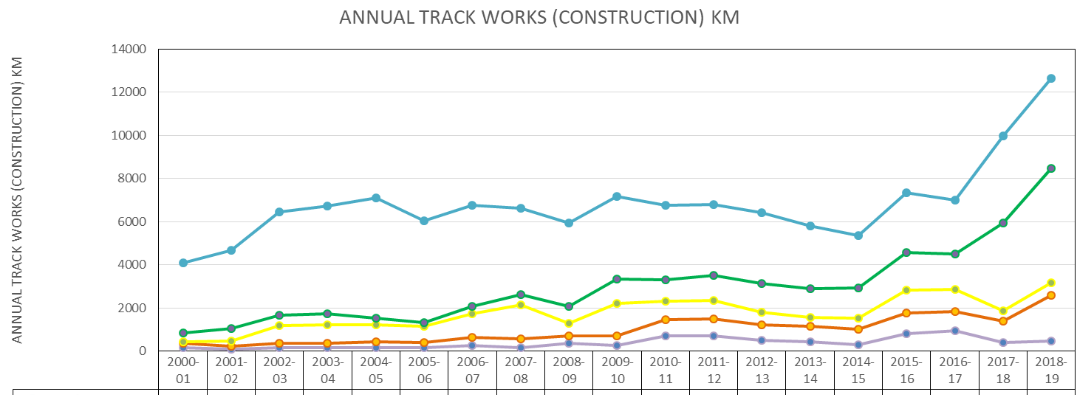


	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Narrow gauge	3,265.00	3,265.00	3,136.00	3,124.00	3,054.00	2,924.00	2,886.00	2,749.00	2,734.00	2,537.00	2,463.00	2,297.00	2,297.00	2,297.00	2,297.00	2,297.00	2,209.00	1,685.00	1,686.00
Metre gauge	14,987.00	14,776.00	14,364.00	13,290.00	12,662.00	11,834.00	10,622.00	9,442.00	8,473.00	7,180.00	6,809.00	6,347.00	5,999.00	5,334.00	4,908.00	3,880.00	3,479.00	3,200.00	2,839.00
Broad gauge	44,776.00	45,099.00	45,622.00	46,807.00	47,749.00	48,574.00	49,819.00	51,082.00	52,808.00	54,257.00	55,188.00	55,956.00	57,140.00	58,177.00	58,825.00	60,510.00	61,680.00	63,558.00	62,890.00

Fig. 1.6: Past trend of capacity addition of BG, MG & NG

(Source - By author using CMIE data)

Figure 1.6 presents the pattern of capacity addition of Broad Gauge (BG), Meter Gauge (MG) and Narrow Gauge (NG) in the past nineteen years. It represents an increase in the capacity of BG and a decrease in the size of MG and NG. Also, figure 1.5 shows a fascinating insight that there is a decrease in the single line route length and an increase in the multiple or double line routes. The BG length increased from 44,776 km in 2000-01 to 63,558 km in 2017-18; however, the MG and NG had reduced significantly. The track construction works are expected to gain momentum in the years to come. The growing portfolio of newline developments and large ticket programs for the construction of dedicated freight corridor and high-speed rail routes is a good sign for these sectors. Nevertheless, the success of these big projects depends on the effective management of the risk at various stages. Figure 1.7 presents the trend of the construction project of Indian railways in the past nineteen years. The infrastructure projects for capacity augmentation are related to Track renewal, Electrification, Gauge conversion, Doubling and new line construction.

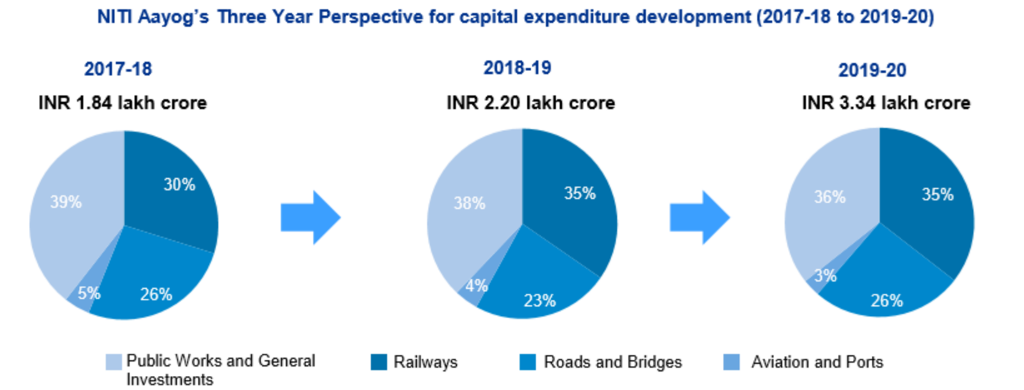


	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Track renewal	3,250.0	3,620.0	4,776.0	4,986.0	5,566.0	4,725.0	4,686.0	4,002.0	3,841.0	3,840.0	3,465.0	3,300.0	3,296.0	2,885.0	2,424.0	2,794.0	2,487.0	4,023.0	4,181.0
Electrification	414	603	455	504	320	170	361	502	797	1,117.0	975	1,165.0	1,317.0	1,350.0	1,375.0	1,730.0	1,646.0	4,087.0	5,276.0
Gauge conversion	92	211	830	854	779	744	1,082.0	1,549.0	563	1,516.0	837	856	605	404	527	1,042.0	1,020.0	454	597
Doubling	200	151	194	206	282	231	386	426	363	449	769	752	705	708	705	973	882	999	2,100.0
New lines	152	94	178	162	150	180	250	156	357	258	709	727	501	450	313	813	953	409	479

Fig. 1.7: Past trend of capacity addition of track related projects (yearly)

(Source - By author using CMIE data)

To increase train speed and load, it is also essential to renovate and maintain the current railway network. Track renewals are allowed either by traffic or by severity (for example, deterioration and track breakage, wear and tear), which is the prevailing circumstances. Apart from the new line construction, the Indian railways also emphasize more on the track renewal projects. Figure 1.7 presents the yearly data of the track renewal construction works from 2000 to 2019, and this shows an upward and consistent growth in the renewal projects from 3250 km in 2000 to 4181 km in 2019. The yearly data of the track electrification work from 2000 to 2019 present a drastic upward growth in the electrification projects from 414 km in 2000 to 5276 km in 2019. Figure 1.7 shows the trend of Gauge conversion, doubling and new line construction in the past nineteen years, it represents a consistent increase in the projects and also the capacity augmentation of the railway's tracks. The Gauge Conversion (GC) construction has picked up from 2006 to 2010 and in 2016-17 with average yearly capacity addition of 1177 km and 1031 km per annum respectively. The doubling construction project has shown a steep upward growth from 2000 to 2019 with an annual construction of 200 km to 2100 km respectively. The new line construction project has shown a consistent increase in the projects with an average 384.74 km per annum from 2000 to 2019. The construction of new line projects picked up from 2010 to 2019 with an average increase of 594.89 km per annum. Figure 1.8 presents the capital expenditure details for the infrastructure projects in India. The three financial year data are shown in figure 1.7; the maximum capital expenditure in all three fiscal years in the infrastructure sector is in the railway sector only. The investment in the railway infrastructure has increased to Rs. 1.6 trillion in 2019-20, from Rs. 64,978.4 million in 2000-2001.



Three year capital expenditure perspective in lakh crore	2017-18	2018-19	2019-20
Railways	0.55	0.77	1.17
Roads and Bridges	0.48	0.51	0.87
Aviation and Ports	0.09	0.08	0.10
Public works and general investments	0.72	0.84	1.20

Source: NITI Aayog Three Year action agenda, 2017-18 to 2019-20, KPMG analysis

Fig. 1.8 - Capital Expenditure for infrastructure projects from 2017-20

(Source - By author using CMIE data)

It has begun to invest in new trains, high capacity wagons, track upgrades for higher axle loads, high-speed trains and terminal growth, logistics parks and freight corridors (DFC). Table 1.4 and figure 1.9 presents the data of infrastructure spending in the railways; the infrastructure spending has grown sharply from Rs. 51,898 Million to Rs. 7,99,929.90 Million from the year 2000 to 2020. The maximum infrastructure investment has seen in the rolling stock, Rs. 8911.7 Million to Rs. 345,148.20 Million from the year 2000 to 2020. In the past considering the significance of railway infrastructure for economy the Government of India has invested huge amount of money to continuously upgrade and maintain it. The demand of the infrastructure is also continuously increasing, may required additional investment to meet the demand.

Table no. 1.4: Past trend of infrastructure spending (yearly)

Year	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Construction of new lines	7,129.10	8,548.60	13,169.30	14,959.80	16,925.80	19,943.70	25,010.40	26,706.90	31,571.80	36,441.80	52,720.30	53,459.80	53,018.20	58,086.60	71,393.90	201,872.8(	143,198.9(	81,952.00	83,853.90	76,777.70
Gauge Conversion	5,090.10	7,397.70	8,475.20	12,175.60	11,832.20	13,235.90	23,173.60	32,324.10	33,374.50	35,805.10	32,320.30	28,217.30	27,001.30	31,033.00	36,635.90	36,156.40	37,699.20	28,801.10	34,865.60	31,183.80
Line Doubling	5,273.00	6,032.90	5,834.10	5,377.10	4,903.20	6,905.30	12,039.70	16,852.30	18,457.70	24,005.90	21,654.40	22,780.40	24,847.30	29,778.20	38,805.90	104,723.5(	90,932.20	112,403.3(	172,541.9(	176,017.6(
Rolling stock	8,911.70	10,099.70	11,093.10	11,306.20	17,028.40	51,973.90	65,783.10	84,366.90	110,765.70	131,610.50	147,077.10	164,107.80	183,655.30	174,983.40	164,897.20	193,794.90	196,109.90	201,392.90	300,791.10	345,148.20
Track renewals	22,446.60	24,629.20	32,977.10	34,843.90	41,252.50	37,789.80	46,183.90	44,791.60	52,490.80	41,058.70	49,845.40	52,859.80	54,261.90	49,853.50	53,715.50	43,675.90	50,763.30	77,277.10	84,716.30	101,200.00
Electrification projects	3,048.30	2,713.40	2,519.70	1,492.70	1,160.00	733.5	2,417.40	4,645.80	7,846.30	7,143.10	6,432.10	8,301.20	9,676.10	12,648.00	13,905.70	22,651.90	28,709.00	37,699.90	70,165.00	69,602.60
Total Infra Spends	51,898.80	59,421.50	74,068.50	80,155.30	93,102.10	130,582.10	174,608.10	209,687.60	254,506.80	276,065.10	310,049.60	329,726.30	352,460.10	356,382.70	379,354.10	602,875.40	547,412.50	539,526.30	746,933.80	799,929.90

The massive investment has made in the purchase of the new rolling stock and up-gradation of the existing one. The doubling project has shown the second-highest investment trend from Rs. 5273 Million to Rs. 176,017.6 Million from the year 2000 to 2020.

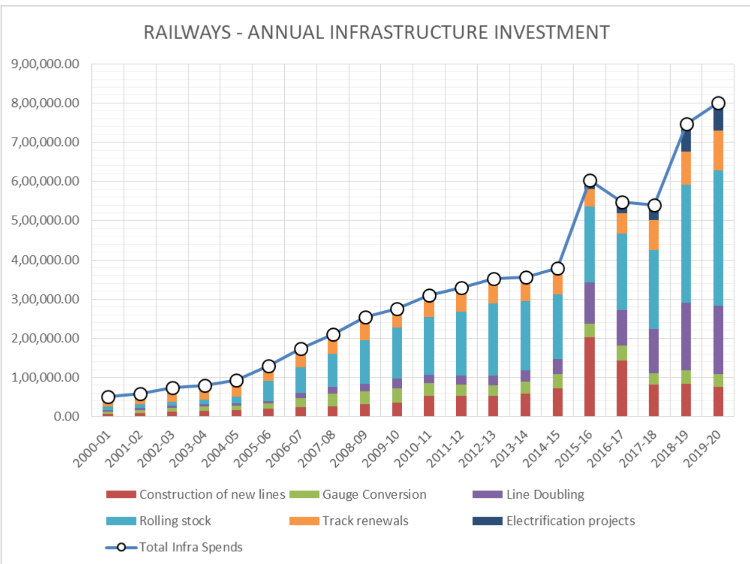


Fig. 1.9: Past trend of infrastructure Investment yearly *(Source - By author using CMIE data)*

The construction of new railways line projects has shown the significant and sharp increase in the investment from Rs. 7,129.10 Million to Rs. 76,777.70 Million from the year 2000 to 2020. Also, there is a substantial increase in the expenditure on gauge conversion, track renewal project and electrification project.

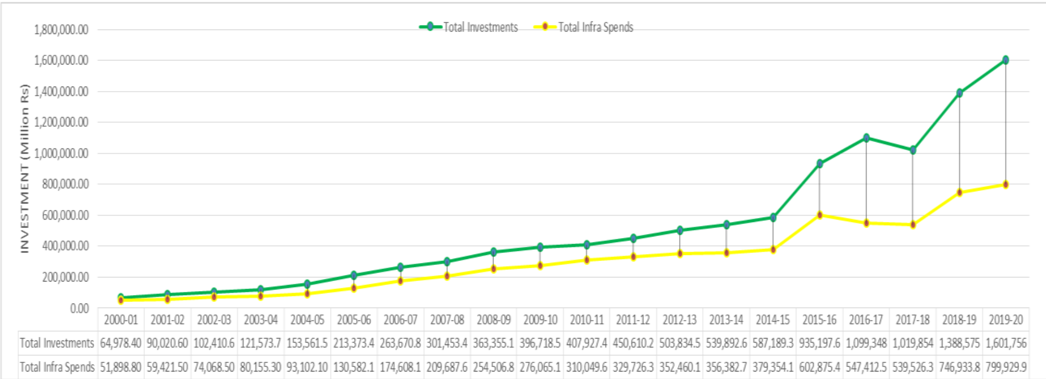


Fig. 1.10: Total railway investment Vs Infrastructure Investment (yearly)

(Source - By author using CMIE data)

Figure 1.10 presents the trend of the total investment and the investment made in the infrastructure projects by the railways. The total investment includes the capital expenditure (CAPEX) and the operational expenditure (OPEX), the total spending has grown sharply on account of the OPEX. The consistent increase in the infrastructure investment has seen in the last twenty years, as presented in figure 1.9 & 1.10. Also, there is a steady increase in the gap of total investment and infrastructure investment in railway projects, as shown in figure 1.10.

There has been tremendous government attention on the IR in the last few years. The government and IR have introduced a variety of significant programs and strategies to improve the industry. Progress has been made, including the upgrade of lines, the 100% automated railway line, capability enhancement of Broad-Gauge including the development of a DFC and port link projects. The DFC project was initiated in the eleventh five-year plan (2007-12) and is perceived to be a game-changer for the logistics network. The initial objective of the DFC project was to triple the freight capacity. Until recently, the project's progress has been slow due to various issues, including land purchase and financing. In the railway's sector, the noticeable improvement has been made on multiple fronts such as the electrification of track network, the introduction of new trains and rolling stock, better services for customers and lower energy costs. In the passenger and freight services, the industry requires massive additional capacity.

1.4. OVERRUNS IN THE RAILWAY PROJECTS IN INDIA

Several railway projects are underway to improve or fulfil the transportation needs of India. As transport efficiency is one of the vital factors of economic growth, transport capacity requirements are significant. During the past, Indian Railways planned and implemented many railway projects. Over recent years, a large number of Indian railway projects were under implementation. Nevertheless, in recent years, these projects have been significantly delayed and not able to stick with the target of budget and timelines. These projects struggled from time and cost overruns consistently. The similar trend of overrun had witnessed in all type of infrastructure projects, as per the latest report from the MOSPI the project worth.

	Cost overrun				Time overrun			
Sector (number of projects)	Original cost*(in INR lakh crore)	Anticipated cost*(in INR lakh crore)	Cost overrun* (%)	No. of projects with cost overrun	Average project duration (in months)	Average time overrun (in months)	Time overrun* (%)	No. of projects with time overrun
Railways (355)	3.55	4.83	36%	218	92	50	54%	43
Roads and highways (509)	3.39	3.45	2%	43	35	19	51%	109
Power (122)	3.37	3.98	18%	43	41	23	56%	67
Oil and Gas (112)	2.01	2.03	1%	17	46	10	22%	35
Urban development (37)	1.42	1.47	4%	7	38	22	58%	23
Coal (92)	0.897	0.892	-1%	9	63	24	38%	38
Steel (30)	0.549	0.552	0.4%	5	58	16	28%	16
Shipping and ports (9)	0.047	0.051	10%	4	32	51	159%	3
Civil aviation (2)	0.0062	0.0099	59%	2	42	51	121%	2
Others **	0.9558	1.0939	14%	5	32	22	69%	16

Fig. 1.11: Sector-wise Performance Infrastructure projects *(Source: KPMG report on Re-vamping the Project management, June 2019)*

As per the MOSPI report (December 2019) presented in above figure 1.11, the 1623 projects costing more than 150 crores, there have been cost overruns of 3.89 lakh crores in three hundred, and seventy-three (373) infrastructure projects and five hundred and fifty-two (552) had shown time overruns. The initial total cost of these 1,634 projects was Rs. 19,40,699 Crore and is expected to end in with Rs. 23,29,746 Crore, which represents the total cost overrun of Rs. 3,89,047 (20.05 % of the original cost). About three-fifths of 373 central projects in India Railway projects face enormous cost overruns due to delays for various reasons in execution. The new flash report of the Ministry for Statistics and Program Integration (MOSPI) for December 2018 shows a cost overrun of Rs. 2.21 lakh crore of over 205 delayed railway projects. Most of the railway projects are showing the delay concerning the planned timelines. The overruns range between some months and five years or more, placing the serious question mark on the feasibility of the project. Delays can contribute to an escalation in project costs and wasteful usage of project resources. A clear time-phase for project completion is provided in a contract document. If the duration is extended, more capital is always spent, which may result in a rise in the project's final cost, as well as losing under-utilizing resources and services. It is, therefore, crucial to delivering the project on schedule, because it will provide ecomic, social and many other benefits to citizens that are missing today.

1.5. RISK MANAGEMENT IN INFRASTRUCTURE PROJECTS IN INDIA

Modern transportation projects are highly challenging to build and deliver. The long-term delivery and complexity of such projects call for an appropriate approach that represents the risk and uncertainty they pose across their life cycles. A wide range of stakeholders also collaborates in infrastructure projects project life cycle. Whereas the complicated nature of these projects involves the delegation of roles between highly specialized entities (such as contractors and customers), the relationships between specific parties are essential and should be planned and handled from the beginning. All these dynamics of the project creates a lot of risks between stakeholders. Surprisingly, the risks associated with large infrastructure projects are often not assigned appropriately to those stakeholders that are appropriate to handle those risks. A more holistic risk management strategy will tackle the critical issues posed by all stakeholders and project partners during their life cycle. As per the Global construction survey (2016) Projects worldwide are increasing in size, become more dynamic and with more complexity. Commenting on India's projections, KPMG India says: India should become the third-largest development in the world market with a size of USD 1 trillion in 2025 and is among the world's fastest-growing construction markets. The increasing scope and scale of projects increasingly push in the construction industry the complexity and project risks. As per the KPMG India report, the risk is rising: over 80 % of project stakeholders in India agree that projects risk is growing quickly and sufficiently in reaction to change, more nuanced project management approaches. The FICCI and PMI report (2015) offers priority areas for action in improving project management in India.

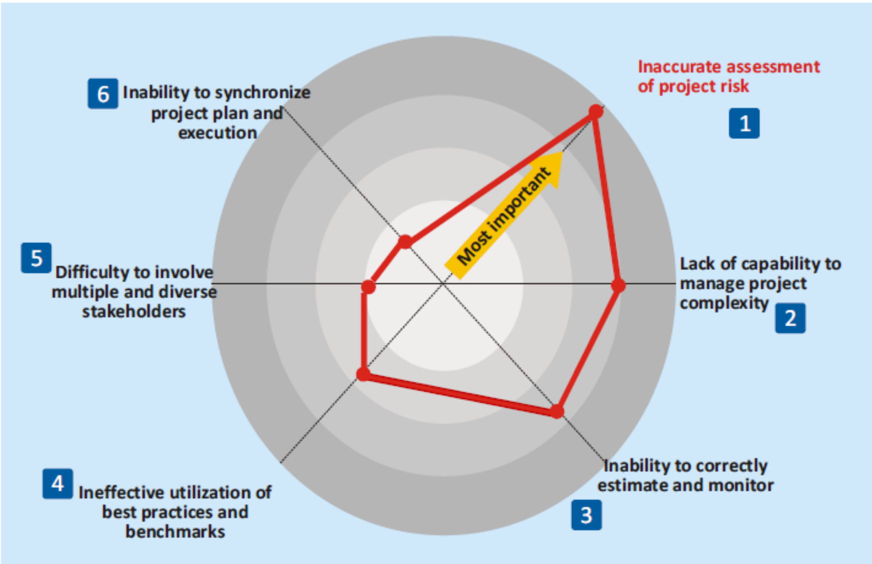


Fig.1.12: Factors causing the inefficiencies in Infrastructure projects *(Source - FICCI and PMI report, 2015)*

The chart above (Fig.1.12) illustrates how important issues are viewed and ranked. The study shows that the most significant obstacle and limitation on PM is the unreliable estimation of risk. The report indicates that a failure in the project is usually triggered by inadequate risk identification and risk management in India, the organization are trying to create a culture where the project team is like on-the-ground reporters who actively feel and convey the risk without fear of being accused to middle or upper management. The report looks at studies on project management execution in different areas, which reveals that transportation and real-estate are two industries in which RM efficiency is very low.

Planning parameters considered

Project Planning Parameters	% Yes
Project Scope	100
Project Budget	100
Project Delivery Schedule	95
Project Management Plan	90
Project Delivery Team	80
Project Target Benefits	85
Project Quality Parameters	80
Project Risk Management	65

Source: FICCI Analysis

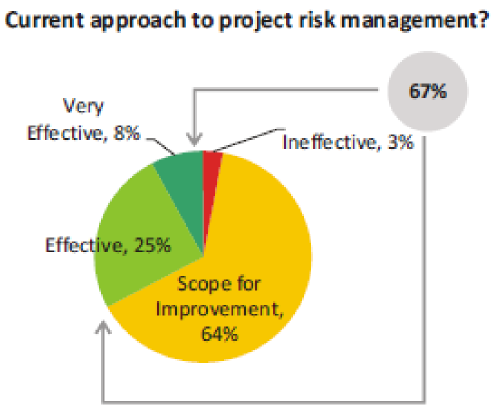


Fig. 1.13: Adoption Level – Project Planning Parameters *(Source: FICCI and PMI report, 2015)*

Figure 1.13 indicates the extent of the use of different knowledge area for successful project execution but clearly shows that there is an immediate need to strengthen the risk assessment and management process in Indian projects. Most companies in India say that insufficient risk control is a crucial cause of concern. The more risks identified and prepared for, the more the project manager would be in place to achieve a good project. Most respondents described risk management as best practice. Respondents indicate a varying degree of risk management effectiveness in their organizations, as shown in figure 1.12.

The research by KPMG & PMI (2010) unravels the issues inhibiting effective project execution. The research analyzed the views of over 100 top executives in many infrastructure sectors from leading Indian firms. The survey identified the need for independent review and monitoring of risk management; a majority of respondents shared a widespread sense that substantial changes should be made for effective implementation and assessment of project risks and Uncertainty will directly affect the project's results.

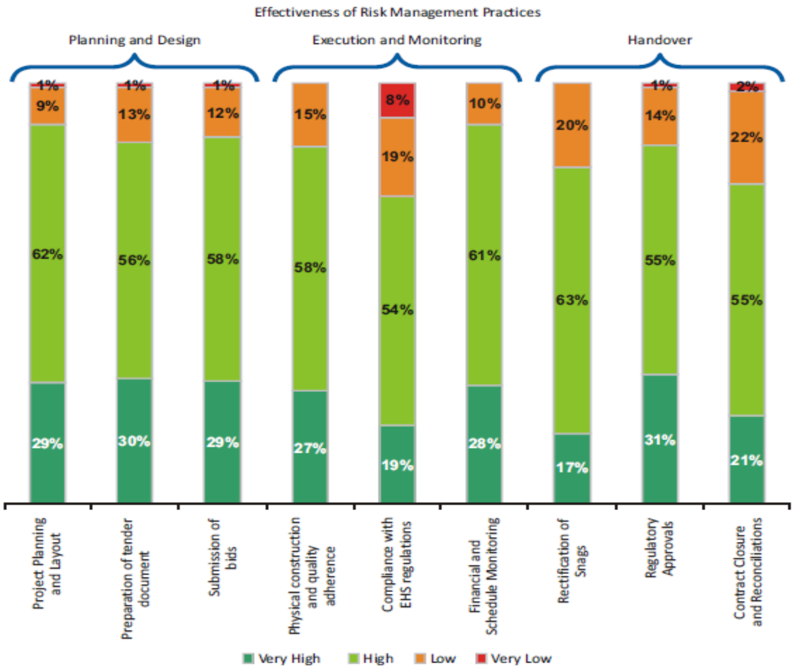


Fig. 1.14: Effectiveness of risk management practices across the life-cycle *(Source: KPMG & PMI report, 2010)*

The need for separate, internal or publicly accountable organizations to promote routine risk assessments and monitoring is another familiar feeling that is key to successful risk management.

Fig. 1.15: Effectiveness of Current risk management practices *(Source: KPMG & PMI, 2010)*

Despite risk management procedures and programs introduced at project, organization or organization stage, the majority of respondents believe that there is a vast potential for increasing the RM practices at the project site.

Sixty-seven percent of respondents viewed risk reduction activities as ineffective or with large potential for improvement. Just 14 per cent of contractors considered their existing risk management practices quite effective based on the respondent profiles.

Wide railway projects are subject to extensive risk at nearly all levels. Most overruns are predictable and avoidable; many of the issues found are attributed to a lack of application of project management and a forward-looking attitude to risk management. The identification, assessment and allocation of risk factors involved in the railway project are also essential to ensure the execution of projects in all respects, i.e. the planning, development and commissioning of projects without overruns of costs and time.

1.6. MOTIVATION FOR THE RESEARCH

Considering that transport efficiency is one of the main drivers of economic growth, it is essential that transportation needs to be fulfilled. There are expected a significant number of railway projects under development to expand efficiency and satisfy India's transport network needs. The substantial number of railway projects proposed and initiated by Indian railway in the past in the railway budget. Nonetheless, over the past few years, these initiatives have frequently fallen short of meeting expected goals. It is a reality that most rail projects had shown overruns, and it has harmed exchequer because financing is one of the major hurdles of the infrastructure project in the past and present projects. If projects consistently show the overruns, then the sentiment of the investors will be influenced, and funding for the future project will also be affected. Large railway projects are profoundly affected by risk at all levels and over the life of the project. Any overruns can be predictable and avoidable; much of the problems identified contribute to a lack of application of project management and forward-looking risk management practices. The current major railway project provides the potential for structuring in such a way that the highest benefit can offer to transportation.

The research on RM has growing in recent years, however, no work has done to examine the overall facets of risk reduction from the experiences of various project participants for railway construction projects systematically.

The research work will be quantitative on the Indian railway construction stakeholders, through surveying the significance of project risks will be identified. The quantitative risk analysis and modelling have conducted to quantify the effect of risk on the planned timelines and budget. Furthermore, the risk quantification model would be developded for the effective management of the risk in the project. The research would be really useful for the sector to established risk management procedures, such that, extra overruns can be reduced.

CHAPTER 02

LITERATURE REVIEW

2.1. INTRODUCTION

The business problem as identified being ‘Inaccurate assessment and management of construction project risk are adversely impacting the construction efficiency of Indian railway projects”, relates to the Project Management (PM), Project Risk management (PRM) and its subsects. A two-part analysis of the literature is needed to critically understand the business problem and further to find a way forward with suggestions. The first part is a review of the key terms using the technical significance of PM and PRM in construction management; whilst the second part is focuses on the comprehensive literature relevant to PRM into the different theme and subsections as noted from the business problem and seeking commonality between them and their associated gaps. Also, utilizing various recommendations drawn from this secondary research, to formalize a conclusion.

2.2. THEORETICAL SIGNIFICANCE

A thorough review of various literature such as books, magazines, academic papers, reports and other online articles was conducted; to understand the theoretical meaning of the key terms, i.e. Projects, construction, PM, project performance, project controls, risk, project risk and risk modelling.

2.2.1 PROJECT

As per the *PMBOK Guide* (2017), “A project is a temporary attempt to create a new product or facility”. The temporary existence implies a definite timelines (start and finish) for the project. The project stops until the aims are accomplished in certain situations or when the project fails that is, whether it is not possible to implement or where there is no longer a requirement for the project being pursued. Temporary doesn't mean project length is limited. The word temporary implies the commitment of stakeholders and the duration of the project. Temporarily does not occur in respect to a product, operation or outcome generated by the product.

The uniqueness of the project is due to the specific design of the projects; most of them may have differences or variations in the outcomes of the facilities or the results achieved by the project. A project can include repeated features in any of its milestones or tasks; however, this repetition does not alter its underlying distinctive traits.

The uniqueness is also due to the standard process involved in the construction and the complex collection of activities planned to meet a particular objective. But the project team also includes individuals who usually don't operate together— sometimes from various companies and through several locations. Project management is also the implementation of expertise, abilities and strategies to carry out tasks successfully and efficiently.

2.2.2 CONSTRUCTION

The Construction is a one-time operation - the first moment it needs to be carried out correctly. It is a dynamic process requiring the multidisciplinary methodology to undertaking a series to interrelated activities to be conducted by experts. Construction entails a high expense and time of implementation, a high probability of delay, often a challenge in determining quality requirements and expectations of the client. That often exudes the essence of the interaction between individuals and untrained workers. Some of the external factors make it more complicated and risky such as market condition, political scenario and economy (micro and macro factors) (Mills., A.,2001, 245-252). Construction is a process of building a structure or facility. The structure may be a building or a public infrastructure such as road, urban facilities or an airport. The construction is a sector of diverse and complex processes. The processes required effective collaboration among separate firms, including consultants, investors, suppliers, labour unions, stakeholders, municipal authorities and others (Keane & Caletka, 2008). Construction varies from that of manufacturing, where production usually requires mass production of identical products without a specified customer.

In contrast, construction generally happens at the specified location, and two projects will not be identical in terms of the product and process also. The construction process includes the planning, design, finance and construction, after a building or infrastructure facility is constructed and occupied for the uses, the operation and maintenance work will start and will continue until the design life of the project. The entire construction and development process involves multidisciplinary expertise and teamwork [Online source - http://en.wikipedia.org/wiki/Construction].

Construction Projects broadly categorized into three broad categories: buildings, industrial and infrastructure. The Infrastructure construction projects categories into the transportation, water & sanitation, energy, telecom and urban infrastructure projects. The Industrial construction projects involve industrial plants, refineries, electricity generation, factories, and production facilities. (Online source - http://en.wikipedia.org/wiki/Construction). Each construction project needs detailed planning of resources, design, and construction of a set of activity and facility, contributing to multiple exposures to the risk. Latham (1994) notes that every project is a risky business and required careful implementation of concepts of project risk management.

2.2.3 PROJECT MANAGEMENT(PM)

PM is to add knowledge, skills, techniques and strategies to project tasks to achieve project goal according to the PMBoK Guide (2017). Project management is accomplished by integrating and incorporating the 49 PM procedures, which are regularly classified and grouped into five process categories. Those five-phase groups initiating, planning, executing, monitoring & controlling and closing. Furthermore, these categorized PM processes are further divided into ten distinct Knowledge Areas, where each represents a particular collection of concepts, terminology, and procedures that form a specialized domain within the knowledge area within project management, or field of specialization. Such Information Areas and Processes are utilized widely by project team members through project management. The knowledge areas provided in PMBoK (2017) are directly linked with constraint such as time, cost, quality, scope, resource & risk. The knowledge area also covers communication management, which is crucial to project progress along with Procurement Management, an essential domain for project resource selection. Stakeholder management, as an essential knowledge area because of various stakeholders and their collaboration in the project, is significantly influencing the efficiency of the project in recent times. Integration management is about putting all the things together to produce a good project. The knowledge areas and the process are presented in figure 2.1.

2.2.4 RISK

The meaning of risk, according to the Cambridge dictionary, is "probability of something going wrong." The word is associated with adverse risk, i.e. explosion, threat, structural collapse and dangers etc. Risk is the likelihood for failure (though not generally an unfavourable outcome) arising from a specified event, activity or inaction, foreseen or unforeseen (Wikipedia). A better definition of “Risk” can be that – it is the probability of an outcome different than being envisaged. In other words, the outcome may be better than what was thought. E.g. currency exchange risks, market risks that are dependent on supply and demand etc. ISO 31000-2009 explains "Risk is the impact that uncertainty has on project objectives." The description emphasizes the unknown probabilistic nature of events and their impact on the predefined objectives. The various companies working in the different sector have defined the risk according to particular field/domain. Risk is the possibility of benefits or loss for some attributes. The attributes may be the physical health, or financial wealth acquired or sacrificed as risk is exposed, resulting from the foreseen or unexpected consequence of an event. Risk can also be characterized as deliberate contact with uncertainty. Uncertainty is a possibility of the unforeseen and uncontrollable event; the risk is attributed to actions taken amid uncertainty.

Knowledge Areas	Project Management Process Groups				
	Initiating	Planning	Executing	Monitoring & Controlling	Closing
Project Integration Management	4.1 Develop Project Charter	4.2 Develop Project Management Plan	4.3 Direct and Manage Project Work 4.4 Manage Project Knowledge	4.5 Monitor and Control Project Work 4.6 Perform Integrated Change Control	4.7 Close Project or Phase
Project Scope Management		5.1 Plan Scope Management 5.2 Collect Requirements 5.3 Define Scope 5.4 Create WBS		5.5 Validate Scope 5.6 Control Scope	
Project Schedule Management		6.1 Plan Schedule Management 6.2 Define Activities 6.3 Sequence Activities 6.4 Estimate Activity Durations 6.5 Develop Schedule		6.6 Control Schedule	
Project Cost Management		7.1 Plan Cost Management 7.2 Estimate Costs 7.3 Determine Budget		7.4 Control Costs	
Project Quality Management		8.1 Plan Quality Management	8.2 Manage Quality	8.3 Control Quality	
Project Resource Management		9.1 Plan Resource Management 9.2 Estimate Activity Resources	9.3 Acquire Resources 9.4 Develop Team 9.5 Manage Team	9.6 Control Resources	
Project Communications Management		10.1 Plan Communications Management	10.2 Manage Communications	10.3 Monitor Communications	
Project Risk Management		11.1 Plan Risk Management 11.2 Identify Risks 11.3 Perform Qualitative Risk Analysis 11.4 Perform Quantitative Risk Analysis 11.5 Plan Risk Responses	11.6 Implement Risk Responses	11.7 Monitor Risks	
Project Procurement Management		12.1 Plan Procurement Management	12.2 Conduct Procurements	12.3 Control Procurements	
Project Stakeholder Management	13.1 Identify Stakeholders	13.2 Plan Stakeholder Engagement	13.3 Manage Stakeholder Engagement	13.4 Monitor Stakeholder Engagement	

Fig. 2.1: Knowledge Areas and Process Groups *(Source: PMBOK, 2017)*

2.2.5 PROJECT RISK

Further PMI has given a more specific definition of risk in the projects, “It is an unpredictable occurrence or situation that, if occurring, affects the project objectives positively or negatively”, objectives may be safety, quality, scope, cost and time for a project. Risk can have one or more triggers and, if it happens, can have one or more consequences. Risk circumstances that involve team characteristics or enterprise effort towards the management of the risk, the insufficient project management procedures, overlapping numerous projects will lead to ineffective management of the project. Project risk originates from complexity and uncertainty inherent in all projects.

The three types of project risk, as described by Tom Kendrick (2015), are a known controllable risk, known uncontrollable risk and unknown risk. Many other works of literature have categorized themselves as established risk controllable and uncontrollable known risk (Sedat Han, 2005; Kodukula P., 2014; Renuka S.M *et al.*, 2014). Known risks are risk that can be timely identified and assessed, allowing responses to those risks to be prepared, which are known controllable risks. The contingency fund will be dedicated to known uncontrollable risks that cannot be actively handled. Unknown risks uncertain in nature and difficult to predict such a risk hence a management reserve can be reserved to deal with such risk (Tom Kendrick, 2015).

The overall risk reflects the effect of uncertainty on entire project. It reflects stakeholders exposure to the consequences of both positive and negative differences in the project result

2.2.6 PROJECT RISK MANAGEMENT (PRM)

It is one of the expertise fields within the professional body of Project Management (PMBOK, 2017). This focuses on processes relevant to risk management to reduce negative outcome and maximize the result of good outcomes (Rita M., 2003, 21-22). There are several benefits of the risk management approach in projects like improved prospects for project performance, proactive control of risks, realistic reduction of risk, cost-effective decision making, optimum performance and higher team engagement. Risk management (RM) has two main characteristics; firstly, risk-based decisions are assessed based on associated risks before selecting an alternative, and secondly, RM procedures should be standardized & iterative across the life cycle of the project. RM can also be an iterative mechanism (Hilson & Simon, 2007). The effectiveness of successful risk management relies on the mindset of the organization, the capabilities of employees, clear and functional procedures and strategies to be utilized within the project. Given the significance of the area, various qualified project management organizations around the world have proactively explored it in the past and continue to be a prominent research area in the future.

As per the PMBoK (2017), the generally accepted risk management process for the project starts with the preparation of the risk management process includes identification, assessment (Qualitative and Quantitative), risk response planning and, ultimately, risk monitoring and control. risk identification is one of the first and necessary measures, since "risk detected is the risk that can be handled." The goal is to define both new, identified and suspected risks in the project. (Smith & Jobling, 2014, 01-19).

2.2.7 PROJECT MONITORING & CONTROLS

The objective of project monitoring and controls is to detect and correct deviation from the planned budget, timelines, quality. The monitoring includes the detection of the progress, issues and problems faced by the project. It involves a mechanism relevant to monitoring, evaluating and reporting on performance in achieving the output targets laid out in the project management program. The main advantage is that it allows stakeholders to recognize the actual state of development, the actions taken, and the strategy, timetable, and range of projections. Controlling may require detecting potential threats and reviewing, recording and controlling current project risks to ensure that threats are detected, that their status is recorded, and that effective risk management strategies are enforced. The controls provide the corrections essential to get project success back on track with plans. The monitoring and controls to be performed throughout the project lifecycle. The PMBoK (2017), standardize the process for the monitoring and the controls of the project.

2.2.8 EARNED VALUE ANALYSIS (EVA)

Among the most commonly known project performance tracking methods employed by project management professionals is the Earned Value Assessment (EVA). Evolution of the EVA has, for the most part, been centred on cost control and cost-based assessment for the schedule and cost performance both. (Brandon, 1998; Fleming and Koppelman, 2004; Kim et al., 2003).

The basic fundamental of EVA is every step to earn the value; it means that whatever you perform or execute in the project has received some value or earned some value, so they return value against its accomplishment. The Earned Value (EV) is the amount of work achieved against the budget for the same quantum of work.

2.3. DETAILED LITERATURE REVIEWS

The comprehensive literature review was conducted about the business problem, few criteria or theme for a comprehensive literature review are construction project management, Project Risk Management, Public Infrastructure and railway projects and Project Performance Mapping or project controls.

The detailed literature review was conducted to explore business problems in a more comprehensive way. The keywords of the business problems are *inaccurate assessment and management of project risk* requires a thorough understanding of RM practice and processes for the projects. A systematic literature analysis has been carried out to understand the contribution of global and Indian research on the RM. The second keyword is performance; a detailed review of literature is carried to understand the performance criteria's. Overruns significantly affect the project performance, hence equally Essential to consider the route-cause of these overruns. Therefore, a systematic literature review needs to be carried out to understand the root cause or attributes, causing the overruns.

2.4. LITERATURE REVIEW ON CONSTRUCTION PROJECT MANAGEMENT

Project management typically involves, including but not confined to, balancing several project constraints such as Scope, Quality, Schedule, Budget, Cost and Risk 'PMBoK Guide (2017), which is seen in pictorial form in Fig. 2.2.

Fig. 2.2 — Six Project Constraints *(Source: PMBoK Guide (2017)*

Tsuda (2006) observed that "Scope, Time, Cost are classic. The other three constraints, i.e. Quality, resources and risk, which are subsequently added as part of the constraints. Moreover, their acceptability as a specific constraint when assessing the project and its performance is the subject of debate among numerous project management experts; although different proposals for grouping the constraint have also been debated for quite a long time.

Ah, Rahschulte, T. J. Milhauser, K. (2010) explained that' Many participants employed with the Project Management Institute are acquainted with the triple' constraints' and their interaction with each other. These efficiency-based measures are also classified as successful and incomplete. Experienced project managers recognize that there is a range of constraints to be satisfied in order to achieve long-term organizational sustainability. Although most have been published regarding the triple constraints, no work has been undertaken to assess the patterns coupled with shifting project planning or constraints priority to meet the (larger) demands of businesses. Success, as calculated by the triple restrictions, of a particular initiative, does not guarantee the performance of the enterprise as a whole. Efficient project managers will strive to execute their programs within the scope, timeline and cost constraints.

However, Nahod and M.M. (2012) claimed and reaffirmed that along with time and costs it constitutes one of the most critical constraints and focuses on the project. Consequent to the above discussions and comments, the triple constraint of Scope, Time and Cost are taken up as the first step of detailed literature review.

2.4.1 SCOPE AS A PROJECT CONSTRAINT

According to the PMBoK Guide (2017), scope as a constraint includes the procedures used to ensure to incorporate both the necessary work and, mostly, the work required to implement the project efficiently. The primary goal in determining the scope is to identify the accurate scope and contols the change in the scope during execution of the project. Defining design with feedback from all stakeholders is a critical activity that requires to be properly executed from an early level. The project definition aims to include sufficient detail that is required to define the project to be completed to prevent significant changes that could adversely impact the performance of the project. (Gibson et al., 2006).

Project success in terms of project performance can-not be accomplished without a structured and properly defined scope (Nahod, M.M. (2012), which can be achieved by identifying the variance to the scope while taking control of them. Osama Hussain (2012) describes the scope of the project as among the peculiar constraints in the construction industry, which significantly impact the output of an industry. The adjustments in scope and creep in the design are completely different. "Scope Change is a legal agreement taken between the stakeholders to alter an ' X ' attribute to extend or reduce its features. In general, improvements in nature include revisions to cost, schedule, certain functions, or the schedule. But at the other side, "Scope Creep is widely referred to as the condition where the initial project scope for creating a product with various items, slowly extends beyond the originally defined quantity in the job statement. It applies to design shifts that arise gradually and unofficially, without adjusting the target dates or having any other modifications to the schedule. The Scope Crip may be regarded as a possibility for a project to extend beyond its initial limits (PMBoK, 2017). Change is inevitable; hence, any form of change management mechanism for each project is necessary. Control scope is often utilized for handling the specific changes; it is combined with the project management process.

Moreover, from the viewpoint of stakeholders, variations in interpretation of scope during the design stage and during execution may lead to variation in the scope. The concept should not only be determined on in advance, but it must also be constantly monitored throughout the project to avoid it from changing in a way that violates the schedule or timetable, stakeholder perceptions of the final outcomes. Typically, this is termed scope creep. (Paul Newton, 2015) (Virginia A. Greiman, 2013).

As most projects are complex and implemented in a fast-track manner, inadequate understanding of project scope, change control and management efficiency lead projects to exceed budgets and delay incompletions, Since the majority of projects are complex projects. The study of Neslihan Alp's survey results, Banning Stack (2012), suggested that 78 per cent of the population replied that unauthorized scope creeps project cost overruns. Henry Alinaitwel, Ruth Apolot, and Dan Tindiwensi (2013) observed that '84% of scope change' was triggered by 'cost overrun' and indicated that stakeholders in the construction industry should minimize project scope changes as that will have the largest effect on cost/time overruns.

Modification of the negotiated framework is known to be inherent in the design of the projects owing to their size and the possible existence of unexpected problems (Ertel, 2000). Although effective front-end project planning, and a consistent project scope description, will minimize the risk for overrun costs; insufficient project preparation and weak scope identification will contribute to expensive revisions, setbacks, rework, increase in cost, and increase in the timeline, and ultimately the projected loss (Assaf & Al-Hejji, 2006).

Project scope shifts involve project expenses, resources, and quality adjustments, whether they reflect a change in scope or a reduction of scope. Some of the more popular reasons of change orders are 'project scope modification by owner (additional- enhancement)', and some of the more popular consequences of change order increase the expense of the project, increase the size & duration of specific tasks and delay in completion schedule (Alaryan *et al.* (2014)), The scope change phenomenon will impact to the client, there is no direct impact to the contractor's on cost or timeline by way of contract variations. As activities shift without increasing the expense or duration of the project, having a scope creep raises the probability of failure to finish the project on schedule as well as the risk. However, overrun can also be considered as a change of scope; this allows the opportunity to deliver quality output. (Fabiola Nibyiza, 2015).

It summarizes that, once the scope creep happens, it may result in risky situations to the project (Paul Newton, 2015), whether known or unknown, by cost overruns and timeline delays; the same should be addressed by Project Risk Management to comply with these incidents and keep the project under the track.

2.4.2 COST AS A PROJECT CONSTRAINT

Cost is one of the key factors in the development process of the project and can be counted among the most significant constraints of a project and the motivating force underlying project performance (Azhar et al., 2008; Ali & Kamaruzzaman, 2010). Despite its proven worth, very few projects fall within the budget allocated to accomplish its objectives (Dinesh Bhatia, M. R. Apte, 2016).

The effort starts with planning and strategy, then estimates, budgets and finally controls over the cost. An estimate is a method of developing an assessment of the cost required for performing Project tasks & Budget assessment is the method of consolidating the total costs of the particular tasks or packages along with the timeline to create an approved cost baseline.

As the literature review on the cost as a constraint in the previous section and the details as stated above, it was noted that the estimated cost of the activity and work package is an only approximation, above which a 'Contingency reserve' is summed to take care of the known risks to finalize the capital cost. In addition to this contingency reserve, however, 'management reserves' to take care of unknown risks to arrive at the final budget.

Though on detailed analysis of the incorrect cost calculation, Ahiaga-Dagbui, et al. (2015) also reported that' it is no wonder that the same variables are highly significant such as - inaccurate assessment of the cost (A.S. Ali, S.N. Kamaruzzaman 2010), bad project management, insufficient risk control, unpredictable ground conditions.

Although knowing that the cost estimate is just an approximation, it is important to make the required allocation to arrive at a baseline cost. This is done by reserve analysis (PMBoK Guide, 2017) Contingency reserves, as mentioned above, required to mitigate the risks in the project.

It also validates that the triple constraints discussed earlier are interlinked with each other and have an effect on each other in the event of some change in one project constraint parameter (Love et al. 2005).

2.4.3 TIME AS A PROJECT CONSTRAINT

Project Time Management, according to the PMBoK Guide (2017), includes various time-control processes for the project. The aim is to deliver the project in due time on the basis of the contract milestone dates. There are different approaches for calculating project time depending on scope and type of the project, while at the same time considering several project limitations, while at the same time arriving at a baseline schedule.

Completing projects on schedule is one of the measures of performance of the construction project, but many variables and complex influences that originate from multiple sources essentially influence the schedule of the construction project. These sources include stakeholders, availability of resources and fund, social & environmental factors, and contractual relationships of various parties. However, a project is seldom performed within the defined timeline and under budget (Assaf & Sadiq, 2006); Although it is also known as incident that extends the duration needed for the execution or fulfilment of a contractual obligation. (Zack, 2003). The impact to owner is in the form of delay and disruption in the development and ultimately the delay in the revenues generation from the facilities. Delay affects the contractors in many ways, such as increased overhead cost, higher material prices by inflation, and rises in labour costs. As reported by Keane and Caletka (2008), the most significant unanticipated costs associated with delay and disruption to the works are the financial impacts on many construction projects.

Delays in construction projects can trigger frustration among all the project parties, and here the key function is to ensure that jobs are finished within the period and expense of the budget. A lot of work has been conducted to clarify the root cause of the delay with respect to different categories of the projects.

Delays detrimentally influence the success of project, especially in terms of time and cost constraints (Association of Project Managers 2006, Arditi and Pattanakitchamroon 2006). The implications of time run are not confined to construction companies but can have an effect on the overall economy of a nation, particularly a nation like India, which suffers from a lack of the infrastructure development fund. (Motaleb and Kishk, 2010).

2.5. LITERATURE REVIEW ON PROJECT RISK MANAGEMENT (PRM)

PRM relates to culture, procedures, & processes aimed at successfully addressing future risks and detrimental impacts on the project. Although other research demonstrates the risk assessment process for construction projects has a low maturity level which has an effect on the efficiency on project outcomes cumulatively in India. The RM is typical to be conducted from the beginning for the improvement in the overall project management with an approach to reduce the risk, which yields adverse outcomes and improve the expectation of the success of project management. Risk is taken care of by using the cost contingencies and floats (time) in the projects (Serpella et al., 2014).

It is necessary to have a consistent and organized methodology and, most significantly, theoretical expertise and practical experience in different domains, to allow accurate and productive risk management. Typically, it takes skill to recognize the unexpected events that might arise during the implementation of a project, the mitigation measures that function best for its prevention when those events occur, while one might not be an expert in dealing with all the risk events in the projects but can identify the most of them and present to the team for the solutions.

The lack of an appropriate risk management mechanism for a project has some negative implications for project participants due to lack of proactive measures toward the risks in the project. RM typically relies primarily on perception, experience and knowledge of the stakeholders. The systematic RM procedures are seldom used because of lack of expertise and reservations regarding the adequacy of such approaches for projects. (Akintoye & MacLeod, 1997). This can contribute to delays, increase in the cost and contractual conflicts among the party.

Construction projects are defined as very dynamic, often special, and there are risks from multiple sources. Control of the construction project includes several stakeholders: end-users; developers; consultants; regulatory bodies, sub-contractors, vendors and other agencies. (Perez et al., 2010, Rasool Mehdizadeh, 2012). Such projects involve constant decision-making because of multiple risk sources, many of which are not actively monitored by project participants. RM is generally recognized as a crucial field of project management. (Anna Klemetti, 2006).

A thorough theoretical analysis on PRM has been conducted to clarify various concerns listed above and the outcome summarized in subsiquent section. As per Rita M (2010) The PRM is a comprehensive & systematic approach for managing or minimizing (unknown) project risk. RM, therefore, includes mainly mitigating the effects of negative outcomes as well as maximizing the positive incidents. Thus outcome may be caused by the positive or negative incidents resulting may be the benefits or loss, respectively. Risk management is a comprehensive approach to look at at-risk areas and consciously evaluate how each will be handled. Risk management can be characterized as a process for finding, assessing & mitigating risks (Ana, Alvaro and Rafaela (2014) to improve opportunities and reduce dangers impacting project goals (Azadeh Sohrabiejad and Mehdi Rahimi (2015)) Although it is described as a systematic method involving risk findings, analysis, review, decision-making & management of risk response strategies and control of risk response plans implemented (Walke et al., 2011).

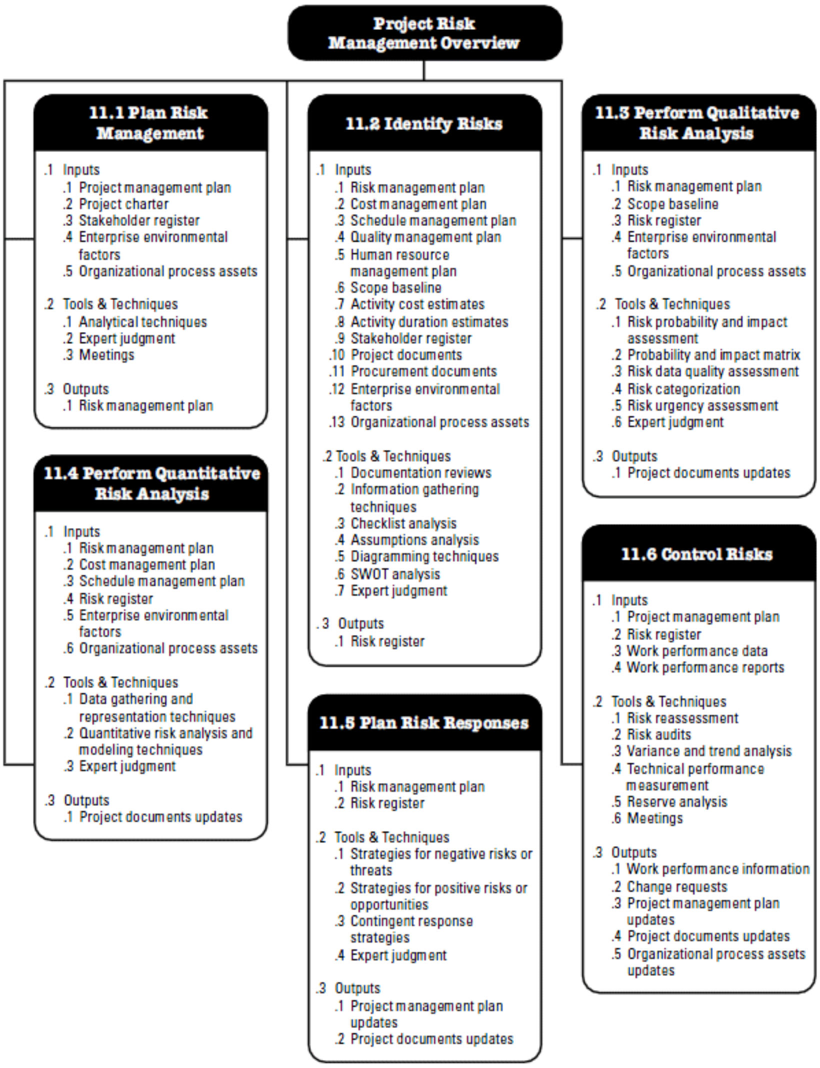


Fig. 2.3 — Project Risk Management Overview *(Source: PMBoK Guide (2017)*

Figure 2.3 describes the six-process of Project Management Institute's PMBOK Guide (2017), It outlines the general procedure, including methods and risk assessment strategies.

2.5.1 PLAN RISK MANAGEMENT

As shown in the above figure 2.3, It is a procedure of determining the entire process of RM exercises in the project. The cycle starts when the project is planned and will be finished early in the preparation stage of the project.

2.5.2 IDENTIFICATION

As per Rita M (2010), risk identification begins at the beginning of the project itself. It is often discussed in depth during the detailed project planning project and persists during the implementation, construction, monitoring and control processes as adjustments are made, and problems are found during the implementation. Risk Variables found through the identification stage are on a wider basis for classification. There are several risks that adversely affect the timely execution, cost, efficiency and scope of construction projects. There are various techniques for risk identification such as Questionnaires, Interviews, Brainstorming, Delphi technique, Focus Group etc.

2.5.3 RISK ANALYSIS

As per PMBoK (2017), the risk analysis includes an assessment of the risks identified, the goal of such a study is to quantify the risk accurately and objectively. It helps the decision-making phase to feel more confident. The risk analysis provides the overall degree and risk profile for the project. This centers planning of the resources on the critical risk elements in the chart. It allows to assess which intervention is required instantly or can prioritize the risk action, and it enables resource distribution to promote action decisions being made by management. The methods to perform the risk assessment categorizes into two-part, i.e. qualitative and quantitative analysis. The *Perform Qualitative risk analysis* is focused on a qualitative or descriptive scale to explain the probability and implications or impact of risks. It is especially useful during an initial examination or evaluation. The Quantitative assessment utilizes numerical combination measures for probabilities and effects rather than descriptive measures.

2.5.4 PLAN RISK RESPONSE

The meaning of response is to respond to something, the retribution, the reciprocation. It is the practice of establishing strategies and measures to improve benefits and minimizing threats to the project goal. The main advantage is that it handles the risks by prioritizing them, incorporating the effort into the plan and in the program in an appropriate way. (PMBoK Guide, 2017).

Selecting the most effective risk treatment involves comparing the costs of carrying out each operation against the advantages obtained. Besides, the expense of risk reduction will be commensurate with the benefits earned.

The risks that affect the project constraints are either related to known or unknown risk. The treatment of known risk (also referred to as known-unknown) is focused on the usage of the contingency reserve in the cost baseline. However, handling the unknown risk (also referred to as unknown-unknowns) is only feasible by utilizing the Management Fund present in the Budget, without any plan to handle such an event. Therefore, literature analysis of the identified threats is carried out.

There are four approaches to react to negative risks: Avoid, Transfer, Mitigate and Accept (PMBoK Guide, 2017; Rita Mulcahy, 2010). The details of each strategy are listed below

Risk avoidance — If the risk is suspected of having negative effects for the entire project are to be evaluated against the objectives of the project. Risk avoidance is a risk mitigation technique through which the Project manager works to eradicate the risk or to secure the project from its consequences. It normally includes modifying strategy to fully remove the risk.

Transfer — It is a technique in which the project manager passes the influence and response to a third party. The transfer may ultimately leaves that organization liable for handling it— not removing it. Taking insurance is a method of transferring risk.

Mitigate — It is a technique in which the project manager operates to reduce the exposure of the risk event. It means reducing the likelihood or result or adverse outcome of falling below acceptable threshold levels. Reaching early measures to reduce the hazard or influence of a project incident is always more successful than attempting to mitigate the damage once the risk has occurred.

Accept — It is a risk management technique where the project manager wants to take the risk into account and takes no steps until the risk is caused. This technique is implemented where the handling of a specific risk in any other form is not the feasible or value-efficient approach. This method is used where the handling of a specific risk in some other manner is not possible or cost efficient. This strategy indicates that perhaps the project manager has chosen not to modify the risk reduction program or is unlikely to find any such acceptable response strategy.

The choice of the most suitable risk reduction strategy will be established in collaboration with relevant stakeholders and process owners. Avoiding risk does not eradicate it; it is best to confront, evaluate it, and take necessary measures if it takes place. (Mohamed K. Khedr — 2006). As indicated, risk affects project objectives, specially cost and timeline are the main impacted objectives, as indicated in the various research. Time overrun can be mitigated to the maximum by accelerating, quick tracking, and crashing. Cost overrun, though, needs continuous supervision from project start-up until it is completed. Construction cost is one of the most critical metrics in terms of construction performance which is by far the most challenging to manage (Dr Dan Patterson, 2006). The cost field for managing construction projects is described in several of the literature for further study (Anna Klemetti, 2006, Ekaterina Osipova, 2008; David James Bryde and Jurgen Marc Volm, 2009; Dan BENTA, 2011; Hans Thamhain, 2013).

2.6. LITERATURE ON TECHNIQUES USED FOR RISK MODELLING

In order to understand the RM techniques and assessment methods commonly utilized by the construction industry, a comprehensive literature review has conducted. The RM practices used by the industry have identified and presented below. The literature suggests that many big clients have their own standard procedure for managing the risk; however, another client likely to seek guidance. The client of complex and high-risk environments projects such as oil & gas, power and utilities widely use the standard risk management procedure.

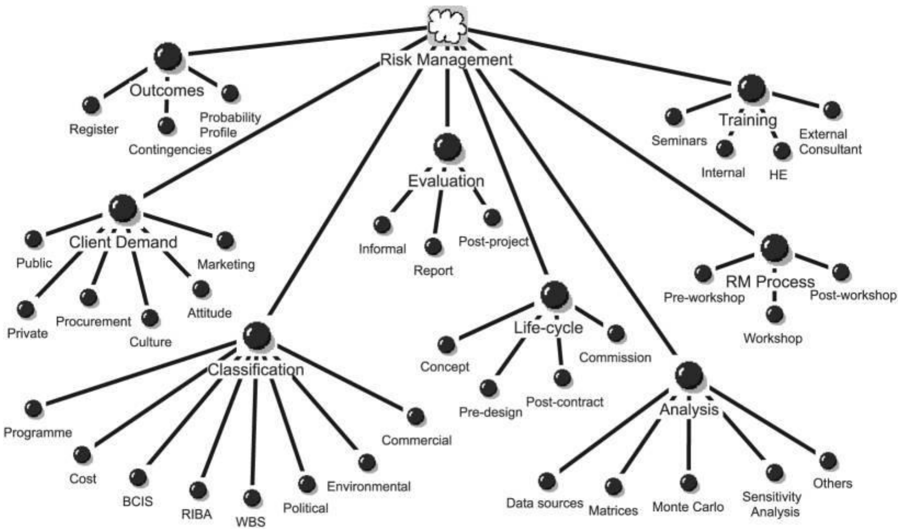


Fig. 2.4 – Industry approach toward the risk management for construction project

2.5.5 RISK ANALYSIS TECHNIQUES

The most common technique adopted in the industry at the initial phase is probability impact matrix, to support evaluate, rate and score the risks defined. The Scoring scale varies from basic small, medium, high scores to more precise quantitative measures, as indicated by ICE et al. (l998) When both the likelihood and the impact are measured on a standardized scale, and one is compounded by the other to give a severity rating. The Monte Carlo simulation has generally recognized a risk analysis method in controlling risk in large infrastructure projects and in estimating minimal, maximum and most probable values of risk or combinations of risks (Wood and Ellis., 2003). The most commonly used software is @ Risk for forecasting and projections of risk. Also, the sensitivity analysis is useful as part of their risk analysis, although never utilized by the construction sector to evaluate the effect of a distribution. The big client and construction company also developed its software-based formats. Multiple methods were utilized to define the various forms of risk. Researchers used stochastic approaches to address time and cost risk, while the risk was seen as associated with planned time or predicted cost volatility.

Table 2.1 – Tools & techniques for risk analysis

Author	Tools and Techniques	Description
Chapman and Cooper (1983)	PERT, probability distributions and decision trees	At the early stage of research in RM, Effort has made to recognize the need for project risk framing and the formal recognition of its origins
Cooper et al. (1985)	Risk breakdown structures (RBS)	Risk is modeled as a distribution of base cost estimate variance
Franke (1987)	Risk Cost & PI matrix	The detailed risk impact assessment, the cumulative project risk, is viewed in a very simplistic way: as the amount of the actual risk costs, excluding any interdependencies between those risks.
Kangari and Riggs (1989)	Fuzzy Sets Theory (FST)	The initial effort to use the FST to fix subjectivity problems in the construction risk evaluation.
Hull (1990)	Monte Carlo Simulation (MSC) and PERT	To assess proposal risk from cost and duration points of view
while Yeo (1990)	Contingency engineering' method	Using both a range estimates method and the PERT technique, to assess cost risk and estimating contingency
Mustafa and Al-Bahar (1991)	Analytic Hierarchy Process (AHP)	Used the principle of value and weight to determine the possibility and effect of risk. Also, recommend that the AHP evaluate the probability of construction programs and explain its limits for these applications.
Dey et al. (1994)	Analytic Hierarchy Process (AHP)	It integrates quantitative and subjective assessments; risk has also been modeled as Probability-Impact (P-I)
Zhi (1995)	P-I risk models	To determine the risk level of overseas construction programs, the P-I model was used.
Baccarini and Archer (2001)	P-I model	Calculates the project cost, time or quality risk score
Hillson (2002)	P-I models qualitatively and quantitatively	proposes assessing both threat and opportunity simultaneously
Shang et al. (2005)	DSS(Decision Support system)	Establish a DSS to promote construction risk management at the planning and design levels
Dikmen and Birgonul (2006)	AHP within a multi-criteria decision making	For risk and opportunity assessment of international construction projects, measure the total risk rating of each project by comparing the relative effect with the relative likelihood of each event and then adding up the scores.
Hsueh et al. (2007)	AHP and Utility Theory	Develop a multi-criteria risk management model for the development of joint ventures
Roetzheim (1988) and Nicholas (2007)	Expected Value Method	Suggested Expected value based method to quatify the risk likelyhood and impact

As mention above in the table 2.1 are the contributions by various researcher such as Chapman and Cooper (1983), Cooper et al. (1985), Franke (1987), Kangari and Riggs (1989) etc.

2.7. LITERATURE REVIEW ON RISK ATTRIBUTES AND CATEGORIES

Assaf *et al.* (1995) studied the main causes of time overrun and relative significance for high rise projects in Saudi Arabia. The total 56 risk attributes have been recognized and classified into nine major categories. Further, a survey is being conducted on project stakeholders, i.e. owner, contractor and consultant. The relative significance of attributes was calculated and arranged as per their relative importance index (RII) for major participants. The author concludes that the contractors and engineers significantly be of the same opinion on the relative significance of the groups of risk attributes, while stakeholders do not have the same opinion. Also, the factors under the financing category were positioned the highest by all three stakeholders, and that environment was given the least priority.

Al-Khalil & Al-Ghafly (1999) researched the significant cause of overruns in the completion of public infrastructure projects in Saudi Arabia. The total of sixty attributes was identified and categorized into eleven major categories. The survey conducted to identify the criticality sixty attributes in terms of time and cost overruns. The questionnaire survey sent to stakeholders from Saudi Arabia, Riyadh was representing the owners of water and sewage projects; the responses received from all of them. In the outcome of the research, the author identified six critical categories that are causing the major delays were: performance of the contractor, administration by the owner, initial planning and schematic design, regulations by the government, environmental and conditions of the site and supervision.

Wang & Chou (2003) identified the critical risk, their allocation and management of risk in highway projects in Taiwan. The total thirty-two risk attributes found out and categorized into two main categories and eight sub-categories. The data were collected from the study of multiple projects through the case studies to identify the attributes of the risk, risk distribution and mitigation measures. The author has analytically analyzed the various allocation techniques (transfer, avoidance, mitigation and retention) by comparing several cases. The author further found that the contractor is in a stronger position to bear the risk related to construction. These are the attributes which have been handled by the contractor, i.e. waste disposal at illegal locations, fear of theft and public contributions. And further author suggests a few other aspects for deciding the risk management strategies, i.e. risk ownership, patterns of risk triggers, risk management capacity were to be considered by the contractor in handling the decision.

Wang *et al.* (2004) identified the critical risks and their successful mitigating strategies. They developed a framework useful for stakeholders while undertaking construction projects in developing countries. The author also created a Alien Eyes model, 'which shows the interdependence with the hierarchicy of the risks. This model allows it possible to categorize risks properly and to reflect the relationship of influence among risks at different hierarchies and also proposes the mitigating order according to the risk priority. The total of twenty-eight factors identified and further divided into three hierarchical categories, i.e. country, market, and project, also suggested for realistic mitigation steps. The country-level risks are more relevant than market-level risks and market level risk more significant than project-level.

Zou et al. (2007) carry out research to identify the critical risks factors in China and developed strategies to handle them. The relative importance has been given to risk based on the impact of risk factors on cost, time, safety, quality and sustainability of the project individually; then risk factors prioritize based on their relative significance on the individual objective. A total fifty-three risk attributes were identified, which further categorized in five above mentioned categories. The 25 critical risks were identified and further compared with the existing outcome of studies conducted in Australia context to draw attention to the exclusive risks related to China. From the point of project stakeholders and lifecycle of the projects, the strategies were suggested. It is also suggested that owner, consultants and government should accept and mitigate their pertinent risks and joint coordinated effort is required from the initial phase onwards to mitigate the risks at triggering state.

El - Sayegh (2007) conducted a study to identify the significant risk attributes and their impact on construction projects and also addresses their proper allocation in the UAE construction industry. The research has varied application in UAE because there is a huge investment in the Country in mega projects. A total of forty-two risk factors were listed on the basis of the literature review on risk assessment in the UAE construction industry, which further categories in ten subcategories and two main categories, i.e. internal and external. The data was gathered through a survey on project stakeholders and further analyzed. The outcome of the study shows that economic risks such as a rise in the price of resources, scarcity of labour & material are very significant. Other important risk factors are; owner risks such as insufficient completion timeline, frequent intervention and design change. It has observed that the financial, social and cultural risks are negligible, and further risks are passed on to contractors or exchanged by contractors and minimal risks held by the owners.

Tang et al. (2007) Researched through the empirical industry survey on overall aspects of the implementation of risk management from identification to monitoring & controls recognized by the project participants and also the challenges confronting the industry in applying risk reduction activities in the Chinese building industry. A questionnaire survey which included thirty-two risk factors identified conducted on industry stakeholders and further analyzed through the ANOVA tool. The research also emphasizes the correlation among stakeholders for different risk factors. The study reveals that the majority risks are common of concerned by all project stakeholders; also, the attitude towards risk mitigation got changed from transfer to acceptance or reduction. Also, the lack of joint risk management practice among stakeholder's obstacle in effective project risk management.

Sweis et al. (2008) research to find out the various reasons for delays and expenditure overruns in Jordan’s construction industry. The reason for the delay has identified and categorize using Darwin's Open Conversion System. The total forty risk attributes found out and considered into eight sub-categories, i.e. Contractor, Equipment, Consultant, Government regulations, Labor, Material, Owner, weather. The survey conducted to collect the data from residential projects consultants, contractors, owners and also by conducting the interviews with the experts. The result indicates that cash management problems of the contractor and regular changes by the client are the key reasons for the overruns in Jordanian development projects.

Al-Kharashi & Skitmore (2009) research the risk attributes responsible for delay in Saudi Arabia’s government projects. The total one hundred and twelve attributes were identified and were categorized into seven categories, i.e. consultant, contractor, client, manpower, materials, contract and coordination causes. The data obtained through a survey of 86 professionals from different stakeholders employed in Saudi Arabia. The study reveals that major direct reason for the delay was due to the failure of strategic plans, level of involvement and participation, disagreement between stakeholdres and lack of trained staff and skilled manpower.

Doloi et al. (2011) identified risk factors which contribute to construction delays in India and built a regression model in order to determine the relative importance of delayed attributes. The most critical reasons that trigger delays are the challenges of cash flow encountered by the contractor, the delay in the decision of the owner and poor quality.

Alnuaimi & Mohsin (2013) researched on the delay of the projects in Muscat area, Oman between the period of 2007–2008 and 2009–2010 in two groups as per the mentioned timeline. The study revealed that there is a 40% delay in completion in both groups. A total forty-nine risk attributes were identified, and further statistical analysis was performed to understand the significance, as per the study, the ten most critical causes of delays. Such factors are (1) the inadequate planning of the contractor, (2) the weak management of the site of the contractor (3) the lack of expertise of the contractor, (4) the financial challenges encountered by the client, (5) the concerns of the subcontractors, (6) the shortage of supplies, (7) the shortage of labor and facilities, (8) the breakdown of the machinery, (9) the cooperation between stakeholders (10) construction defects. The hurricane Guno effect that hits many projects is one of the major reason for legal and contractual problems for ongoing projects in Oman. Another restriction which started by mid of 2008 that the projects affected by the financial crisis on the world and specific on gulf countries.

Khodeir & Mohamed (2014) researched to analyze the political and economic risk on a construction project between 2011-13 in Egypt. It also provides important information for companies that plan to carry out projects in Egypt. The personal interview and survey carry out to gather primary data and site visit and personal observation have been used to collect secondary data. The total 65 attributes were identified and asked the respondents to respond in terms of probability of occurrence. The author has selected 32 construction companies to respond. The top seven key risks identified as a change in currency, changed in tax, scarcity of fuel, the security of operational road, changes by the officials, strike by workers and fire risk.

Baghdadi & Kishk (2015) researched the critical risk attributes and their influence on time and cost in Saudi Arabian airport projects. The fifty-four risk factors established using literature in three categories: internal, external and force majeure. The thirteen semi-structured interviews have conducted on project stakeholders who involved in a similar type of projects. The findings show that overruns remain in Saudi Arabia's aviation projects. The most important five risks found to be changed in design, variation in demand, delay in payment, bureaucratic issues and incomplete scope.

Aziz (2015) Author conducted research to identify, explore and priorities the risk factor faced by the contractors in Qatar. A survey conducted among the contractors which comprise the 37 potential risk factors, based on previous relevant studies. The data were analyzed based on the RII of risk attributes. The results obtained reveal the following as the critical risk factors, (1) delay in a decision by the client; (2) late payment by client; (3) changes by the client; (4) design and drawings errors; (5) shortage of materials; (6) contractor's cash flow; (7) errors in details; (8) scarcity of staff and skilled workmanship; (9) delayed materials delivery; and (10) delay in response to contractors query. The risks related to the "owner" are known to be quite high, followed by those linked to the consultant, contractor, and external factors. The findings also show that the "transfer" is the common response of contractors to the risk associated with "owner" and "consultant," while the "retention" is the primary pattern linked to the group "contractor" and "exogenous".

El-Karim et al. (2017) The author suggested that forecasting costs and scheduling contingencies are critical considerations for achieving a reasonable budget and schedule for a construction project in the construction industry in Egypt. Further research conducted to identify, evaluate and measure the factor which influences the objective of the researcher. Based on an intensive literature review, the seventy risk attributes were identified, which further categories into thirteen subcategories and four main categories. All the identified attributes are divides in two categories based on their impact on time and cost, the data collected from sixteen construction companies.

Table 2.2: Risk attributes in the International context

Sr.	Attributes	Assa et al (1995)	Khalil & Ghafly (1999)	Wang et al(2003)	Wang et al (2004)	Tang at al (2007)	El-Sayegh (2007)	Zou et al (2007)	Sweis et al (2007)	Kharashi & Skitmore (2009)	Doloi at al (2012)	Alnuaimi & Mohsin (2013)	Aziz (2013)	El-karim et al (2015)	Baghdadi & Kishk (2015)	Khodeir & Mohamed (2015)
1	Approvals and clearances		√	√	√		√	√	√	√		√	√	√		
2	Land aquasition and site handover	√			√											
3	Environmental and Tree Cutting					√							√			√
4	Changes in regulations and laws	√	√	√	√	√	√	√	√	√	√	√	√		√	√
5	Social and Cultural influences on workman	√					√			√					√	
6	Inter-state issues in coordination			√				√	√							
7	Traffic control and restriction at job site	√								√						
8	Pollution and Safety compliances				√			√							√	√
9	Rehabilitation & Resettlement															
10	Security requirements			√	√				√							
11	Wars & revolutions				√		√								√	
12	Flood	√		√	√	√			√						√	
13	Terrain condition	√											√			
14	Earthquake			√	√	√			√						√	√
15	Landslide					√										√
16	Unexpected weather conditions	√	√		√		√			√	√	√	√	√	√	√
17	Mistakes and inadequate details	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
18	Delays in producing design documents	√		√	√	√	√		√		√			√	√	√
19	Complexity of project design		√		√									√		√
20	Incomplete survey and feasibility studies	√		√	√	√		√	√	√						√
21	Misunderstanding of Client's requirements	√	√			√	√	√			√				√	√
22	Differing site (ground) conditions	√	√	√	√	√	√	√	√	√	√			√	√	√
23	Inadequate design-team experience				√		√									
24	High interest rate				√											√
25	Inaccurate project cost estimating	√			√	√		√			√		√	√		√
26	Inflation / price fluctuation		√	√	√	√	√	√	√	√	√	√	√	√	√	√
27	Unavailability of incentive clause							√			√					
28	Cash flow of project		√		√			√		√					√	√
29	Profit rate of project				√											
30	Cost of rework			√	√				√		√		√	√		
31	Cost of variation/Change orders		√	√	√			√	√	√	√	√	√	√		√
32	Change in currency price				√		√								√	√
33	Availability of Funds from lenders		√					√								√
34	Exchange Rate Fluctuation				√	√										
35	Financial Default of Contractor/Subcontractor	√	√		√			√		√					√	
36	Incomplete contract details												√			
37	Week design coordination		√							√		√		√		√
38	Slow response to RFI or technical quaries				√							√		√		
39	Delay in inspection	√				√				√	√			√		√
40	Level of involvement in quality control				√											√
41	Change in scope of work		√		√	√	√	√		√	√		√		√	
42	Delay in approving major changes						√			√	√	√				
43	Delay in claim approval					√	√			√	√	√		√		√
44	Deployment of technical staff on site									√		√				√

Table 2.2: Risk attributes in the International context (Continued)

Sr.	Attributes	Assa et al (1995)	Khalil & Ghafly (1999)	Wang et al(2003)	Wang et al (2004)	Tang at al (2007)	El-Sayegh (2007)	Zou et al (2007)	Sweis et al (2007)	Kharashi & Skitmore (2009)	Doloi at al (2012)	Alnuaimi & Mohsin (2013)	Aziz (2013)	El-karim et al (2015)	Baghdadi & Kishk (2015)	Khodeir & Mohamed (2015)
45	Inadequate definition of substantial completion							√		√					√	
46	Lack of method to identify the time		√		√			√								
47	Supervision, Quality assurance & Control	√	√		√		√					√	√		√	√
48	Quality assessment system in organization		√		√	√	√	√				√			√	√
49	Implementation of method statement						√									√
50	Accidents and Labour Injuries	√			√		√				√			√	√	
51	Damage to Existing Structure(Utilities)						√								√	
52	Theft of material and be managed			√	√		√		√							
53	Safety assessment system in organization			√		√		√	√	√		√				√
54	The project location is safe to reach		√		√									√		√
55	Lack of technical professionals	√	√		√		√	√		√		√		√	√	√
56	Lack of coordination with subcontractors	√	√	√	√	√		√	√	√	√	√		√		
57	Delay in mobilisation						√	√		√	√	√				√
58	Poor planning or resource management	√	√		√	√	√	√		√		√	√		√	√
59	Congested construction site				√						√				√	
60	Lack of experience in similar projects	√	√		√						√			√	√	√
61	Shortage of labor	√	√		√	√	√			√		√	√	√		√
62	skills of manpower and Low productivity	√			√	√		√		√	√	√		√	√	√
63	Contractors cash flow	√						√		√		√			√	√
64	Irregular payments to sub-contractors	√					√	√		√	√	√		√	√	√
65	Construction Work Permits	√	√		√			√						√		
66	Strike			√			√		√						√	√
67	Conflicts between stakeholders	√	√			√		√		√	√	√			√	√
68	Improper construction methods	√		√				√	√	√	√	√			√	√
69	Delays in sub-contractors work	√		√	√	√			√	√					√	
70	Poor site management and supervision	√	√			√	√	√		√	√		√	√	√	√
71	Lack of Training personnel for model operation	√		√	√			√	√	√	√	√				√
72	Inaccurate tender cost estimating			√					√	√	√	√		√		√
73	Shortage of equipment	√	√	√	√		√		√	√		√	√			√
74	Low productivity of equipment	√	√	√	√	√	√	√	√	√	√	√		√	√	√
75	Lack of high-technology equipment	√	√	√	√	√	√	√	√		√					√
76	Shortage of materials	√	√	√	√		√		√	√	√	√	√	√	√	√
77	Nominated vendors				√											√
78	Delay in material procurement	√		√	√		√	√	√	√	√	√		√		√
79	Frequent interference	√					√			√		√		√	√	
80	Unrealistic duration imposed by client		√		√		√	√		√	√		√	√	√	
81	Irregular payments	√	√		√	√	√	√		√	√	√	√	√	√	√
82	Permissions, approvals & statutory clearances	√	√	√	√				√	√	√	√		√		√
83	Learning from best practice		√												√	√
84	Delay in Decision making	√								√	√	√	√	√	√	√
85	Lack of capability of client			√	√				√							
86	Suspension of work by owner									√		√				√
87	Breach of contract by owner				√		√				√				√	
88	Delay in final inspection	√								√	√	√		√		
	Total Attributes	56	34	32	70	32	42	53	32	60	45	40	20	37	54	63

The author concluded that the new technology, site location, experience of the project team, change in law & regulations, war & revolution and funding are considered very critical in the Egyptian construction industry, and a contingency should be considered for the same. A computerized risk impact assessment model (RIAM) has been developed by the author using the Crystal ball, and Microsoft Excel to analyze the risk attributes.

Al-Hazim *et al.* (2016) identified the critical risk attributes that may cause the time, cost and resource overrun in Jordan's construction industry. To accomplish this goal, the author collected and further analysed data concerning time and cost overruns from the 40 public infrastructure projects implemented between 2001 and 2008. The outcome of the research reflects that there are 20 important factors that predominantly cause overruns in infrastructure

The topography and climate conditions are the top factors causing project overruns in Jordan. Also, an inconsistency had observed public infrastructure projects between planned and actual spending ranges from 1 to 6 times with an average of 2.14 times, and overruns of time vary from 1.25 to 4.55 times with an average of 2.26 times. Ghanim & Samarah (2016) author conducted a study to make out the critical risk that may cause the cost, time and resource overrun for the infrastructure project in Jordan. A total of fifty-three risk attributes have identified from the extensive literature review and grouped in four categories, i.e. technical, management, financial and market, political social and environmental.

2.8. CATEGORIES OF VARIOUS RISK ATTRIBUTE

Financial and economic

Two financial parameters are at the heart of any project, the profitability and the cash flow. In the construction industry, both of these parameters are affected by the various attributes such as high-interest rate, inaccurate project cost, inflation, timely payment, profit rate, rework, changes, availability of funds from lenders, exchange rate fluctuation and financial default by the client or contractors. The following authors have suggested this category in their research, Al-Hazim, Salem, & Ahmad (2017), Nawawy & Abdel-Alim (2015), Zou, Zhang & Wang (2007), Dziadosz, Tomczyk & Kapliński (2015), Alnuaimi & Mohsin (2013, December), Al-Khalil & Al-Ghafly (1999), Ogunsanmi (2016), El-Sayegh (2008), Khodeir & Mohamed (2015), Dziadosz, Tomczyk, & Kapliński (2015), Alnuaimi & Mohsin (2013, December), Ogunsanmi (2016).

Contractor

The most popular way of executing construction work is to select a contractor for the projects. Hiring a correct and efficient contractor is a difficulty for the company, but, if due diligence is not granted, then the cost of implementation of the project may increase. The attributes responsible for the project delay are shortage of skilled expertise, lack of communication with subcontractors, insufficient resource control, delay in mobilization, ineffective preparation, insufficient familiarity with related projects, lack of resources, manpower & facilities, poor resource efficiency, ineffective cash flow, erratic subcontractor payments Stakeholders, insufficient construction methods, ineffective site administration and supervision, poor staff planning for construction, unreliable tendering cost forecasts, shortage of high-tech facilities, delays in the purchase and distribution of materials etc. The following authors have suggested these attributes in their research, Nawawy& Abdel-Alim (2015), Tang, Qiang, Duffield, Young & Lu (2007), El-Sayegh (2008), Baghdadi & Kishk (2015), Aziz (2013), Al-Kharashi & Skitmore (2009), Ogunsanmi (2016), Wang & Chou (2003), Sweis, Sweis, Hammad & Shboul (2008).

Owner/Client

The owner/client decide potential positive and negative outcomes, implementation strategies and risks, feasibility studies, site studies, takes major decisions regarding the scope, timeline, and cost of the project. However, there is research which suggests the various risk attributes related to owners are Frequent interference, unreasonable length of the contract enforced by the client, financial difficulty & irregular job payments, delays in permission, permits & regulatory clearances, delays in decision-making, lack of power, suspension by the owner, violation or changes to the contract by the owner and delays in taking over. The following authors have suggested these attributes in their research, Nawawy & Abdel-Alim (2015), Zou, Zhang &

Wang (2007), El-Sayegh (2008), Baghdadi & Kishk (2015), Aziz (2013), Al-Kharashi & Skitmore (2009), Ogunsanmi (2016), Sweis, Sweis, Hammad & Shboul (2008).

Design

Design is the process of creating an elucidation to a project brief and then preparing directions allowing that solution to be constructed. There are various risk attributes responsible for the delay in the projects are related to design efforts are Errors and insufficient data, delays in preparing design information, ineffective analysis, insufficiant survey and feasibility tests, misunderstanding of customer needs by design engineer, differing site (ground) circumstances, insufficient construction-team experience etc. The following authors have suggested these risk attributes in their research Nawawy & Abdel-Alim (2015), Tang, Qiang, Duffield, Young & Lu (2007), El-Sayegh (2008), Baghdadi & Kishk (2015), Alnuaimi & Mohsin (2013, December), Ogunsanmi (2016).

Project management consultant/ Engineer

Project Management Consultancy plays a multifaceted role in managing the projects and provides the services from inception to completion of projects. The PMC offers a wide scope of services in the management of construction project; these services are project time, cost, quality, design and safety management, implementation and resource management. there are various attributes related to P.M.C. are incomplete contract details, week design coordination, delay in communication, slow response to technical queries, delay in inspection, level of involvement in quality control, change in scope of work, delay in approving major changes, delay in claim approval, less deployment of technical staff on-site, the inadequate definition of substantial completion, lack of systematic engineering method to identify the time. The following author has authors have suggested these risk attributes in their research; Nawawy& Abdel-Alim (2015), Tang, Qiang, Duffield, Young & Lu (2007), Baghdadi & Kishk (2015), Aziz (2013), Al-Khalil & Al-Ghafly (1999), Al-Kharashi & Skitmore (2009), Sweis, Sweis, Hammad & Shboul (2008).

Nature

The nature-related risk characteristics have a profound affect on the objectives of the project, i.e. time, cost, quality, safety & scope. The risk attributes related to this category include; flood, terrain condition, earthquake, landslide and unexpected weather conditions. The following authors have suggested these risk attributes in their research; Nawawy& Abdel-Alim (2015), El-Sayegh (2008), Baghdadi & Kishk (2015), Zou, Zhang & Wang (2007), Assaf, Al-Khalil & Al-Hazmi (1995), Ogunsanmi (2016), Wang & Chou (2003), Sweis, Sweis, Hammad & Shboul (2008).

Resource

Infrastructure project needs a massive quantity of all the resources, i.e. material, labour and equipment. The effort is required to plan and timely procurement and management of these resources. As per the research in the past, there are various risk attributes related to resources such as shortage of manpower, equipment and materials, Low productivity, Lack of high-technology equipment, delay in material procurement and delivery. The following authors have suggested these risk attributes in their research, Nawawy & Abdel-Alim (2015), Assaf, Al-Khalil & Al-Hazmi (1995), Al-Khalil & Al-Ghafly (1999), Al-Kharashi & Skitmore (2009), Wang & Chou (2003), Sweis, Sweis, Hammad & Shboul (2008).

Political and social

The projects have a substantial impact on the economy and society. The projects face huge political risk if it does not suit political will and ideology and not consider the local public needs; therefore, the risk must be managed meticulously to survive the project. As per the research in the past there are various risk attributes related to political and social categories; Changes in Government Laws and Policies, Social and Cultural Effects on Workmanship, Interstate or Central-state communication Problems. The following authors have suggested these risk attributes in their research; Nawawy & Abdel-Alim (2015), El-Sayegh (2008), Baghdadi & Kishk (2015), Khodeir & Mohamed (2015), Wang & Chou (2003)

2.9. COUNTRY SPECIFIC RISK ATTRIBUTES AND CATEGORIES

The literature of various countries like China, Egypt, Saudi Arabia, UAE, Qatar, Oman, Jordan, Poland, Nigeria, Taiwan and India is considered for review. It is primarily based on the recognition of risk attributes impacting on the construction project, their assessment in terms of impact on project objectives and further identification of critical risk factors which has maximum impact on the project objectives.

China

China's has seen speedy infrastructure development after the economic reforms and liberalization 1978 onwards. The substantial investment has made in the construction project in the past; however, as per the research conducted in china to identify the risk attributes and further the critical risk affecting the projects in the Chinese construction industry, it shows that industry lacks in terms of implementation of risk management practices. The top risk attributes in China's construction industry are financial risk related to difficulty in payment and funding of the project, Inadequate or incorrect design by the design consultant, Contractors management ability, Lack of awareness of construction safety and pollutions, Unwillingness to buy insurance, Poor quality and premature failure of the facility before the design life.

Egypt

The development of the Egyptian construction industry was 10.3 per cent in 2016, accompanied by an average annual increase of 5.3 per cent in the following four years. The significant investment has been announced to improve the infrastructure in Egypt. however as per the research conducted in Egypt the construction industry, the projects lack in terms of financial risk related to difficulty in payment and funding of the project, change in law, and regulation imposed by the government, site location (rural & urban), defective work done by the project team, lack of new technology, security requirements for the project, team experience, currency price fluctuation, lack of fuel, new tax regime, changes in the scope, war/revolution and workers' strikes.

Table 2.3 – Country-specific risk factors

Country	Egypt	Jordan	China	Saudi Arabia	Singapore	UAE	Qatar	Oman	Taiwan	India
Attributes	Change in law	Changes in design	Financial risk	Bureaucratic Problems	Government Policies	Change in design	Incomplete details	Designer changes	Potential risk	Improper planning
	Defective work	Conflicting clauses	Inadequate or incorrect design	Changing demands	Political Instability	Delay in material supply	Cash problem faced by contractors	Economic conditions	support by the local community	Inefficient site management
	New technology	Errors in design and contract	Poor quality of work	Design Changes	Approval and Permit	Delays in approvals	Delayed response to query	Increase in quantities	Illegal waste disposal	Incomplete project scope
	Site security	Cash problem faced by contractors	Premature failure of the facility	Inadequate Scope	Change in Law	Price escalation	Delayed payment by owner	Delay in deliveries	Threats by gangs	Lack of commitment
	Site location (rural & urban)	Week communications	Safety	Payment Delays	Corruption	Lack of qualified staff	Frequent change by client	Site conditions	Unexpected disturbance by a third party	Lack of communication
	Team experience	Lack of planning	Poor site management	Financing	Cost Overrun	Frequent intervention by Owners	Delay in delivery of materials	Weather		Poor site coordination
	Type of fund	Bureaucracy problems	Funding problem	Environment	Disputes and Termination of JV	Unrealistic timeline by owner	Shortage in staff and skilled labour			Incomplete contract details
	War & revolution	poor site management	Awareness of safety and pollutions norms	Lack of agreement among the parties	Inflation and Interest rates	Shortage in manpower	Slow decision making by client			
	Change in currency	Material wastage	Unwillingness to buy insurance	Consultant performance	Prevailing legal framework	Shortage in material	Shortage of materials			
	Fire risk	Rework due to labor mistakes		Contractor inexperience	Local Partner's Creditworthiness	Subcontractors poor performance	Contract prices			
	Lack of fuel	Terrain		Low skill manpower			Coordination			
	New tax rates	Weather		Shortage of construction materials			Initial estimation and contingency planning			
	Official changes	Financial difficulties faced by the contractor		Shortage of manpower			Monitoring and control systems			
	Workers strikes									

Saudi Arabia

The Saudi Arabia construction industry is recording a 4.1 % increase in 2018-19, the average annual growth rate (AAGR) at 6.1% in the construction sector. However the construction industry lack in terms of financial risk related to difficulty in payment to contractors, funding of the project, bureaucratic problems, frequent changes, inadequate scope, environment, lack of agreement among the stakeholders, consultant performance to expedite the progress, lack of experience of the contractor, low skills of manpower, shortage of construction

Oman

According to the research on Oman Construction Sector, the growth will carry on in the upcoming years due to encouraging policy in the sultanate that motivate the investments, as well as governments intention to diversify the economy into different sectors. However, as per the research conducted in Oman, the project faces the various critical risks such as a frequent change in design by the client, delay in deliveries of materials, site conditions and extreme weather conditions

United Arab Emirates (UAE)

The U.A.E.'s economy has a greatly depends on the construction market, nearly 4,000 projects are under development with an approximate investment of $313.6 billion, however as per the research conducted in UAE the construction industry lack in terms of frequent changes in design by the owner, delay of material supply, delays in approvals by the authority, inflation and sudden changes in prices, lack of qualified staff, the frequent intervention of owner during construction, unreasonably tight schedule imposed by the owners, shortage material & manpower, subcontractors' poor performance and management

Jordan

The big investment has announced to improve the infrastructure in Jordan. Also, good GDP growth has observed in Jordan in the year 2018. However, as per the research conducted in the past the critical risk faced by construction projects in Jordan are; frequent change of design & change orders, conflicting conditions in the contract document, errors in design details, the financial difficulty faced by the contractor, coordination issues between stakeholders, lack of planning and budgeting of project, delay due to bureaucracy & approval, poor waste management, rework due to mistakes, terrain and weather condition.

Taiwan

To expedite the economic growth, the Taiwan government directed an eight-year investment program that comprises eight categories of infrastructure projects and will be funded by a special budget of US $ 13.9 billion over four years. The big investment has been announced by the government to improve the infrastructure in Taiwan, which further leads to improving the economy. However, as per the research conducted in the past, the critical risk faced by construction projects in Taiwan are as follows; project lacks in terms of Public participation and acceptance, illegal waste disposal, Threats by gangs and unexpected disturbance by the third party.

India

Indian infrastructure developments needed an investment of Rs 50 trillion by 2022. The various mega projects are coming up in the country such the Sagar mala, Bharat mala, dedicated freight corridor and smart cities etc. However, as per the research conducted in the past, the critical risk faced by construction projects are Improper planning, In-efficient site management, Lack of clarity in project scope, Lack of commitment by the stakeholders, Lack of communication among the stakeholders, Poor site management and Sub-standard of a contract document.

2.10. LITERATURE REVIEW ON PROJECT RISK MANAGEMENT IN INDIAN SCENARIO

Hariharan S, P.H. Sawant (2012) data of schedule & cost overruns of the past 20 years on Infrastructure projects have been collected and presented in the study. The researchers suggest that an innovative risk management strategy has to be introduced in the future to reduce overruns. K. Deeppa & I.

Krishnamurthy (2014). The study showed that the cost & time overruns in infrastructure projects are continuing despite the implementation of a modern bidding model & E tendering technique. Reasons are no budgetary support for the work, inaccurate estimation, design & drawing not ready while estimation & Changes all these are very critical. Kumar Neeraj Jha and M. N. Devaya (2012) used Interpretive Structural Modeling (ISM) to display a hierarchical model showing the inter-relationships between risk factors. The MICMAC analysis was used to measure and identify risk factors based on their impact and dependence on other risk factors, R. C. Walke, V.M. Topkar (2012) Significant consideration has to be given to risk quantification. Risk Quantification, which helps in the project risk exposure estimation and risk mitigation preparation aids, i.e. the evaluation of which risk events warrant a response and the extent of the cost and timeline of contingency reserves.

2.11. LITERATURE REVIEW ON RAILWAY PROJECT

Sangsomboon and yan (2011) identified factors and divide them into categories, further risk response measure for all the identified factors has been suggested. Dindar *et al.* (2014) used the Integrated Risk Analysis Approach in Rail Turnout Systems was followed using effective multidisciplinary risk identification approaches for complex systems. Boholm (2010) emphasises on implementation of formal risk management procedures in a Swedish rail administration are applied. Qinga *et al.* (2014) done systematically assessment of the data parameters of RCPQRMIS and establishes a dynamic quality risk monitoring model for the prediction of pre-warning details on quality risk and for the automated generation of quality risk parameters ('automated quality risk ads' model). Sunduck *et al.* (2005) examine the risk control background of the Korean Seoul-Pusan KTX. The project structuring issues discussed by Agarwalla and Raghuram (2012) including asset ownership, functionality and entry into the market, scope and layout, financing, revenue and risk, and contracting strategies. It explains how the systems have changed in a direction where DFCCIL's control has been diminished to render IR the single owner and single client. The unbundling that has taken place in many transportation industries (aeronautics, maritime and road) to gain greater flexibility and transparency has not yet existed in the rail industry. Bodhibrata Nag, Jeetendra Singh & Ved Mani Tiwari (2013) emphasize on various issues related to project financing, Land acquisition, Project procurement process & stakeholders management and also suggest mitigation measures

2.12. LITERATURE REVIEW ON PUBLIC INFRASTRUCTURE PROJECTS

Prasanta Kumar Dey (2012) suggested a project risk assessment framework by using multiple criteria decision-making technique and decision-making tree analysis for oil and gas projects. It incorporates a systematic and innovative system that incorporates four approaches –cause and effect diagram for risk documentation, AHP for likelihood calculation, risk chart for effects derivation, and decision-making. It also uses EMV method for cost & Time Impact assessment. McKinsey & Company working paper (2013) on Indian infrastructure project addresses that a shortage of competent professionals, forward-looking attitude to risk reduction is responsible for much of the issues found in public infrastructure projects. Direct valuation damages related to under-risk management for today's large-scale project portfolio could reach $1.5 trillion in the next five years. Pawar *et al.* (2015) studied the Qualitative risk analysis (QRA) with the case of three flyovers construction project. K. Rajkumar1., Kumar A. & Krishnamoorthy V. (2013) emphasize on the Factors affecting infrastructure development projects under the Public-Private Partnership in the case of Wastewater and Sewerage, Municipal Infrastructure, Highways and Expressways, Ports. Thomas *et al.* (2003) Emphasize risk management study of the Indian participants in BOT road projects.

2.13. LITERATURE REVIEW ON PROJECT CONTROLS

The Time and Cost are universally accepted project success criteria; the performance of the infrastructure projects have been measured through the performance for time and cost. The third point, i.e. Scope, is certainly given less priority in terms of the direct performance indicator. The scope can be replaced with quality, efficiency etc. These three constraints are mutually competing in nature. The PMBoK (2017) suggest various standard tools and techniques map the efficiency of project.

The objective of project monitoring and controls is to detect and correct deviation from the planned budget, timelines, Quality. The monitoring includes the detection of the progress, issues and problems faced by the project. This consist the process linked to monitoring, evaluating, and documenting progress to meet the output targets laid out in the project management plan. The main advantage is that it allows stakeholders to consider the current situation, the measures taken, and projections on spending, schedule, and scope. Monitoring and controls may involve the identification of potential risk, review, recording and monitoring of current project risks to ensure that the risks are recognized, their status is reported and that effective risk management plans are enforced. The controls include the corrections to take project success back on track with plans. The monitoring and controls to be performed throughout the project lifecycle. As per figure 2.5 by the PMBoK (2017), it suggests standardizing the process for project monitoring which include the input, tools & techniques and outputs of the project.

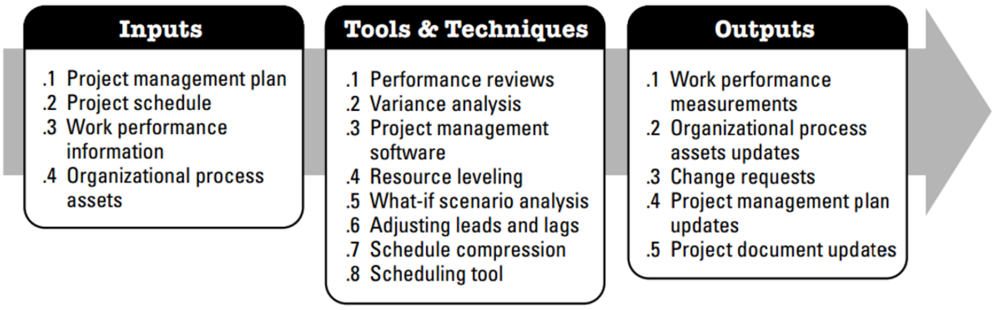


Fig. 2.5 Control schedule Tools & Techniques

The function of monitoring and project is to provide a forecast of project performance by updating the current cost and schedule information. It offers information to support status monitoring, progress assessment and forecasting. The PMBoK (2017) suggests several methods and techniques, as shown in Figure 2.5, to manage the schedule. Performance evaluations is a systematic process which assesses the progress and decides whether corrections is needed or not. The variance analysis is useful to assess the degree of variation from the plan; this information is helpful to decide on upon corrective action. The software helps to understand the planned v / s actual performance, the forecast effect of changes to the overall program. The levelling of resources helps optimize the distribution of resources within the project. What-If Scenario Analysis applicable to evaluate the likely outcome of delay and compare with the plan. The software will help to understand the lead, lags and adjustments to align lagging activities with the program. Schedule compression can be done in the software to take corrective action to bring the overall schedule back on track. Scheduling tools (can be combined with software) are useful for reviewing and documenting real progress and corrective/revised plans. The PMBoK (2017) suggests several methods and techniques, as shown in Figure 2.5, to manage the control the cost. The Earned Value analysis (EVA) is a widely accepted method which is the Integration of project scope, budget & schedule performance and to forecast possible financial outcome. The Forecasting techniques helpful to calculate & compare of Estimate at Completion based upon executed data and information. The following techniques are primarily used by the construction industry of measuring the progress of variance analysis.

2.13.1 TO COMPLETE PERFORMANCE INDEX (TCPI)

The PMBoK (2017) suggest TCPI is one of the techniques useful for the Calculation of acceptable cost performance to meet the management goal. The following formula used to calculate the TCPI at any stage in the construction project.

$$TCPI = (BAC-EV)/(BAC-AC) \qquad \text{Eqn. (2.1)}$$

Where the BAC = Budget at Completion, EV = Earned Value, AC= Actual Cost. The Performance Reviews can be possible by Comparison of cost over time with a budget to understand the overrun or underrun of the project. The Variance Analysis is used to determine the cause and degree of cost variance to decide upon corrective/preventive action.

2.13.2 EARNED VALUE ANALYSIS (EVA)

EVA, is one of the most commonly known project control systems used by project management professionals. Over the decades, the development of the EVM has concentrated on cost schedule control and financial reporting (Brandon, 1998; Fleming and Koppelman, 2004; Kim et al., 2003). The U.S. government and departments have opted to use EVA for projects in the Federal contract and procurement process. A wide variety of literature available on EVA, its core concepts and significances (see, for example, Anbari, 2003; Fleming and Koppelman, 2010), In brief, a clear timeline and a detailed budget provide the base for the introduction of the EVA and its project. The budget plan and the timeline for handling and monitoring the elements of the Work Breakdown System (WBS) shall be established. Such a schedule will be considered a project baseline, and success will be measured towards the baseline (Ciofi, 2006). EVA defines the Planned Value (PV) as the budget amount to be expended on the job done in keeping with the initial timetable at any period or concerning baseline. PV referred to as planned Budget Cost of work schedule (BCWS). Earned Value (EV) is, at any stage in time, the monetary value of the progress achieved (work completed) in terms of the budgeted cost. EV was initially referred to as the Budgeted cost of work performed (BCWP). Actual Cost (AC) reflects the monetary value that was actually spent on achieving progress at some point in time. 0 AC was historically referred to as the Actual Cost of Work Performed (ACWP). The EVM approach can also be useful in predicting project progress based on past results and in implementing the control measure. The EVM offers two major indicators for Cost Performance Indicator (CPI) and Schedule Performance Indicator (SPI). The equation below was used to measure the EV.

CPI = EV/AC

CPI = BCWP/ACWP…………………….…………… Eqn. (2.2)

SPI = EV/ PV

SPI = BCWP/ BCWS…………………….…………… Eqn. (2.3)

The value of CPI & SPI if less than 1, it shows the cost & time overrun at a given point of time.

2.14. LITERATURE REVIEW ON THEORETICAL PREMISE (DECISION THEORY)

Because of the increasing popularity of risk management in the infrastructure development projects, risk management has grown considerably over the last decade. Decision theory has been around for a long time and could provide some useful tools for strengthening decision making on risk and uncertainty in the construction project. Decision theory is a valuable framework for evaluating project risk and uncertainty. This is particularly complicated for the whole project because a project faces a number of risks. The various risks and uncertainties can influence Projects; If this occurs, a robust risk management strategy is needed to increase the project's likelihood of success (Sutterfield, 2006).

Littau (2010) noted that a significant number of papers on project risk management, project performance, project environment and project management social dimensions were included in the project management literature. Risk assessment and decision-making was also described as a key area in the field of project management research. (PMBoK 2006, Themistocleous & Wearne 2000, Simister, S. 1994).

The purpose of decision theory is to give a rational decision-making account in risk and uncertain situations. Almost every decision that can be considered is made in a sense in which the decision-maker has limited information. This again implies that the decision-maker poses the possibility that the results will vary from the one he hopes to accomplish, probably with worse repercussions. How should we tackle this risk and the uncertainties it entails? This issue is important both in terms of what is in our personal interest and in terms of what is ethically correct. The decision theory depends on the principle of maximizing expected utility.

2.14.1 ORIGIN, DEFINITION AND USAGE

Decision theory is a multidisciplinary research theory for decision-making comprehension (O'connell & Buchanan 2006). It is a useful theory which explains, develop and forecast decision-making outcome under specific conditions. The roots of current decision-making theory lie in Bernoulli's (1738) finding that the intrinsic value, i.e. worth, reduces as the overall value of capital rises. He suggested a logarithmic method to reflect this pattern of decline in utility. But until the seminal work of von Neumann and Morgenstern (1947), efficiency remained a conceptual concept. They extended the qualitative idea of benefits (which was restricted to the effects of wealth) by Bernoulli, created lotteries to quantify them, developed normative axioms, and standardized the mix into a mathematic, economic utility theory. Since then, the volume of research has exploded in decision-making. Bell, Raiffa and Tversky (1988) split efforts in this area into three interest groups "that recognize various issues. The different methods (Goldstein and Hogarth 1997) are known to be sufficient, These are the normative descriptive and prescriptive decision-making systems.

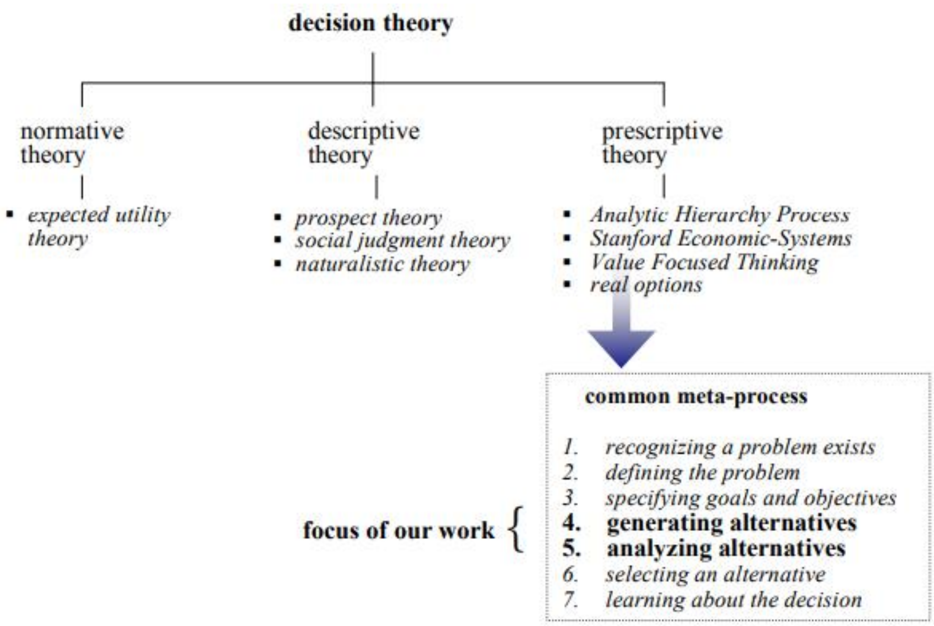


Fig. 2.6 - Component of decision theory

We follow Keeney (1992) and summarize their salient features in Table 2.4

Table 2.4 Summary of theories

	normative	descriptive	prescriptive
focus	how people should decide with logical consistency	how and why people decide the way they do	help people make good decisions prepare people to decide
criterion	theoretical adequacy	empirical validity	efficacy and usefulness
scope	all decisions	classes of decisions tested	specific decisions for specific problems
theoretical foundations	utility theory axioms	cognitive sciences psychology about beliefs and preferences	normative and descriptive theories decision analysis axioms
operational focus	analysis of alternatives determining preferences	prevention of systematic human errors in inference and decision-making	processes and procedures end-end decision life-cycle
judges	theoretical sages	experimental researchers	applied analysts

2.14.2 NORMATIVE DECISION THEORY

In relation to planetary movement or the attraction of charged particles, actions do not occur naturally; they are actions of will (Howard, 1992). Which is why we need guidelines, laws and norms and, that is the role of normative theory. The normative theory is about reasoning, decision-making rationale and optimum results decided by their utility. The utility is an unequivocal indicator of the desirability or degree of satisfaction with the results of the decision-maker's preferred course of action (e.g. Baron 2000). The utility relies on the principle of gambling, where only two variables are relevant: one convictional strength (probabilities) and one output desirability (Goldstein and Hogarth 1997). A variable polynomial of its probability and outcomes functions (e.g. Keeney and Raiffen 1993, de Neufville 1990) takes the expected utility function for a sequence of events with given probability. For consequence X=x1,x2,..xn, the anticipated utility of this risky situation is (X)=Σpi u(xi) where Σpi = 1

As per the Booker and Bryson (1985) in project management, the Decision theory deals with many different subjects and consider to be the heart of project management. The theory emphasizes on R&D in various areas such as decision making, Risk and uncertainty.

As per the Raiffa (1970) Utility Theory can vary from a monetary value to a qualitative value. The decision-makers approach is to analyze the anticipated benefits of utilities and to agree on the desired utility.

2.14.3 BAYESIAN PRINCIPLES AND THE WORTH OF DATA

As per T. J. Stewart (1980) on Bayesian theory, a fundamental concept for decision-analysis is that the practical choice maximizes the expected value of utility with predictions of some uncertainty-characteristic distribution. In many decision applications, Bayesian principles are directly applied. Often interactive computer programs continuously ask the user about his estimates and update the forecast according to conditional probabilities with the Bayesian theory.

2.14.4 MINIMAX PRINCIPLES AND GAME THEORY

The minimax theory can be seen as a solution to the pre-distribution robustness problem: instead of optimizing the expected utility for all previous distribution, optimize the total utility for all 0. Minimal optimization is addressed by Mood et al. in a mathematical context and Lindley in a decision-analytical context. The principle is based on Von Neumann and Morgenstern's classic game-theoretical analysis, which aims at maximizing the payoff against an intelligent opponent, namely winning in a poker game or profiting from a competing mark. After review of theories, it has been observed that the very few articles are related to the decision theory application for the construction project.

2.15. MAJOR GAPS

- The project risks to be taken into consideration in the management of the construction project must be identified.
- This is important to research the possibility and effect of risk on the construction project and to model it in order to enhance decision-making on the mitigating steps taken by the various risks.
- There is a need to track the decisions made on the risks, causes and their effect on project performance in terms of time and cost for construction projects.

- No study could be found which suggests a model for risk for the railway construction project in India.

2.16. RESEARCH GAPS

SN.	Area of Study	Literature Details
1	Risk management in Construction Project	Tsuda (2006), Ah, Rahschulte, T. J. Milhauser, K. (2010), Nahod and M.M. (2012), Gibson et al., (2006), Nahod, M.M. (2012), Osama Hussain (2012), Virginia A. Greiman (2013)
	Gaps	
	Time and cost are the critical project constraints required detailed examination for effective management of the project	
2	Risk management in Construction Project	K. Jayasudha Dr. B.Vidivelli and E.R. Gokul Surjith (2014), Ossama A. Abdou (1996) Shou Qing Wang, Mohammed Fadhil Dulaimi & Muhammad Yousuf Aguria (2004) Rasool Mehdizadeh, (2012),

		Anna Klemetti, (2006)
	Gaps	
	Since the projects require continuous decision making, they are exposed to numerous sources of **risk**, which needs critical and intensive research.	
	Intensive research is required for an individual type of construction contract before the tendering to complete the project as per planned performance.	
	Stakeholders perception on risk management required a more detailed approach also a coordinated effort is needed	
	Activity and risk relationship or RBS & WBS risk relation required more critical research so that risk planning can be implemented in projects	
3	Project Risk Management in Global scenario	Wenzhe Tang, Maoshan Qiang, Colin F. Duffield, David M. Young, and Youmei (2007) Artem Aleshin (1999) Remon Fayek Aziz (2013) Ahmad Baghdadi, Mohammed Kishk (2007) Ruqaya Al-Sabah, Carol C. Menassa, Awad Hanna (2008) Patrick X. W. Zou; Ying

		Chen; and Tsz-Ying Chan, (2010), William Imbeah; and Seth Guikema, (2009), Sumit Datta, S.K. Mukherjee, (2001), Dr Dan Patterson, (2006)
	Gap	
	Detailed **Risk Analysis** is required to quantify the impact of risk factors on project.	
	Strategies to be formulated for Managing Risk.	
	The risk mitigation measures specific to the project and sector to be developed.	
4	Project Risk Management in Indian scenario	Hariharan S, P.H. Sawant (2012) K. Deeppa & I. Krishnamurthy (2014), Florence Yean Yng Ling, Linda Hoi(2006), Kumar Neeraj Jha & M. N. Devaya(2012), R. C. Walke, V.M. Topkar (2012)
	Gap	
	There is a need to identify the relationship between factors probability	

	of occurrence /Impact in terms of Time & Cost.	
	Intensive research is required to established the relation between stakeholders risk appetite and allocated risk	
	Intensive research is required to established the relation between risk factors and activity, and this should be specific to a type of infrastructure	
	The risk assessment model is not developed and the relationship between activity and risk factors impacting cost and time not analysed	
5	Risk management in Railway projects.	Serdar Dindar, Sakdirat Kaewunruen and Min An (2014) Âsa Boholm (2010) Zhang Junb, Sun Quanxinc (2014) Sunduck D. Suh (2010) Agarwalla and G. Raghuram (2012) Sobhesh Kumar Bodhibrata Nag, Jeetendra Singh & Ved Mani Tiwari (2013)
	Gap	
	Research on the identification, assessment and response strategy for the rail project in India is desperately required.	
	The likelihood & impact of factors need to be considered at the planning stage itself to reduce the impact on time and cost because once government project Budget sanctioned, it will be difficult to revise the	

	cost.	
	There is no literature available on steps taken to boost the construction progress rate of IR initiatives in India.	
6	Project Risk management in Public Infrastructure projects	Prasanta Kumar Dey (2013), Amaan Iqbal Thakur, Sakib Khan, Mohd Junaid Siddiqui(2016), Chaitali S. Pawar* Suman S. Jain Jalinder R. Patil(2015), K. Rajkumar., Dr. S. AnandaKumar V. Krishnamoorthy(2013), Cheng Siew Goh1; Hamzah Abdul-Rahman2; and Zulkiflee Abdul Samad(2013), K. Deeppa & I. Krishnamurthy(2014), T.H. Nguyen, G. Bhagavatulya and F. Jacobs (2014) K. Jayasudha Dr. B.Vidivelli And E.R. Gokul Surjith(2014) A. V. Thomas, Satyanarayana N. Kalidindi* And K.

		Anantha narayanan(2003)
	Gap	
	There is an urgent need to have research on Quantitative risk assessment for sector or area-specific in public infrastructure projects.	
7	Literature Review on Theoretical Premise (Decision Theory)	Sutterfield (2006), Littau (2010),
		PMBoK (2006), Themistocleous & Wearne (2000), Simister, S. (1994)
		Buchanan (2006), Bernoulli's (1738), von Neumann and Morgenstern (1947), Bell, Raiffa and Tversky (1988), Goldstein and Hogarth (1997)
	Gap	

	The project risks that need to be taken into account when planning the construction project need to be identified.	
	The likelihood and effect of risk on the construction project ought to be analyzed and modeled to enhance decision-making on the preventive action taken by the various risks.	
	The decisions made on the risk, cause and their effect on project performance need to be tracked in terms of the time and cost of construction projects.	
	No study could be found which suggests a model for risk for the railway construction project in India.	
8	Earned Value & Expected Value Method in Public Infrastructure projects	Brandon (1998); Fleming and Koppelman (2004); Kim et al. (2003), Anbari (2003); Fleming and Koppelman (2010) Cioffi (2006); Sarkar, D., & Dutta, G. (2011); Roetzheim.W. (1988); Nicholas, J.M. (2007); Dey, P.K. and Ogunlana, S.O. (2002) Sarkar, D. (2011).
	Gap	
	Expected Value Method based work conducted in Oil & Gas but not for the Railway project.	

	Research is needed to explore the concept of the Earned Value in risk management, although a lot of emphases is given to the concept of EDM, very less research being conducted with the inclusion of risk management.
	Intensive work is required to establish the interaction between risk factors, activity, and that would be specific to the type of infrastructure.

2.17. PROBLEM STATEMENT

2.17.1 BUSINESS PROBLEM

"Inaccurate assessment and management of construction project risk are adversely affecting the performance of construction in Indian railway projects." Further Project performance may be assessed and analyzed using a broad variety of performance indicators that could be connected to specific measurements (groups) such as time, cost, efficiency, consumer loyalty, change, business performance, health and safety (Cheung et al. 2004; DETR 2000). Time, cost and quality are, therefore, the three prevailing dimensions of success assessment. However, for the research, we are considering cost as a primary performance indicator and time as a secondary indicator.

2.17.2 RESEARCH PROBLEM

Research on the identification, assessment and management strategy for the railway projects in India is urgently required. The likelihood & impact of factors needs to be considered at the planning stage itself to reduce the impact on time and cost because once government project Budget sanctioned, it will be difficult to revise the cost. There is no work available on steps to boost the efficiency of development of IR projects in India.

- Risk assessment and management model is not developed for construction in Indian railway projects, and the relationship of project risk in construction with project performance is not analysed.

2.18. RESEARCH QUESTION

The overarching goal of this research is to enhance the effectiveness of risk management practices utilized in railway projects and to establish the appropriate framework to strengthen the existing risk management process, thus increasing the effectiveness of the project outcome. The responses to the following research questions should determine the overall purpose.:

Q1. What are the various significant project risk factors in the construction of IR projects, causing time & cost overruns?

Q2. What is the probability and impact of identified risk factors on activities in the construction of railway projects?

Q3. What is the relationship of project risk and project performance in the construction of Indian railway projects?

2.19. OBJECTIVES

- Objective 1

To identify the various significant risk factors in railway construction projects, causing time and cost overruns.

- Objective 2

To identify the likelihood of occurrence and impact of identified risk factors on construction activities in railway construction projects.

- Objective 3

To develop a risk assessment and management model in terms of the relationship between project risk and project performance for the identified risk factors in railway construction projects.

2.20. SCOPE OF THE RESEARCH

The research is limited to the construction of new lines for all the projects of IR railway constructions, dedicated freight corridor and and any other private railway construction projects.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. THEORETICAL BACKGROUND

The research methodology is a systematic process that begins with the identifying the problem, collecting data relevant to the problem in terms of feedback needed to solve the problem, analyzing the data, and finally the outcome and results of the analysis and conclusions. It helps the researcher to switch from problem to solution in the right direction and further towards the contribution of the thesis in the currently available research theories. The research methodology is a process that defines the methodology to be used, such as research design, sampling procedure, measurement & instrumentation, data collection, data analysis, the outcome may be in terms of a framework/model formulation and finally the validation of the result.

This research on the railway construction project has three specific objectives: to define important risk factors influencing overruns, to evaluate the risk and activity relationship in terms of the likelihood of the occurrence and effects of these risks on time and cost throughout the lifecycle of the project and to finalize the model to predict time and cost overruns

This chapter analyses how the researcher responded to the research questions relevant to the objectives, as mentioned above, by evaluating the various approaches and following the correct methodology for the research. Chapter 1 has already explained how the business problem specific to railway projects in India has defined.

Research Classification - The research can categorized differently as being perceived, Kumar (1999) demonstrates the overall classification of the type of research from its applications, objectivity and enquiry mode.

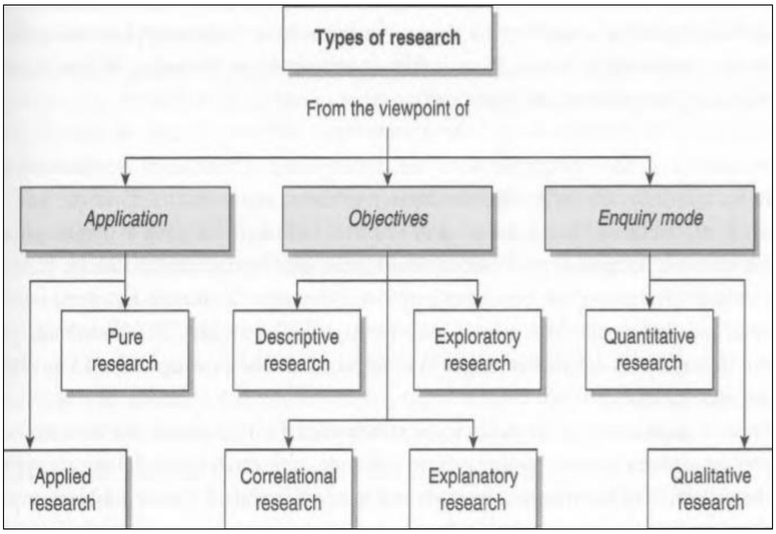


Fig. 3.1: Classification of Type of research (Source: Kumar 1999)

It is exploratory and analytical research. In this study, for the development of the railway construction project in India, detailed risk identification and evaluation is carried out. The Factor analysis is a good method to assess the major risk variables based on their factor load. Subsequently, the identified risk factors can be useful for risk activity relationship. Despite having various methods for the model formulation, the Expected value method ((Roetzheim (1988), Nicholas (2006) and Sarkar & Dutta (2011)) used for arriving at the model for the risk quantification for time and cost overruns.

Research data (variables) obtained from different sources and literature review are large, to reduce information to significant variables with different characteristics, further analysis of the variables based on the perception of industry professionals is needed. To measure the large numbers of variables, a "Likert 5 Point Scale", which was Ordinal Data Form, is chosen. The total score or mean level have identified for all the risk variables. Between many debates about the use of parametric tests and non-parametric tests for ordinal data such as Likert scale data, many works of literature stated the suitability of using parametric tests because they are more reliable than non-parametric tests.

The parametric analyses may be helpful if the population data is well understood at periods where clear conclusions can be made about the population. The parametric test is applicable only for the variables in the population, and the sample is independent. It assumes the normal distribution and also handles the interval and ratio data. The test can be performed more suitably when the spread of each group is different, might not provide valid results if groups have the same spread. Parametric tests are thus reasonably reliable to produce essentially impartial answers that are acceptably similar to "the reality" when evaluating the Likert scale answers. Experts proposed 'Factor Analysis Methodology' (Sullivan & Artino, 2013) to provide proof that the components of the scale are adequately interrelated and that the grouped elements measure the underlying variable. A single question related to a construct is not reliable and should not be used to map conclusions. The method used to define trends of interrelationships, data reduction, development of tools, information identification and explanation, data transformation, hypothesis testing, the discovery of relationships in different areas of interest and visualization of the build is Factor analysis. Factor analysis is beneficial for research involving a many variables, questionnaire items to be measured and similarly can be reduced to a smaller number, to get to the fundamental concept and to encourage interpretations. Focusing on certain main factors is better than trying to weigh so many variables that might be irrelevant, and an overview of the component is helpful when putting variables inappropriate categories. Data processing, hypothesis checking, visualization and scaling are among common applications in factor analysis (Rummel, 1970). The confirmatory factor analysis (CFA) enables the researcher to quantitatively evaluate the factor structure and provide additional evidence of the validity of the new measure.

Nevertheless, it is still subject to the use of judgment, and it is very important to report the confirmatory factor analyses thoroughly and explicitly (Hinkin, 1998). The principal component analysis is concerned with describing a set of variables. It deals with the definition of a collection of variables, variance-covariance form, utilizing a few linear combinations of such variables.

Examination of the key components also indicate correlations that were not previously known and therefore required explanations that would not usually occur. For even broader cases, an analysis of the principal components also serves as intermediate phases for large research work. This theoretical framework of Factor Analysis with 'Principal Component Analysis' extraction approach is considered to be the most appropriate methodology for a large number of variables found from literature review to make them the most relevant for railway project development.

3.2. RESEARCH METHOD FOR OBJECTIVE 1

To identify the various significant risk factor in railway construction projects, causing time and cost overruns.

Variables obtained from review of literature related to time and cost overrun in railway project further considered for Pilot study with a group of senior railways experts. The data are obtained by gathering input responses from respondents employed in railway projects to evaluate the importance of such variables in terms of time and cost overrun impact. A questionnaire study performed to consider the impact on railway projects in India of different risk factors linked to the overruns. 01 refers Not concerned at all, and 05 refers to Extremely concerned. The sample population for the study was an infrastructure and management employee with different parties employed in the railway sector of differing expertise from owners, contractors, consultants, PMC, manufacturer and inspection agencies. The statistical method Exploratory Factor Analysis (EFA), as well as a part of it, Principle Component Analysis (PCA), used to reduce attributes to risk factors; the responses evaluated using SPSS. Principal Component Analysis (PCA) has developed to further study a wide variety of interactions between such factors in a simplified way. PCA have chosen the variance information and covariance associated with the set of variables, as it is performed in an ordinary matrix, completed with the correlations of each variable. PCA was done to aid study a wide variety of interactions between such factors in a simplified way. Preqequsite for PCA: a) interactions must be formed between variables, and b) the greater the sample size, the more precise the usual resulting factors are. PCA lacks a clear definition of distribution. Thus, 'Descriptive Analysis' was initially implemented in SPSS applications to test, a) Is there a connection between the variables triggering the overruns b) to gain an output assessment matrix and c) to establish the basis for the factor analysis. Calculating the Cronbach Alpha coefficient can help to know the internal consistency of the items. It is based on the formula as follows:

Cronbach Alpha Coefficient = rk /[1 + (k -1)r]…… Eqn. (3.1)

Where - k is the number of variables (items) considered

r is the mean of the inter-item correlations.

Alpha value equal to 0.8 is a reasonable goal with value < 0.8 is good and <0.9 is excellent. PCA is dependent on correlations, so the variables should be linked linearly (in pairs) with each other so that at least several variables should be correlated at a moderate level. Bartlett's Sphericity check discusses this assumption. More 'Descriptive Statistics' were determined to identify the component solution with Scree plot and un-rotated Component Matrix. The rotated component matrix provides factor loading for each factor (parameter), and the component plot gives a visual depiction of the loads in space. The factor obtained from the study objective one will be used for activity and risk relationship in objective two.

3.3. RESEARCH METHOD FOR OBJECTIVE 2

To identify the probability and impact of identified risk factors on construction activities in railway construction projects

The quantification of risk was performed based on the approach of the expected value method. In this objective, the risks associated with each activity in the network have been established. The technique is based on research carried out by Roetzheim (1988), Nicholas (2007), and Sarkar and Dutta (2011).

For objective two work, it is required to standardize the activity and the risk factors relationship. The activity details established from the study of the project plan (In progress railway project) and standardized based on the opinion of the expert through a pilot study. The major activities in the construction of railway track consist of Mobilization and Commencement, Site survey and Investigations, Approvals for General Arrangements Drawing, Approvals for formation (C/S & L section, Drainage and other structures), Utility shifting and Tree cutting, Barricades (safety), Toe wall and Drainage work, Earthwork for formation, Foundation work for Electric pole, Pole Erection and fixing, HT wiring works, Signaling & Tele-communication work, Subgrade Blanketing, Ballast Spreading, Sleeper Laying, Rail laying & Fixing, Temping and Compaction, Rail De-stressing, Dressing and Boxing, Documentation for CRS Inspection, Commissioning, Inspection & Handover. A questionnaire containing the details of all the activities and risk factors (the outcome of Objective 01) arranged in the matrix form. The effect of each risk factor on all the activities have also been standardized through the Pilot study to get the similar responses from respondents during questionnaire survey. The risk factors which do not influence the activities have frozen, and the factors which affect the activities have kept open for the questionnaire survey.

According to Roetzheim (1988), as cited by Nicholas (2007), the probability of risks will vary from 0 to 1, suggesting a chance of 0 to 100% occurrence. But the summation of the weighting of an activity that is associated with all risk sources is often equal to 1. The sum of the probability and the product of the respective weight of each risk factor on an activity is equal to the Composite likelihood factor (CLF). We presume a deterministic a network time and cost. We also presume that the network of critical path models has "N" activities defined by x = (1 ...... N) and that "M" risk source r = (1 ..... M) indicates "M" risk sources. In this purpose, we extended the work of Roetzheim (1988) and Nicholas (2007), and used the definition of the Expected Value Method (EVM) for risk analysis. The variables are defined as follows:

Lrx: Probability of r risk source for x activity

Wrx: Weightage of r risk source for x activity

Irx: Impact of r risk source for x activity

CLFx: Composite Likelihood Factor for x activity

CIFx: Composite Impact Factor for x activity

An activity may have several risk sources, each with its probability. The probability, impact and weightage of risks mentioned above obtained through a questionnaire survey of the identified sources of risk for each activity. The targets were engineering and management professionals involved in planning, building and managing the railway construction project, including the client, representatives and consultants involved.

3.3.1 PROBABILITY AND IMPACT SCALE

The concepts of risk likelihood and impact degree (Scales) are unique to the project context, according to PMBoK (6th edition, 407). The range of ratings represents the degree of information required to manage the project risks management method by utilizing more ratings with a more complex (typically five) methodology and fewer grades (usually three) for a straightforward procedure. The table offers suggestive risk descriptions and impacts from PMBoK (2017) can be useful for the risk management application in the industry.

Table 3.1 - PI Scale (PMBoK)

SCALE	PROBABILITY	+/– IMPACT ON PROJECT OBJECTIVES		
		TIME	COST	QUALITY
Very High	>70%	>6 months	>$5M	Very significant impact on overall functionality
High	51-70%	3-6 months	$1M-$5M	Significant impact on overall functionality
Medium	31-50%	1-3 months	$501K-$1M	Some impact in key functional areas
Low	11-30%	1-4 weeks	$100K-$500K	Minor impact on overall functionality
Very Low	1-10%	1 week	<$100K	Minor impact on secondary functions
Nil	<1%	No change	No change	No change in functionality

Karim et al. (2015) published an article on recognizing and assessing the risk factors that impact construction ventures. They used the scale below to calculate the probability and impact of risk factors on the project.

Table 3.2 - Probability Scale (Karim *et al., 2015*)

Rank	*Descriptor*	*Description*	*Probability*
Very high	Almost Certain	Even chance	> 50%
High	Likely	One in every 4 projects	> 25%
Moderate	Possible	One in every 10 projects	>10%
Low	Unlikely	One in every 20 projects	>5%
Very low	Rare	Less than 1 in every 20 projects	< 5%

Table 3.3 - Impact scale (Karim *et al, 2015*)

Rank	*Schedule*	*Cost*	*Safety*	*Quality*
Very high	>3 months	>$10 million	Fatality	>10 %
High	2-3 months	$ 5-10 million	Severe injury	5-10 %
Moderate	1-2 months	$ 2-5 million	Medical treatment	3-5 %
Low	2-4 weeks	$1-2 million	First Aid	1-3 %
Very low	< 2 weeks	< $1 million	No injury	<1 %

The influence of the identified risk factors on the activities have identified through a questionnaire survey. The input from the respondents has established in terms of Weightage (W), Likelihood of occurrence (L) and Impact (I). The Scale for the Probability and Impact have decided based on the literature review (PMBoK guidelines and past similar research) and pilot study to modified the PI scale specific to the railway sector through the expert.

3.3.2 SCALE TO BE USED FOR THE STUDY

The scale to be used to fill the responses are as follows.

Weightage - The Weighing value would be between 0 and 1. The cumulative weightings will be equivalent to 01 for an activity.

Example – Mobilization and Commencement (An activity) affected by 07 risk factors (Contractor, Management consultant, Client, Nature, approvals and site clearances, fundamental risk), so the weightages of all the risk factors on the activity can be considered as 0.15, 0.05, 0.05, 0.1, 0.4, 0.1 and 0.15 respectively and summation of all weightages should be equal to 01.

Likelihood of occurrence (L)

Table 3.4 – Scale for the Likelihood of occurrence (L)

Scale	Very Low	Low	Medium	High	Very High
Description	Rare	Unlikely	Possible	Likely	Almost certain
Descriptor	Less than one0 in every 20 project	One in every 20 project	One in every 10 project	One in every 04 project	Even Chance
Probability	1-10%	11-30%	31-50%	51-70%	71-99%
Values	.01 - 0.1	0.11 - 0.3	0.31 - 0.5	0.51 - 0.7	0.71 - 0.99

Impact (I)

Table 3.5 – Scale for the Impact (I)

Scale	Very Low	Low	Medium	High	Very High
Values	.01 - 0.2	0.21-0.4	0.31 - 0.5	0.51 - 0.7	0.71 - 0.99
Time	Delayed by by less than 1%	Delayed by by 02 to 05%	Delayed by by 06 to 10%	Delayed by by 10 to 20%	Delayed by by 21 to 40%
Cost	Over budget less than 1%	Over budget by 02 to 05%	Over budget by 06 to 10%	Over budget by 10 to 20%	Over budget by 21 to 40%

The value of *Likelihood of occurrence (L)* and Impact (I) should be in between 0 to 1 as per the above details. The respondents were asked to fill the above details of Weightages (W), Likelihood of occurrence (L) and Impact (I) as per the above table. In addition, a questionnaire study between experts revealed the corresponding weighting (Wrx) of each risk factors on each activity. The weight summation of all the risk factors on an individual activity will be equivalent to 1

$$\sum_{x=1}^{M} W_{rx} = 1 \text{ for all } x \text{ (} x = 1 \text{ …. N)} \qquad \text{……………………………. Eqn. (3.2)}$$

The probability (Lrx) of all risk factors (r) for an activity (x) can be integrated and represented as a common Composite Likelihood Factor (CLF)x. The weights (Wrx) of the risk sources of an activity are compounded by their respective probabilities and the summation of all values for obtaining CLF of the activity. Below is a formula for the calculation of the CLFx:

$$\text{Composite Likelihood Factor } (CLF)_x = \sum_{x=1}^{M} L_{rx} W_{rx} \text{ for all } x \qquad \text{………… Eqn. (3.3)}$$

$0 \leq Lrx \leq 1$ and $\sum Wrx = 1$ for all r

The effects of risk may be measured in terms of the impact to time and cost of an activity triggered by the risk. This time and cost impact may be regarded as the activity's Risk Time (RT) and Risk Cost (RC). A similar calculation to that of likelihood can be made for achieving a single Composite Impact Factor (CIF) by considering the weighted average as seen below for the relationship:

$$\text{Composite Impact Factor } (CIF)_x \sum_{x=1}^{M} I_{rx} W_{rx} \text{ for all } x \qquad \text{………………. Eqn. (3.4)}$$

$0 \leq Irx \leq 1$ and $\sum Wrx = 1$ for all r

The mean value of all the respondents will be used for analysis. The outcome will be in the form of a table highlighting value of likelihood of occurrences (Lrx), Impacts (Irx) and weightages (Wrx) of all the risk factors on each activity and also the CLF and CIF for all the activities.

Severity

The Risk Severity (RS) of the risk may be represented as a component of the probability of risk and its impact. Therefore the numerical value varies between 0 and 1. This magnitude may also be described as "no magnitude" for value 0 and "very strong severity" for value 1, in terms of qualitative scoring. The Risk Severity (RS) numerical value is obtained from the equation listed below:

RSx = L x I for all x ……….…………..…. Eqn. (3.5)

The Severity of individual risk on an activity can be determined by calculating the average of probability and impact responses for a risk factor on an activity. The relative severity of a factor on various activities has been identified from the Monte Carlo simulation by calculating the mean and standard deviation and Normal Distribution of the data of a risk factor.

3.4. RESEARCH METHOD FOR OBJECTIVE 3

The analysis is required to develop a model for risk management which provide the relationship between the project risk and project performance. The risk management Model should include Risk Identification, Assessment, Response Planning, Monitoring and Controls. The methodology for the model should also be related to project performance indicators to depict the relationship between the risk and project performance. The Earned Value Analysis (EVA) is being widely accepted tool for the project performance assessment. The CPI and SPI are two important outcomes of EVA, which indicates the health of a project progress in terms of the time and cost.

A network with deterministic time and costs for the development of the railway track project will be developed to achieve Objective three. A quantitative risk assessment and management model is developed using expected value. The development of the model is split into two stages, i.e. the first stage through the application of Expected Value Method (EVM), under which Roetzheim's (1988) and Nicholas '(2007) study expanded for the risk assessment and evaluation. The second stage is based on EVA, in which impact of risk quantified in terms of time and cost and calculated over the project's lifecycle. The Expected Value Method (EVM) for analysis of the risk is used for the project. For objective number three, the following variables are described for an activity (x):

BTEx: Base Time Estimate
BCEx: Base Cost Estimate
CCx: Corrective Cost
CTx: Corrective Time
RCx: Risk Cost
RTx: Risk Time
ECx: Expected Cost
ETx: Expected Time

The BTE of project is estimated base project duration considering the base time of each activity schedule using the CPM method. The Base Cost of project is calculated by addition of base cost of each activity in the project and referred to as the BCE. The BTE and BCE are measured using the comprehensive plan, design, item details and their specification for all major project activities. The associated CT or time necessary to correct activity in the event of a trigger of one or more risk for an activity has been estimated by multiplying the base time or BTE with the CIF of that activity calculated earlier for that particular activity. The CC is calculated by multiplying the BCE with the CIF of the associated activity (x). The following equations are used to calculate the CC & CT of an activity (x)

Corrective Cost (CC) x = BC x CIF………..…………………………... Eqn. (3.6)

Corrective Time (CT) x = BT x CIF………..……………...………... Eqn. (3.7)

The RC and RT for an activity are calculated based on the composite probability of the risk factors on the activity. The following equation will be used to calculate the RC and RT for an activity (x)

Risk Cost (RC) x = CC X CLF of x activity……………………….... Eqn. (3.8)

Risk Cost (RT) x= CC X CLF of x activity……………………….... Eqn. (3.9)

For each project activity, the Expected Cost (EC)x and Expected Time (ET)x, and subsequently the expected cost and time of the project is determined from the decision tree analysis concept of the expected value (EV).

Expected value (EV) = Likelihood (p) [higher payoff] + (1-p) [lower payoff] ……….... Eqn. (3.10)

Expected cost and time in both the scenario when risk occurs and when risk will not occurs

- The first scenario – If a risk occurs, the likelihood of occurrence (L) x on any activity having a time and cost impact would be BTE+CT and BCE+CC, respectively.
- Second Scenario - If no risk occurs, the likelihood of occurrence (1-L) x of some activity having a time and cost impact would be BTE and BCE respectively.

  Expected Cost (EC)x = Lx (BCEx + CCx) + (1-Lx) BCEx

  = BCEx + CCx (Lx)

  = BCEx + RCx for all x activities ……………………….... Eqn. (3.11)

  Expected Time (ET)x = Lx (BTEx + CTx) + (1-Lx) BTEx

  = BTEx + CTx (Lx)

  =BTEx + RTx for all x activities ………………………….. Eqn. (3.12)

The severity of risk presented as a result of the probability and impact of risk. Hence, the numerical significance varies from 0 to 1. The value 0 represents as no severity and 01 represent as "Extremely high severity". The risk severity deriving from the above equation 3.5, defines how important the risk to the success of the project will be. Small values are unimportant risks that can be overlooked and big values are huge risks that require close treatment and monitoring.

3.4.1 EARNED VALUE ANALYSIS (EVA)

EVA, is one of the most commonly known project control systems used by project management professionals. EVA sets parameters which allow project monitoring and controls. It defines the planned value (PV) as the budget amount to be expended on the job done in keeping with the initial timetable at any period or with respect to baseline. PV referred to as planned Budgeted Cost of Work Schedule (BCWS). Earned Value (EV) is, at any stage in time, the monetary value of the progress achieved (work completed) in terms of the budgeted cost. EV was initially referred to as the Budgeted cost of work performed (BCWP). Actual Cost (AC) reflects the monetary value that was spent on achieving progress at some point of time. AC is referred to as the Actual Cost of Work Performed (ACWP). The EVM approach can be useful in predicting project progress based on past results and in implementing the control measure. The EVM offers two major indicators for CPI and SPI. The equation 2.2 and 2.3 mentioned below was used to measure the EV.

$$CPI = BCWP/ ACWP \quad \text{Eqn. (3.13)}$$

$$SPI = BCWP/ BCWS \quad \text{Eqn. (3.14)}$$

The value of CPI & SPI if less than 1, it shows the cost & time overrun at a given point of time. The EVM model will be applied in the present work by evaluating the Base Cost based Earned Value and Expected Cost-based Earned Value and further analyzing the risk effect on the project. Below is the methodology used for the definition of indicators. The input required for the calculation is the monthly planned value of Base Cost (BCp), the monthly physical progress or work done (percentage) achieved on the project (From the updated schedule) and the actual cost spent on the progress. The WD value will be in the percentage, but for the calculation, purpose considered in the 0-1 digits. The Earned Value calculations for a month will be as follows,

$$CPI_B = BCWP/ACWP = WD*BCm/AC \quad \text{Eqn. (3.15)}$$

$$SPI = BCWP/BCWS = WD*BCm/PV \quad \text{Eqn. (3.16)}$$

The CPI is calculated using the EV and AC of the work done for a month. Now, the concept of the EVM is further extended to measure the cost overrun by reference to the threshold limits set for a month. The threshold limit is Expected cost (EC), which is the consequence of the pessimistic risk scenario by taking into account all the risk that is likely to occur in the project. The actual cost of work done should not exceed the monthly expected cost estimated in any case. The Expected Cost of Work Performed (ECWP) for a given month will be identified, and the risk-based CPI for the project will be calculated for a given month. The Risk-based CPI will be helpful to quantify the cost impact of the risk on a monthly basis.

CPI_R = BCWP/ECWP = WD*EC/EC……………………... Eqn. (3.17)

In the formula, the ACWP is replaced by the ECWP (which is risk-based Earned Value, considering the extent of all risks with a negative scenario). If CPI (Base Cost) is more than the CPI_R (Risk), it suggests that the AC incurred for a month is less than the EC. It ensures that the project is within the limits of the risk cost range and also the actual cost incurred is less than the expected cost, a portion of the risk cost is also, left which can be added to the contingency fund to cope with the future risk. When CPI(Base) is less than CPI(Risk), it indicates that the AC incurred for a month is greater than the EC , so urgent action is required to control cost overrun. The CPI (Risk) and CPI (Base) were also used to calculate the percentage of overruns concerning the Expected Value. The following formula will be used,

Quantified Risk Effect on Cost = 100*(ACWP-ECWP)/ECWP…...Eqn. (3.18)

The Quantified Risk Effect on Cost will be in the Percentage form, which is the difference of the Actual Cost of Work Performed and Expected Cost of Work performed concerning the Expected Cost of Work Performed. The percentage value may be negative or positive if it is negative, then it means that the risk reserve is balanced or remains for a month, and it is good for the project. if it is positive, it means that the actual cost incurred is higher than the expected cost, that is the threshold for the project, and that is not a healthy sign for the project.

The quantified risk effect on time will be calculated based on the completion dates of the project using the Critical path method of project schedule. The Project Completion Date based on the Baseline completion date $(PCD)_B$, Project Completion Date based on the Risk-based Expected completion date $(PCD)_R$ and Project Completion Date based on the updates $(PCD)_U$. The following formula will be used to quantify the time overrun with reference to the Expected Completion date,

$$\text{Quantified Risk Effect based on Time} = ((PCD)_U - (PCD)_R) / ((PCD)_R - (PCD)_B) * 100 \quad \text{Eqn. (3.19)}$$

The value of the Quantified Time-based Risk Effect may be negative or positive in percentage form. If it is negative, the risk allowance will still offset the future risk; if it is positive, it implies that the actual time taken is greater than the planned time-based threshold and is not a healthy sign for the project.

3.5. SOURCES OF DATA

The Primary data obtained from various respondents and organizations participating in the railway construction project. Secondary data is often used from various sources to gather additional data such as timetable, BOQ and other relevant project information from different sources.

PRIMARY DATA Primary data had obtained from the representatives of the:

- Owner companies such as Indian railways, Rail Vikas Nigam Limited
- Consultants
- Contractor
- Sub-contractors

SECONDARY DATA: Secondary data will be obtained from the following sources:

- Indian Railways knowledge portals
- International Railway Journal
- Project Management Journal
- CAG audit report

- MOSPI website
- Major contractors / sub-contractors websites in India
- Other Research Journal / Research Papers / Articles/Forums

3.6. SAMPLING

Sampling is used in the study to identify the size of the population. The present study consists of a population involved in the development of the railway project in India. This population is too large to collect data directly. However, a set of members who are either involved in design, construction, planning or executing the railway construction project in India are targeted for data collection of the study.

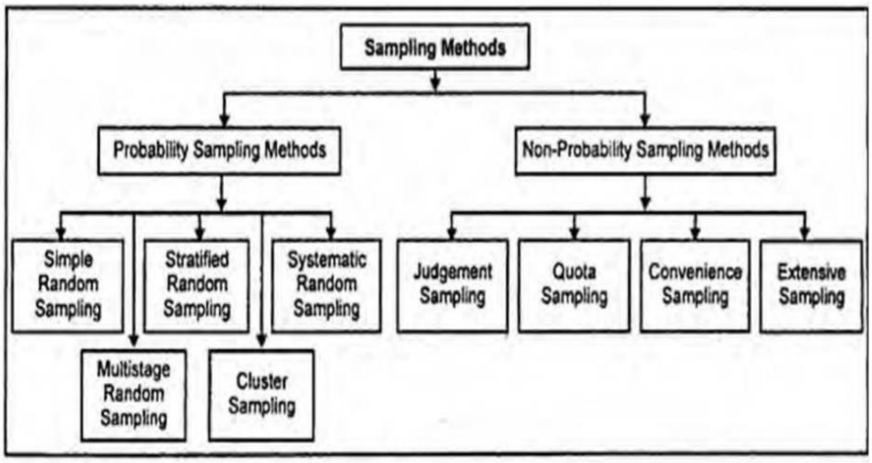


Fig. 3.2 Sampling Methods

(Source - http:/research-methodology.net/sampling)

In this research, the judgmental sampling technique is used because of the above population and the unique requirement of involvement. The Expert Judgmental sampling technique used for the completion of the initial questionnaire. The sample size is the foundation for calculating the error of sampling and the potential to accurately estimate the influence of the model. The critical question, as in any statistical method, is how big a sample is required. Bentler states that the criteria for sample size in SEM differ for calculation and structural models (Bentler and Chou 1987). To test a measurement model, cited in (Williams, 2010) by Flynn and Pearcy (2001), a thumb rule of ten subjects per item is prudent in scale development. According to MacCallum *et al.* (1999), these thumb rules may often be simplistic and also ignore much of the specific aspects of factor analysis. They also found that where populations are large (greater than.60), and several objects describe each element, the sample sizes can be fairly low. Guadagnoli and Velicer also showed that approaches with correlation coefficients > .80 need smaller sample sizes, whereas Sapnas and Zeller point out that only 50 cases can be sufficient for factor analysis. Questionnaire surveys usually include just a proportion of the community of which the study is involved (Veal 1997). While it is argued that there are no fixed guidelines for how many questionnaires will be provided, the goal will be to elicit a variety of responses that are as diverse as practicable to enable the goals of the research to be met and to include answers to key questions. In this study, it is decided to submit questionnaires to established professionals directly involved in the construction of railway projects in India.

CHAPTER 4

DATA ANALYSIS AND INTERPRETATION - OBJECTIVE NO 01

4.1. INTRODUCTION

The objective is to identify the significant risk factor in railway projects, causing time and cost overruns. Data gathered from engineering and management personnel of varied expertise from various public and private entities participating with railway construction projects, such as owners, contractors, consultants, PMCs, suppliers and inspection authorities. The likert scale used for questionnaire, the survey conducted, and the analysis was carried out using the factor analysis. Feedback responses of 520 personnel from these railway projects were analyzed using SPSS software. The KMO and Bartlett test used to verify the adequacy of the sample size. Community tested to recognize Principle Component Analysis is sufficient for data. (Brett Williams, 2012). The data collected based on the respondent's interpretation of the specific variables and their effect on the overrun of the railway construction project. A five-point ordinal scale used for the assessment of the questionnaire. The descriptive analysis used to achieve a range of exploratory data analysis. The study and interpretation of the results are described below based on the objectives.

4.2. IDENTIFICATION OF CRITICAL RISK FACTORS

The statistical method Exploratory Factor Analysis (EFA) and part of its Principle Component Analysis (PCA) used to minimize the attributes of risk factors. The Principal Component Analysis (PCA), has been developed to analyze better many of these variable relationships in a more straightforward way; the SPSS software used to evaluate the data. The KMO and Bartlett test used for adequacy of the sample size. Community assessed to recognize the data that is necessary for the Principal Component Analysis (Williams Brett, 2012). The study began with the correlation matrix for every coefficient value, if it is greater than 0.9 and all values are smaller than 0.9, it represents the suitability of the factor analysis, as there is no correlation between the factors. The multi-colinearity has been verified by the matrix determinant; the value is 0.000822, which is higher than the acceptable value of 0.00001. Hence, multi-collinearity is not a concern for the data set in question; all variables are reasonably well associated; none of the coefficients is exceptionally high. Consequently, no elements are to be excluded.

4.3. KMO AND BARTLETT'S TEST OUTCOME

The second outcome is for Kaiser-Mayer-Olkin (KMO) and Bartlett test of sphericity for sampling adequacy calculation. The KMO number ranges from 0 to 1, the value of 0 means that the sum of the partial correlations is high compared to the summation of correlations, suggesting the distribution of the sequence of correlations, rendering the factor analysis does not hold good for the study.

Table 4.1- KMO Value and Acceptable Range

KMO value	Remark
> 0.5	Acceptable
0.5-0.7	Moderate
0.7-0.8	Good
0.8-0.9	Very good
> 0.9	Superb

Table 4.2- Outcome of KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling		.934
Bartlett's Test of Sphericity	Approx. Chi-Square	39599.108
	df	3486
	Sig.	0.000

The KMO value is 0.934 and comes inside the 'Superb' category showing the sufficiency of the data samples. The Bartlett test has a value of 0.000 that is less than 0.05. It provides trust that the data obtained will be accurate and will yield excellent outcomes, rendering the data ideal for factor analysis.

4.4. RELIABILITY

The Cronbach alpha coefficient was measured using SPSS tool to determine the reliability of the scale:

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

Where N –Number of items, c-bar – The average inter-item covariance among the items, v-bar – the average variance.

The most suitable reliability coefficient for a two-item scale is the Spearman-Brown statistic and is given by applications such as SPSS, SAS and R along with standardized alpha coefficient; it's corresponding for two-item scales (Peters, Rob Eisinga, October 2012) (Devellis, 2012). The Cronbach alpha coefficient was calculated using the SPSS to assess the correctness and reliability of the scale. The general rule of thumb is that the 0.70 and above Cronbach alpha is good, 0.80 and above is better, and 0.90 and above are best. The result, as presented below, are considered to be good and reflects the precision of the data collection and internal consistency.

Table 4.3- Cronbach's Alpha value of all factors

Reliability Statistics		
Factor No	**N of Items**	**Cronbach's Alpha**
1	23	0.965
2	10	0.94
3	10	0.913
4	10	0.928
5	6	0.874
6	5	0.838
7	4	0.852
8	5	0.773
9	3	0.905
10	4	0.81
11	2	0.67

4.5. COMMUNALITY

The following table illustrates before and after-extraction commonalities. Before all communities are extracted, 1 shows all common variances before extraction.

Table 4.4 – Communalities

Communalities					
Variables	**Initial**	**Extraction**	**Variables**	**Initial**	**Extraction**
V1	1.000	.622	V43	1.000	.700
V2	1.000	.686	V44	1.000	.802
V3	1.000	.622	V45	1.000	.804
V4	1.000	.619	V46	1.000	.815
V5	1.000	.742	V47	1.000	.750
V6	1.000	.644	V48	1.000	.751
V7	1.000	.664	V49	1.000	.597
V8	1.000	.632	V50	1.000	.781
V9	1.000	.578	V51	1.000	.679
V10	1.000	.769	V52	1.000	.699
V11	1.000	.784	V53	1.000	.773
V12	1.000	.782	V54	1.000	.687
V13	1.000	.633	V55	1.000	.775
V14	1.000	.743	V56	1.000	.648
V15	1.000	.653	V57	1.000	.696
V16	1.000	.688	V58	1.000	.702
V17	1.000	.750	V59	1.000	.764
V18	1.000	.749	V60	1.000	.739
V19	1.000	.655	V61	1.000	.691
V20	1.000	.747	V62	1.000	.676
V21	1.000	.662	V63	1.000	.791
V22	1.000	.754	V64	1.000	.701
V23	1.000	.662	V65	1.000	.770
V24	1.000	.656	V66	1.000	.752
V25	1.000	.734	V67	1.000	.701
V26	1.000	.776	V68	1.000	.695
V27	1.000	.677	V69	1.000	.594
V28	1.000	.696	V70	1.000	.735
V29	1.000	.720	V71	1.000	.724
V30	1.000	.689	V72	1.000	.673
V31	1.000	.741	V73	1.000	.794
V32	1.000	.730	V74	1.000	.715
V33	1.000	.728	V75	1.000	.681
V34	1.000	.682	V76	1.000	.709
V35	1.000	.773	V77	1.000	.708
V36	1.000	.729	V78	1.000	.710
V37	1.000	.749	V79	1.000	.704
V38	1.000	.702	V80	1.000	.702
V39	1.000	.747	V81	1.000	.733
V40	1.000	.669	V82	1.000	.743
V41	1.000	.748	V83	1.000	.760
V42	1.000	.730	V84	1.000	.668
	Extraction Method: Principal				
		Average	**.712**		

The populations represented widespread variability in the post-extraction data framework, which ranged from 0.578 to 0.85 in a significant portion. The average population after extraction is 0.712, rendering the results ideal for factor analysis (The communities should be greater than 0.6 after extraction).

4.6. SCREE PLOT

In SPSS, the study of the Principle component analysis performed to determine the primary risk factors from the data of 520 collected responses. The initial Solution extracted to demonstrate 'Un-rotated Factor Solution' and 'Scree Chart' to test for shifts in interpretation due to rotation. The Scree plot reflects fifteen (15) variables whose own importance is greater than one (1). The cumulative variance stated for this 15-factor is 71.198%. The following graph demonstrates the values of Eigen associated with each linear component and the variance degree defined by the linear component in question. The graph below displays Eigenvalues correlated with each linear component and the amount of variance shown by that linear component in question.

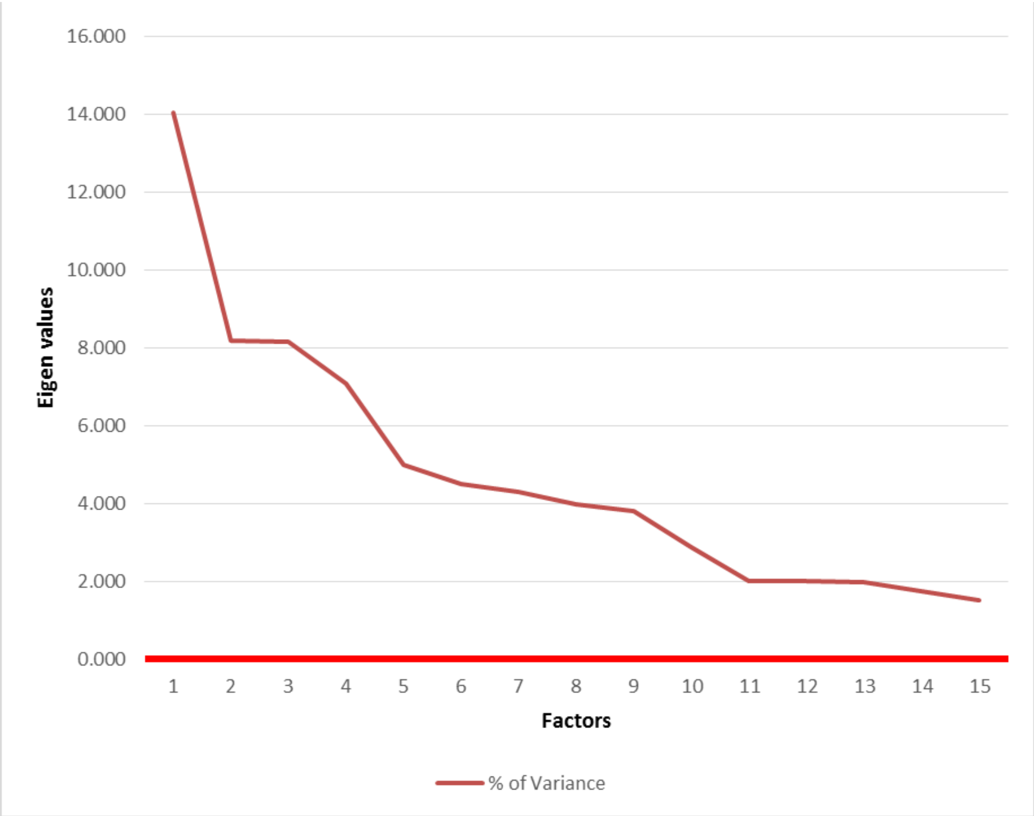


Fig. 4.1: Scree Plot

4.7. TOTAL VARIANCE EXPLAINED

The total variance table displays the Eigenvalues for the amount of variance defined before rotation.

Table 4.5 - Total Variance Explained

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	33.15	39.46	39.46	33.15	39.46	39.46	11.79	14.04	14.04
2	4.38	5.22	44.68	4.38	5.22	44.68	6.88	8.19	22.22
3	2.98	3.55	48.23	2.98	3.55	48.23	6.86	8.16	30.38
4	2.77	3.29	51.52	2.77	3.29	51.52	5.95	7.08	37.46
5	2.33	2.77	54.29	2.33	2.77	54.29	4.19	4.99	42.45
6	2.10	2.50	56.79	2.10	2.50	56.79	3.79	4.51	46.96
7	1.96	2.33	59.12	1.96	2.33	59.12	3.60	4.29	51.25
8	1.71	2.03	61.16	1.71	2.03	61.16	3.35	3.99	55.24
9	1.46	1.74	62.89	1.46	1.74	62.89	3.20	3.81	59.06
10	1.29	1.53	64.43	1.29	1.53	64.43	2.43	2.89	61.95
11	1.24	1.48	65.91	1.24	1.48	65.91	1.69	2.01	63.96
12	1.19	1.41	67.32	1.19	1.41	67.32	1.68	2.00	65.96
13	1.18	1.40	68.72	1.18	1.40	68.72	1.66	1.97	67.94
14	1.06	1.26	69.98	1.06	1.26	69.98	1.47	1.75	69.69
15	1.02	1.21	71.20	1.02	1.21	71.20	1.27	1.51	71.20
16	1.00	1.19	72.39						
17	0.95	1.13	73.52						
18	0.91	1.08	74.60						
19	0.88	1.04	75.64						
20	0.84	1.00	76.64						
21	0.80	0.95	77.59						
22	0.77	0.91	78.50						
23	0.74	0.88	79.38						
24	0.70	0.83	80.21						
25	0.67	0.80	81.01						
26	0.63	0.74	81.76						
27	0.62	0.74	82.50						
28	0.58	0.70	83.20						
29	0.57	0.68	83.87						
30	0.55	0.66	84.53						
31	0.53	0.63	85.16						
32	0.52	0.62	85.79						
33	0.50	0.60	86.39						
34	0.49	0.59	86.98						
35	0.49	0.58	87.56						
36	0.47	0.56	88.12						
37	0.44	0.53	88.65						
38	0.42	0.50	89.15						
39	0.42	0.50	89.65						
40	0.41	0.49	90.14						
41	0.38	0.45	90.59						
42	0.36	0.43	91.03						
43	0.36	0.42	91.45						

Table 4.5 - Total Variance Explained (Continued)

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
43	0.36	0.42	91.45						
44	0.34	0.40	91.85						
45	0.33	0.39	92.24						
46	0.32	0.38	92.62						
47	0.31	0.37	92.98						
48	0.29	0.35	93.33						
49	0.29	0.34	93.67						
50	0.28	0.33	94.01						
51	0.26	0.31	94.32						
52	0.26	0.31	94.63						
53	0.25	0.30	94.93						
54	0.24	0.28	95.21						
55	0.23	0.27	95.48						
56	0.22	0.26	95.75						
57	0.21	0.25	95.99						
58	0.20	0.24	96.24						
59	0.20	0.23	96.47						
60	0.19	0.23	96.70						
61	0.19	0.22	96.92						
62	0.17	0.21	97.12						
63	0.17	0.20	97.33						
64	0.17	0.20	97.53						
65	0.16	0.19	97.71						
66	0.15	0.18	97.89						
67	0.14	0.17	98.07						
68	0.14	0.17	98.23						
69	0.14	0.17	98.40						
70	0.13	0.16	98.56						
71	0.13	0.15	98.71						
72	0.12	0.14	98.85						
73	0.11	0.13	98.99						
74	0.11	0.13	99.12						
75	0.10	0.12	99.23						
76	0.09	0.11	99.35						
77	0.09	0.10	99.45						
78	0.08	0.10	99.55						
79	0.08	0.09	99.64						
80	0.07	0.09	99.73						
81	0.07	0.08	99.82						
82	0.06	0.07	99.88						
83	0.05	0.06	99.94						
84	0.05	0.06	100.00						
Extraction Method: Principal Component Analysis.									

The first element constitutes 13.653% of the overall variation explained after rotation. The Eigenvalues associated with these factors are again displayed in the extraction sums of squared loadings. The outcome of the factors with Eigen-value more than 1 in extraction sum of square loading & rotation sum of square loading are reduced to 15. The following table shows the values of Total Variance Explained with Extraction Sums of Squared Loadings and Rotation Sums of Squared Loadings. The table is showing the details of only 20 components out of 84 components which includes 15 components having Eigen-value more than 1. Rotated Solution maximizes loading of each variable on one of the extracted factors while minimizing the loading on all other factors. We expected the factors to be independent hence chose orthogonal rotation 'Verimax'. The rotation has the effect of optimizing the factor structure, and the consequence of this Solution was the relative importance of these 15 factors equalized.

4.8. TOTAL VARIANCE EXPLAINED AFTER ROTATION

We were expecting the variables to be independent, so we chose "Verimax" orthogonal rotation. The rotation has the effect of improving the factor structure, and the relative importance of these 15 factors has been equalized as a result of this approach.

Table 4.6 - Total Variance explained after rotation

Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	11.79	14.04	14.04
2	6.88	8.19	22.22
3	6.86	8.16	30.38
4	5.95	7.08	37.46
5	4.19	4.99	42.45
6	3.79	4.51	46.96
7	3.60	4.29	51.25
8	3.35	3.99	55.24
9	3.20	3.81	59.06
10	2.43	2.89	61.95
11	1.69	2.01	63.96
12	1.68	2.00	65.96
13	1.66	1.97	67.94
14	1.47	1.75	69.69
15	1.27	1.51	71.20

4.9. FINDINGS AND OUTCOME

Principle component Analysis extracted 15 significant Factors, in factor 12, 13, 14 and 15 the total variance explained is very low, and the characteristics of the elements aligned with factor no 12, so these factors clubbed with factor number 12.

Factor 01; has a total variance explained of 14.035 % and contributing maximum among all the factors. This factor involves maximum variables contributing to overruns in railways project. The variables presented here in descending order of score are; Financial Default of Contractor/Subcontractor, Lack of technical professionals, Lack of coordination with subcontractors, delay in mobilization, Poor planning, scheduling or resource management, Congested construction site, Lack of experience of similar projects, Shortage of manpower, Low productivity and Inadequate skills of labour, Contractors cash flow, Irregular payments of sub-contractors, Construction Work Permits, Conflicts between the contractor, consultant and owner, Improper construction methods implemented by contractor, Delays in sub-contractors work, Poor site management and supervision, Lack of Training personnel for model construction operation, Inaccurate tender cost estimating, Shortage of equipment, Low productivity and efficiency of equipment, Lack of high-technology mechanical equipment, Shortage of materials and delay in material procurement & delivery. All the variable explaining the factors associated with the risk related to contractors performance in the construction project; hence the name of the factor can be considered as "Contractors risk".

Factor 02; has total variance explained of 8.185% and it indicates the second-highest value and considered to be the second-highest risk of project overruns in railways construction. The variables presented here in descending order of score are; Week design coordination and delay in communication, Slow response to Request For Information (RFI) or technical quarries, Delay in inspection, Level of involvement in quality control, Change in scope of work, delay in approving major changes, delay in claim approval, Deployment of technical staff on-site, Inadequate definition of substantial completion, Lack of systematic engineering method to identify the time. All the variable explaining the factors are closely associated with the risk related to PMC's performance in the construction project; hence the name of the factor can be considered as "Risk related to PMC".

Factor 03; has total variance explained of 8.163%, and it indicates the third-highest value and considered to be the third-highest risk factor causing the project overruns. The variables presented here in descending order of score are; Frequent interference, Unrealistic contract duration imposed by the client, Financial difficulties & Irregular payments of work-done, Delay in Permissions, approvals & statutory clearances, Learning from best practice and experience of others, Delay in decision making, Lack of capability of the client representative, Suspension of work by owner, Breach or modifications of contract by the owner, delay in performing final inspection and certification. All the variable explaining the factors are closely associated with the risk related to the client's performance in the construction project; hence the name of the factor can be considered as "Risk related to Client".

Factor 04; has total variance explained of 7.081%, and it indicates the fourth-highest value and considered to be the fourth-highest risk factor causing the project overruns. The factor has a weightage of 5.776%. The variables presented here in descending order of score are; Mistakes and inadequate details, Delays in producing design documents, Complex project design, Incomplete investigation and survey and feasibility studies, Misunderstanding of Client's requirements, Unforeseen or Differing site conditions, Inadequate experience, Inaccurate project cost estimating, Inflation/price fluctuation, Incomplete contract details. All the variable explaining the factors are closely associated with the risk related to design consultant performance in the construction project; hence the name of the factor can be considered as "Risk related to Design".

Factor 05; has total variance explained of 4.99%, and it indicates the fifth-highest value and considered to be the fifth-highest risk factor causing the project overruns. The variables presented here in descending order of score are; Pollution and Safety compliance, accidents and labour Injuries, damage to existing Structure (Utilities beneath the ground), Theft of material and equipment's, Safety assessment system in the organization, Project location is safe to reach. All the variable explaining the factors are closely associated with the risk related to safety & security in the construction project; hence the name of the factor can be considered as "Risk related to safety & security".

Factor 06; has total variance explained of 4.51%, and it indicates the sixth-highest value and considered to be the sixth-highest risk factor causing the project overruns. The variables presented here in descending order of score are; High-interest rate, Cost of variation/Change orders, Change in currency price, Availability of Funds from lenders, Exchange Rate Fluctuation. All the variable explaining the factors are closely associated with the risk related to Finance in the construction project; hence the name of the factor can be considered as "Financial risk".

Factor 07; has total variance explained of 4.289%, and it indicates the seventh-highest value and considered to be the seventh-highest risk factor causing the project overruns. The variables presented here in descending order of score are; flood, earthquake, landslide and unexpected weather conditions. All the variable explaining the factors are closely associated with the risk associated with nature; hence the name of the factor can be considered as risk related to nature.

Factor 08; has total variance explained of 3.992%, and it indicates the eighth-highest value and considered to be the eighth-highest risk factor causing the project overruns. The variables presented here in descending order of score are; Approvals and clearances, Land acquisition & site handover, Environmental & Tree Cutting, Changes in government regulations and laws and Rehabilitation & Resettlement of affected families. All the variable explaining the factors are closely associated with the government approvals and site clearances; hence the name of the factor can be considered as risk related to government approvals and site clearances.

Factor 09; has total variance explained of 3.813%, and it indicates the ninth-highest value and considered to be the ninth-highest risk factor causing the project overruns. The variables presented here in descending order of score are; Site Supervision, Quality assurance & Control and Quality assessment system in the organization and implementation of a method statement. All the variable explaining the factors are closely associated with the government approvals and site clearances; hence the name of the factor can be considered as "Risk related to Quality".

Factor 10; has total variance explained of 2.89%, and it indicates the tenth-highest value and considered to be the tenth-highest risk factor causing the project overruns. The variables presented here in descending order of score are; Unavailability of incentive clause for early completion, Cash flow of project, Profit rate of project and cost of rework. All the variable explaining the factors are closely associated with the contractor's cash flow; hence the name of the factor can be considered as "Risk related to the Contract administration".

Factor 11; has total variance explained of 2.89%, and it indicates the eleventh-highest value, and further, it is considered to be the eleventh -highest risk factor causing the project overruns. All the remaining factors and their variables presenting the similar characteristic as of factor eleventh so clubbed into one factor. The variables presented here in descending order of score are; Social and Cultural influences of workmanship, Issues in interstate or central to state coordination, Strike, Traffic control and restriction at the job site. All the variable explaining the factors are external in nature that means the project team cannot control it. Hence the name of the factor can be considered as "Fundamental risk".

Each factor is a linear combination of its components with the component score as the variance of each component within the factor, and hence each factor is expressed in terms of all its components.

4.10. OUTCOME

The objective one of the study established the eleven (11) Critical risk factors that explained the eighty-four (84) risk attributes causing overruns in railway development projects.

CHAPTER 5

DATA ANALYSIS AND INTERPRETATION - OBJECTIVE NO 02

5.1. EXPECTED VALUE METHOD

The risk quantification and modelling are carried out based on the Expected Value Method EVM and EVA. A questionnaire survey is conducted to assess the probability and effect of defined risk factors on construction activities of a railway track construction project. The questionnaire contains the significant activities of the railway's project and risk factors which affects these activities. The perception of respondents on the influence of various risk factors on each activity in terms of the likelihood of occurrence (Lrx), Impact (Irx) and weightage (Wrx) had identified through the questionnaire survey. The questionnaire includes two important components, first, the risk factors, and the second the activities. The risk factors had identified from the analysis of the objective one. The activity details have been standardized based on the study of project schedule (railway project) and the opinion of an expert. The outcome of the expert opinion is in the form of standardized activities and risk factor - activity relationship. The questionnaire floated among 75 professionals working for the railway construction project. These respondents expected to provide details concerning the probability, impact and weightages associated with each risk factor on each activity. The input from the respondents are purely based on their perception, experience and standardized based on the scale available with the questionnaire survey. The experts were from middle and senior engineering and management professionals from Indian railways, RVNL and consultants, out of 75 experts, 51 replied to this survey, an mean of all the answers of the respective risk probabilities, impact and their related weights on the specific activities has identified. For each activity(x) the likelihood (Lrx) and impact (I) of all risk factors may be combined and represented as a single CLF and CIF for x activity. The weightages (Wrx) of risk sources on activities are multiplied respective likelihoods, Impact and summed to obtain CLF and CIF for each activity. The equation of weighted average computation of the CLF and CIF are as follows:

Composite Likelihood Factor

$$CLF_x = \sum_{x=1}^{M} L_{rx} * W_{rx} \text{ for all } x \text{........ Eqn. (5.1)}$$

$$0 \leq Lrx \leq 1 \text{ and } \sum Wrx = 1 \text{ for all } r$$

Composite Impact Factor

$$CIF_x = \sum_{x=1}^{M} I_{rx} * W_{rx} \text{ for all } x \text{........ Eqn. (5.2)}$$

$$0 \leq Irx \leq 1 \text{ and } \sum Wrx = 1 \text{ for all}$$

The mean values of the filled questionnaire are presented below in the form of a table. Based on the above formula, the equation for each activity has formulated to calculate the CLF and CIF. These equations of CIF and CLF for each activity are held good for the development of the model for the construction of railway track project.

Table – 5.1 Influence of risk factors on the activities

Activities and risk factors relationship	**Contractor Specific**			**PMC Consult. Specific**			**Client Specific**			**Design Specific**			**Safety & security**			**Financial risk**			**Nature specific**			**Approval & site clearance**			**Quality**			**Contract specific**			**Fundam-ental**		
Activities	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**
Mobilization and	0.2	0.4	0.4	0.1	0.3	0.2	0.1	0.4	0.4										0.1	0.4	0.4	0.2	0.5	0.5				0.1	0.3	0.3	0.1	0.3	0.3
Site survey and Investigations	0.3	0.4	0.4	0.2	0.3	0.3	0.2	0.4	0.4													0.3	0.5	0.5									
Approvals for General Arrangements Drawing	0.2	0.3	0.3	0.2	0.4	0.3	0.2	0.4	0.4	0.2	0.5	0.5																0.2	0.3	0.3			
Approvals for formation (C/S & L section, Drainage and other structures)	0.2	0.3	0.4	0.2	0.3	0.4	0.2	0.4	0.3	0.3	0.5	0.4																0.2	0.3	0.3			
Utility shifting and Tree cutting	0.2	0.3	0.3	0.1	0.3	0.3	0.2	0.3	0.3				0.2	0.4	0.4							0.3	0.5	0.4									
Barricades (safety)	0.2	0.4	0.4	0.2	0.3	0.3	0.1	0.3	0.4				0.3	0.5	0.5													0.2	0.3	0.3			
Toe wall and Drainage work	0.2	0.4	0.4	0.1	0.3	0.3	0.1	0.3	0.3	0.1	0.4	0.4	0.1	0.3	0.4	0.1	0.3	0.3	0.1	0.3	0.3	0.1	0.3	0.4	0.1	0.3	0.4						
Earthwork for formation	0.2	0.4	0.4	0.1	0.3	0.3	0.1	0.3	0.3	0.1	0.3	1.4	0.1	0.4	0.4	0.1	0.3	0.4	0.1	0.3	0.3	0.1	0.4	0.4	0.1	0.4	0.4						
Foundation work for Electric	0.2	0.4	0.4	0.2	0.3	0.3	0.1	0.3	0.3	0.2	0.4	1.2	0.1	0.4	0.4	0.1	0.3	0.3							0.2	0.4	0.4						
Pole Erection and fixing	0.2	0.4	0.4	0.2	0.3	0.3							0.2	0.4	0.4	0.2	0.4	0.4							0.2	0.4	0.4						
HT wiring works	0.2	0.4	0.4	0.1	0.3	0.3	0.1	0.3	0.3	0.1	0.4	0.4	0.2	0.4	0.4	0.1	0.3	0.4				0.1	0.5	0.3	0.1	0.4	0.6						
Signaling & Tele-communication work	0.2	0.3	0.4	0.1	0.3	0.3	0.1	0.3	0.3	0.1	0.4	0.4	0.1	0.4	0.4	0.1	0.3	0.4				0.1	0.4	0.4	0.1	0.4	0.4						
Subgrade Blanketing	0.1	0.4	0.4	0.1	0.3	0.3	0.1	0.3	0.3	0.1	0.4	0.4	0.1	0.4	0.4	0.1	0.4	0.4	0.1	0.4	0.3	0.1	0.5	0.5	0.1	0.4	0.5						
Ballast Spreading	0.2	0.3	0.4	0.1	0.3	0.3	0.1	0.3	0.3				0.1	0.4	0.3	0.1	0.3	0.4	0.1	0.4	0.4	0.1	0.4	0.4	0.1	0.5	0.5				0.1	0.3	0.4
Sleeper Laying	0.2	0.4	0.5	0.2	0.3	0.3	0.1	0.4	0.3				0.2	0.4	0.5										0.3	0.6	0.5						
Rail laying & Fixing	0.3	0.4	0.5	0.1	0.3	0.4	0.1	0.3	0.3				0.2	0.5	0.5										0.3	0.5	0.6						
Temping and Compaction	0.3	0.4	0.5	0.2	0.3	0.4							0.2	0.5	0.4										0.3	0.5	0.5						
Rail Destressing	0.3	0.5	0.4	0.2	0.3	0.4							0.2	0.5	0.5										0.3	0.5	0.4						
Dressing and Boxing	0.3	0.4	0.5	0.2	0.4	0.3							0.2	0.4	0.4										0.3	0.5	0.4						
Documentation for CRS Inspection	0.2	0.3	0.4	0.2	0.4	0.4	0.1	0.5	0.4							0.2	0.3	0.4							0.2	0.4	0.4	0.1	0.4	0.4			
Commissioning, Inspection & Handover	0.2	0.4	0.5				0.3	0.4	0.5				0.2	0.4	0.4										0.2	0.5	0.5	0.2	0.4	0.4			

5.2. CLF AND CLF IN EQUATION FORM

The following equations have been drawn on the basis of the formula as mentioned above to calculate the CLF & CIF of each activity considering the effect of individual risk factors on each activity. There are two equation for each activity i.e. equation for CLF and CIF respectively. The equation from CLF are starting from equation 5.3 and ending at equation no 5.23, the equation for CIF are starting from 5.14 and ending at 5.25

5.2.1 EQUATIONS FOR COMPOSITE LIKELIHOOD FACTOR (CLF)

- CLFa1= 0.2*Lr1a1+0.1*Lr2a1+0.1*Lr3a1+0.1*Lr7a1+0.2*Lr8a1+0.1*Lr1a1+0.1*Lr11a1… Eqn. (5.3)
- CLFa2 = 0.3*Lr1a2+.2*Lr2a2+0.2*Lr3a2+0.3*Lr8a2
- CLFa3 = 0.2*Lr1a3+0.2*Lr2a3+0.2*Lr3a3+0.2*Lr4a3+0.2*Lr10a3
- CLFa4 = 0.2*Lr1a4+0.15*Lr2a4+0.2*Lr3a4+0.3*Lr4a4+0.15*Lr10a4
- CLFa5 = 0.2*Lr1a5+0.1*Lr2a5+0.2*Lr3a5+0.2*Lr5a5+0.3*Lr8a5
- CLFa6 = 0.2*Lr1a6+0.2*Lr2a6+0.1*Lr3a6+0.3*Lr5a6+ 0.2*Lr10a6
- CLFa7 = 0.2*Lr1a7+0.1*Lr2a7+0.1*Lr3a7+0.1*Lr4a7+0.1*Lr5a7+ 0.1*Lr6a7+ 0.1*Lr7a7+0.1*Lr8a7+0.1*Lr9a7
- CLFa8=0.2*Lr1a8+0.1*Lr2a8+0.1*Lr3a8+0.1*Lr4a8+0.1*Lr5a8+0.1*Lr6a8 + 0.1*Lr7a8+0.1*Lr8a8+0.1*Lr9a8
- CLFa9=0.2*Lr1a9+0.2*Lr2a9+0.1*Lr3a9+0.2*Lr4a9+0.1*Lr5a9+0.1*Lr6a9 +0.2*Lr9a9
- CLFa10=0.2*Lr1a10+0.2*Lr2a10+0.2*Lr5a10+0.2*Lr6a10+0.2*Lr9a10
- CLFa11=0.2*Lr1a11+0.1*Lr2a11+0.1*Lr3a11+0.1*Lr4a11+0.2*Lr5a11+0.1 *Lr6a11+0.1*Lr8a11+0.1*Lr9a11
- CLFa12=0.2*Lr1a12+0.1*Lr2a12+0.1*Lr3a12+0.1*Lr4a12+0.1*Lr5a12+0.1 *Lr6a12+0.1*Lr8a12+0.1 *Lr9a12

- CLFa13=0.1*Lr1a13+0.1*Lr2a13+0.1*Lr3a13+0.1*Lr4a13+0.1*Lr5a13+0.1 *Lr6a13+ 0.1*Lr7a13+0.1*Lr8a13+0.1*Lr9a13
- CLFa14=0.2*Lr1a14+0.1*Lr2a14+0.1*Lr3a14+0.1*Lr5a14+0.1*Lr6a14+ 0.1*Lr7a14+0.1*Lr8a14+0.1*Lr9a14+0.1*Lr11a14
- CLFa15=0.2*Lr1a15+0.2*Lr2a15+0.1*Lr3a15+0.2*Lr5a15 +0.3*Lr9a15
- CLFa16=0.3*Lr1a16+0.1*Lr2a16+0.1*Lr3a16+0.2*Lr5a16 +0.3*Lr9a16
- CLFa17=0.3*Lr1a17+0.2*Lr2a17+0.2*Lr5a17 +0.3*Lr9a17
- CLFa18=0.3*Lr1a18+0.2*Lr2a18+0.2*Lr5a18 +0.3*Lr9a18
- CLFa19=0.3*Lr1a19+0.2*Lr2a19+0.2*Lr5a19 +0.3*Lr9a19
- CLFa20=0.2*Lr1a20+0.2*Lr2a20+Wr3a20*Lr3a20+0.2*Lr6a14 +0.2*Lr9a20+0.1*Lr10a20
- CLFa21=0.2*Lr1a21+0.3*Lr2a21 +0.2*Lr6a21+ 0.2*Lr9a21+0.2*Lr10a21

…………Eqn. (5.23)

5.2.2 EQUATIONS FOR COMPOSITE IMPACT FACTOR (CIF)

- CIFa1 = 0.2*Ir1a1+0.1*Ir2a1+0.1*Ir3a1+0.1*Ir7a1+0.2*Ir8a1+ 0.1*Ir10a1+0.1*Ir11a1 …………Eqn. (5.24)
- CIFa2 = 0.3*Ir1a2+.2*Ir2a2+0.2*Ir3a2+0.3*Ir8a2
- CIFa3=0.2*Ir1a3+0.2*Ir2a3+0.2*Ir3a3+0.2*Ir4a3+0.2*Ir10a3
- CIFa4=0.2*Ir1a4+0.2*Ir2a4+0.2*Ir3a4+0.4*Ir4a4+0.2*Ir10a4
- CIFa5= 0.2*Ir1a5+0.1*Ir2a5+0.2*Ir3a5+0.2*Ir5a5+0.3*Ir8a5
- CIFa6= 0.2*Ir1a6+0.2*Ir2a6+0.1*Ir3a6+0.3*Ir5a6+ 0.2*Ir10a6
- CIFa7=0.2*Ir1a7+0.1*Ir2a7+0.1*Ir3a7+0.1*Ir4a7+0.1*Ir5a7+0.1*Ir6a7+ 0.1*Ir7a7+0.1*Ir8a7+0.1*Ir9a7
- CIFa8=0.2*Ir1a8+0.1*Ir2a8+0.1*Ir3a8+0.1*Ir4a8+0.1*Ir5a8+0.1*Ir6a8+ 0.1*Ir7a8+0.1*Ir8a8+0.1*Ir9a8

- CIFa9=0.2*Ir1a9+0.2*Ir2a9+0.1*Ir3a9+0.2*Ir4a9+0.1*Ir5a9+0.1*Ir6a9+0.2 *Ir9a9
- CIFa10=0.2*Ir1a10+0.2*Ir2a10+0.2*Ir5a10+0.2*Ir6a10+0.2*Ir9a10
- CIFa11=0.2*Ir1a11+0.1*Ir2a11+0.1*Ir3a11+0.1*Ir4a11+0.2*Ir5a11+0.1*Ir6 a11+0.1*Ir8a11+0.1*Ir9a11
- CIFa12=0.2*Ir1a12+0.1*Ir2a12+0.1*Ir3a12+0.1*Ir4a12+0.1*Ir5a12+0.1*Ir6 a12+0.1*Ir8a12+0.1 *Ir9a12
- CIFa13=0.1*Ir1a13+0.1*Ir2a13+0.1*Ir3a13+0.1*Ir4a13+0.1*Ir5a13+0.1*Ir6 a13+ 0.1*Ir7a13+0.1*Ir8a13+0.1*Ir9a13
- CIFa14=0.2*Ir1a14+0.1*Ir2a14+0.1*Ir3a14+0.1*Ir5a14+0.1*Ir6a14+ 0.1*Ir7a14+0.1*Ir8a14+0.1*Ir9a14+0.1*Ir11a14
- CIFa15=0.2*Ir1a15+0.2*Ir2a15+0.1*Ir3a15+0.2*Ir5a15 +0.3*Ir9a15
- CIFa16=0.3*Ir1a16+0.1*Ir2a16+0.1*Ir3a16+0.2*Ir5a16 +0.3*Ir9a16
- CIFa17=0.3*Ir1a17+0.2*Ir2a17+0.2*Ir5a17 +0.3*Ir9a17
- CIFa18=0.3*Ir1a18+0.2*Ir2a18+0.2*Ir5a18 +0.3*Ir9a18
- CIFa19=0.3*Ir1a19+0.2*Ir2a19+0.2*Ir5a19 +0.3*Ir9a19
- CIFa20=0.2*Ir1a20+0.2*Ir2a20+Wr3a20*Ir3a20+0.2*Ir6a14 +0.2*Ir9a20+0.1*Ir10a20
- CIFa21=0.2*Ir1a21+0.3*Ir2a21 +0.2*Ir6a21+ 0.2*Ir9a21+0.2*Ir10a21 ……..….Eqn. (5.44)

5.3. OUTCOME IN THE FORM OF CLF AND CIF

The following table depicts the details of the CLF and CIF for all the activities. The CLF and CIF is used further for Expected Value Calculation in objevctive three.

Table 5.2 - CLF and CIF for all the activities

Activities	(CLF)	(CIF)
Mobilization and Commencement	0.372	0.389
Site survey and Investigations	0.405	0.391
Approvals for General Arrangements Drawing	0.386	0.364
Approvals for formation (C/S & L section, Drainage and other structures)	0.382	0.392
Utility shifting and Tree cutting	0.373	0.371
Barricades (safety)	0.370	0.396
Toe wall and Drainage work	0.345	0.351
Earthwork for formation	0.330	0.502
Foundation work for Electric pole	0.356	0.480
Pole Erection and fixing	0.386	0.382
HT wiring works	0.379	0.387
Signaling & Tele-communication work	0.365	0.389
Subgrade Blanketing	0.384	0.387
Ballast Spreading	0.356	0.382
Sleeper Laying	0.447	0.438
Rail laying & Fixing	0.423	0.486
Temping and Compaction	0.449	0.464
Rail De-stressing	0.450	0.420
Dressing and Boxing	0.423	0.391
Documentation for CRS Inspection	0.373	0.396
Commissioning, Inspection & Handover	0.428	0.453

5.4. SEVERITY

The The Risk Severity of the risk may be represented as a component of the probability of risk and its impact. Therefore the numerical value varies between 0 and 1. This magnitude may also be described as "no magnitude" for value 0 and "very strong severity" for value 1, in terms of qualitative scoring. The Risk Severity (RS) numerical value is obtained from the equation listed below:

RSx = L x I for all x………………………………………………...Eqn. (5.45)

The Severity of individual risk factor on activity has been identified by calculating the mean of the severity of all the responses for a risk factor. The following severity scale had used for the interpretation of the data.

Table 5.3 Severity Scale

Severity Scale		
Severity	**Classification**	**Qualitative presentation**
0.00-0.02	V. Low	
0.02-0.05	Low	
0.05-0.15	Medium	
0.15-0.20	High	
0.20-1.00	V. High	

The relative severity of a factor on various activities has been identified by using the Monte Carlo simulation by calculating the mean and standard deviation and Normal Distribution of the data of a risk factor. Table 5.4 provides the consolidated presentation of the data of the Severity of Individual risk factor on all the project activity. The details is useful to understand and interpret the risk factors severity on each activity. The assessment is purely based on the perception of the respondents. Based on the information of severity presented below in table 5.4, the activities which are expected to suffer from risk factors have identied and further sufficient mitigation measure can improve the project performance.

Table 5.4 Severity of Individual risk factor on all the activities

Dashboard - Risk Severity Anaysis											
Activities and risk factors Severity	Contractor Specific	PMC Consult. Specific	Owner Specific	Design Specific	Safety & security	Financial risk	Nature specific	Approval & site clearance	Quality	Contract specific	Fundam-ental
Activities	RF 01	RF 02	RF 03	RF 04	RF 05	RF 06	RF 07	RF 08	RF 09	RF 10	RF 11
Mobilization and Commencement	0.204	0.056	0.157	0.000	0.000	0.000	0.178	0.286	0.000	0.096	0.105
Site survey and Investigations	0.175	0.126	0.148	0.000	0.000	0.000	0.000	0.254	0.000	0.000	0.000
Approvals for General Arrangements Drawing	0.115	0.130	0.165	0.232	0.000	0.000	0.000	0.000	0.000	0.130	0.000
Approvals for formation (C/S & L section, Drainage and other structures)	0.117	0.147	0.149	0.242	0.000	0.000	0.000	0.000	0.000	0.130	0.000
Utility shifting and Tree cutting	0.118	0.083	0.116	0.000	0.163	0.000	0.000	0.246	0.000	0.000	0.000
Barricades (safety)	0.160	0.096	0.125	0.000	0.276	0.000	0.000	0.000	0.000	0.103	0.000
Toe wall and Drainage work	0.159	0.108	0.103	0.192	0.155	0.089	0.123	0.252	0.162	0.000	0.000
Earthwork for formation	0.188	0.078	0.092	0.364	0.151	0.125	0.133	0.245	0.408	0.000	0.000
Foundation work for Electric pole	0.152	0.110	0.107	0.388	0.161	0.119	0.000	0.000	0.180	0.000	0.000
Pole Erection and fixing	0.160	0.113	0.000	0.000	0.186	0.150	0.000	0.000	0.175	0.000	0.000
HT wiring works	0.192	0.111	0.087	0.188	0.229	0.168	0.000	0.149	0.271	0.000	0.000
Signaling & Tele-communication work	0.135	0.091	0.129	0.204	0.178	0.147	0.000	0.308	0.174	0.000	0.000
Subgrade Blanketing	0.162	0.121	0.088	0.165	0.194	0.198	0.142	1.285	0.297	0.000	0.000
Ballast Spreading	0.152	0.089	0.093	0.000	0.159	0.146	0.433	0.171	0.753	0.000	0.134
Sleeper Laying	0.223	0.118	0.141	0.000	0.212	0.000	0.000	0.000	0.529	0.000	0.000
Rail laying & Fixing	0.185	0.184	0.098	0.000	0.264	0.000	0.000	0.000	0.385	0.000	0.000
Temping and Compaction	0.224	0.152	0.000	0.000	0.225	0.000	0.000	0.000	0.502	0.000	0.000
Rail Destressing	0.192	0.142	0.000	0.000	0.241	0.000	0.000	0.000	0.276	0.000	0.000
Dressing and Boxing	0.213	0.152	0.000	0.000	0.175	0.000	0.000	0.000	0.203	0.000	0.000
Documentation for CRS Inspection	0.156	0.173	0.225	0.000	0.000	0.121	0.000	0.000	0.183	0.168	0.000
Commissioning, Inspection & Handover	0.198	0.000	0.266	0.000	0.182	0.000	0.000	0.000	0.256	0.192	0.000

5.5. RISK SEVERITY ON PROJECT ACTIVITIES

Contractor specific risk

The contractor's specific risk is one of the most critical risks affecting most activities. The result of the analysis is in the context of the severity of the risk factor for each activity. The activities with a very high level of risk severity by the contractor's risk are mobilization & commencement, sleeper laying, testing & compaction and dressing/boxing activities. The activities which have high severity are site survey and investigations, barricades (safety), toe wall & drainage work, earthwork for formation, foundation work for electric pole, pole erection and fixing, ht wiring works, subgrade blanketing, ballast spreading. The activities which have medium severity are approvals for general arrangements drawing, approvals for formation design (C/S & L section, drainage and other structures), utility shifting & Tree cutting and Signaling & Tele-communication work.

The timely mobilization of resources, i.e. equipment, materials, staff, other facilities needed for construction operation and the kickoff of the project, depends primarily on the efforts of the contractor. In order to mobilize the necessary resources at the project site, the contractor often faces a variety of constraints, such as availability of working capital, the project team and other resources needed. Any delay due to the mobilization of resources will postpone the start date of the project and have a substantial effect on the overall contract delivery date of the project. Risk can be minimized by offering advance payment for mobilization in the form of a bank guarantee to the contractor for timely mobilization. Progress and quality of track work depend primarily on the effort of the contractor to carry out essential activities such as earthwork for formation, subgrade blanketing, ballast spreading, sleeper laying, testing & compaction, toe wall & drainage, dressing & boxing work. Any issue relating to the stability of the embankment will lead to severe problems regarding the operation of the railway track. Any inadequate site investigations will lead to a false design of the structure that will cause structural safety problems in the future. Barricades are required to work in a partially operational area during construction, and in the absence of barricades, the entire project may face the safety risk. The Foundation works for electrical pole, pole installation and repair; HT wiring work needs special care and commitment on the part of the contractor to avoid any potential failure. contractors risk affects the efficiency of most of the project activities.

Figure 5.1 below illustrates the tornado diagram showing the distribution of contractor-specific risk responses to different activities by various respondents. The distributive spread of responses is very high at the top and low at the bottom.

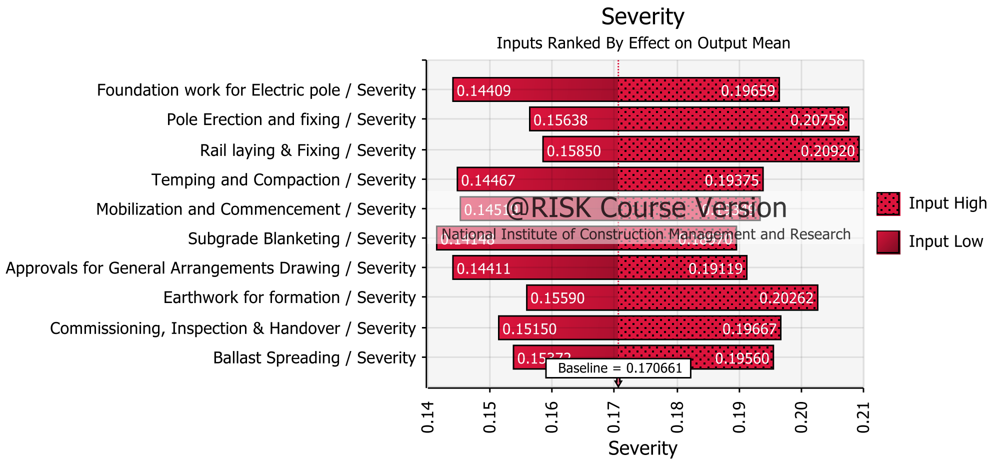


Fig. 5.1: Contractor Specific risk

PMC Consultant specific risk

The PMC risk is associated with the performance of the PMC; the result shows that the activities with a high level of PMC risk are rail laying & fixing, tempering & compaction, dressing & boxing and CRS inspection. The role of the PMC in managing the overall project is significant, so there are various activities listed in Table 5.4 that are moderately affected by the risk associated with the PMC.

The responsibility for supervision and quality control of the work done by the contractor rests with the PMC. The supervision and management of above described activities, i.e. temping and compaction, rail laying & fixing and dressing and boxing are very critical activities from an operational viewpoint of railway track. Inadequate project management during the project can create structural instability during the operation, which will result in quality risk. The handover of the facility to the client would require the inspection of the CRS (Chief of Railway Safety), the track construction and performance assessed based on the operational criteria during the CRS inspection. The entire task of document preparation to support the inspection to be handled by the PMC. Failure to receive approval from the CRS would pose a concern in the overall construction.

Figure 5.2 below shows the Tornado diagram showing the distribution of PMC-related risk responses to different activities. The spread of the responses is very high at the top, where the distribution is less at the end.

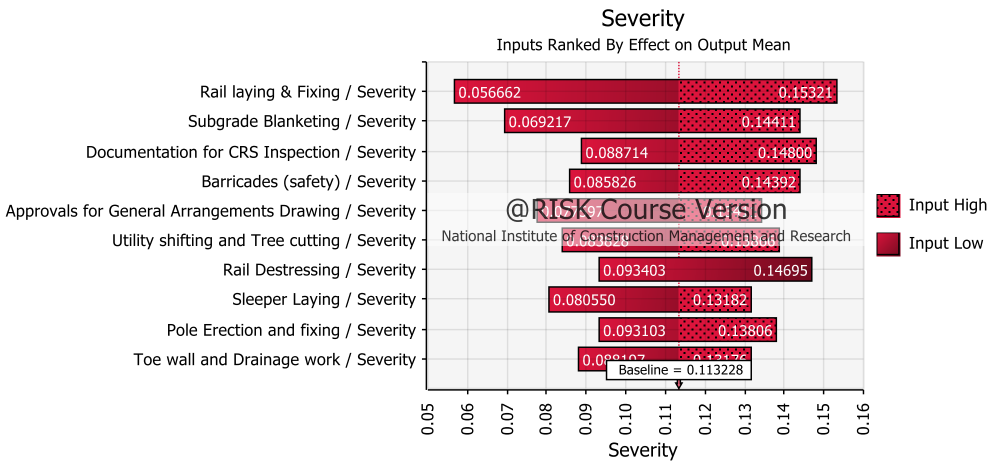


Fig. 5.2: PMC Consultant specific risk

Owner/Client specific risk

Client-specific risk covers all risks associated with the client's action towards the project. The result shows that CRS inspection, commissioning, inspection & handover documents are activities with very high severity of owner/client related risk. Activities with a high level of risk identified by the owner are mobilization & commencement and approvals for general arrangements drawing. There are various activities which have moderate severity of owner related risk presented in table no 5.2.

From the initial stage of the project to final commissioning, the role of clients in the overall management of the project is very significant. Mobilization and start-up of the project depend primarily on the delivery of the encumbrance free site to the contractor by the owner. If possession of site delayed or provided in pieces, the overall performance of the project will be affected. It is crucial that the client should acquire all the land needed for permanent construction and that all issues related to rehabilitation and settlement should be resolved well in advance to minimize the risk. The client also plays an essential role in the decision-making process concerning the design of the project. The role of clients in the commissioning and inspection of the project by the CRS is also significant.

Figure 5.3 below displays the tornado diagram showing the distribution of client-related risk responses to various activities. The spread of the responses are very high at the top, where the distribution is less at the bottom.

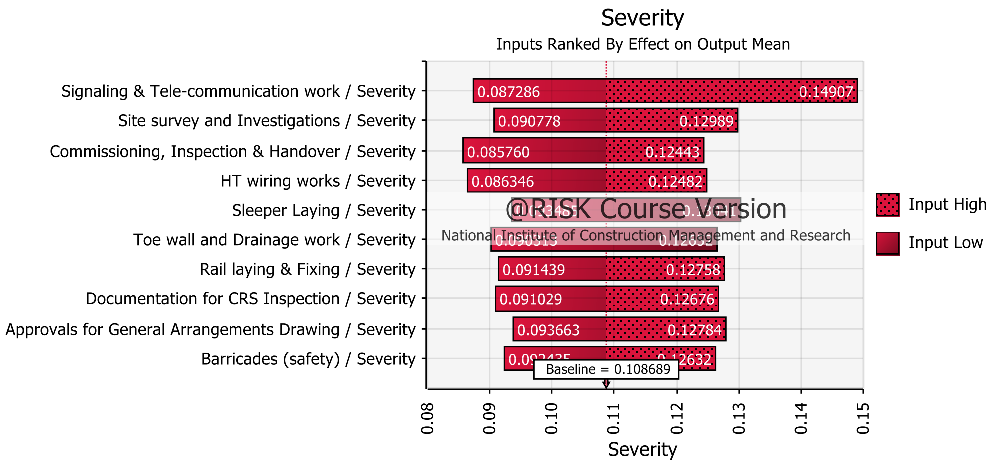


Fig. 5.3: Client/Owner Specific risk

Design specific risk

The design specific risk involves all the risks associated with the design of the project. The result indicates that activities with a very high degree of design specific risks are approvals for general arrangements drawing, approvals for formation (c/s & L section, drainage and other structures), earthwork for formation, foundation work for electric pole and signalling & telecommunication work. The activities which have high severity of design risk are toe wall & drainage work and HT wiring works. The coordinated efforts are required to mitigate the design risk.

Figure 5.4 below shows the tornado diagram of design risk for different activities. The spread of the responses is very high at the top, where the distribution is less at the bottom.

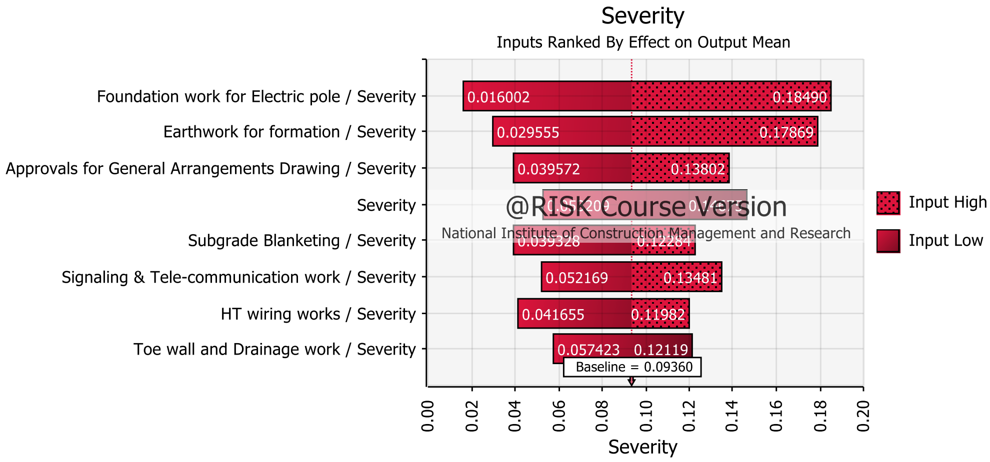


Fig. 5.4: Design Specific risk

Safety & security-related risk

The risk associated with are associated to safety & security of the project. The result shows that activities with very high severity of safety & security-related risk are safety barricades, HT wiring works, Sleeper laying, rail laying & fixing, temping & compaction and rail destressing. Activities with high severity of safety & security risk include utility shifting & tree cutting, toe wall & drainage work, earthwork for formation, electric pole foundation, pole erection & fixing, signaling & telecommunication work, subgrade blanketing, ballast Spreading, dressing & boxing, commissioning, inspection & Handover. Health and security risk affects almost all operations that involve on-site work. Among all the activities listed above, high tension work and rail laying & fixing are very severe; proper safety measures are necessary to carry out these activities.

The below figure no 5.5 presents the Tornado diagram for safety and security related risk on various activities. The spread of responses is very high at the top, whereas range is less at the bottom.

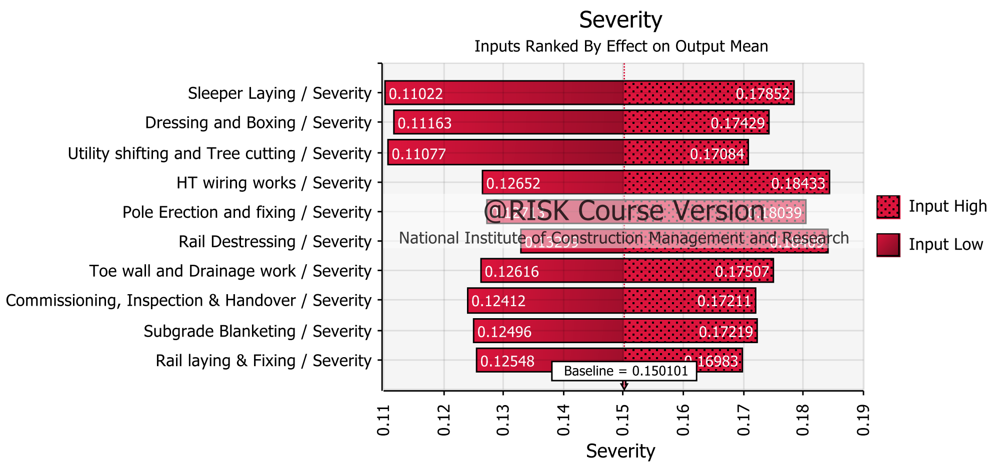


Fig. 5.5: Safety & security-related risk

Financial risk

The financing risk includes all financial-related risks which affect the project. The financial risk affects almost all activities that require a quantum of capital and are to be carried out on-site and required procurement of resources. Risk-affected activities are earthwork for formation, toe wall & drainage work, base work for electrical pole, pole installation and repairing, HT wiring work, signaling & telecommunication work, subgrade blanking, ballast spreading, sleeper laying, and CRS inspection documentation.

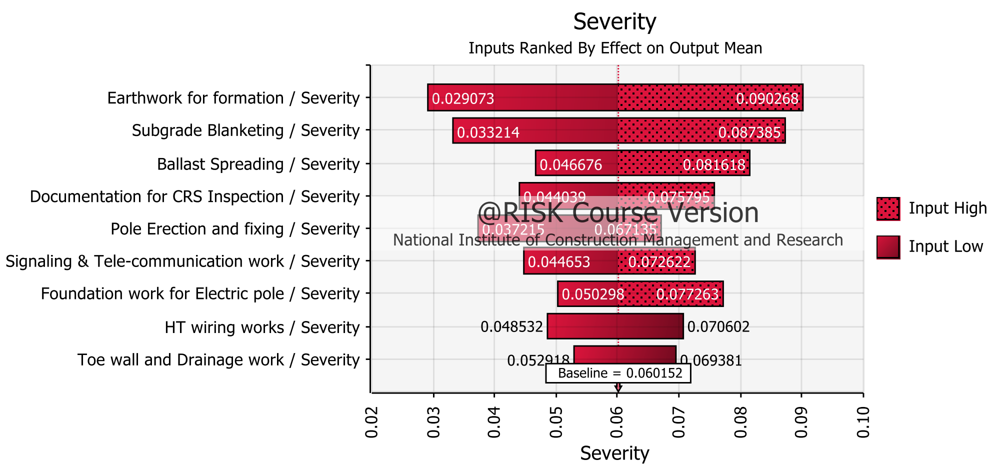


Fig. 5.6: Financial Risk

The mitigation of financial risk is vital to all stakeholders and also, for the success of the project. The allocation of the client's fund, the provision of the contractor's working capital, the timely approval and payment of the contractor 's bill are of the highest importance in project management, and any deficit will adversely affect project management.

Figure 5.6 below depicts the Tornado diagram of financial risk for different activities. The spread of the responses is very high at the top, where the distribution is less at the bottom edge.

Nature specific risk

The essence of the particular risk depends on geography and climate conditions of the region. The risk is linked to flooding, earthquakes, landslides and extreme weather conditions. The result shows that the risk-affected activities are mobilization and commencement, toe wall and drainage works, forming earthworks, subgrade blanketing and spreading of ballasts. As stated above, the extent of the risk depends on the geography and climate of the project site, the preparation and mitigation steps needed to mitigate this risk. The following figure 5.7 illustrates the tornado diagram of the extent of the risk relevant to the different activities. The distribution of responses at the top is very high, and the spread is less at the bottom.

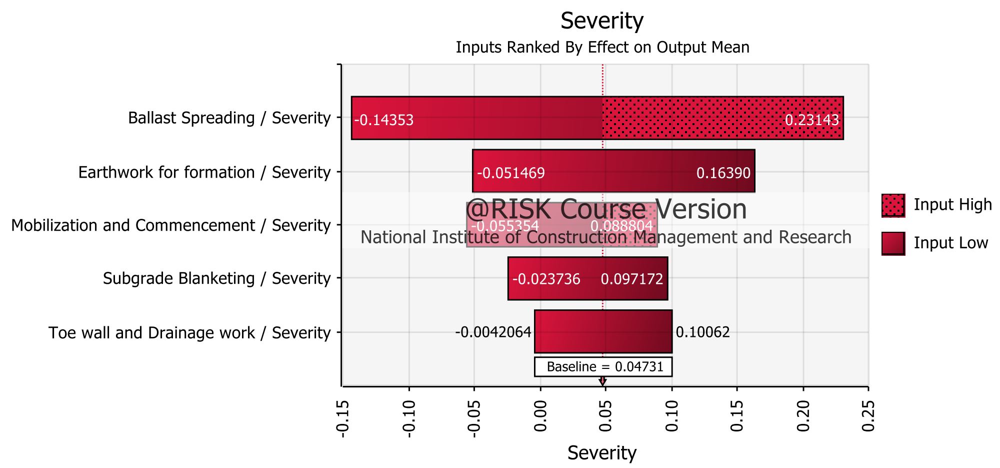


Fig. 5.7: Nature specific

Approval & site clearance related risk

The approval & site clearance risk covers all risks associated with the land acquisition & site clearances, environmental & tree cutting and rehabilitation & resettlement, etc. The result shows that the risk-affected activities are site surveys and investigations, utility shifts and tree cutting, toe wall and drainage work, the groundwork for construction, signalling & telecommunications work and ballast spreading. Railway construction projects required approvals from the various authorities, with few approvals needed even before the start of the project. Delays in obtaining these approvals can delay the mobilization and delay the project as a whole. Without the acquisition of land, the survey and investigation of the site would be inaccurate, and commencement of work would be difficult. The shifting of existing utilities needs the approval of the various organizations because it will affect their operation. Figure 5.8 below describes the Tornado diagram for the approvals & clearances related risk to different activities. The spread of the responses is very high at the top, where the distribution is low at the bottom edges.

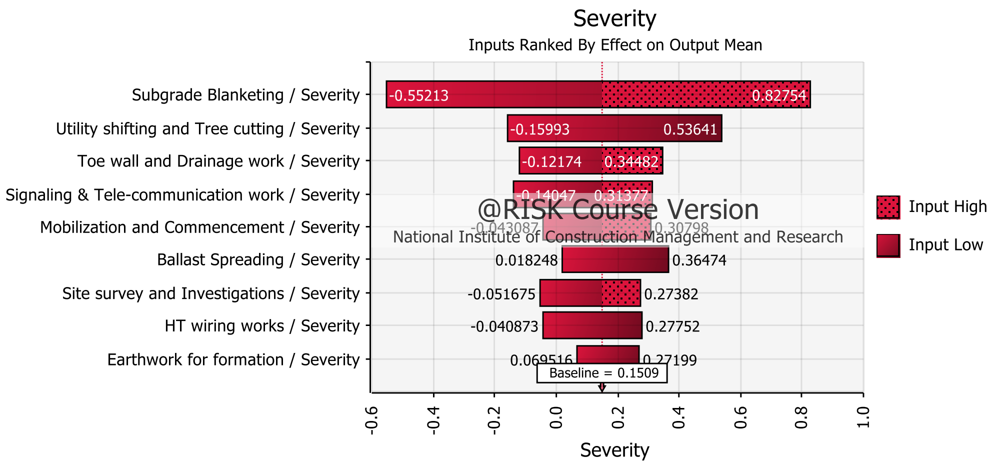


Fig. 5.8: Approval & site clearance risk

Quality related risk

The quality risk covers all risks associated with quality such as inadequate site supervision, inadequate QA / QC mechanism and failure of structures etc. The results show that risk-affected activities include toe wall and drainage work, earthwork for construction, base work for electric pole, pole erection and fixing, HT wiring work, signaling & telecommunication work, subgrade blanking, ballast spreading, sleeper laying, rail laying & fixing, temping and compaction, rail destressing, dressing and boxing, documentation for CRS inspection, commissioning, inspection & handover. In the railway construction project, quality is very important and critical to achieve, any compromise in the quality during construction may create operational risk during operation.

Figure 5.9, below depicts the tornado diagram for quality-related risk for different activities. The spread of the responses is very high at the top, where the distribution is less at the bottom edge.

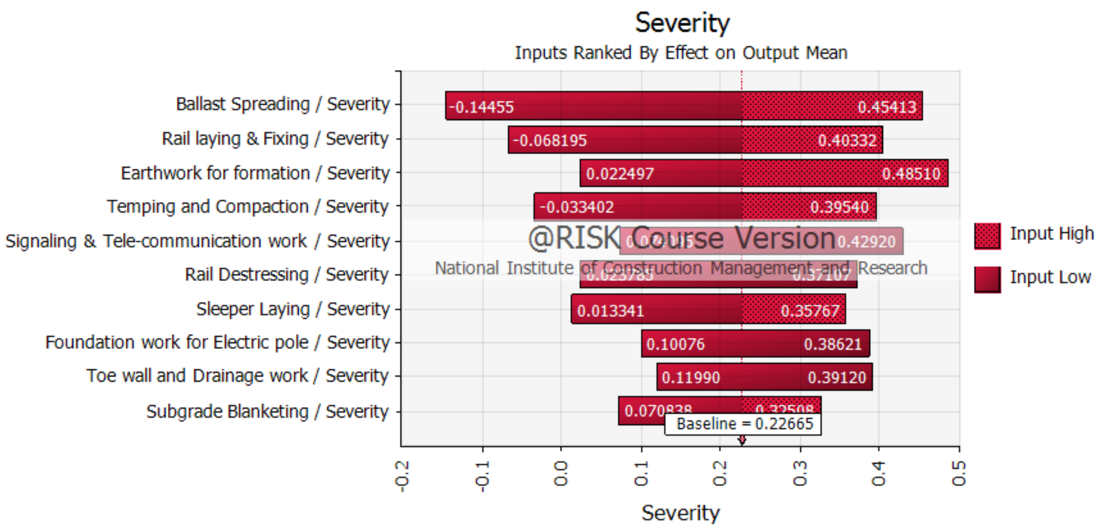


Fig. 5.9: Quality related risk

Contract specific risk

The Contract Specific Risk covers all risks associated with contract administration. The result shows that the risk-affected activities are mobilization and commencement, approvals for general arrangement drawing, approvals for construction (C / S & L section, drainage and other structures), ballast spreading, documentation for CRS inspection, commissioning, inspection and handover.

The contractor mobilises the resources only after obtaining the mobilisation advance from the client, also the start timeline & mobilisation defined in the contract; any delay would have a significant impact on the contractual obligation. In any contract, design and site survey to be carried out by the contractor and permissions to be obtained from the client. The CRS inspection is an activity to be carried out by the client and has often been delayed due to the dependency on higher authority of the client, which may provide the contractor with room in the event of an EOT evaluation.

Figure 5.10 below depicts the Tornado diagram of contract risk for different activities. The spread of responses is very high at the top, whereas the range is less at the bottom.

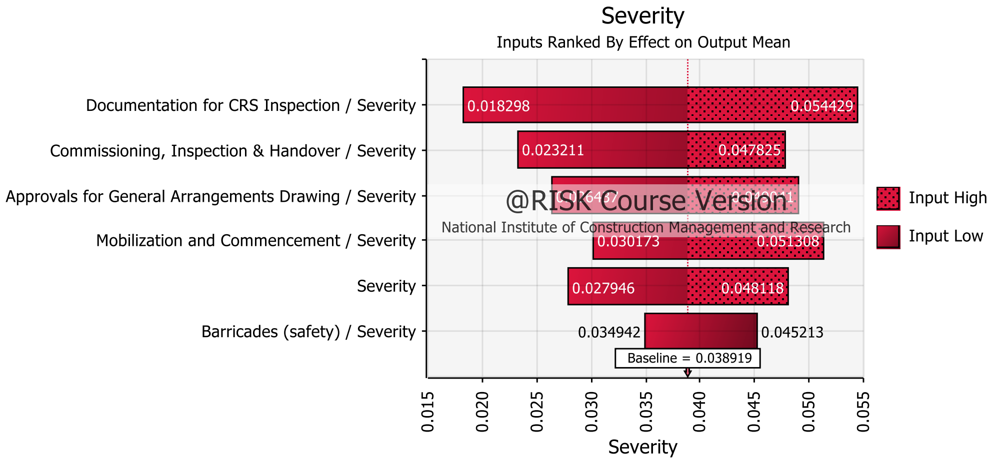


Fig. 5.10: Contract specific risk

Fundamental risk

The fundamental risk involves the possibility of event that project manager has far less control and influence, such as social & cultural Influences of labour, interstate or central state coordination problems, strike, traffic control and workplace restriction. The outcome indicates that the risk-affected activities are mobilization & commencement and ballast distribution. Figure 5.3 below depicts the Tornado diagram of contract risk for different activities. The spread of the reactions is very high at the top, where the distribution is less at the bottom edge.

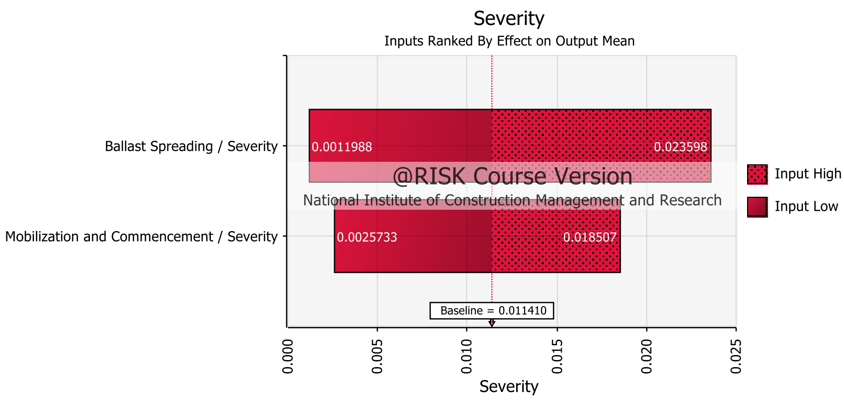


Fig. 5.11: Fundamental risk

CHAPTER 6

DATA ANALYSIS AND INTERPRETATION - OBJECTIVE NO 03

6.1. RISK MANAGEMENT MODEL

The analysis for objective three requires to develop a model for risk management which provide the relationship between the project risk and project performance. The risk management Model should include Risk Identification, Assessment, Response Planning, Monitoring and Controls. The concept of EVA is a widely accepted method for project monitoring and controls. The pre-requisite to attain objective three is a network of deterministic data and outcome of objective two for the railway track development project.

6.1.1 EXPECTED VALUE METHOD (EVM)

A quantitative risk assessment and management model using the expected value is established to refine the risk analysis and control process. For the research work of objective three, the EVM is used for risk assessment. The project's Base Time Estimate (BTE) is the estimated project base duration to complete the project, calculated by using the critical path method of project scheduling. Likewise, the Project's Base Cost is the addition of the cost of each activity available in the project drawn considering the resource involved in the execution of various activities and referred to as the BCE. The BTE and BCE for all the major project activities are calculated by using the information from the detailed design, Bill of quantities and specifications for the project. The CT is calculated by multiplying the BC with CIF of that activity. The following formula has used to calculate the CC and CT for each activity involved in the project.

Corrective Cost (CC) = Base Cost (BC) x Composite Impact Factor (CIF) ……………………………………………………..Eqn. (6.1)

Corrective Time (CT) = Base Time (BT) x Composite Impact Factor (CIF) ……………………………………………………..Eqn. (6.2)

The RC and RT for an activity are calculated based on the composite probability or CLF of the risk factors on the activity. The following equation will be used to calculate the RC and RT for an activity (x)

RC = CC x CLF ……..Eqn. (6.3)

RT = CT x CLF ……..Eqn. (6.4)

The EC and ET for each project activity (x) and subsequently the computation of project cost and time were carried out from the concept of the EVM of a decision tree analysis.

Expected value (EV) = probability of occurrence (p) [higher payoff] + (1-p) [lower payoff]. Expected cost and time in both the scenario when the risk occurs and the risk not occurs ……..Eqn. (6.5)

- The first scenario - If a risk occurs then (L) x is the Likelihood of Occurrence of any activity than impact in terms of time and cost will be BTE+CT and BCE+CC respectively
- Second Scenario - If the risk does not occur then the Likelihood of Occurrence (1-L) x of any activity than impact in terms of time and cost will be BTE and BCE respectively
    - Expected Cost (EC)x = Lx (BCEx + CCx) + (1-Lx) BCEx

      = BCEx + CCx (Lx)

      = BCEx+RCx for all x activities……..Eqn. (6.6)
    - Expected Time (ET)x = Lx (BTEx + CTx) + (1-Lx) BTEx

      = BTEx + CTx (Lx)

      =BTEx+RTx for all x activities ……..Eqn. (6.7)

The severity of risk presented as a result of probability of risk and impact of risk; Hence, the numerical significance varies from 0 to 1. The value 0 represents no severity and 01 serve as “Extremely high severity”. The risk severity (RS) number value is extracted from the reference below:

$RSx = L \times I$ for all x ……………………………………..…..Eqn. (6.7)

The severity calculated using above equation determines how significant the risk would be to the project’s performance.

6.1.2 EARNED VALUE ANALYSIS (EVA)

EVA, is one of the most commonly known project control systems used by project management professionals. EVA sets parameters which allow project monitoring and controls. It defines the planned value (PV) as the budget amount to be expended on the job done in keeping with the initial timetable at any period or with respect to baseline. PV referred to as planned Budgeted Cost of Work Schedule (BCWS). Earned Value (EV) is, at any stage in time, the monetary value of the progress achieved (work completed) in terms of the budgeted cost. EV was initially referred to as the Budgeted cost of work performed (BCWP). Actual Cost (AC) reflects the monetary value that was spent on achieving progress at some point of time. AC is referred to as the Actual Cost of Work Performed (ACWP). The EVM approach can be useful in predicting project progress based on past results and in implementing the control measure. The EVM offers two major indicators for CPI and SPI. The equation below was used to measure the EV.

$CPI = BCWP / ACWP$……………………………..…..…..Eqn. (6.8)

$SPI = BCWP / BCWS$……………………………..…..…..Eqn. (6.9)

The value of CPI & SPI if less than 1, it shows the cost & time overrun at a given point of time. The EVM model will be applied in the present work by evaluating the Base Cost based Earned Value and Expected Cost-based Earned Value and further analyzing the risk effect on the project. Below is the methodology used for the definition of indicators. The input required for the calculation is the monthly planned value of Base Cost (BCp), the monthly physical progress or work done (percentage) achieved on the project (From the updated schedule) and the actual cost spent on the progress. The WD value will be in the percentage, but for the calculation, purpose considered in the 0-1 digits. The Earned Value calculations for a month will be as follows,

CPI_B = BCWP/ACWP = WD*BCm/AC …………..………Eqn. (6.10)

SPI = BCWP/BCWS = WD*BCm/PV…………..…………Eqn. (6.11)

The CPI is calculated using the EV and AC of the work done for a month. Now, the concept of the EVM is further extended to measure the cost overrun by reference to the threshold limits set for a month. The threshold limit is Expected cost (EC), which is the consequence of the pessimistic risk scenario by taking into account all the risk that is likely to occur in the project. The actual cost of work done should not exceed the monthly expected cost estimated in any case. The Expected Cost of Work Performed (ECWP) for a given month will be identified, and the risk-based CPI for the project will be calculated for a given month. The Risk-based CPI will be helpful to quantify the cost impact of the risk on a monthly basis.

CPI_R = BCWP/ECWP = WD*EC/EC………….……..…Eqn. (6.12)

In the formula, the ACWP is replaced by the ECWP (which is risk-based Earned Value, considering the extent of all risks with a negative scenario). If CPI (Base Cost) is more than the CPI_R (Risk), it suggests that the AC incurred for a month is less than the EC. It ensures that the project is within the limits of the risk cost range and also the actual cost incurred is less than the expected cost, a portion of the risk cost is also, left which can be added to the contingency fund to cope with the future risk. When CPI(Base) is less than CPI(Risk), it indicates that the AC incurred for a month is greater than the EC , so urgent action is required to control cost overrun. The CPI (Risk) and CPI (Base) were also used to calculate the percentage of overruns concerning the Expected Value. The following formula will be used,

Quantified Risk Effect on Cost = 100*(ACWP-ECWP)/ECWP…...Eqn. (6.13)

The Quantified Risk Effect on Cost will be in the Percentage form, which is the difference of the Actual Cost of Work Performed and Expected Cost of Work performed concerning the Expected Cost of Work Performed. The percentage value may be negative or positive if it is negative, then it means that the risk reserve is balanced or remains for a month, and it is good for the project. if it is positive, it means that the actual cost incurred is higher than the expected cost, that is the threshold for the project, and that is not a healthy sign for the project.

The quantified risk effect on time will be calculated based on the completion dates of the project using the Critical path method of project schedule. The Project Completion Date based on the Baseline completion date $(PCD)_B$, Project Completion Date based on the Risk-based Expected completion date $(PCD)_R$ and Project Completion Date based on the updates $(PCD)_U$. The following formula will be used to quantify the time overrun with reference to the Expected Completion date,

Quantified Risk Effect based on Time = $((PCD)_{U.} - (PCD)_{R)})/ ((PCD)_{R.} - (PCD)_{B)})*100$……………………………………………………….Eqn. (6.14)

The value of the Quantified Time-based Risk Effect may be negative or positive in percentage form. If it is negative, the risk allowance will still offset the future risk; if it is positive, it implies that the actual time taken is greater than the planned time-based threshold and is not a healthy sign for the project.

6.2. RISK MANAGEMENT MODEL FOR RAILWAY PROJECTS IN INDIA

Figure 6.2 presents the risk quantification model (RQM), which is the outcome of all objectives of the study. It also depicts the detailed steps followed for model formulation. The developed model application is limited to railway track contruction projects in India only. The model is converted in the dashboard form to make it ready use for the industry. It is formulated purely based on the perception of the industry people. The primary application of the model would be to identify, assess and quantify the risk at the beginning of the project and make concise decision about the budget and timeline of the project. This model is intended for users as Indian Railways, RVNL, EPC Contractors, and consultants working in the sector. The model will further be valiadated on an case of a railway project in India.

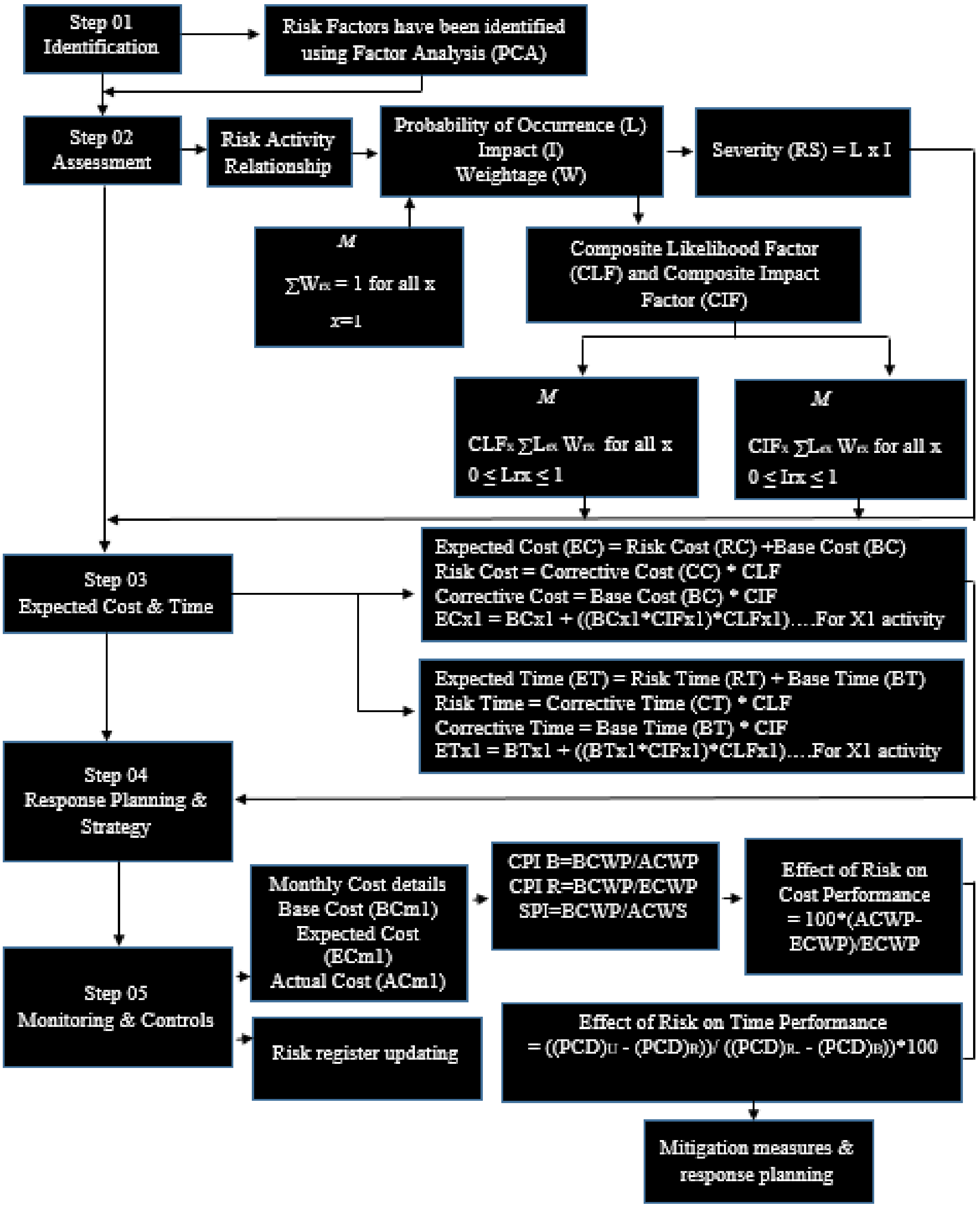


Fig. 6.2 - Risk Management Model for Railway Projects in India

6.3. A CASE TO VALIDATE THE MODEL

A case of a railway project had used to validate the model. The Rail Vikas Nigam Limited (RVNL) is client, L&T was the contractor for the project. The RVNL at Bhopal Division of West Central Railway, Madhya Pradesh awarded the project to Contractor Larsen & Toubro with a cost of 215 Cr. The project is located from Habibganj to Bina (IIIrd line constructions) in Madhya Pradesh. The detailed scope includes the 46 KM track length 27 minor Bridges, 9 Major Bridges, 81.5 KM Over Head Electrical Wiring, S&T cabling of 920 KM. The start timeline of the project is 01st October 2009, and the planned Completion timeline is 30th September 2011. Total timeline to complete the work is 02 Years. The development of railway track including Signal & Telecommunication and Overhead Electrical line & General Electrical work in connection with the third line between Habibganj & Bina was the scope under this project. The Ganj Basoda is situated on Delhi-Mumbai, and Delhi-Chennai mainlines whereas Sanchi railway station is a small railway station in Raisen district, Madhya Pradesh.

Table 6.1: Expected Cost analysis for the project

EXPECTED COST FOR THE PROJECT						
Activities	**Base Cost (INR)**	**Composite Likilihood Factor**	**Composite Impact Factor**	**Corrective Cost (INR)**	**Risk Cost (INR)**	**Expected Cost (INR)**
Mobilization and Commencement	6,48,88,278.80	0.372	0.389	2,52,50,379.33	94,00,835.63	7,42,89,114.43
Site survey and Investigations	20,00,000.00	0.405	0.391	7,82,406.54	3,16,604.22	23,16,604.22
Approvals for General Arrangements Drawing	10,05,420.16	0.386	0.364	3,65,590.83	1,41,074.67	11,46,494.83
Approvals for formation (C/S & L section, Drainage and other structures)		0.382	0.392	-	-	-
Utility shifting and Tree cutting	4,88,451.42	0.373	0.371	1,81,317.20	67,627.70	5,56,079.12
Barricades (safety)	15,57,502.39	0.370	0.396	6,16,565.38	2,28,116.98	17,85,619.37
Toe wall and Drainage work	-	0.345	0.351	-	-	-
Earthwork for formation	14,85,52,380.12	0.330	0.502	7,46,28,226.65	2,46,56,417.22	17,32,08,797.34
Foundation work for Electric pole	1,87,55,835.53	0.423	0.480	89,96,957.25	38,05,712.92	2,25,61,548.45
Pole Erection and fixing	15,84,886.69	0.386	0.382	6,05,661.31	2,33,889.40	18,18,776.09
HT wiring works	6,76,61,663.07	0.379	0.387	2,61,84,916.63	99,31,662.03	7,75,93,325.09
Signaling & Tele-communication work	20,74,81,811.68	0.365	0.389	8,07,73,451.03	2,94,95,830.87	23,69,77,642.55
Subgrade Blanketing	10,43,94,646.17	0.384	0.387	4,03,98,604.85	1,55,01,764.77	11,98,96,410.94
Ballast Spreading	1,09,78,043.14	0.356	0.382	41,89,146.56	14,91,549.90	1,24,69,593.04
Sleeper Laying	61,21,370.46	0.447	0.438	26,78,375.17	11,98,106.72	73,19,477.18
Rail laying & Fixing	76,51,713.07	0.423	0.486	37,16,523.24	15,72,686.60	92,24,399.68
Temping and Compaction	24,38,210.57	0.449	0.464	11,30,217.46	5,07,145.18	29,45,355.74
Rail Destressing	10,86,304.46	0.450	0.420	4,56,468.39	2,05,553.98	12,91,858.45
Dressing and Boxing	15,30,342.61	0.423	0.391	5,97,614.97	2,52,886.48	17,83,229.10
Documentation for CRS Inspection		0.373	0.396	-	-	-
Commissioning, Inspection & Handover		0.428	0.453	-	-	-
	64,81,76,860.35			**27,15,52,422.79**	**9,90,07,465.27**	**74,71,84,325.62**

Table 6.2: Expected Time analysis for the project

EXPECTED TIME FOR THE PROJECT						
Activities	**Base Time**	**Composite Likilihood Factor**	**Composite Impact Factor**	**Corrective Time (Day)**	**Risk Time (Days)**	**Expected Time (Days)**
Mobilization and Commencement	20	0.372	0.389	8	3	22.90
Site survey and Investigations	20	0.405	0.391	8	3	23.17
Approvals for General Arrangements Drawing	15	0.386	0.364	5	2	17.10
Approvals for formation (C/S & L section, Drainage and other structures)	15	0.382	0.392	6	2	17.25
Utility shifting and Tree cutting	30	0.373	0.371	11	4	34.15
Barricades (safety)	20	0.370	0.396	8	3	22.93
Toe wall and Drainage work	60	0.345	0.351	21	7	67.28
Earthwork for formation	90	0.330	0.502	45	15	104.94
Foundation work for Electric pole	30	0.423	0.480	14	6	36.09
Pole Erection and fixing	30	0.386	0.382	11	4	34.43
HT wiring works	30	0.379	0.387	12	4	34.40
Signaling & Tele-communication work	30	0.365	0.389	12	4	34.26
Subgrade Blanketing	60	0.384	0.387	23	9	68.91
Ballast Spreading	50	0.356	0.382	19	7	56.79
Sleeper Laying	40	0.447	0.438	18	8	47.83
Rail laying & Fixing	30	0.423	0.486	15	6	36.17
Temping and Compaction	30	0.449	0.464	14	6	36.24
Rail Destressing	20	0.450	0.420	8	4	23.78
Dressing and Boxing	18	0.423	0.391	7	3	20.97
Documentation for CRS Inspection	15	0.373	0.396	6	2	17.22
Commissioning, Inspection & Handover	7	0.428	0.453	3	1	8.35

The detailed analysis for the computation of CC, RC, EC, CT, RT and ET for all the project activities is presented above in Table 6.1. For an activity A (Mobilization and commencement) the CLF is 0.375 obtained from the outcome of objective two. The base cost estimate (BCE) for the activity is INR 6,48,88,278/- the corrective cost (CC) is INR 2,52,50,379; the base time estimate (BTE) is 20 days; the corrective time (CT) is 08 days, The calculation is based on the equation 06 & 07. As per equations (08) and (09), Risk cost (RC) INR 94,00,835/- Risk time (RT) 03 days. Thus as per equations (7) and (8), the expected cost (EC) = BCE+ RC = INR 32, 03, 80,752.00, expected time (ET) = BTE + RT = 17.77 days. The similar computation has carried out for all the activities (refer table 6.1 & 6.2).

Table 6.3 - Risk cost of each factor

Risk factors	Risk Cost (Rs.)
Contractor Specific risk	1,71,19,453.29
PMC Consult. Specific risk	1,13,39,104.70
Owner Specific	97,96,124.21
Design Specific	1,13,80,711.14
Safety & security	1,19,11,383.57
Financial risk	81,86,148.79
Nature specific	54,47,383.17
Approval & site clearance	1,08,64,819.95
Quality	1,09,26,703.84
Contract specific	9,40,805.95
Fundamental	11,19,847.51
Total Risk Cost	**9,90,32,486.11**

The risk cost of individual factor is calculated based on weightage of each factor on an activity calculate above as per table 6.3. The Expected Cost for the Project will be a summation of all the expected cost, i.e. (Base Cost + Risk Cost) of all activities. And Expected Time (ET) = Calculated by using the expected timeline derived from the above calculations in Critical path method based Schedule.

Table 6.4 - Outcome of Expected Value Method Model

	Cost /Time
Base Cost Estimate	INR 64,81,76,860
Risk Cost	INR 9,90,07,465
Expected Cost	INR 74,71,84,325
Expected Time	45 days

Thus, according to the study and the model, the project's EC is 15 per cent greater than the project's BCE, and the project's ET is 45 days greater than the BTE. Therefore, the risk mitigation and management steps must be carefully implemented to ensure that the project finishes within the planned period and cost objectives.

6.4.1 RISK SEVERITY USING THE CLF & CIF

The compound of CLF & CIF can determine the severity of risks. This definition of severity can be expanded to involve several sources of risk for an activity, the likelihood and effect of which can be represented in terms of CLFx and CIFx, respectively. The scale for risk severity classification is presented, as seen in Table 6.5 below. Therefore, for the railway construction project, the risk severity of growing project operation is measured and displayed in the following Table 6.6

Table 6.5 Scale for Severity

Severity	Classification
0.00-0.02	V. Low
0.03-0.05	Low
0.06-0.15	Medium
0.16-0.20	High
0.21-1.00	V. High

Table 6.6 - Severity of Risk Factors on various activity

Dashboard - Activity Severity Anaysis			
Activities	**Composite Likilihood Factor**	**Composite Impact Factor**	**Severity**
Mobilization and Commencement	0.372	0.389	0.145
Site survey and Investigations	0.405	0.391	0.158
Approvals for General Arrangements Drawing	0.386	0.364	0.140
Approvals for formation (C/S & L section, Drainage and other structures)	0.382	0.392	0.150
Utility shifting and Tree cutting	0.373	0.371	0.138
Barricades (safety)	0.370	0.396	0.146
Toe wall and Drainage work	0.345	0.351	0.121
Earthwork for formation	0.330	0.502	0.166
Foundation work for Electric pole	0.423	0.480	0.203
Pole Erection and fixing	0.386	0.382	0.148
HT wiring works	0.379	0.387	0.147
Signaling & Tele-communication work	0.365	0.389	0.142
Subgrade Blanketing	0.384	0.387	0.148
Ballast Spreading	0.356	0.382	0.136
Sleeper Laying	0.447	0.438	0.196
Rail laying & Fixing	0.423	0.486	0.206
Temping and Compaction	0.449	0.464	0.208
Rail Destressing	0.450	0.420	0.189
Dressing and Boxing	0.423	0.391	0.165
Documentation for CRS Inspection	0.373	0.396	0.148
Commissioning, Inspection & Handover	0.428	0.453	0.194

6.4.2 RISK RESPONSE PLANNING

As PMBOK 6 (Sixth Edition) the response to risk can be given by Accept, avoid, mitigate & transfer and response strategy can be developed based on the type of contract. The expert's opinion of five experts working for the railway projects has taken to provide the response and mitigation strategy of identified variables specific to railway project. The responses are highlighted in the risk management dashboard in the Exibits.

6.4.3 MONITORING AND CONTROLS

The input needed to perform the calculation are Monthly planned value of Base Cost (BCp), Monthly Physical progress achieved during the month or % of work done (WD) at the project (From Updated Schedule) and actual cost (AC) spent to achieve the progress. Earned Value calculations for October 2009 are as follows,

- Base Cost (BCp) = 3,39,46,849/-
- Work done (WD) = 75%
- Actual Cost of Work Performed (ACWP) = 2,65,55,868/-
- Expected Cost of Work Performed = 2,69,91,879/-

The Cost Performance Index based on the budgeted cost is calculated

- CPI_B = Base Cost (BCp)*WD/ACWP
- CPI_B = 0.96

The Value of CPI should be equal to 01 or should be more than the 01, if it is less than 01 than it indicates the Cost Overrun of the project. The above calculation is showing the cost overrun for the month.

The Schedule Cost Performance Index based on the budgeted cost is calculated by using equation 10

- SPI = Base Cost (BCp)*WD/BCWS
- SPI = 0.75

The Value of SPI should be equal to 01 or should be more than the 01, if it is less than 01 than it indicates the time overrun of the project. The above calculation is showing the time overrun for the month.

The risk-based CPI_R is calculated by using the following equation.

- CPI_R = BCWP/ECWP = WD*EC/EC
- **CPI_R = 0.94**

$CPI_R < CPI_B$, This indicates that the Contingency fund is sufficient enough to handle all the risk and actual cost incurred is less than the Threshold limit set for the month.

If $CPI_R > CPI_B$, This indicates that the actual cost incurred is more than the Expected cost (Threshold limit) to mitigate the risk and the Contingency fund is not sufficient enough to handle the risk.

Quantified Risk Effect on Cost = 100*(ACWP-ECWP)/ECWP

The Quantified Risk Effect on Cost will be in Percentage of the difference of Actual Cost of Work Performed and Expected Cost of Work performed with reference to the Expected Cost of Work Performed. The percentage value may be the negative or positive, If it is in negative than it signifies the risk reserve is balanced for the month and impact of risk are well withing the contingencies. If it is Positive than it signifies that the actual cost incurred is more than the expected cost, the expected cost is a threshold limit for the project, and this is not a healthy sign for the project.

- Quantified Risk Effect on Cost = -1.62%

This figure indicates that the Risk fund is sufficient enough to handle the risk, and the risk is within the Threshold limits.

The following formula is used to quantify the time overrun based on the Expected Completion date calculated by using the following equation,

Quantified Risk Effect based on Time = $((PCD)_{U.} - (PCD)_{R)})/ ((PCD)_{R.} - (PCD)B))*100$

- Project Completion based on Expected Time-based Schedule $(PCD)_R$ = 15/12/2011
- Project Completion based on monthly Updated Schedule $(PCD)_B$ = 08/11/2011

- Project Completion based on the baseline Schedule $(PCD)_U$= 01/10/2011
- **Quantified Risk Effect based on Time = -49%**

The maximum permissible duration of the project is 75 days, i.e. the difference between Initial Completion and Planned Completion dates. The percentage value may be negative or positive; if it is negative, then it means that the risk reserve is still balanced to deal with the future risk, if it is positive then it means that the actual time taken is more than the expected time-based threshold and this is not a healthy sign for the project.

CHAPTER – 07

CONCLUSIONS AND SUGGESTIONS

7.1. INTRODUCTION

At the essence of this study were the project management and risk management of railway construction projects in India, that was badly affected by overruns of costs and time which turned into a business problem. The research questions and the objectives have framed from the business problem; further, the research carried out as per the planned research methodology advised in earlier chapter three. The findings properly implemented in sequence by presenting a solution to the problem in this study.

This chapter summarizes the study and outlines Key Findings, Research limitations and list out the context and the scope for future research. This chapter highlights the researcher's observation and remarks that other researchers should carry on further risk analysis work on railway construction projects in India.

7.2. FINDINGS

The initial definition of risk variables was done with reference to the detailed literature review resulting in the identification of 228 risk variables affecting the overrun of the infrastructure project. subsequently incorporating suggestions from railway project experts in India to achieve a variable list specific to Indian railway project, the total of 84 risk variables have identified.

Based on the questionnaire survey and factor analysis (PCA), the 84 variables have reduced to 11 factors. The factors that affect time and costs for the railway projects are defined as follows – Contractor Specific risk, Project Management consultant specific risk, Client specific risk, Design related risk, Safety & security-related risk, Financial risk, Nature related risk, Government approvals and site clearances risk, Quality related risk, Risk related to Contract administration and Fundamental risk. The risk quantification has done using the EVM and EVA, The perception of respondents on the effects of various risk factors (r) on each activity (x) have quantified considering the Likelihood of Occurrence (Lrx), Impact (Irx) and Weightages (Wrx). The CLF and CIF of the various risk factor on each activity has established.

The severity of risk factors (r) on the activities (x) has developed using the Monte-Carlo simulation, which in turn provided the tornado profile of severity of risk factors on the activities.

The risk quantification model was developed using EVM & EVA method, the model quantifies impact of the project risk on project performance. The input information used are the BC and BT by considering the CLF and CIF of each activity, the outcome was identified in terms of the EC and ET for each activity. The summation of EC of all activity suggests a project cost identified considering all risk events and considered as an EC for the project. The AC of the project should not be more than the EC in any of the project scenarios for a healthy project. The ET value of each activity had used to make a Critical path of the project, which in turn provide the ET of completion for the whole project. While updating the schedule, the project duration should not cross the ET based duration.

Further, the model quantifies the effect of risk on the performance of the project. The monthly details, i.e. the Planned and actual value of work done, have identified considering the monthly BC, EC, BT and ET data. The Concept of EVM extended in the model to quantify the risk impact on the project by analysing and comparing the BC-based Earned Value, and EC based Earned value (risk-based). The quantified risk effect of time on the project duration has also been identified. This developed model used for validation on an existing project where the actual cost and time data was considered as input and distributed against each activity, resulting in an expected cost detail is 13% more than the project cost an extended duration of 30 days had observed.

The result as obtained by risk management model by using the EVM and EVA provides the outcome that the values are more than the CPI and SPI but within the contingency limits calculated by using the model. Hence, not impacting much the project performance, in this way with the help a case the model has validated. This model can be utilized for the risk analysis and management for the construction of the railway project in India with limitations.

7.3. FUTURE RESEARCH SCOPE

The model built is focused on the selection of risk factors after statistical analysis of the response. It may be expanded or redefined:

- Adding or reducing potential factors to the current layout of this research.
- Extending the present study into the Railway station construction project, since Govt. of India has a big plan to redevelop the new railway station in India

Many statistical analysis tools, such as Range Estimation, Artificial Neural Networks, Analytical Hierarchy Process, Fuzzy Sets, etc., can be considered for model formulation in future studies.

7.4. SUGGESTIONS

While several project risk management theories are accessible and most project practitioners are aware of the specific processes even; they fall behind their usage in the project. Hence, proper implementation of project risk management is required in order to achieve a better result at all times.

To avoid overrun in the project, adequate estimation considering the contingency shall be made during the project sanctioned & budget preparation. Also, utilizing some validated form of models rather than allocating contingency based on the Rule of Thumb can be a better professional approach.

7.5. CONCLUSION

A detailed literature review unlocks the gaps prevailing in the system, causing the overrun and also, the business problem of the research. It was resulting into a requirement of detailed analysis on “How the risk assessment and management model can be developed for the construction of railway projects and how the relationship of project risk with project performance can be analyzed for the railway project”. The perception of the stakeholders on various risk variables (identification) affecting project performance and further risk assessment and modelling plays an important role towards firm value maximization’ being the problem statement that revolves around this core theme. This problem statement was further broken down into meaningful and attainable research objectives to answer the questions raised.

This research initially work focused at identifying the significant project risk factors in the construction of Indian railway projects causing time and cost overruns, which was accomplished as part of the objective one using factor analysis. Thereafter upon identification of the risk factor, the factor and activity relationship has been established by assessing the Likelihood of Occurrence (L), Weightage (W) and Impact (I) of individual risk factors on the various project activities by using the EVM. Also, the risk severity effect on activity had established using Monte-carlo simulation under objective two.

Subsequent to the identification and establishment of risk and activity relationship affecting the project performance; a model named “Risk Quantification Model (RQM)” was formulated using EVM and EVA. The primary data and secondary data collected have utilized for the purpose of risk management and modelling of the railway project in India. The model as formulated was tested on the basis of an actual project data which confirms the validity of the formulated model.

On contribution to the theory, this study had provided a way forward for consideration for the initial problem. By considering the Decision Theory, the firm value can be maximized by means of better project performance which was validated by the risk quantification model.

The current research provides support for the railway projects development in India by giving a Risk Quantification Model, by considering the perception of industry people in formulating model. This model shall be utilized for developing the project sanctioned/budget, after taking into account the project risks; for implementation to mitigate the cost overrun, with all the assumptions and limitations stated therein be considered appropriately by the organizations and the Project Managers.

CHAPTER – 08

SIGNIFICANCE OF THE RESEARCH

8.1. ANTICIPATED USES OF THE RESEARCH:

This research is anticipated to be useful to manage the risk i.e. to identify, assess and quantify the risk at the beginning of the project and make concise decision about the budget and timeline of the project.

This research is intended for users as Indian Railways, RVNL, EPC Contractors, and consultants working in the sector.

8.2. RELEVANCE OF THE RESEARCH IN INTERNATIONAL ARENA:

The holistic approach can be helpful for International construction companies eyeing towards the Indian market in railway transportation projects since there are many project in pipeline and also future investment in the sector.

8.3. RELEVANCE OF THE RESEARCH IN RISK MANAGEMENT

This Expected Value based quantitative model will provide a significance application based approach for risk quantification in the real life project. The study emphasize on risk identification, assessment and support decision making for the projects. This study can be used as an aid to plan for the quantitative risk management for railway transportation projects.

8.4. RELEVANCE OF THE RESEARCH IN PROJECT PERFORMANCE

The project performance in terms of time and cost can be measured using the Expected Value based modelling and Earned Value methods. The CLF and CIF can quantify the multiple risk effect on an activity.

8.5. CONTRIBUTION TO LITERATURE

Several studies were made on decision theory Sutterfield (2006), Littau (2010), Themistocleous & Wearne (2000), Simister, S. (1994), Buchanan (2006), Bernoulli's (1738), von Neumann and Morgenstern (1947), Bell, Raiffa and Tversky (1988), Goldstein and Hogarth (1997)

However, implementation of the decision theory for ‘value maximization of the firm’ by proper assessment of risk and quantification of the risk is very limited in Construction of railway projects in India. Generally a qualitative assessment of risk conducted at both the Governance level of the organization as well as the Management level of the project; while list of project risks variables were identified & listed out in the Risk Registers as a common practice without analyzing and implementing the mitigation plan to control them. Furthermore, proper risk quantification based on Quantitative analysis and also project performance based monitoring of the risk and proper implementation of the Project Risk Management in terms of risk mitigation is missing.

The expected Value based risk assessment and modelling is a quantitative modelling for railway project which is purely based on the probability of expected values. The Earned Value Method will significantly improve the monitoring and control the risk management. As the concept is practical, analytical and can easily be useful by the project stakeholders specially by the owner of the project to take critical decisions related to appraisal, viability, funding, and award of the contract. Hence Expected Value based model for railway project is a contribution to literature. The practical approach towards the management of the risk in the projects are more qualitative and fragmented hence a holistic model based on the expected value will be useful in the literature.

The result of current study to the problem as stated above had provided an insight and to ponder further, that, ‘the flow of information related to project decisions, i.e. risk quantification fixing up the expected value of the cost and time, which will affect the Organization Governance’ improves the ‘overall management of the risk in the organization.

CHAPTER – 09

SUMMARY AND IDEA

9.1. SUMMARY AND IDEAS WITH INDICATION FOR FUTURE WORK.

- It is time for the stakeholders involved in the railway projects to control the unnecessary cost and time in terms of value loss of taxpayers money.
- The expected value based approach is more holistic and analytical and can be very much useful for all type of railway projects expected in the future.
- As the country is under development stage, plans are being created for a variety of rail construction projects that are expected to come up over the next two decades.
- Research work opens up door to take up future research to validate the model for the projects
- The concept may be applied to many other categories of large infrastructure projects, such as roads, oil and gas refineries, airports, power plants and other kinds of MRTS projects.

9.2. LIMITATION OF STUDY

- Applying relationships to multiple variables is a complex process owing to the many complicated variations of variables under study. However, these are focused on a small number of responses obtained and also, the responses depend on the personnel capacity may vary depending upon time and mood which may restrict the results of this study.

- A significant limitation of the model implemented for research is that the whole process is probabilistic, the prediction outcome primarily relies on the estimation of the probability and weighting of the defined risks obtained from the questionnaire survey. Any kind of confusion presented can also result in incorrect outcomes, but the model's validity has been tested via a railway construction project.
- Study is based on the details of the activity and other details of project related to Track Construction of railways, However, the model can-not be applied on the project other than the track construction.
- Responses taken from personnel may vary depending upon time, mood, experience and his understanding toward questions.
- Study is based on the deterministic scenario of time and cost. The Project schedule and cost details had used to determine the project performance trend
- Study is limited to Railways Track Construction project, a similar study can also be possible for other railway construction projects.
- Sometimes the actual cost to mitigate the risk will be more than the Quantified by the model in that case we should assume the anticipated based on the real condition and use in the model.

BIBLIOGRAPHY

1. Abd El-Karim, M. S. B. A., Mosa El Nawawy, O. A., & Abdel-Alim, A. M. (2015). Identification and assessment of risk factors affecting construction projects. HBRC Journal. https://doi.org/10.1016/j.hbrcj.2015.05.001

2. Abd El-Karim, M. S. B. A., Mosa El Nawawy, O. A., & Abdel-Alim, A. M. (2017). Identification and assessment of risk factors affecting construction projects. HBRC journal, 13(2), 202-216.

3. Abdou, O. A. (1996). Managing construction risks. Journal of Architectural Engineering, 2(1), 3-10.

4. Agarwalla, S. K., & Raghuram, G. (2012). Structuring the Dedicated Freight Corridor Project A Lost Opportunity.

5. Ahiaga-Dagbui, D, Smith, S D, Love, P E D and Ackermann, F (2015). Spotlight on construction cost ovemin research: Superficial, replicative and stagnated In: Raidén A B and Aboagye-Nimo, E (Eds). Procs 31st Annual ARCOM Conference, 7-9 September 2015, Lincoln, UK, AssociationofResearchersinConstructionManagement,863-872.

6. Akintola S Akintoye, Malcolm J MacLeod (1997). Risk analysis and management in construction. International Journal of Project Management Vol. 15, No. 1, pp. 31-38,1997.

7. Aleshin, A. (2001). Risk management of international projects in Russia. International Journal of Project Management, 19(4), 207-222.

8. Alfredo Federico Serpella, Ximena Ferrada, Rodolfo Howard, Larissa Rubio (2014). Risk Management in Construction Projects :A Knowledge- based Approach, 27th IPMA World Congress, Procedia - Social and Behavioral Sciences, 119 (2014) 653 —662

9. Al-Hazim, N., Salem, Z. A., & Ahmad, H. (2017). Delay and Cost Overrun in Infrastructure Projects in Jordan. Procedia Engineering, 182, 18–24. https://doi.org/10.1016/j.proeng.2017.03.105

10. Ali A.S., Kamaruzzaman S.N., (2010). Cost Performance for Building Construction Projects in Klang Valley .Journal of Building Performance,

11. Alia Alaryan, Emadelbeltagi, Ashraf Elshahat and Mahmoud Dawood (2014).Causes and Effects of Change Orders on Construction Projects in Kuwait. Int. Journal of Engineering Research and Applications, Vol.4,

12. Al-Khalil, M. I., & Al-Ghafly, M. A. (1999). Important causes of delay in public utility projects in Saudi Arabia. Construction Management and Economics, 17(5), 647–655. https://doi.org/10.1080/014461999371259

13. Al-Kharashi, A., & Skitmore, M. (2009). Causes of delays in Saudi Arabian public sector construction projects. Construction Management and Economics, 27(1), 3–23. https://doi.org/10.1080/01446190802541457

14. Alnuaimi, A. S., & Al Mohsin, M. A. (2013). Causes of Delay in Completion of Construction Projects in Oman. International Conference on Innovations in Engineering and Technology (ICIET'2013) Dec. 25-26, 2013 Bangkok, 99231200, 267–270. https://doi.org/10.15242/IIE.E1213590

15. Al-Sabah, R., Menassa, C. C., & Hanna, A. (2012, October). Evaluating significant risks in the Middle East North Africa (MENA) construction projects from perspective of multinational firms. In Proceedings of the CIB W (Vol. 78, p. 2012).

16. Anbari, F. T. (2003). Earned value project management method and extensions. Project management journal, 34(4), 12-23.

17. Anna Klemetti, (2006). Risk Management in Construction Project Networks. Helsinki University of Technology, Laboratory of Industrial Management - Report2006/2.

18. Arditi,D.,and Pattanakichamroon, T.(2006). Selecting a delay analysis method in resolving construction claims. Project Management, 24(2), 145- 155.

19. Assaf A. Sadi, Al-HejjiSadiq, (2006). Causes of delay in large construction projects. International Journal of Project Management, 24 (2006) 349-357,doi:10.1016/j.ijproman.2005.11.010.

20. Assaf, S. A., Al-Khalil, M., & Al-Hazmi, M. (1995). Causes of Delay in Large Building Construction Projects. Journal of Management in Engineering, 11(2), 45–50. https://doi.org/10.1061/(ASCE)0742-597X(1995)11:2(45)

21. Atout, M. M. (2013, September). Factors Caused By Consultant Engineers Affecting Project Progress. In International Conference on Management and Information Systems September (Vol. 22, p. 24).

22. Azadeh Sohrabinejad and Mehdi Rahimi (2015). Risk Determination, Prioritization,and Classifying in Construction Project Case Study: Gharb Tehran Commercial-Administrative Complex. Journal of Construction Engineering, vol. 2015, Article ID 203468, 10 pages, 2015. doi:10.1155/2015/203468

23. Azhar, N., Farooqui, R. U., & Ahmed, S. M. (2008, August). Cost overrun factors in construction industry of Pakistan. In First International Conference on Construction In Developing Countries (ICCIDC–I), Advancing and Integrating Construction Education, Research & Practice (pp. 499-508).

24. Aziz, R. F. (2013). Ranking of Delay Factor in Construction Projects After Egyption Revolution. Alexandria Engineering Journal, 52(3), 387–406. https://doi.org/10.1016/j.aej.2013.03.002

25. Aziz, R. F. (2013). Ranking of delay factors in construction projects after Egyptian revolution. Alexandria Engineering Journal, 52(3), 387-406.

26. Baccarini, D. and Archer, R. (2001) “The risk ranking of projects: a methodology” International Journal of Project Management 19, 139-145

27. Baghdadi, A., & Kishk, M. (2015). Saudi Arabian Aviation Construction Projects: Identification of Risks and Their Consequences. Procedia Engineering, 123, 32–40. https://doi.org/10.1016/j.proeng.2015.10.054

28. Banik, G. C., & May, A. L. (2006). Emerging legal risks for construction management professionals. Leadership and Management in Engineering, 6(3), 102-109.

29. Baram, G. E. (2003). Project management oversight: An effective risk management tool. AACE International Transactions, RI31.

30. Beckers, F., Chiara, N., Flesch, A., Maly, J., Silva, E., & Stegemann, U. (2013). A risk-management approach to a successful infrastructure project. Mckinsey Work. Pap. Risk, (52), 18.

31. Bekr, G. A., & Samarah, A. (2016). Identifying the Significant Risk Management Factors for Construction of Public Projects in Jordan, 13(3), 53–60. https://doi.org/10.9790/1684-1303045360

32. Bentler, P. M., & Chou, C. P. (1987). Practical issues in structural modeling. Sociological Methods & Research, 16(1), 78-117.

33. Boholm, Å. (2010). On the organizational practice of expert-based risk management: A case of railway planning. Risk management, 12(4), 235-255.

34. Brandon Jr, D. M. (1998). Implementing earned value easily and effectively. Project Management Journal, 29(2), 11-18.

35. Chapman, C and Ward, S. (2000) “Estimation and evaluation of uncertainty: a minimalist first pass approach” International Journal of Project Management 18, 369-383.

36. Chapman, C. and Cooper, D. (1983) “Risk Engineering: Basic Controlled Interval and Memory Models” Journal of the Operational Research Society, 34(1) 51-60

37. Chen, H., Guilin, H., Poon, S. W., & Ng, F. F. (2004). Cost risk management in West Rail project of Hong Kong. AACE International Transactions, IN91.

38. Chen, S., & Zhang, X. (2012). An analytic review of earned value management studies in the construction industry. In Construction Research Congress 2012: Construction Challenges in a Flat World (pp. 236-246).

39. Cioffi, D. F. (2006). Designing project management: A scientific notation and an improved formalism for earned value calculations. International Journal of Project Management, 24(2), 136-144.

40. Cohen, M. W., & Palmer, G. R. (2004). Project risk identification and management. AACE International Transactions, IN11.

41. Construction companies should seize opportunities to benefit from new technologies: KPMG report, 2016

42. Cooper, D.F., MacDonald, D.H. and Chapman, C.B. (1985) "Risk analysis of a construction cost estimate" International Journal of Project Management 3(3), 141–14

43. Dan BENTA (2011). Software development and risk management in complex projects (Doctoral Thesis). BABES-BOLYAI UNIVERSITY OF CLUJ-NAPOCA, September2011.

44. David James Bryde, and Jurgen Marc VolM, (2009), 'Perceptions of owners in German construction projects: congruence with project risk theory', Construction Management and Economics(November2009)27, 1059-1071, ISSN 0144-6193 print/ISSN 1466-433X online O 2009 Taylor & Francis, DOI:10.1080/01446190903222403

45. Dey, K.P. (2001), "Decision Support System for Risk Management: A case study" Management Decision 39(8) 634-649

46. Dey, P.K. and Ogunlana, S.O. (2002) "Risk based Decision Support System for Effective Implementation of Projects" International Journal of Risk Assessment & Management Vol. 3, pp. 189 – 204.

47. Dikmen, I. and Birgonul, M.T (2006) "An analytic hierarchy process based model for risk and opportunity assessment of international construction projects" Canadian Journal of Civil Engineering 33(1), 58-68.

48. Dindar, S., Kaewunruen, S., &An, M. (2018). Identification of appropriate risk analysis techniques for railway turnout systems. Journal of Risk Research, 21(8), 974-995.

49. Dinesh Bhatia, M. R. Apte (2016). Schedule Ovemin and Cost Overrun In the Construction of Private Residential Construction Project: Case Study of Pune India. International Journal of Technical Research and Applications, e-ISSN: 2320-8163, www.ijtra.com Volume 4, Issue 2 (March-April, 2016), PP.174-177.

50. Dione, S., Ruwanpura, J. Y., & Hettiaratchi, J. P. (2005). Assessing and managing the potential environmental risks of construction projects. Practice Periodical on Structural Design and Construction, 10(4), 260-266.

51. Doloi, H., Sawhney, A., Iyer, K. C., &Rentala, S. (2012). Analysing factors affecting delays in Indian construction projects. International Journal of Project Management, 30(4), 479–489. https://doi.org/10.1016/j.ijproman.2011.10.004

52. Dr. Dan Patterson, (2006). Managing Project Cost Risk. AACE International Transactions, 2006 - IT.05, page1-7.

53. Dr. Prasad S. Kodukula (2014). Organizational Project Portfolio Management - A Practitioner 's Guide J. Ross Publishing Inc., ISBN: 978-1-932159-42-4

54. Dziadosz, A., Tomczyk, A., &Kapliński, O. (2015). Financial Risk Estimation in Construction Contracts. Procedia Engineering, 122(Orsdce), 120–128. https://doi.org/10.1016/j.proeng.2015.10.015

55. Edwards, P. J., & Bowen, P. A. (1998). Risk and risk management in construction: a review and future directions for research. Engineering Construction and Architectural Management, 5(4), 339-349.

56. EkaterinaOsipova(2008).’Risk management in construction projects : a comparative study of the different procurement options in Sweden. LICENTIATE IS2008:15.

57. El-Sayegh, S. M. (2008). Risk assessment and allocation in the UAE construction industry. International Journal of Project Management, 26(4), 431–438. https://doi.org/10.1016/j.ijproman.2007.07.004

58. Enshassi, A., Mohamed, S., & Abushaban, S. (2009). Factors affecting the performance of construction projects in the Gaza strip. Journal of Civil engineering and Management, 15(3), 269-280.

59. Ertel,D.,&Rudner,S.(2000).Scope change negotiations : Are write-off inevitable? Consulting to Management, 11 (2):3-8.

60. Fabiola Nibyiza(2015).Analysis of project scope change management as a tool for project success - case study of Akazi Kanoze projects. A research project report Kenyatta University of Agriculture And Technology Kigali Campus).

61. Fasoranti, M. M. (2012). The effect of government expenditure on infrastructure on the growth of the Nigerian economy, 1977-2009. International Journal of Economics and Financial Issues, 2(4), 513-518.

62. Flynn, L. R., & Pearcy, D. (2001). Four subtle sins in scale development: some suggestions for strengthening the current paradigm. International Journal of Market Research, 43(4), 1-14.

63. Franke, A. (1987), "Risk analysis in project management", International Journal of Project Management 5(1), 29-34

64. Gajewska, E., & Ropel, M. (2011). Risk Management Practices in a Construction Project–a case study. Swedia, Chalmers University Of Technology.

65. GCP, G. C. P., & Economics, O. (2015). Global Construction 2030: A Global Forecast for the Construction Industry to 2030. Global Construction Perspectives and Oxford Economics: London, UK.

66. Gibson Jr, G.E., Wang, Y.R., Cho,C.S., & Pappas, M.P.(2006). What Is Pre-project Planning, Anyway? Journal of management in engineering, 22(1), pp.35-42.

67. Goh, C. S., Abdul-Rahman, H., & Abdul Samad, Z. (2013). Applying risk management workshop for a public construction project: Case study. Journal of Construction Engineering and Management, 139(5), 572-580.

68. Grigoriou, C. (2007). Landlockedness, Infrastructure and trade: new estimates for central Asian countries. The World Bank.

69. Guadagnoli, E., &Velicer, W. F. (1988). Relation of sample size to the stability of component patterns. Psychological bulletin, 103(2), 265.

70. Hans Thamhain, (2013). Managing Risks in Complex Projects. Project Management

71. Hariharan, S., & Sawant, P. H. (2012). Analysis of Relationship between Time and Cost Overruns in Some Infrastructure Projects. NICMAR Journal Of Construction Management, 27(2), 5-16.

72. Henry Alinaitwel, Ruth Apolotand Dan Tindiwensi (2013).Investigation into the Causes of Delays and Cost Overruns in Uganda's Public Sector ConstructionProjects.JournalofConstructioninDevelopingCountries, 18(2), 33-47,2013.

73. Hillson, D. (2002) “Extending the risk process to manage opportunities” International Journal of Project Management 20, 235–240.

74. Hillson, D., & Simon, P. (2007). Practical project risk management. The ATOM methodology. Vienna, Virginia: Management Concepts, chapter 1, the challenges of managing the risk, 03-07.

75. Hinkin, T. R. (1998). A brief tutorial on the development of measures for use in survey questionnaires. Organizational research methods, 1(1), 104-121.

76. Hsueh, S.L., Perng, Y.H., Yan, M.R. and Lee, J.R. (2007) “On-line multi-criterion risk assessment model for construction joint ventures in China” Automation in Construction 16, 607–619

77. httos://www.pmi.ore/learning/librarv/triple-constraints-success-additional-factors-6591

78. http://www.xinhuanet.com/english/2018-09/09/c_137455844.htm

79. https://tradingeconomics.com/jordan/gdp-from-construction

80. https://www.constructionweekonline.com/article-49769-omani-construction-will-grow-faster-next-year

81. https://www.export.gov/article?id=United-Arab-Emirates-Construction

82. https://www.ibef.org/industry/infrastructure-sector-india.aspx

83. https://www.kenresearch.com/manufacturing-and-construction/infrastructure/construction-egypt-key-trends-opportunities/142358-97.html

84. https://www.khl.com/international-construction/saudi-arabia-construction-sector-to-increase-4/135454.article

85. https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/WESP2018_Full_Web-1.pdf

86. https://www.worldconstructionnetwork.com/opinion/qatar-gulf-crisis-and-its-impact-on-construction

87. Hull, J.K. (1990) “Application of risk analysis techniques in proposal assessment” International Journal of Project Management 8(3), 152–157.

88. ICE and Faculty and Institute of Actuaries (1998), Risk Analysis and Management for Projects, Thomas Telford, London.

89. Imbeah, W., & Guikema, S. (2009). Managing construction projects using the advanced programmatic risk analysis and management model. Journal of construction engineering and management, 135(8), 772-781.

90. Jha, K. N., & Devaya, M. N. (2008). Modelling the risks faced by Indian construction companies assessing international projects. Construction Management and Economics, 26(4), 337-348.

91. K. Deeppa & I. Krishnamurthy (2014), Analysis of time and cost overrun in infrastructure projects in India, NICMAR-Journal of construction management, Vol XXIX No 3 July-September 2014

92. Kangari, R. and Riggs, L.S (1989) "Construction Risk Assessment by Linguistics" IEEE Transaction on Engineering Management 36(2), 126-131.

93. Karimi Azari, A., Mousavi, N., Mousavi, S. F., & Hosseini, S. (2011). Risk assessment model selection in construction industry. Expert Systems with Applications, 38(8), 9105-9111.

94. Keane, P. J. and Caletka, A. F. (2008). Delay Analysis in Construction Contracts. Oxford, system. In Proceedings of the Eastern Asia Society for Transportation Studies (Vol. 5, pp. 175-189).Vol41,Issue10,pp.118—6

95. Keane, P. J., &Caletka, A. F. (2015). Delay analysis in construction contracts. John Wiley & Sons.

96. Kessides, C. (1993). The contributions of infrastructure to economic development: A review of experience and policy implications. The World Bank

97. Khodeir, L. M., & Mohamed, A. H. M. (2015). Identifying the latest risk probabilities affecting construction projects in Egypt according to political and economic variables. From January 2011 to January 2013. HBRC Journal, 11(1), 129–135. https://doi.org/10.1016/j.hbrcj.2014.03.007

98. Kim, S. Y., Van Tuan, N., & Ogunlana, S. O. (2009). Quantifying schedule risk in construction projects using Bayesian belief networks. International Journal of Project Management, 27(1), 39-50.

99. Kim, S. Y., Van Tuan, N., & Ogunlana, S. O. (2009). Quantifying schedule risk in construction projects using Bayesian belief networks. International Journal of Project Management, 27(1), 39-50.

100. Klemetti, A. (2006). Risk management in construction project networks.

101. KPMG/PMI report on time and cost overruns of Infrastructure projects.

102. Kumar R (1999). Research Methodology — a step by step guide for beginners, 1" edition’, SAGE Publications Ltd., London, 1999

103. Lakshmanan, T. R. (2011). The broader economic consequences of transport infrastructure investments. Journal of transport geography, 19(1), 1-12.

104. Lakshmanan, T. R., & Anderson, W. P. (2007). Transport's role in regional integration processes.

105. Latham, Sir, M, (1994) Constructing the team: final report joint review of procurement & contractual arrangements in the UK construction industry. H. M. S. O

106. Laura Walker, Peter Walker, Brian Francis(2014).A Common Scheme for Cross-Sensory Correspondences across Stimulus Domains. Perception,

107. Le-Hoai, L., Dai Lee, Y., & Lee, J. Y. (2008). Delay and cost overruns in Vietnam large construction projects: A comparison with other selected countries. KSCE journal of civil engineering, 12(6), 367-377.

108. Ling, F. Y. Y., & Hoi, L. (2006). Risks faced by Singapore firms when undertaking construction projects in India. International journal of project management, 24(3), 261-270.

109. Liu, J. Y., & Low, S. P. (2009). Developing an organizational learning-based model for risk management in Chinese construction firms. Disaster Prevention and Management: An International Journal.

110. Liu, J. Y., Zou, P. X., & Gong, W. (2013). Managing project risk at the enterprise level: Exploratory case studies in China. Journal of Construction Engineering and Management, 139(9), 1268-1274.

111. Liu, J., Li, B., Lin, B., & Nguyen, V. (2007). Key issues and challenges of risk management and insurance in China's construction industry. Industrial Management & Data Systems.

112. Liu, J., Meng, F., & Fellows, R. (2015). An exploratory study of understanding project risk management from the perspective of national culture. International Journal of Project Management, 33(3), 564-575.

113. Love, P. E. D., Edwards, D. J., & Smith, J. (2005). Contract documentation and the incidence of rework in projects. Architectural Engineering and Design Management, 1(4),247-259.

114. MacCallum, R. C., Widaman, K. F., Zhang, S., & Hong, S. (1999). Sample size in factor analysis. Psychological methods, 4(1), 84.

115. Merna, A., & Merna, T. (2004). Development of a model for risk management at corporate, strategic business, and project levels. The Journal of Structured Finance, 10(1), 79-85.

116. Mills, A. (2001). A systematic approach to risk management for construction. Structural survey, 19(5), 245-252.

117. Ministry of Statistics and Programme Implementation (Infrastructure & Project Monitoring Division) Flash Report for December 2018 release

118. Mohamed K. Khedr, (2006). Project Risk Management Using Monte CarloSimulation.2006AACEInternationalTransactions,RISK.02, page 1-10.

119. Morcos, A. (2001). Risk management critical to effective project development. Power Engineering, 105(5), 45-45.

120. Motaleb, O and Kishk, M, (2010) 'An Investigation Into Causes And Effects Of Construction Delays In UAE', Egbu, C. tEd) Procs 26th Annual ARCOMConference,6-8September2010,Leeds,UKAssociation of Researchers in Construction Management,1149-1157.

121. Mustafa, M.A. and Al-Bahar, J.F. (1991) "Project Risk Analytic Assessment Using the Hierarchy Process" IEEE Transaction on Engineering Management 38(1), 46-52.

122. Nadiri, M. I., & Mamuneas, T. (1996). Contribution of highway capital to industry and national productivity growth.

123. Naeni, L. M., &Salehipour, A. (2011). Evaluating fuzzy earned value indices and estimates by applying alpha cuts. Expert systems with Applications, 38(7), 8193-8198.

124. Nag, B., Singh, J., & Tiwari, V. (2012). Choosing the appropriate project management structure, project financing, land acquisition and contractual process for Indian railway mega-projects: a case study of the Dedicated Freight Corridor project. Journal of Project, Program & Portfolio Management, 3(2), 39-54.

125. Nag, B., Singh, J., & Tiwari, V. (2012). Choosing the appropriate project management structure, project financing, land acquisition and contractual process for Indian railway mega-projects: a case study of the Dedicated Freight Corridor project. Journal of Project, Program & Portfolio Management, 3(2), 39-54.

126. Nahod, M.M. (2012). Scope Control Through Managing Changes in Construction Projects. Organization, Technology And Management In Construction An International Journal 4(1)2012, pp438-447

127. Nataraj, G. (2014). Infrastructure Challenges in India: The Role of Public-Private Partnerships. Observer Research Foundation.

128. Nicholas, J.M. (2007) Project Management for Business and Technology: Principles and Practice, Second edition, Pearson Prentice Hall, New Delhi

129. Nieto-Morote, A., & Ruz-Vila, F. (2011). A fuzzy approach to construction project risk assessment. International Journal of Project Management, 29(2), 220-231.

130. Ogunsanmi, O. E., Salako, O. a, & Ajayi, O. M. (2011). Risk Classification Model for Design and Build Projects. Journal of Engineering, Project, and Production Management, 1(1), 46–60. https://doi.org/10.1080/01446190110066146

131. Osama Abbas Hussain, D. (2012). Direct Cost Of Scope Creep In Governmental Construction Projects In Qatar. Global Journal Of Management And Business Research, 72(14). Retrieved from httos://iournalofbusiness.ore/index.php/GJMBR/article/view/775

132. Osipova, E. (2008). Risk management in construction projects: a comparative study of the different procurement options in Sweden (Doctoral dissertation, Luleå tekniska universitet).

133. Paul Newton (2015). Managing Project Scope : Project skills

134. Perez-Gonzalez, Francisco and Yun, Hayong (2010). Risk Management and Firm Value: Evidence from Weather Derivatives. AFA 2010 Atlanta Meetings Paper. Available at SSRN: https://ssrn.com/abstract=1357385 or http://dx.doi.org/10.2139/ssrn.1357385

135. PMI – KPGM report on Revamping Project management (2019)

136. PMI-KPMG Study on Drivers for Success in Infrastructure Projects, (2010) Managing for Change, dated 2010

137. Project Management in India; Insights from Six Key Sectors, FICCI and PMI reports (2014)

138. QAQISH, T. (2011). Cost Risk Management for a Small to Medium-sized Enterprise in the Cladding Industry (Doctoral dissertation, Durham University).

139. Qing, L., Rengkui, L., Jun, Z., &Quanxin, S. (2014). Quality risk management model for railway construction projects. Procedia Engineering, 84, 195-203.

140. Queiroz, C., & Gautam, S. (1992). Road Infrastructure and Economic Development. Western Africa Department and Infrastructure and Urban Development Department, World Bank: Washington, DC.

141. Rahschulte, T. J. & Milhauser, K. (2010). Beyond the triple constraints: nine elements defining project success today. Paper presented at DOORGlobal Congress 2010 - North America, Washington, DC.

142. Rakesh, J. & Hariharan, S. (2014). Critical Risk Attributes In Public Private Partnership Projects In India. NICMAR Journal Of Construction Management, Special Issue, 109-124

143. Ramanathan, C., Narayanan, S. P., & Idrus, A. B. (2012). Construction delays causing risks on time and cost-a critical review. Construction Economics and Building, 12(1), 37-57.

144. Rathi, A. S., & Khandve, P. V. (2014). Study of factors influencing cost overruns: An overview. Int. J. Sci. Research (IJSR), 5, 334.

145. Ren, Z., Atout, M., & Jones, J. (2008, September). Root causes of construction project delays in Dubai. In Procs 24th Annual ARCOM Conference (pp. 1-3).

146. Renuka S.M.,Umarani C., Kamal S.,(2014).A Review on CriticalRisk Factors in the Life Cycle of Construction Projects. Journal of Civil Engineering Research, p-ISSN: 2163-2316 e-ISSN:2163-2340,

147. Rita Mulcahy (2010). Risk Management Tricks of the Trade for Project Managers,Second Edition. RMC Publications Inc.,ISBN978-1-932735-32-1

148. Roetzheim. W. (1988) Structured Computer Project Management, Prentice Hall, New Jersy

149. Royer, P. S. (2000). Risk management: The undiscovered dimension of project management. Project Management Journal, 31(1), 6-13.

150. Rummel, R. J. (1970). Understanding factor analysis. Journal of conflict resolution, 11(4), 444-480.

151. Salanke, P. V., & El-Gafy, M. Model Construction Schedule Delays: A Bayesian Belief Networks Approach.

152. Sangsomboon, P., & Yan, S. (2014). Analysis of Risk-Response based on Railroad Construction Project. International Journal of Management Sciences and Business Research, 3.

153. Sarkar, D. (2011). Simulation application in project risk management for infrastructure transportation project. International Journal of Project Organisation and Management, 3(3-4), 374-392.

154. Sarkar, D., & Dutta, G. (2011). A framework of project risk management for the underground corridor construction of metro rail. International Journal of Construction Project Management, 4(1), 21-38.

155. Sedat Han (2005). Estimation of Cost Overrun Risk in International Projects by Using Fuzzy Set Theory (Master's thesis), Middle East Technical University, Turkey, 2005 Retrieved fromhtto://citeseerx.ist.osu.edu/viewdoc/download?doi=10.1.1.633.4269&reo=reo1&tvoe=odf.

156. Senouci, A., Ismail, A., & Eldin, N. (2016). Time Delay and Cost Overrun in Qatari Public Construction Projects. Procedia Engineering, 164(June), 368–375. https://doi.org/10.1016/j.proeng.2016.11.632

157. Seyedhoseini, S. M., Noori, S., & Hatefi, M. A. (2009). An integrated methodology for assessment and selection of the project risk response actions. Risk Analysis: An International Journal, 29(5), 752-763.

158. Shang, H., Anumba, C.J., Bouchlaghem, D.M., Miles, J.C., Cen, M. and Taylor, M. (2005) "An intelligent risk assessment system for distributed construction teams" Engineering, Construction and Architectural Management 12(4) 391-409

159. Simister, S. 1994. Usage and Benefits of Project Risk Analysis and Management. International Journal of Project Management, 12, 5–8.

160. Skorupka, D. (2003). Risk management in building projects. AACE International Transactions, RI191.

161. Sullivan, G. M., & Artino Jr, A. R. (2013). Analyzing and interpreting data from Likert-type scales. Journal of graduate medical education, 5(4), 541-542.

162. Sunduck, D., Keun-Yul, Y. A. N. G., Jae-Hoon, L. E. E., &Byung-Min, A. H. N. (2005). Effects of Korean Train Express (KTX) operation on the national transport

163. Sunjka, B. P., & Jacob, U. (2013). Significant causes and effects of project delays in the Niger delta region, Nigeria. Southern African Institute of Industrial Engineering.

164. Sutterfield, J. S., Friday-Stroud, S. S., & Shivers-Blackwell, S. L. (2006). A case study of project and stakeholder management failures: lessons learned. Project Management Journal, 37(5), 26-35. Retrieved from: https://www.pmi.org/learning/library/project-stakeholder-management- failures-lessons-learned-5544

165. Sweis, G., Sweis, R., Abu Hammad, A., &Shboul, A. (2008). Delays in construction projects: The case of Jordan. International Journal of Project Management, 26(6), 665–674. https://doi.org/10.1016/j.ijproman.2007.09.009

166. Tah, J. H. M., & Carr, V. (2000). Information modelling for a construction project risk management system. Engineering Construction and Architectural Management, 7(2), 107-119.

167. Tang, W., Qiang, M., Duffield, C. F., Young, D. M., & Lu, Y. (2007). Risk management in the Chinese construction industry. Journal of construction engineering and management, 133(12), 944-956.

168. Tang, W., Qiang, M., Duffield, C. F., Young, D. M., & Lu, Y. (2007). Risk management in the Chinese construction industry. Journal of Construction Engineering and Management, 133(12), 944–956. https://doi.org/10.1061/(ASCE)0733-9364(2007)133:12(944)

169. Themistocleous, G., and Wearne, S.H. (2000). Project Management Topic Coverage in Journals. International Journal of Project Management, 18, 7–11

170. Thomas, A. V., Kalidindi, S. N., & Ananthanarayanan, K. A. B. T. (2003). Risk perception analysis of BOT road project participants in India. Construction Management and Economics, 21(4), 393-407.

171. Thomas, A. V., Kalidindi, S. N., & Ananthanarayanan, K. A. B. T. (2003). Risk perception analysis of BOT road project participants in India. Construction Management and Economics, 21(4), 393-407.

172. Tom Kendrick(2015).Identifying and Managing Project Risk :Essential Tools for Failure-proofing Your Project, 3'dEdition. Amacom, ISBN 0814436080, 9780814436080, 390pages.

173. Tsuda, A. (2006). Are the triple constraints still useful? Retrieved from http://svprojectmanagement.com/are-the-triple-constraints-still-useful

174. Van Beest, O. M. (2003). The risk management of construction project's consent availability. AACE International Transactions, RI201.

175. Veal, Anthony James (1997). Research Methods for Leisure and Tourism: A Practical Guide. Pitman [in association with] Institute of Leisure and Amenity Management, 1997, 320 pages

176. Vidivelli, K. J. D. B., & Surjith, E. G. (2014). Risk Assessment and Management in Construction Projects. International Journal of Scientific & Engineering Research, 5(8), 387-396.

177. Virginia A. Greiman (2013).Mega project Management: Lessons on Risk and Project Management from the Big Dig. John Wiley & Sons, 2013, 496 pages, ISBN 1118416341,9781118416341

178. Walke, R. C., & Topkar, V. (2012). Risk Quantification Model for Construction Projects using Score Model and EV Analysis approach. International Journal of Engineering Research and Applications, 2312-2317.

179. Walke, R. C., Topkar, V. M., & Matekar, N. U. (2011). An Approach to risk quantification in construction projects using EMV analysis. International Journal of Engineering Science and Technology, 3(9), 6847-6855.

180. Wang, M.-T., & Chou, H.-Y. (2003). Risk Allocation and Risk Handling of Highway Projects in Taiwan. Journal of Management in Engineering, 19(2), 60–68. https://doi.org/10.1061/(ASCE)0742-597X(2003)19:2(60)

181. Wang, S. Q., Dulaimi, M. F., &Aguria, M. Y. (2004). Risk management framework for construction projects in developing countries. Construction Management and Economics, 22(3), 237–252. https://doi.org/10.1080/0144619032000124689

182. Wang, X., Li, Y., & Foo, C. T. (2014). Towards sustainability in the high-speed railway industry: modeling of cases from China. Chinese Management Studies.

183. Williams, B. (2012). Exploratory Factor Analysis: A Five-Step Guide. Australasian Journal of Paramedicine, 8(3).

184. Wood, G. D., & Ellis, R. C. (2003). Risk management practices of leading UK cost consultants. Engineering, Construction and Architectural Management.

185. www.cag.gov.in/sites/default/files/press_release/48of2015.pdf - CAG report on Status of Ongoing Projects in Indian Railways, June 2015

186. www.free-management-ebooks.com, ISBN 978-1-62620-980-7.

187. www.investindia.gov.in/sector/construction (Accessed 8th June 2019).

188. Yang, R. J., Zou, P. X., & Wang, J. (2016). Modelling stakeholder-associated risk networks in green building projects. International journal of project management, 34(1), 66-81.

189. Zack, J. G. (2003). Schedule delay analysis; is there agreement? Proceedings of PMI-CPM College of Performance Spring Conference. May7-9,2003.New Orleans: Project Management Institute—College of Performance Management.

190. Zeynalian, M., Trigunarsyah, B., & Ronagh, H. R. (2013). Modification of advanced programmatic risk analysis and management model for the whole project life cycle's risks. Journal of construction engineering and management, 139(1), 51-59.

191. Zhao, X., Hwang, B. G., & Low, S. P. (2013). Critical success factors for enterprise risk management in Chinese construction companies. Construction Management and Economics, 31(12), 1199-1214.

192. Zhi, H. (1995) "Risk management for overseas construction projects" International Journal of Project Management 13(4), 231-237.

193. Zou, P. X. W., Zhang, G., & Wang, J. (2007). Understanding the key risks in construction projects in China. International Journal of Project Management, 25(6), 601–614. https://doi.org/10.1016/j.ijproman.2007.03.001 10.1068!p7149

194. Zou, P. X., Zhang, G., & Wang, J. (2007). Understanding the key risks in construction projects in China. International journal of project management, 25(6), 601-614.

EXIBHIT 01

QUESTIONNAIRE SURVEY 01

Identification of critical risk factors responsible for overruns in completion of railway construction Projects

Dear respondent,

You are requested to participate in this research study on identification of critical risk factors responsible for overruns in completion of railway construction Projects. I would be grateful if you could complete following questionnaire.

Please note the following:

- You are requested to provide complete answers; this should not take you more than 10 minutes.
- This research study involves an anonymous survey. You cannot be identified by person based on the answers you give.
- You would be provided with a summary of the findings on request.
- The results may be published locally or internationally, and the results of the study might also be considered for future research purposes.

SECTION A: PERSONAL INFORMATION

Part 01

Name of the Respondent	:	____________________
Designation	:	____________________
Total Years of work experience	:	____________________
Qualification	:	____________________
Name of the Company	:	____________________
Address	:	____________________
E-mail I.D.	:	____________________
Telephone and Mobile No.	:	____________________
Name of the Project	:	____________________
Department and	:	____________________
(Presently working)	:	____________________

Part 02

A. **Your company's role as a stakeholder's** (Please choose by (✓) in the appropriate box)

Client	Client's representative	Consultants	Contractor's	Other if any, Please specify

B. Type of Railway Project

Based on your past experience please indicate which of the following railway projects were part of your professional exposure. Please choose by (✓) in the appropriate box. You may tick on every type of projects where you have worked in the past.

New Lines (NL)	Doublings (DL)	Gauge Conversion (GC)	Other if any, Please specify

C. Project Life Cycle Stage

While Handling any Infrastructure Development Project undertaken by your Company, in which stages of Project Life Cycle you are normally involved. You may tick on every area where you have worked in the past.

Project Life Cycle Stage	**Choose (P)**
Concept and feasibility Study	
Funding Raising and Financial Closure	
Scope, Tendering / Bidding and Award	
Project Planning and Main Procurement	
Contract Execution, Monitoring and Control	
Contract closure and claims settlement	
Project Operations and Maintenance	

SECTION B:

IDENTIFICATION OF CRITICAL RISK FACTORS

Please respond to the Risks listed below, which are likely to be faced; kindly rate them as per your opinion and experience. The Five point Llikert scale as shown below has been used to understand the respondent's opinion for different factors.

Rating/scale	1	2	3	4	5
Risk criticality	Not at all concerned	Slightly concerned	Somewhat concerned	Moderately concerned	Extremely concerned

		RATING				
CATEGORY	**RISK VARIABLES**	**1**	**2**	**3**	**4**	**5**
EXTERNAL	Approvals and clearances					
	Land acquisition & site handover					
	Environmental & Tree Cutting					
	Changes in regulations and laws					
	Social and Cultural influences of workmanships					
	Issues in interstate or Central to state coordination					
	Traffic control and restriction at job site					
	Pollution and Safety compliances					
	Rehabilitation & Resettlement					
NATURAL	Flood					
	Earthquake					
	Landslide					
	Unexpected weather conditions					
DESIGN	Mistakes and inadequate details					
	Delays in producing design documents					
	Complexity of project design					
	Incomplete investigation & studies					
	Misunderstanding of Client's requirements by design engineer					
	Differing ground conditions					
	Inadequate design-team experience					
FINANCE / ECONOMIC	High interest rate					
	Inaccurate project cost estimating					

		RATING				
CATEGORY	RISK VARIABLES	1	2	3	4	5
	Inflation / price fluctuation					
	Unavailability of incentive clause for early completion					
	Cash flow of project					
	Profit rate of project					
	Cost of rework					
	Cost of variation/Change orders					
	Change in currency price					
	Availability of Funds from lenders					
	Exchange Rate Fluctuation					
	Financial Default of Contractor/Subcontractor					
PMC CONSULTANT	Incomplete contract details					
	Week design coordination and delay in communication					
	Slow response to technical queries					
	Delay in inspection					
	Level of involvement in quality control					
	Change in scope of work					
	Delay in approving major changes					
	Delay in claim approval					
	Deployment of technical staff on site					
	Inadequate definition of substantial completion					
	Lack of systematic engineering method to identify the time					
QUALITY	Site Supervision, QA/QC					
	Quality assessment system in organization					
	Implementation of method statement					
SAFETY	Accidents and Labour Injuries					
	Damage to Utilities beneath ground					
	Theft of material and equipment's					
	Safety process of organization					
	Project location is safe to reach					
CONTRACTOR	Lack of technical professionals					
	Lack of coordination					
	Delay in mobilization					
	Poor planning, scheduling or resource management					

CATEGORY	RISK VARIABLES	1	2	3	4	5
	Lack of experience of similar projects					
	Shortage of labour					
	Inadequate skills of manpower and Low productivity					
	Contractors cash flow					
	Irregular payments of sub-contractors					
	Construction Work Permits					
	Strike					
	Conflicts between contractor, consultant and owner					
	Improper construction methods implemented by contractor					
	Delays in sub-contractors work					
	Poor site management and supervision					
	Lack of Training personnel for model construction operation					
	Inaccurate tender cost estimating					
	Shortage of equipment					
	Low productivity and efficiency of equipment					
	Lack of high-technology mechanical equipment					
	Shortage of materials					
	Delay in material procurement and delivery					
CLIENT	Frequent interference					
	Unrealistic contract duration					
	Financial difficulties & Irregular payments of work done					
	Delay in approvals					
	Learning from best practice and experience of others					
	Delay in Decision making					
	Lack of capability of client representative					
	Suspension of work by owner					
	Breach or modifications of contract by owner					
	Delay in performing final inspection and certification					

EXHIBIT 02

QUESTIONNAIRE SURVEY 02

Identification of the Probability, Impact and weightages of Critical risk factors on construction activities of a railways project

Dear respondent,

You are requested to participate in this research study on *Identification of the Probability (P), Impact (I) and weightages (W) of Critical risk factors on construction activities for a railways project*. I would be grateful if you could complete the following questionnaire.

Please note the following:

- You are requested to provide complete answers; this should not take you more than 15 minutes.
- This research study involves an anonymous survey. You cannot be identified by a person based on the answers you give.
- You would be provided with a summary of the findings on request.
- The results may be published locally or internationally, and the results of the study might also be considered for future research purposes.
- *You are requested to fill the details in sheet no 01 and sheet no 04*

PERSONAL INFORMATION

Name of the Respondent : ______________________________

Designation : ______________________________

Total Years of work experience : ______________________________

Qualification : ______________________________

Name of the Company : ______________________________

E-mail I.D. : ______________________________

Telephone and Mobile No. : ______________________________

Name of the Project : ______________________________

Department : ______________________________

(Presently working) ______________________________

Interpretation of the various risk factors

Contractor Specific risks

Shortage of equipment, efficiency of equipment, Lack of high-technology, Shortage of materials, Delay in material procurement and delivery, Lack of experience, cash flow, Financial Default, Irregular payments of sub-contractors, Technical competency, Coordination with subcontractors, Delay in mobilization, Manpower, Poor planning, scheduling or resource management, Congested construction site, Inadequate skilled manpower, Low productivity, Work Permits, Conflicts, Construction methods, Sub-contractors Performance, Poor site management, Training personnel, Inaccurate tender cost estimating

Management consultant Specific risks

Week design coordination, Delay in response to RFI, Delay in inspection, quality control, Change in scope, Delay in approving changes, Delay in claim approval, Deployment of technical staff, Inadequate definition of substantial completion, Lack of systematic engineering methods to identify the time

Client related risk

Frequent interference, Unrealistic contract duration, Financial difficulties & Irregular payments, Delay in approvals, Permissions & statutory clearances, lack of learning from best practice and experience of others, Delay in Decision making, Lack of capability of client representative, Suspension of work, Breach or modifications of contract, Delay in performing final inspection and certification

Design related risk

Mistakes and inadequate details, Delays in producing design documents, Complex project design, Incomplete investigation and survey and feasibility studies, Misunderstanding of Client's requirements, Unforeseen or Differing site conditions, Inadequate experience, Inaccurate project cost estimating, Inflation/price fluctuation, Incomplete contract details

Safety & security-related risk

Pollution and Safety compliance, accidents and labour Injuries, damage to existing Structure (Utilities beneath the ground), Theft of material and equipment's, Safety assessment system in the organization, Project location is safe to reach.

Financial risk - High-interest rate, Cost of variation/Change orders, Change in currency price, Availability of Funds from lenders, Exchange Rate Fluctuation

Nature related risk - Flood, earthquake, landslide and unexpected weather conditions

Government approvals and site clearances risk - Approvals and clearances, Land acquisition & site handover, Environmental & Tree Cutting, Changes in government regulations and laws and Rehabilitation & Resettlement of affected families

Quality related risk - Site Supervision, Quality assurance & Control and Quality assessment system in organization and Implementation of the method statement

Risk related to Contracts - Unavailability of incentive clause for early completion, Cash flow of project & Profit rate of project and Cost of rework

Fundamental risk - Social and Cultural influences of workmanship, Issues in interstate or central to state coordination, Strike, Traffic control and restriction at the job site

SCALE TO BE USED

WEIGHTAGE

The value of weightage should be in between 0 to 1. Summation of all the weightages to an activity should be equal to 01. The value of *probability and Impact* should be in between 0 to 1 as per the above details

PROBABILITY

Scale	Very Low	Low	Medium	High	Very High
Description	Rare	Unlikely	Possible	Likely	Almost certain
Descriptor	Less than one0 in every 20 project	One in every 20 project	One in every 10 project	One in every 04 project	Even Chance
Probability	1-10%	11-30%	31-50%	51-70%	71-99%
Values	.01 - 0.1	0.11 - 0.3	0.31 - 0.5	0.51 - 0.7	0.71 - 0.99

IMPACT

Scale	Very Low	Low	Medium	High	Very High
Values	.01 - 0.2	0.21-0.4	0.31 - 0.5	0.51 - 0.7	0.71 - 0.99
Time	Delayed by by less than 1%	Delayed by by 02 to 05%	Delayed by by 06 to 10%	Delayed by by 10 to 20%	Delayed by by 21 to 40%
Cost	Over budget less than 1%	Over budget by 02 to 05%	Over budget by 06 to 10%	Over budget by 10 to 20%	Over budget by 21 to 40%

The value of ***Probability & Impact*** should be in between 0 to 1 as per the above details.

Activities and risk factors relationship	Contractor Specific			PMC Consult. Specific			Client Specific			Design Specific			Safety & security			Financial risk			Nature specific			Approval & site clearance			Quality			Contract specific			Fundam-ental		
Activities	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**
Mobilization and Commencement																																	
Site survey and Investigations																																	
Approvals for General Arrangements Drawing																																	
Approvals for formation (C/S & L section, Drainage and other structures)																																	
Utility shifting and Tree cutting																																	
Barricades (safety)																																	
Toe wall and Drainage work																																	
Earthwork for formation																																	
Foundation work for Electric pole																																	
Pole Erection and fixing																																	
HT wiring works																																	
Signaling & Tele-communication work																																	
Subgrade Blanketing																																	
Ballast Spreading																																	
Sleeper Laying																																	
Rail laying & Fixing																																	
Temping and Compaction																																	
Rail Destressing																																	
Dressing and Boxing																																	
Documentation for CRS Inspection																																	
Commissioning, Inspection & Handover																																	

W – Weightage **P - Probability** **I – Impact**

Instruction – The detail to be filled only in the white cells. It is requested to provide the details in the sequence of Weightage, Probability & Impact respectively. It means that at the first, details of weightages (W) of all the risk factors of an activity to be filled than the probability of occurrence (P) and at the end the Impact (I) of the all factors to be filled.

EXHIBIT 03

RISK MANAGEMENT DASHBOARD

EXHIBIT 3.1

DASHBOARD: IDENTIFICATION

Sr.	Risk Factor Code	Risk Factor	Risk Variable Code	Variables
1	RF1	Contractor Specific	RF1V1	Financial Default of Contractor/Subcontractor
2			RF1V2	Lack of technical professionals
3			RF1V3	Lack of coordination with subcontractors
4			RF1V4	Delay in mobilization
5			RF1V5	Poor planning, scheduling or resource management
6			RF1V6	Congested construction site
7			RF1V7	Lack of experience of similar projects
8			RF1V8	Shortage of manpower
9			RF1V9	Inadequate skills of manpower and Low productivity
10			RF1V10	Contractors cash flow
11			RF1V11	Irregular payments of sub-contractors
12			RF1V12	Construction Work Permits
13			RF1V13	Conflicts between contractor, consultant and owner
14			RF1V14	Improper construction methods implemented by contractor
15			RF1V15	Delays in sub-contractors work
16			RF1V16	Poor site management and supervision
17			RF1V17	Lack of Training for model construction operation
18			RF1V18	Inaccurate tender cost estimating
19			RF1V19	Shortage of equipment
20			RF1V20	Low productivity and efficiency of equipment
21			RF1V21	Lack of high-technology mechanical equipment
22			RF1V22	Shortage of materials
23			RF1V23	Delay in material procurement and delivery
24	RF2	PMC related risk	RF2V1	Week design coordination and delay in communication
25			RF2V2	Slow response of technical query
26			RF2V3	Delay in inspection
27			RF2V4	Level of involvement in quality control
28			RF2V5	Change in scope of work
29			RF2V6	Delay in approving major changes
30			RF2V7	Delay in claim approval
31			RF2V8	Deployment of technical staff on site
32			RF2V9	Inadequate definition of substantial completion
33			RF2V10	Lack of systematic engineering method to identify the time
34	RF3	Owner related risk	RF3V1	Frequent interference
35			RF3V2	Unrealistic contract duration imposed by client
36			RF3V3	Financial difficulties & Irregular payments of work-done
37			RF3V4	Delay in Permissions, approvals & statutory clearances
38			RF3V5	Learning from best practice and experience of others
39			RF3V6	Delay in Decision making
40			RF3V7	Lack of capability of client representative
41			RF3V8	Suspension of work by owner
42			RF3V9	Breach or modifications of contract by owner
43			RF3V10	Delay in performing final inspection and certification

EXHIBIT 3.1

DASHBOARD: IDENTIFICATION (CONTINUE)

Sr.	Risk Factor Code	Risk Factor	Risk Variable Code	Variables
44	RF4	Design related risk	RF4V1	Mistakes and inadequate details
45			RF4V2	Delays in producing design documents
46			RF4V3	Complexity of project design
47			RF4V4	Incomplete investigation, survey and feasibility studies
48			RF4V5	Misunderstanding of Client's requirements by design engineer
49			RF4V6	Unforeseen or Differing site (ground) conditions
50			RF4V7	Inadequate design-team experience
51			RF4V8	Inaccurate project cost estimating
52			RF4V9	Inflation / price fluctuation
53			RF4V10	Incomplete contract details
54	RF5	Safety & security relate	RF5V1	Pollution and Safety compliance
55			RF5V2	Accidents and Labour Injuries
56			RF5V3	Damage to Existing Structure(Utilities beneath ground)
57			RF5V4	Theft of material and equipment's
58			RF5V5	Safety assessment system in organization
59			RF5V6	Project location is safe to reach
60	RF6	Financial Risk	RF6V1	High interest rate
61			RF6V2	Cost of variation/Change orders
62			RF6V3	Change in currency price
63			RF6V4	Availability of Funds from lenders
64			RF6V5	Exchange Rate Fluctuation
65	RF7	Nature related	RF7V1	Flood
66			RF7V2	Earthquake
67			RF7V3	Landslide
68			RF7V4	Unexpected weather conditions
69	RF8	Approvals & Site Clear	RF8V1	Approvals and clearances
70			RF8V2	Land acquisition & site handover
71			RF8V3	Environmental & Tree Cutting
72			RF8V4	Changes in government regulations and laws
73			RF8V5	Rehabilitation & Resettlement of affected families
74	RF9	Quality related risk	RF9V1	Site Supervision, Quality assurance & Control
75			RF9V2	Quality assessment system in organization
76			RF9V3	Implementation of method statement
77	RF10	Cash flow & Contract s	RF10V1	Unavailability of incentive clause for early completion
78			RF10V2	Cash flow of project
79			RF10V3	Profit rate of project
80			RF10V4	Cost of rework
81	RF11	Fundamental risk	RF11V1	Social and Cultural influences of workmanship
82			RF11V2	Issues in interstate or Central to state coordination
83			RF11V3	Strike
84			RF11V4	Traffic control and restriction at job site

EXHIBIT 3.2

DASHBOARD : COMPOSITE IMPACT FACTOR (CIF) & COMPOSITE LIKILIHOOD FACTOR(CLF)

Activities and risk factors relationship			Contractor Specific			PMC Consult. Specific			Client Specific			Design Specific			Safety & security			Financial risk			Nature specific			Approval & site clearance			Quality			Contract specific			Fundamental		
Activities	**CLF**	**CIF**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**	**W**	**P**	**I**
Mobilization and Commencement	0.372	0.389	0.19	0.41	0.44	0.13	0.26	0.2	0.12	0.38	0.35										0.12	0.38	0.4	0.23	0.47	0.53				0.09	0.3	0.32	0.1	0.28	0.312
Site survey and Investigations	0.405	0.391	0.29	0.38	0.39	0.21	0.33	0.31	0.2	0.37	0.37													0.29	0.51	0.46									
Approvals for General Arrangements Drawing	0.386	0.364	0.2	0.33	0.3	0.2	0.35	0.33	0.23	0.39	0.37	0.22	0.49	0.46																0.15	0.34	0.34			
Approvals for formation (C/S & L	0.382	0.392	0.21	0.29	0.37	0.19	0.34	0.43	0.18	0.38	0.35	0.26	0.52	0.45																0.16	0.33	0.34			
Utility shifting and Tree cutting	0.373	0.371	0.19	0.33	0.35	0.14	0.29	0.27	0.17	0.31	0.31				0.19	0.36	0.41							0.31	0.48	0.44									
Barricades (safety)	0.370	0.396	0.2	0.38	0.37	0.16	0.27	0.31	0.15	0.31	0.35				0.3	0.51	0.52													0.19	0.27	0.33			
Toe wall and Drainage work	0.345	0.351	0.17	0.4	0.36	0.1	0.29	0.33	0.1	0.31	0.3	0.13	0.4	0.42	0.12	0.33	0.39	0.09	0.31	0.27	0.1	0.34	0.31	0.09	0.32	0.37	0.11	0.35	0.37						
Earthwork for formation	0.330	0.502	0.18	0.4	0.43	0.1	0.26	0.27	0.09	0.28	0.27	0.14	0.3	1.36	0.12	0.35	0.37	0.1	0.29	0.36	0.1	0.32	0.35	0.09	0.37	0.42	0.1	0.36	0.43						
Foundation work for Electric pole	0.362	0.480	0.2	0.35	0.37	0.15	0.34	0.28	0.1	0.35	0.27	0.16	0.37	1.21	0.13	0.37	0.36	0.1	0.33	0.32							0.16	0.4	0.41						
Pole Erection and fixing	0.386	0.382	0.25	0.38	0.4	0.18	0.34	0.31							0.23	0.39	0.44	0.15	0.37	0.37							0.19	0.44	0.37						
HT wiring works	0.379	0.387	0.19	0.4	0.39	0.11	0.31	0.27	0.1	0.28	0.33	0.11	0.39	0.38	0.17	0.42	0.41	0.1	0.34	0.43				0.11	0.46	0.33	0.1	0.38	0.55						
Signaling & Tele-communication work	0.365	0.389	0.16	0.35	0.36	0.11	0.3	0.27	0.1	0.31	0.33	0.14	0.43	0.41	0.14	0.36	0.42	0.1	0.33	0.44				0.12	0.45	0.45	0.13	0.36	0.42						
Subgrade Blanketing	0.384	0.387	0.14	0.38	0.39	0.12	0.3	0.31	0.1	0.28	0.3	0.13	0.36	0.41	0.1	0.41	0.39	0.09	0.43	0.36	0.11	0.35	0.35	0.09	0.54	0.48	0.11	0.44	0.49						
Ballast Spreading	0.356	0.382	0.17	0.35	0.42	0.12	0.27	0.3	0.09	0.29	0.27				0.12	0.41	0.35	0.09	0.32	0.38	0.11	0.38	0.41	0.1	0.36	0.39	0.11	0.46	0.55				0.09	0.33	0.351
Sleeper Laying	0.447	0.438	0.24	0.44	0.46	0.15	0.33	0.33	0.12	0.35	0.31				0.17	0.39	0.48										0.31	0.58	0.5						
Rail laying & Fixing	0.423	0.486	0.26	0.39	0.46	0.15	0.33	0.44	0.13	0.31	0.29				0.21	0.5	0.47										0.26	0.51	0.65						
Temping and Compaction	0.449	0.464	0.27	0.44	0.46	0.19	0.34	0.4							0.21	0.5	0.42										0.32	0.49	0.53						
Rail Destressing	0.450	0.420	0.28	0.45	0.41	0.21	0.33	0.36							0.25	0.49	0.46										0.26	0.51	0.45						
Dressing and Boxing	0.423	0.391	0.27	0.42	0.46	0.2	0.38	0.31							0.21	0.41	0.36										0.32	0.46	0.39						
Documentation for CRS Inspection	0.373	0.396	0.2	0.35	0.36	0.21	0.38	0.38	0.14	0.46	0.42							0.15	0.29	0.4							0.15	0.41	0.42	0.15	0.36	0.41			
Commissioning, Inspection & Handover	0.428	0.453	0.23	0.39	0.48				0.25	0.45	0.48				0.16	0.41	0.38										0.2	0.48	0.47	0.17	0.4	0.42			

EXHIBIT 3.3

DASHBOARD: RISK SEVERITY

Dashboard - Risk Severity Anaysis											
Activities and risk factors Severity	**Contractor Specific**	**PMC Consult. Specific**	**Client Specific**	**Design Specific**	**Safety & security**	**Financial risk**	**Nature specific**	**Approval & site clearance**	**Quality**	**Contract specific**	**Fundam-ental**
Activities	**RF 01**	**RF 02**	**RF 03**	**RF 04**	**RF 05**	**RF 06**	**RF 07**	**RF 08**	**RF 09**	**RF 10**	**RF 11**
Mobilization and Commencement	0.204	0.056	0.157	0.000	0.000	0.000	0.178	0.286	0.000	0.096	0.105
Site survey and Investigations	0.175	0.126	0.148	0.000	0.000	0.000	0.000	0.254	0.000	0.000	0.000
Approvals for General Arrangements Drawing	0.115	0.130	0.165	0.232	0.000	0.000	0.000	0.000	0.000	0.130	0.000
Approvals for formation (C/S & L section, Drainage and other structures)	0.117	0.147	0.149	0.242	0.000	0.000	0.000	0.000	0.000	0.130	0.000
Utility shifting and Tree cutting	0.118	0.083	0.116	0.000	0.163	0.000	0.000	0.246	0.000	0.000	0.000
Barricades (safety)	0.160	0.096	0.125	0.000	0.276	0.000	0.000	0.000	0.000	0.103	0.000
Toe wall and Drainage work	0.159	0.108	0.103	0.192	0.155	0.089	0.123	0.252	0.162	0.000	0.000
Earthwork for formation	0.188	0.078	0.092	0.364	0.151	0.125	0.133	0.245	0.408	0.000	0.000
Foundation work for Electric pole	0.152	0.110	0.107	0.388	0.161	0.119	0.000	0.000	0.180	0.000	0.000
Pole Erection and fixing	0.160	0.113	0.000	0.000	0.186	0.150	0.000	0.000	0.175	0.000	0.000
HT wiring works	0.192	0.111	0.087	0.188	0.229	0.168	0.000	0.149	0.271	0.000	0.000
Signaling & Tele-communication work	0.135	0.091	0.129	0.204	0.178	0.147	0.000	0.308	0.174	0.000	0.000
Subgrade Blanketing	0.162	0.121	0.088	0.165	0.194	0.198	0.142	1.285	0.297	0.000	0.000
Ballast Spreading	0.152	0.089	0.093	0.000	0.159	0.146	0.433	0.171	0.753	0.000	0.134
Sleeper Laying	0.223	0.118	0.141	0.000	0.212	0.000	0.000	0.000	0.529	0.000	0.000
Rail laying & Fixing	0.185	0.184	0.098	0.000	0.264	0.000	0.000	0.000	0.385	0.000	0.000
Temping and Compaction	0.224	0.152	0.000	0.000	0.225	0.000	0.000	0.000	0.502	0.000	0.000
Rail Destressing	0.192	0.142	0.000	0.000	0.241	0.000	0.000	0.000	0.276	0.000	0.000
Dressing and Boxing	0.213	0.152	0.000	0.000	0.175	0.000	0.000	0.000	0.203	0.000	0.000
Documentation for CRS Inspection	0.156	0.173	0.225	0.000	0.000	0.121	0.000	0.000	0.183	0.168	0.000
Commissioning, Inspection & Handover	0.198	0.000	0.266	0.000	0.182	0.000	0.000	0.000	0.256	0.192	0.000

EXHIBIT 3.4

DASHBOARD: EXPECTED COST

EXPECTED COST FOR THE PROJECT						
Activities	**Base Cost (INR)**	**CLF**	**CIF**	**Corrective Cost (INR)**	**Risk Cost (INR)**	**Expected Cost (INR)**
Mobilization and Commencement	6,48,88,278.80	0.372	0.389	2,52,50,379.33	94,00,835.63	7,42,89,114.43
Site survey and Investigations	20,00,000.00	0.405	0.391	7,82,406.54	3,16,604.22	23,16,604.22
Approvals for General Arrangements Drawing	10,05,420.16	0.386	0.364	3,65,590.83	1,41,074.67	11,46,494.83
Approvals for formation (C/S & L section, Drainage and other structures)		0.382	0.392	-	-	-
Utility shifting and Tree cutting	4,88,451.42	0.373	0.371	1,81,317.20	67,627.70	5,56,079.12
Barricades (safety)	15,57,502.39	0.370	0.396	6,16,565.38	2,28,116.98	17,85,619.37
Toe wall and Drainage work	-	0.345	0.351	-	-	-
Earthwork for formation	14,85,52,380.12	0.330	0.502	7,46,28,226.65	2,46,56,417.22	17,32,08,797.34
Foundation work for Electric pole	1,87,55,835.53	0.423	0.480	89,96,957.25	38,05,712.92	2,25,61,548.45
Pole Erection and fixing	15,84,886.69	0.386	0.382	6,05,661.31	2,33,889.40	18,18,776.09
HT wiring works	6,76,61,663.07	0.379	0.387	2,61,84,916.63	99,31,662.03	7,75,93,325.09
Signaling & Tele-communication work	20,74,81,811.68	0.365	0.389	8,07,73,451.03	2,94,95,830.87	23,69,77,642.55
Subgrade Blanketing	10,43,94,646.17	0.384	0.387	4,03,98,604.85	1,55,01,764.77	11,98,96,410.94
Ballast Spreading	1,09,78,043.14	0.356	0.382	41,89,146.56	14,91,549.90	1,24,69,593.04
Sleeper Laying	61,21,370.46	0.447	0.438	26,78,375.17	11,98,106.72	73,19,477.18
Rail laying & Fixing	76,51,713.07	0.423	0.486	37,16,523.24	15,72,686.60	92,24,399.68
Temping and Compaction	24,38,210.57	0.449	0.464	11,30,217.46	5,07,145.18	29,45,355.74
Rail Destressing	10,86,304.46	0.450	0.420	4,56,468.39	2,05,553.98	12,91,858.45
Dressing and Boxing	15,30,342.61	0.423	0.391	5,97,614.97	2,52,886.48	17,83,229.10
Documentation for CRS Inspection		0.373	0.396	-	-	-
Commissioning, Inspection & Handover		0.428	0.453	-	-	-
	64,81,76,860.35			**27,15,52,422.79**	**9,90,07,465.27**	**74,71,84,325.62**
					Contingency	**15%**

EXHIBIT 3.5

DASHBOARD: INDIVIDUAL FACTORS RISK COST

Risk factors	Cost (Rs.)
Contractor Specific risk	1,71,19,453.29
PMC Consult. Specific risk	1,13,39,104.70
Owner Specific	97,96,124.21
Design Specific	1,13,80,711.14
Safety & security	1,19,11,383.57
Financial risk	81,86,148.79
Nature specific	54,47,383.17
Approval & site clearance	1,08,64,819.95
Quality	1,09,26,703.84
Contract specific	9,40,805.95
Fundamental	11,19,847.51
	9,90,32,486.11

EXHIBIT 3.6

DASHBOARD: EXPECTED TIME FOR THE PROJECT

EXPECTED TIME FOR THE PROJECT						
Activities	**Base Time**	**CLF**	**CIF**	**Corrective Time (Day)**	**Risk Time (Days)**	**Expected Time (Days)**
Mobilization and Commencement	20	0.372	0.389	8	3	23
Site survey and Investigations	20	0.405	0.391	8	3	23
Approvals for General Arrangements Drawing	15	0.386	0.364	5	2	17
Approvals for formation (C/S & L section, Drainage and other structures)	15	0.382	0.392	6	2	17
Utility shifting and Tree cutting	30	0.373	0.371	11	4	34
Barricades (safety)	20	0.370	0.396	8	3	23
Toe wall and Drainage work	60	0.345	0.351	21	7	67
Earthwork for formation	90	0.330	0.502	45	15	105
Foundation work for Electric pole	30	0.423	0.480	14	6	36
Pole Erection and fixing	30	0.386	0.382	11	4	34
HT wiring works	30	0.379	0.387	12	4	34
Signaling & Tele-communication work	30	0.365	0.389	12	4	34
Subgrade Blanketing	60	0.384	0.387	23	9	69
Ballast Spreading	50	0.356	0.382	19	7	57
Sleeper Laying	40	0.447	0.438	18	8	48
Rail laying & Fixing	30	0.423	0.486	15	6	36
Temping and Compaction	30	0.449	0.464	14	6	36
Rail Destressing	20	0.450	0.420	8	4	24
Dressing and Boxing	18	0.423	0.391	7	3	21
Documentation for CRS Inspection	15	0.373	0.396	6	2	17
Commissioning, Inspection & Handover	7	0.428	0.453	3	1	8

EXHIBIT 3.7

DASHBOARD – RISK RESPONSE PLANNING

Risk Factor	Variables	Response Plan	Mitigation Strategy
Contractor Specific	Financial Default of Contractor/Subcontractor	Mitigate	Get credibility information of Contractor during prequalification and also keep 10% of contract value as performance Bank Guarantee from the contractor
	Lack of technical professionals	Mitigate	Clear definition of scope of work and Competency required to complete the project. Fix the qualification and experince requirements for the engineering, management staff, and also the certification for the skilled manpower
	Lack of coordination with subcontractors	Transfer	In contract the subcontract clause has to be precise and clear, It should fix the limit, the ultimate responsibility and necessary conscent from the PMC & Client
	Delay in mobilization	Mitigate	To be stricytly control by the client and PMC, link all the necessary activities of mobilisation with the contractual events, such as kickoff, submission of bank guaranties, insurance, advance payment.
	Poor planning, scheduling or resource management	Transfer	Clear definition of Type of schedule to be submitted by Contractor, Signoff the baseline, set the frequency of upadation of Schedule, fix MIS processes to be used for the project, link this with the General condition of Contract.
	Congested construction site	Mitigate	Ask contractor to prepare the Site Layout plan and get it approved by all the stakeholders
	Lack of experience of similar projects	Mitigate	Prequalification - ask contractor to submit the information related to similar Projects (Completed & Ongoing), Conduct market study and obtain the information of past completed project by the contractor.
	Shortage of manpower	Transfer	ask contractor to submit the labour deployment plan for the complete duration of the project during the Kick of meeting itself.
	Inadequate skills of manpower and Low productivity	Transfer	Stick with the clause of Training and certification requirements of the skilled labour and also observe the labour attrition rate and immediately raise to the contractor
	Contractors cash flow	Mitigate	Contract should have early paymengt release provision/adhoc provision
	Irregular payments of sub-contractors	Transfer	Ensure that the payment made to the Contractor being used for the same project should not being used for other project
	Construction Work Permits	Mitigate	Establish the process for work permits based on the risk identification and hazard in during the execution and and provide timely approvals
	Conflicts between contractor, consultant and owner	Mitigate	Appoint a PMC to coordinate for all the Speedy resolution of issues, provide unbiased recommendation. Also Provide dispute settlement clauses in the contract
	Improper construction methods implemented by contractor	Mitigate	Specifiy the Workmenship/methodology to be followed and ensure a provision in the contract agreement to bound to all the party
	Delays in sub-contractors work	Transfer	Specify delay/penalty clause in contract
	Poor site management and supervision	Mitigate	Adopt proper safety control programme, processes, supervision, incentives and preventive measures
	Lack of Training personnel for model construction operation	Mitigate	Understand the details/Process/risk involve in the new operation. Provide the training to the Engineering staff to reduce the chances of failure
	Inaccurate tender cost estimating	Transfer	To be managed by the contractor, deployment of experirnced quantity surveyor for the project.
	Shortage of equipment	Transfer	Ask contractor to submit the equipment deployment schedule based on the baseline of the project.
	Low productivity and efficiency of equipment	Transfer	Optimum selsction site layout to maximise resource productivity, also the labour productivity details should be the part of MIS. If it is very less than escalate to the contractor.
	Lack of high-technology mechanical equipment	Mitigate	Appoint PMC at early stage and ask PMC to provide details of the modern technology to optimize the project. Selected technology should be the part of the contract documents.
	Shortage of materials	Transfer	Adequate Inventory monitoring
	Delay in material procurement and delivery	Mitigate	Adequate Inventory monitoring and also long lead Item tracking
	Week design coordination and delay in communication	Mitigate	Design Review meeting with fixed frequency, also set time line to resolve the Issues.
	Slow response to Request For Information(RFI) or technical query	Mitigate	Set Process, Hierarchy to escalate the query and fix the timeline in the contract to resolve the Issues throgh the contractual provision
	Delay in inspection	Mitigate	Link it with contractual provision of consultants and ensure timely decision from the owner side as well
	Level of involvement in quality control	Mitigate	Adopt proper quality control procedures, supervision and incentives
	Change in scope of work	Mitigate	Try to reduce the changes, If it is actually required than quickly decide and process the same to maintain the progress at site
	Delay in approving major changes	Mitigate	Changes if actually required than quickly decide and process the same to maintain the progress at site
	Delay in claim approval	Mitigate	Learn the lessions from the old project, modified contract documents with all the details at engineering stage and at all if there is a claim then timely decide and communicate with the stakeholders
	Deployment of technical staff on site	Mitigate	Qualification, Experience, Organisation chart and deployment for the staff to be deployed from the Contractor & Consultant
	Inadequate definition of substantial completion	Mitigate	Adequate details related to milestones completion, Project completion to be in the contract
	Lack of systematic engineering method to identify the time	Mitigate	Clear definition of Type of schedule to be submitted by Contractor, Signoff the baseline, set the frequency of upadation of Schedule, fix MIS processes to be used for the project. Link this with the General condition of Contract

Risk Factor	Variables	Response Plan	Mitigation Strategy
Owner Specific	Frequent interference	Accept	Needed to control the project
	Unrealistic contract duration imposed by client	Mitigate	The timeline mention in the contract to complete the work should be realistic enough to complete the project and also check the the avalability of land
	Financial difficulties & Irregular payments of work-done	Mitigate	Have the agreement with the lender also the payment timeline and continioulsy Coordinate with the Lender
	Delay in Permissions, approvals & statutory clearances	Mitigate	Prepare a plan for all the approvals, assigned the responsibility to parties, ensure to adher with the complinces
	Learning from best practice and experience of others	Mitigate	Study the project completion report of the similar projects identify the risk occurred and mitigation measures implemented by the authorities
	Delay in Decision making	Mitigate	Quick, coordinated and timely decision is required
	Lack of capability of client representative	Mitigate	Appoint a good PMC/ If required proof and Third party consultatnts
	Suspension of work by owner	Mitigate	Get the inpriciple approvals for the land including rehabilitation and finance needed for the project. Also, closely monitor the performance of contractor
	Breach or modifications of contract by owner	Mitigate	Review plans jointly with contractor to modify the contract
	Delay in performing final inspection and certification	Mitigate	Expedite the documentation process and apply for CRS inspection timely
Design risk	Mistakes and inadequate details	Transfer	Consultant to ensure the appropriate engineering design and correctness of details, design and drawing and also design and drawing review should be in the Scope of PMC services and contractor
	Delays in producing design documents	Transfer	Ask consultant to prepare Design Delivery Schedule
	Complexity of project design	Transfer	Adopt Design & Build option which enables contractor to design in harmony with site conditions thus minimizing design/drawing disputes
	Incomplete investigation, survey and feasibility studies	Transfer	Adopt Design & Build option which enables contractor to design in harmony with site conditions thus minimizing error related to investigation
	Misunderstanding of Client's requirements by design engineer	Transfer	Introduce adjustment clauses in contract to review plan and constructability
	Unforeseen or Differing site (ground) conditions	Transfer	Adopt Design & Build option which enables contractor to design in harmony with site conditions thus minimizing error related to investigation
	Inadequate design-team experience	Mitigate	Hire competent Proof consultant and project management team
	Inaccurate project cost estimating	Mitigate	By review of cost proposals of consultants by PMC and also compae with the market price
	Inflation / price fluctuation	Mitigate	Have the Price variation clause in the contract
	Incomplete contract details	Mitigate	Thoroughly review the risk balancing in the contract and also insure the appropriate standard for GCC & PCC have been used
Safety & Security related risk	Pollution and Safety compliance	Mitigate	Ensure that construction and operation are as per compliances of concerned approving authority's expectation
	Accidents and Labour Injuries	Transfer	Implement the effective safety operating procedures
	Damage to Existing Structure(Utilities beneath ground)	Transfer	Get Third Party Insurance
	Theft of material and equipment's	Transfer	Adopt proper safety control programme, management system, supervision, incentives and preventive measures
	Safety assessment system in organization	Mitigate	Ensure that construction and operation are as per examination and concerned approving authority's expectation
	Project location is safe to reach	Mitigate	laisoning with the Local administration for the safety of approch road for the construction
Financial risk	High interest rate	Mitigate	Can be reduced by identifying the alternative source of funding such as global funding
	Cost of variation/Change orders	Mitigate	Have detailed site survey and investigation so that change can be avoided, Use design Build Contract to transfer the risk to the contractor
	Change in currency price	Mitigate	Affect to the international suppliers, fix a base rate and give the variation to the supplier
	Availability of Funds from lenders	Mitigate	Client to secure standby financing
	Exchange Rate Fluctuation	Mitigate	Affect to the international suppliers, fix a base rate and give the variation to the supplier
Nature related risk	Flood	Transfer	Insure all of the insurable force majeure risks
	Earthquake	Transfer	Insure all of the insurable force majeure risks
	Landslide	Transfer	Insure all of the insurable force majeure risks
	Unexpected weather conditions	Transfer	study the Past trends of severity of weather
Approvals and site clearance related risk	Approvals and clearances	Mitigate	Comply with international and/or local environmental laws, standards and regulations
	Land acquisition & site handover	Mitigate	Have a detailed landaquasition, rehabilitation and resettlement plan
	Environmental & Tree Cutting	Mitigate	Strictly follow the Environmental guidelines
	Changes in government regulations and laws	Mitigate	Comply with international and/or local environmental laws, standards and regulations
	Rehabilitation & Resettlement of affected families	Mitigate	Make a detailed R&R plan, Involve local adminitration and Conduct public hearing
Quality related risk	Site Supervision, Quality assurance & Control	Transfer	Adopt proper quality control procedures, supervision and incentives
	Quality assessment system in organization	Mitigate	Ask contractor to submit their Quality plan & processes to be implemented at the site
	Implementation of method statement	Mitigate	Ask contractor to submit their Quality plan & processes to be implemented at the site
Contract related risk	Unavailability of incentive clause for early completion	Mitigate	Incentive Clause will always motivate contractor to achieve project objective
	Cash flow of project	Transfer	Timely payment of the Contractor
	Profit rate of project	Transfer	Timely payment of the Contractor
	Cost of rework	Transfer	Proper record keeping and cause of rework is required
Fundamental risk	Social and Cultural influences of workmanship	Transfer	Arrange Social events for the workmanship to diversify them with different culture
	Issues in interstate or Central to state coordination	Mitigate	Coordinate closely with the Government
	Strike	Mitigate	Have the sufficient Inventory of materials at the site
	Traffic control and restriction at job site	Mitigate	Coordinate with City Traffic department for smooth functioning of the project

Risk Factor	Variables	Response Plan	Mitigation Strategy
Owner Specific	Frequent interference	Accept	Needed to control the project
	Unrealistic contract duration imposed by client	Mitigate	The timeline mention in the contract to complete the work should be realistic enough to complete the project and also check the the avalability of land
	Financial difficulties & Irregular payments of work-done	Mitigate	Have the agreement with the lender also the payment timeline and continioulsy Coordinate with the Lender
	Delay in Permissions, approvals & statutory clearances	Mitigate	Prepare a plan for all the approvals, assigned the responsibility to parties, ensure to adher with the complinces
	Learning from best practice and experience of others	Mitigate	Study the project completion report of the similar projects identify the risk occurred and mitigation measures implemented by the authorities
	Delay in Decision making	Mitigate	Quick, coordinated and timely decision is required
	Lack of capability of client representative	Mitigate	Appoint a good PMC/ If required proof and Third party consultatnts
	Suspension of work by owner	Mitigate	Get the inpriciple approvals for the land including rehabilitation and finance needed for the project. Also, closely monitor the performance of contractor
	Breach or modifications of contract by owner	Mitigate	Review plans jointly with contractor to modify the contract
	Delay in performing final inspection and certification	Mitigate	Expedite the documentation process and apply for CRS inspection timely
Design risk	Mistakes and inadequate details	Transfer	Consultant to ensure the appropriate engineering design and correctness of details, design and drawing and also design and drawing review should be in the Scope of PMC services and contractor
	Delays in producing design documents	Transfer	Ask consultant to prepare Design Delivery Schedule
	Complexity of project design	Transfer	Adopt Design & Build option which enables contractor to design in harmony with site conditions thus minimizing design/drawing disputes
	Incomplete investigation, survey and feasibility studies	Transfer	Adopt Design & Build option which enables contractor to design in harmony with site conditions thus minimizing error related to investigation
	Misunderstanding of Client's requirements by design engineer	Transfer	Introduce adjustment clauses in contract to review plan and constructability
	Unforeseen or Differing site (ground) conditions	Transfer	Adopt Design & Build option which enables contractor to design in harmony with site conditions thus minimizing error related to investigation
	Inadequate design-team experience	Mitigate	Hire competent Proof consultant and project management team
	Inaccurate project cost estimating	Mitigate	By review of cost proposals of consultants by PMC and also compae with the market price
	Inflation / price fluctuation	Mitigate	Have the Price variation clause in the contract
	Incomplete contract details	Mitigate	Thoroughly review the risk balancing in the contract and also insure the appropriate standard for GCC & PCC have been used
Safety & Security related risk	Pollution and Safety compliance	Mitigate	Ensure that construction and operation are as per compliances of concerned approving authority's expectation
	Accidents and Labour Injuries	Transfer	Implement the effective safety operating procedures
	Damage to Existing Structure(Utilities beneath ground)	Transfer	Get Third Party Insurance
	Theft of material and equipment's	Transfer	Adopt proper safety control programme, management system, supervision, incentives and preventive measures
	Safety assessment system in organization	Mitigate	Ensure that construction and operation are as per examination and concerned approving authority's expectation
	Project location is safe to reach	Mitigate	laisoning with the Local administration for the safety of approch road for the construction
Financial risk	High interest rate	Mitigate	Can be reduced by identifying the alternative source of funding such as global funding
	Cost of variation/Change orders	Mitigate	Have detailed site survey and investigation so that change can be avoided, Use design Build Contract to transfer the risk to the contractor
	Change in currency price	Mitigate	Affect to the international suppliers, fix a base rate and give the variation to the supplier
	Availability of Funds from lenders	Mitigate	Client to secure standby financing
	Exchange Rate Fluctuation	Mitigate	Affect to the international suppliers, fix a base rate and give the variation to the supplier
Nature related risk	Flood	Transfer	Insure all of the insurable force majeure risks
	Earthquake	Transfer	Insure all of the insurable force majeure risks
	Landslide	Transfer	Insure all of the insurable force majeure risks
	Unexpected weather conditions	Transfer	study the Past trends of severity of weather
Approvals and site clearance related risk	Approvals and clearances	Mitigate	Comply with international and/or local environmental laws, standards and regulations
	Land acquisition & site handover	Mitigate	Have a detailed landaquasition, rehabilitation and resettlement plan
	Environmental & Tree Cutting	Mitigate	Strictly follow the Environmental guidelines
	Changes in government regulations and laws	Mitigate	Comply with international and/or local environmental laws, standards and regulations
	Rehabilitation & Resettlement of affected families	Mitigate	Make a detailed R&R plan, Involve local adminitration and Conduct public hearing
Quality related risk	Site Supervision, Quality assurance & Control	Transfer	Adopt proper quality control procedures, supervision and incentives
	Quality assessment system in organization	Mitigate	Ask contractor to submit their Quality plan & processes to be implemented at the site
	Implementation of method statement	Mitigate	Ask contractor to submit their Quality plan & processes to be implemented at the site
Contract related risk	Unavailability of incentive clause for early completion	Mitigate	Incentive Clause will always motivate contractor to achieve project objective
	Cash flow of project	Transfer	Timely payment of the Contractor
	Profit rate of project	Transfer	Timely payment of the Contractor
	Cost of rework	Transfer	Proper record keeping and cause of rework is required
Fundamental risk	Social and Cultural influences of workmanship	Transfer	Arrange Social events for the workmanship to diversify them with different culture
	Issues in interstate or Central to state coordination	Mitigate	Coordinate closely with the Government
	Strike	Mitigate	Have the sufficient Inventory of materials at the site
	Traffic control and restriction at job site	Mitigate	Coordinate with City Traffic department for smooth functioning of the project

EXHIBIT 3.8

DASHBOARD: RISK REGISTER

RISK MONITORING AND CONTROLS											
Sr	Risk Factors	Risk Variables	Cost Contingency (Risk Cost)	Response Plan	Mitigation Strategy	Triger	Actual Mitigation cost	Contigency Reserve (Balanced)	Risk Owner		Status (Active Dormait/Retired)
									Organisation	Name of the person	
RF1	Contractor Specific risk		1,71,19,453.29	Mitigate		Yes	8900000	82,19,453.29			
		Financial Default of Contractor/Subcontractor		Mitigate	Get credibility information of Contractor during prequalification and also keep 10% of contract value as performance Bank Guarantee from the contractor	Yes					
		Lack of technical professionals		Mitigate	Clear definition of scope of work and Competency required to complete the project. Fix the qualification and experince requirements for the engineering, management staff, and also the certification for the skilled manpower	No					
		Lack of coordination with subcontractors		Transfer	In contract the subcontract clause has to be precise and clear, It should fix the limit, the ultimate responsibility and necessary conscent from the PMC & Client	No					
		Delay in mobilization		Mitigate	To be stricytly control by the client and PMC, link all the necessary activities of mobilisation with the contractual events, such as kickoff, submission of bank guaranties, insurance, advance payment.	Yes					
	Note - all the identified and assessed risk variables have given Risk Variable Code starting with RF no and V no i.e. Rik Factor number and Variable no. Risk identification is an iterative process because new risks may become known as the project progresses through its life. The new risk will be Considered under a factor and will be given a Variable Code starting with N	Poor planning, scheduling or resource management		Transfer	Clear definition of Type of schedule to be submitted by Contractor, Signoff the baseline, set the frequency of upadation of Schedule, fix MIS processes to be used for the project, link this with the General condition of Contract.						
		Congested construction site		Mitigate	Ask contractor to prepare the Site Layout plan and get it approved by all the stakeholders						
		Lack of experience of similar projects		Mitigate	Prequalification - ask contractor to submit the information related to similar Projects (Completed & Ongoing), Conduct market study and obtain the information of past completed project by the contractor.						
		Shortage of manpower		Transfer	ask contractor to submit the labour deployment plan for the complete duration of the project during the Kick of meeting itself.						
		Inadequate skills of manpower and Low productivity		Transfer	Stick with the clause of Training and certification requirements of the skilled labour and also observe the labour attrition rate and immediately raise to the contractor						

EXHIBIT 3.9

DASHBOARD : MONTHLY MONITORING AND CONTROL

MONTHLY MONITORING AND CONTROLS (COST)										
	Base Cost (Monthly)	Expected Cost	Actual Cost (INR)	Work done (%)	Earned Value (INR)	Expected Cost of Work performed (ECWP)	CPI Budget = Earned Value/Actual Cost	CPI Risk = Earned Value/Expected Cost (For Pessimistic Scenario)	Quantified Risk Effect on Cost = 100*(ACWP-ECWP)/ECWP	Interpretation
Nov-09	33946849	38559828	26555868	0.75	25460136.75	28919871	0.96	0.88	-8.17%	CPI Budget should be Greater than the CPI risk, this means that Contingency fund is sufficient enough to handel the risk and risks are within the Threshhold limits
Dec-09	33946849	38559828	28655256	0.72	24441731.28	27763076.16	0.85	0.88	3.21%	CPI Budget should not less than the CPI risk this means that the actual cost is more than the Expected cost. The Contingency fund is not sufficient enough to handel the risk. Project risks are crossing the Threshhold limits
Jan-10										
Feb-10										
Mar-10										
Apr-10										
May-10										
Jun-10										
Jul-10										
Aug-10										
Sep-10										
Input	Planned Value from Schedule with Base Cost	Planned Value by Expected Cost Schedule	Workdone (From Budget Tracker & Billing data)	% Completion of monthly plan	Budgeted Cost of Work Performed (BCWP)	Expected Cost of Work performed (ECWP)	Output	Output	Output	Output

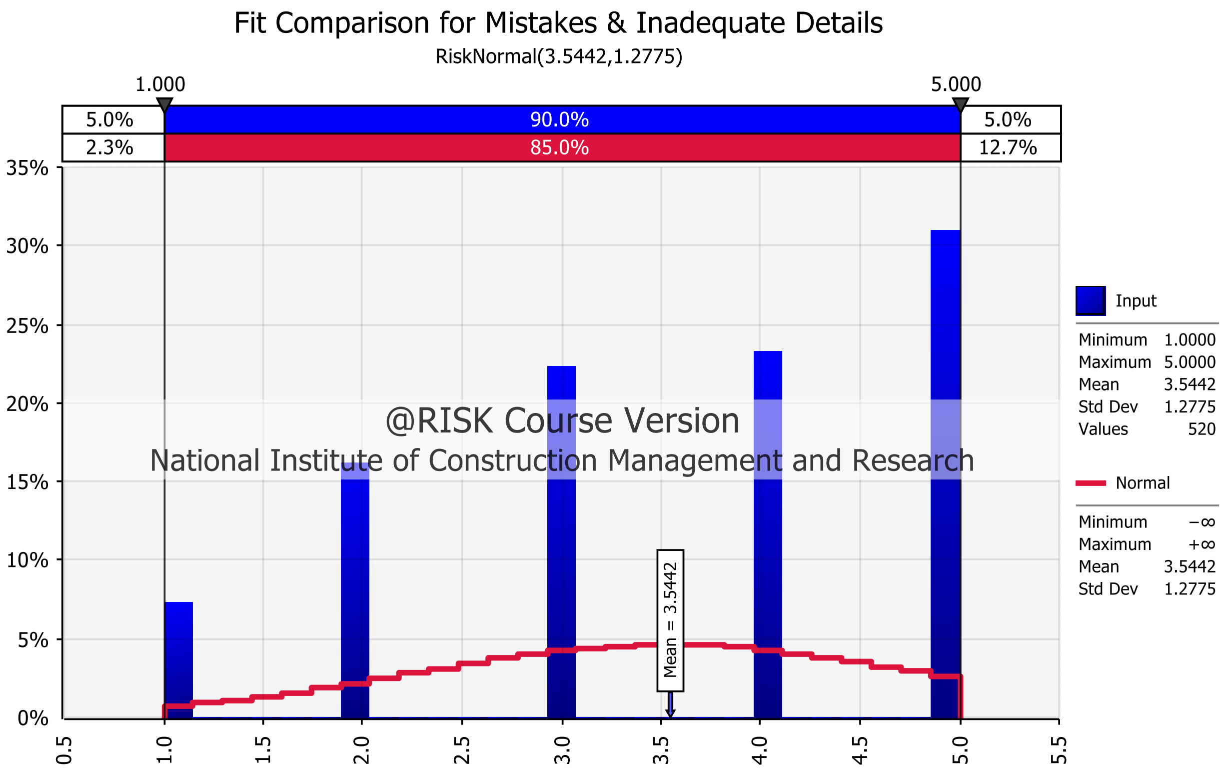
EXHIBIT 3.10

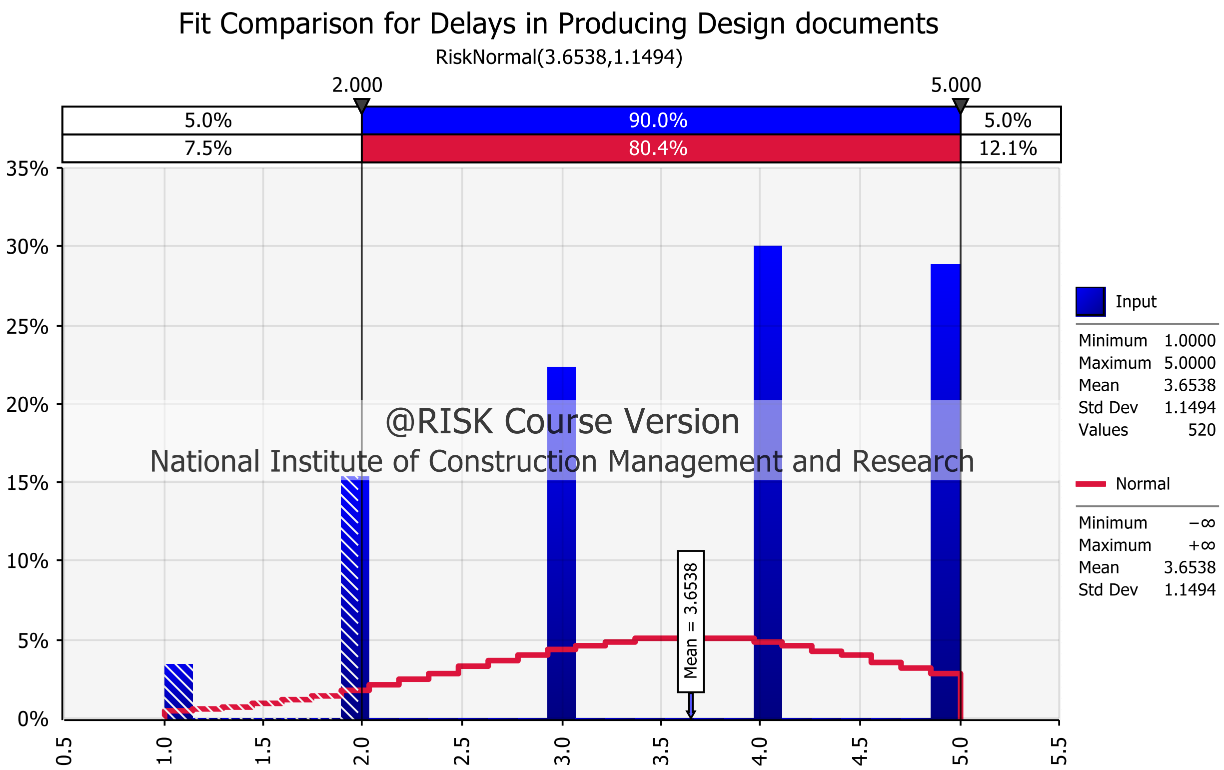
DASHBOARD : MONTHLY MONITORING AND CONTROL (TIME)

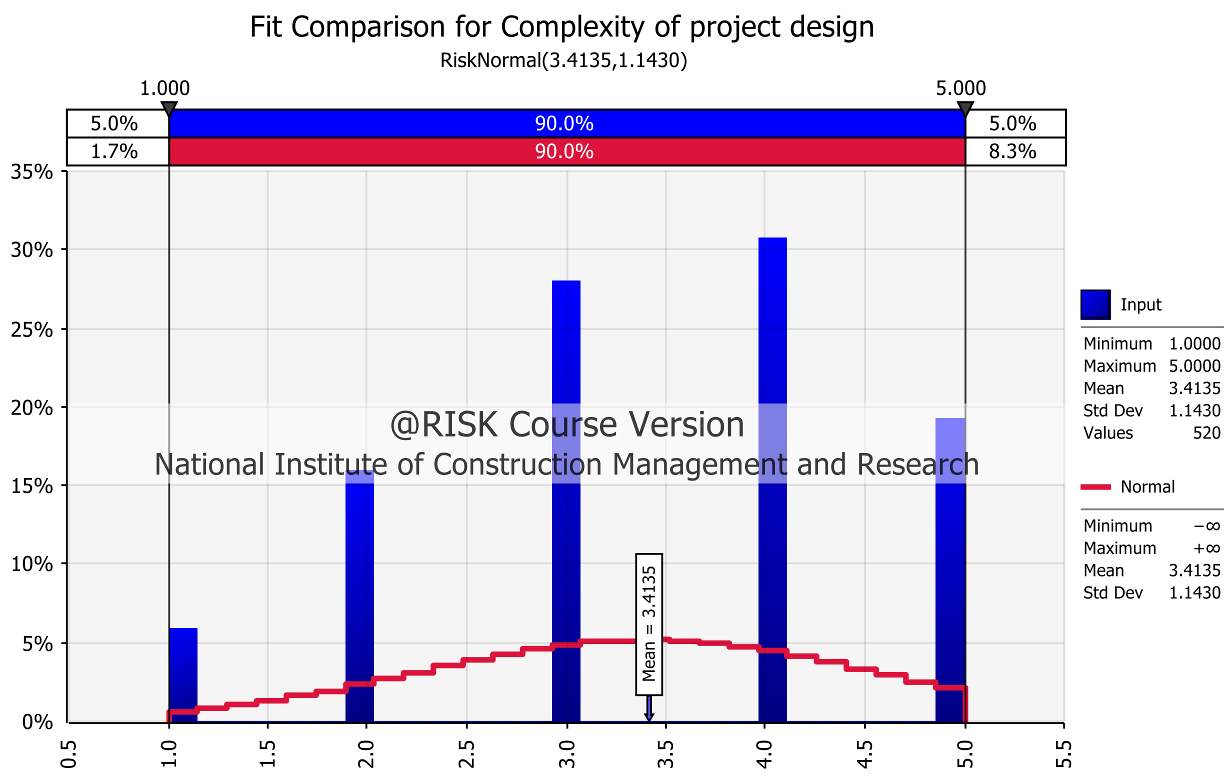
	MONTHLY MONITORING AND CONTROLS (TIME)							
	SPI Budget = Earned Value/Planned Value	Interpretation	Project Completion based on Expected Time based Schedule (PCD)R	Project Completion based on monthly Updated Schedule (PCD)U	Project Completion based on the baseline Schedule (PCD)B	Maximum Allowable Delay	Quantified Risk Effect based on Time = ((PCD)U - (PCD)R))/((PCD)R - (PCD)B))*100	Quantified Risk Effect on Time
Nov-09	0.75	Behind the Schedule	15-12-2011	08-11-2011	01-10-2011	75	-49%	The Maximum allowable delay is the difference between the Completion date Schedule based on the Expected time and the completion date of updated Schedule based on the Base Time details.
Dec-09	0.72	Behind the Schedule	15-12-2011	20-11-2011	01-10-2011	75	-33%	
Jan-10								
Feb-10								
Mar-10								
Apr-10								
May-10								
Jun-10								
Jul-10								
Aug-10								
Sep-10								
Input	Output	Output	Input at Initial Phase	Monthly Input from Schedule	Input at Initial Phase	Processed	Output	Output

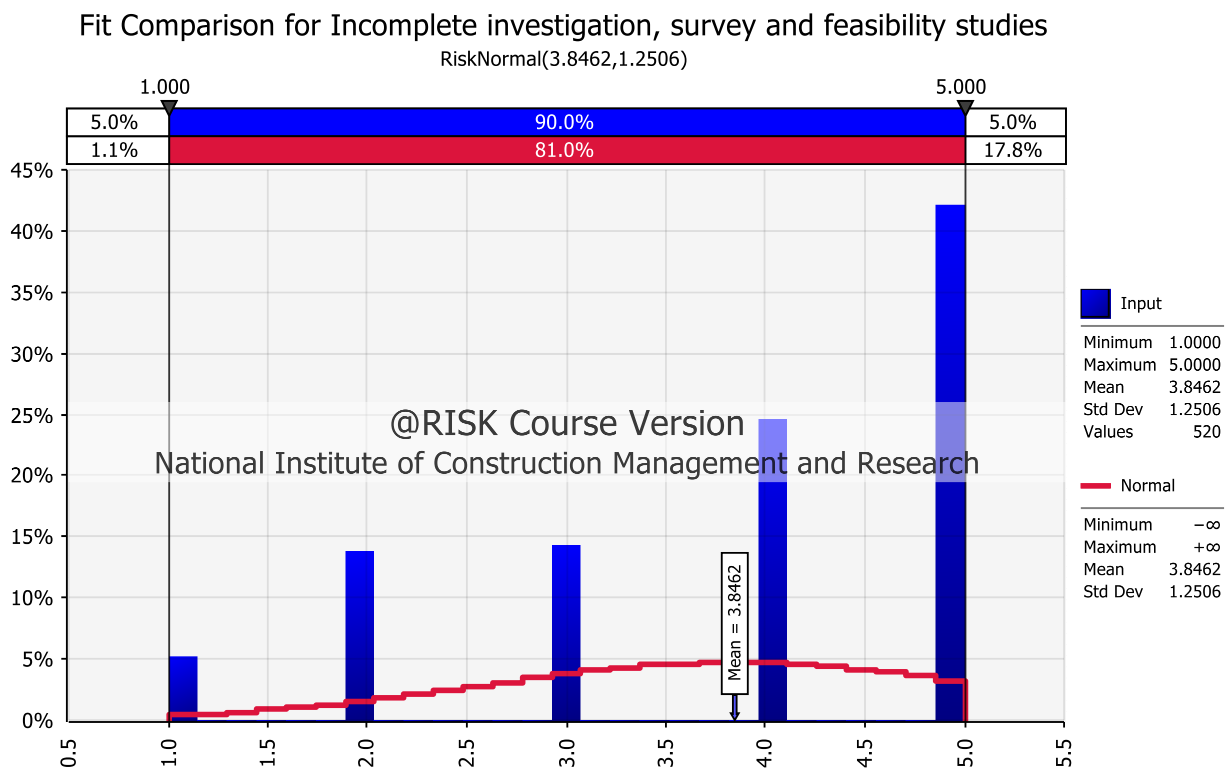
EXHIBIT 04

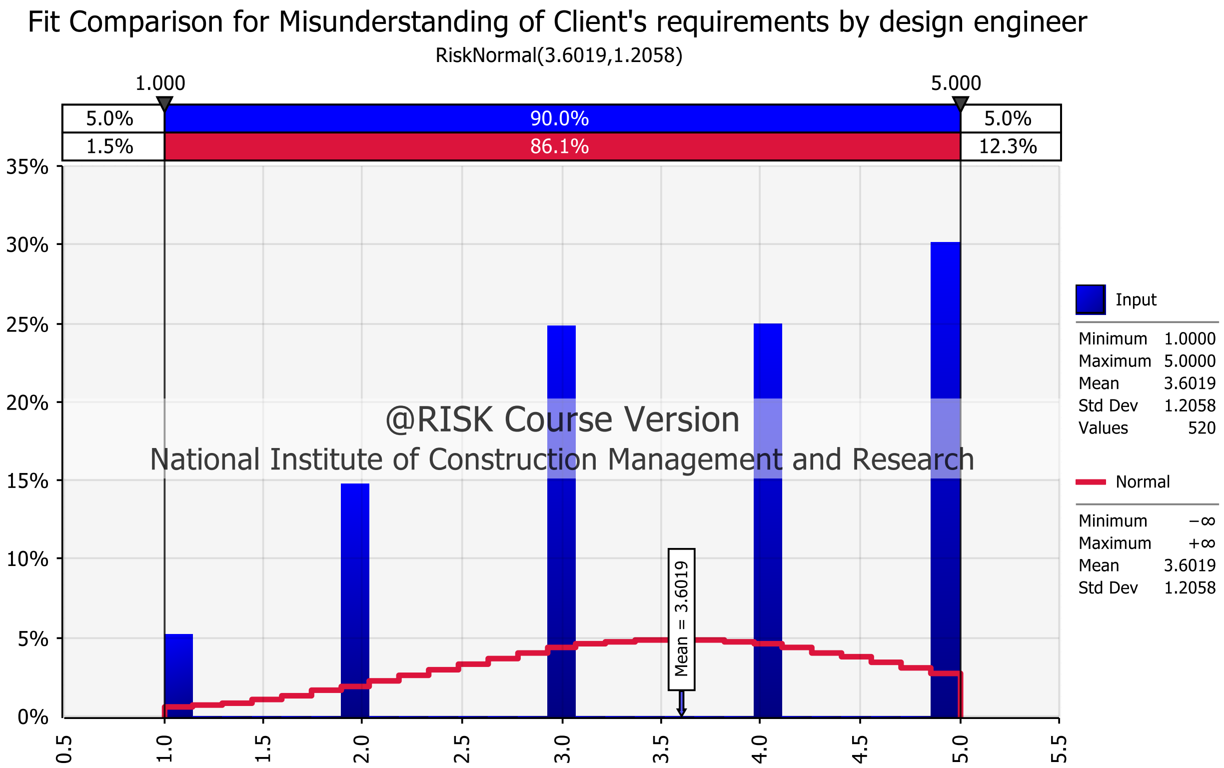
DISTRIBUTION OF THE RESPONSES FOR EACH VARIABLES



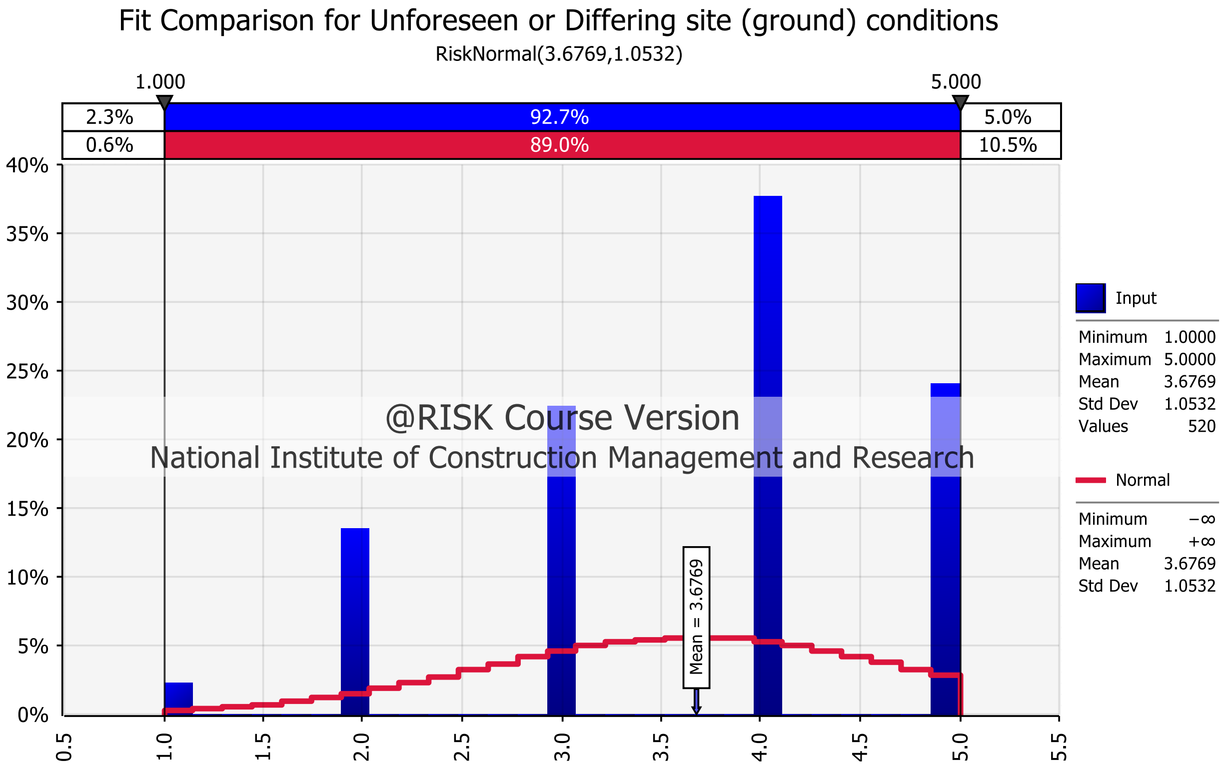



Fit Comparison for Complexity of project design
RiskNormal(3.4135,1.1430)
1.000
5.000
5.0%
90.0%
5.0%
1.7%
90.0%
8.3%
Mean = 3.4135
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.4135
Std Dev 1.1430
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.4135
Std Dev 1.1430

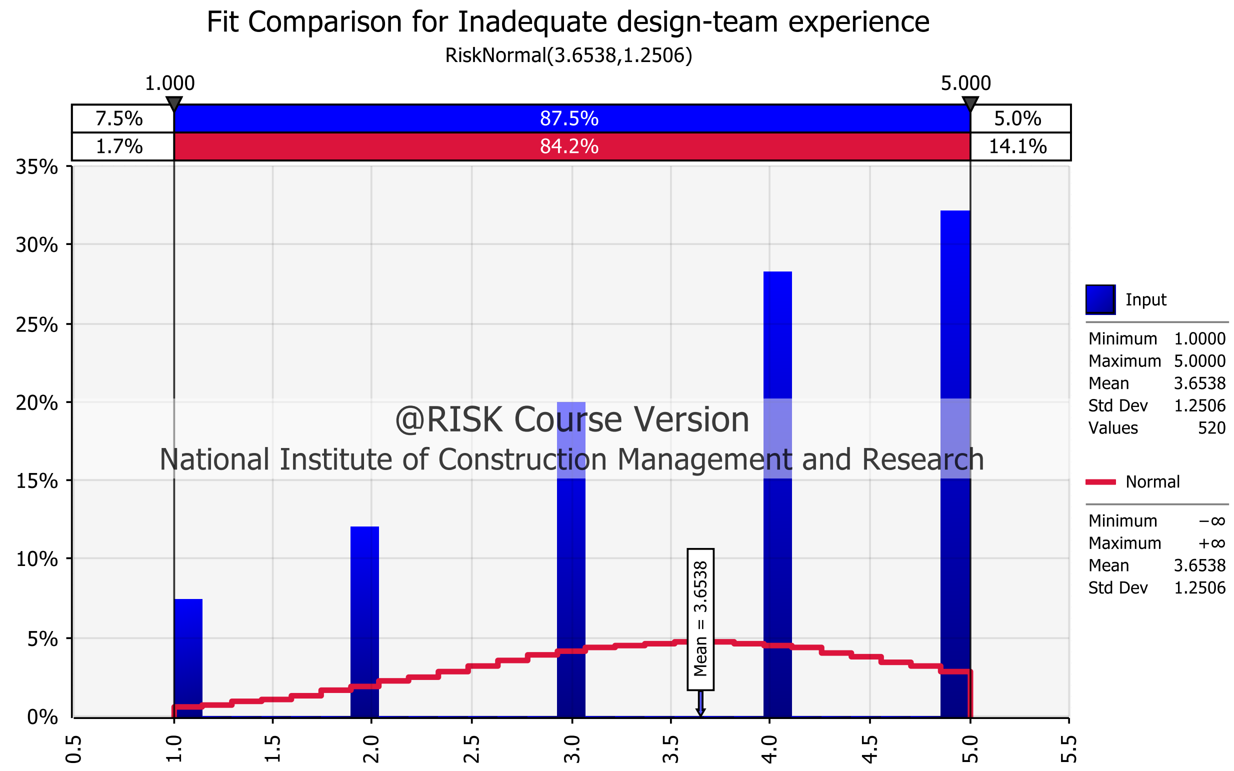

Fit Comparison for Incomplete investigation, survey and feasibility studies
RiskNormal(3.8462,1.2506)
1.000
5.000
5.0%
90.0%
5.0%
1.1%
81.0%
17.8%
Mean = 3.8462
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.8462
Std Dev 1.2506
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.8462
Std Dev 1.2506

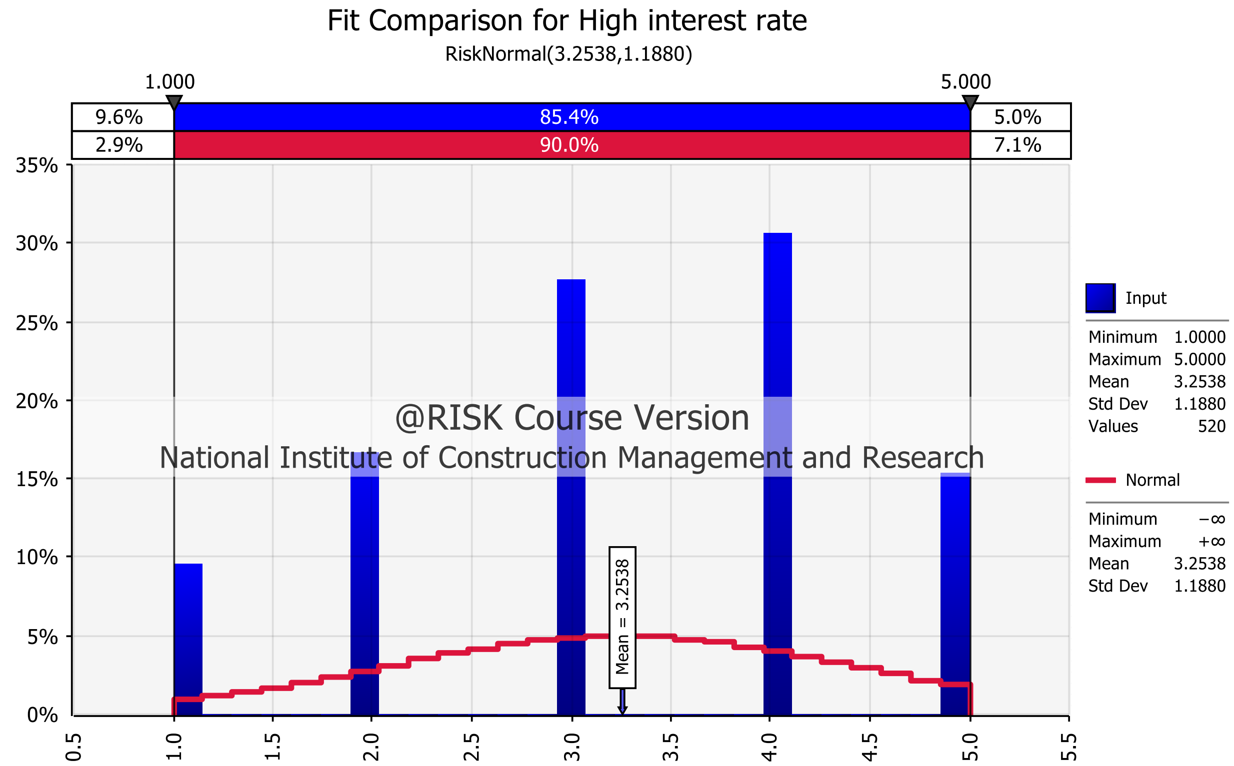


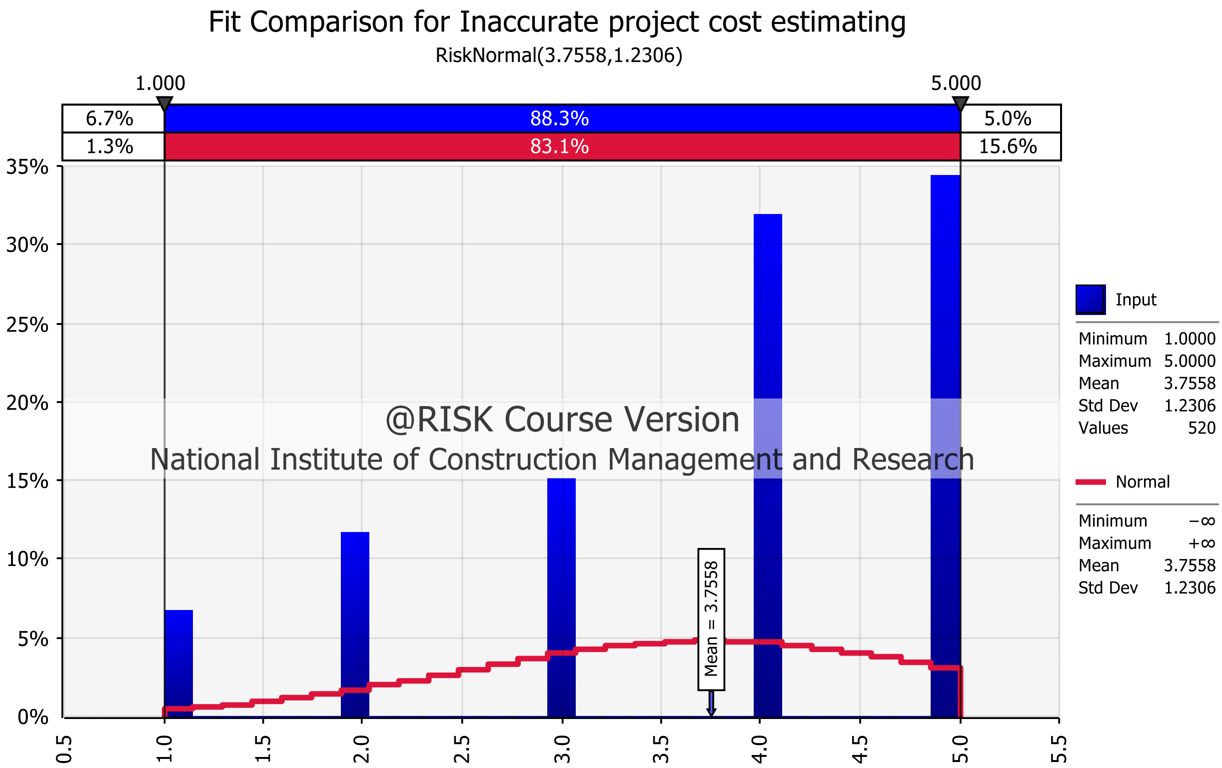
Fit Comparison for Misunderstanding of Client's requirements by design engineer
RiskNormal(3.6019,1.2058)
1.000
5.000
5.0%
90.0%
5.0%
1.5%
86.1%
12.3%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.6019
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6019
Std Dev 1.2058
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6019
Std Dev 1.2058



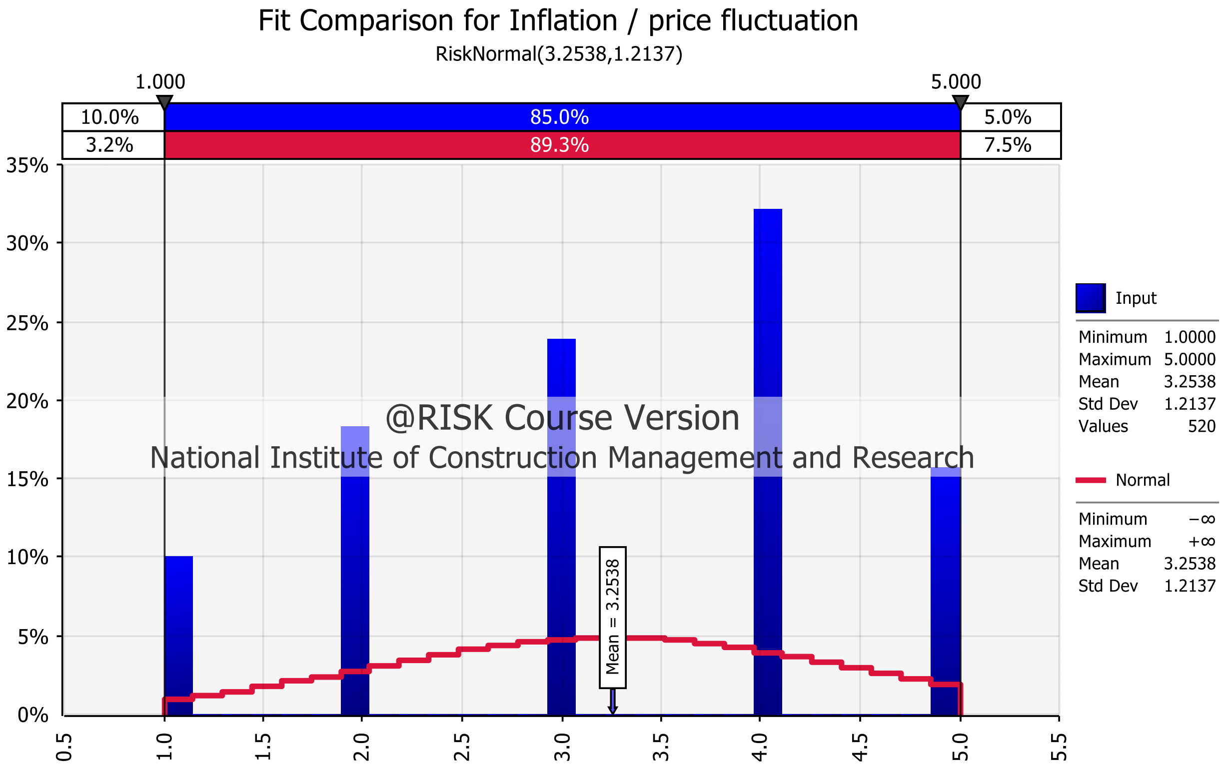
Fit Comparison for Unforeseen or Differing site (ground) conditions
RiskNormal(3.6769,1.0532)
1.000
5.000
2.3%
92.7%
5.0%
0.6%
89.0%
10.5%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.6769
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6769
Std Dev 1.0532
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6769
Std Dev 1.0532


Fit Comparison for Inadequate design-team experience
RiskNormal(3.6538,1.2506)
1.000
5.000
7.5%
87.5%
5.0%
1.7%
84.2%
14.1%
35%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.6538
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6538
Std Dev 1.2506
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6538
Std Dev 1.2506

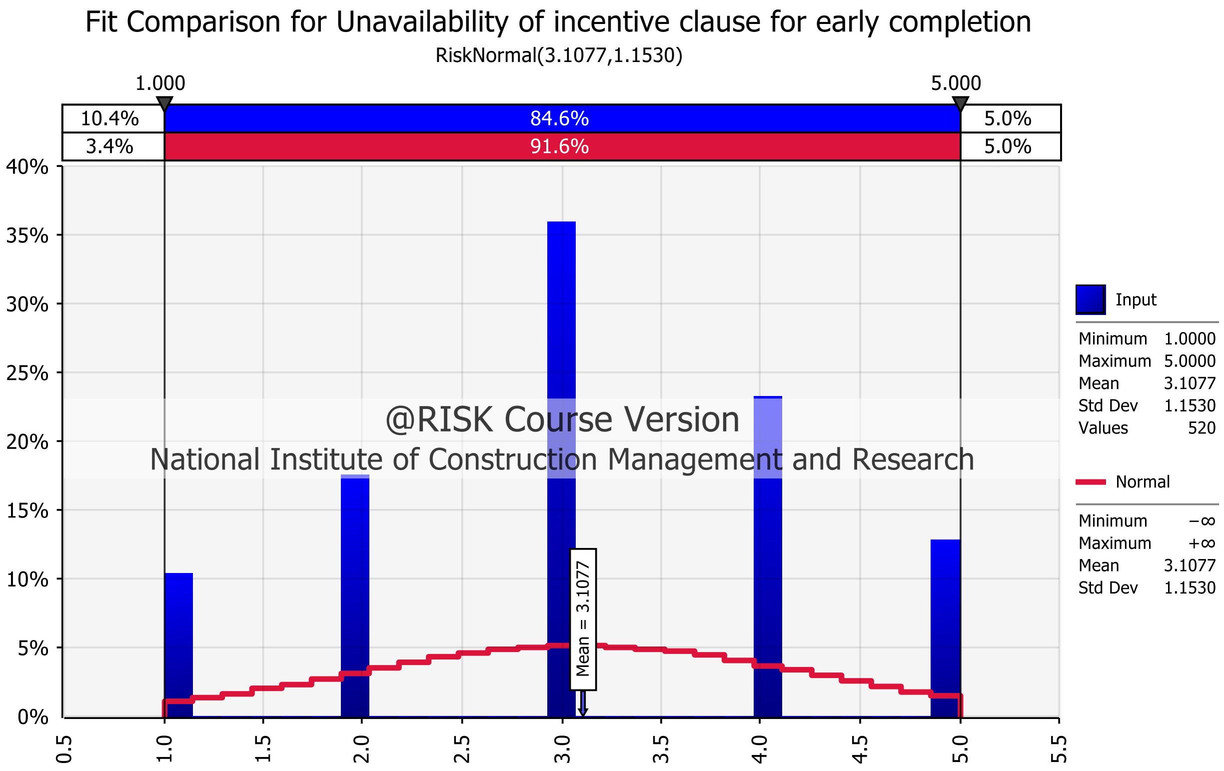

Fit Comparison for High interest rate
RiskNormal(3.2538,1.1880)
1.000
5.000
9.6%
85.4%
5.0%
2.9%
90.0%
7.1%
35%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.2538
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.2538
Std Dev 1.1880
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.2538
Std Dev 1.1880

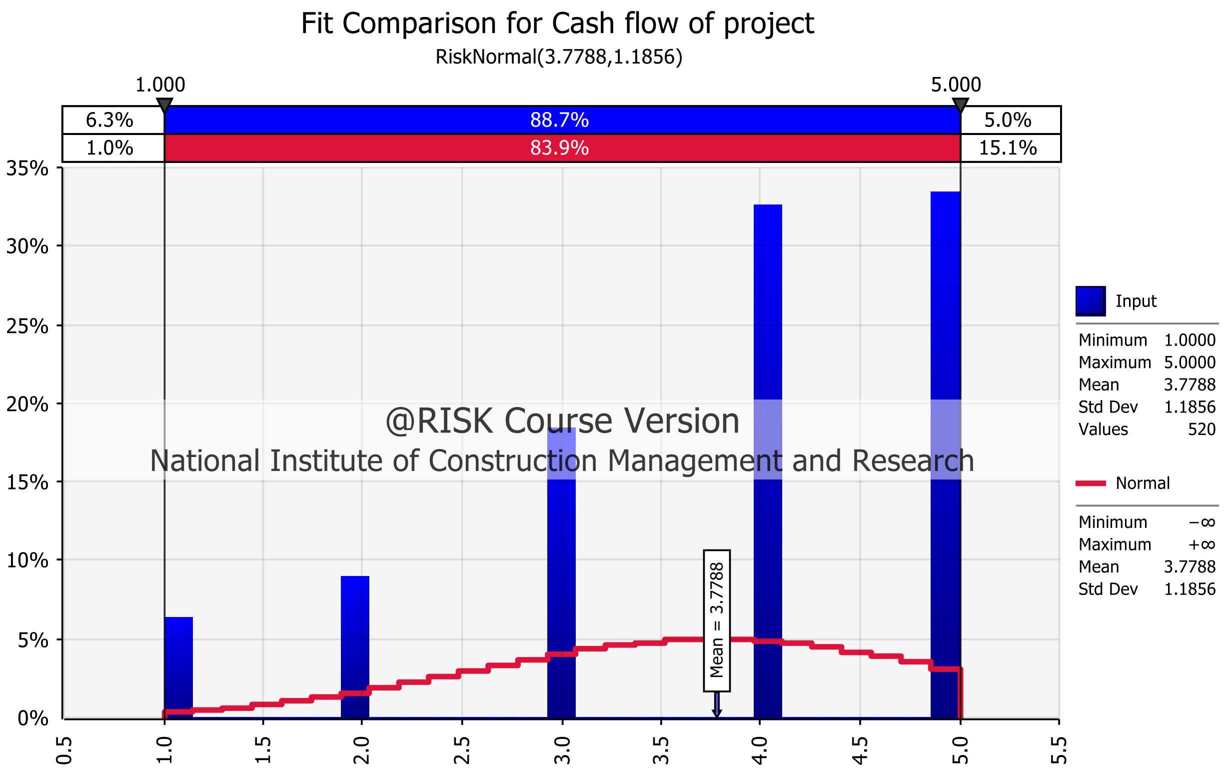


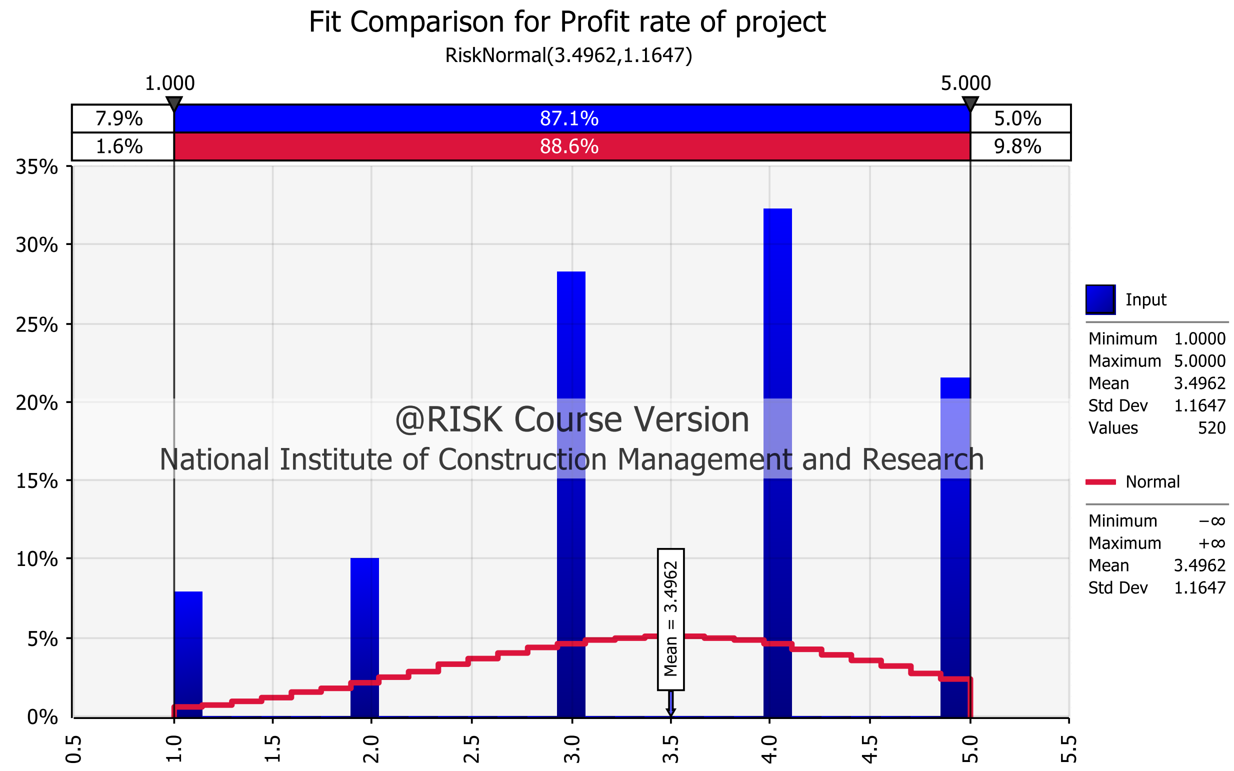
Fit Comparison for Inaccurate project cost estimating
RiskNormal(3.7558,1.2306)
1.000
5.000
6.7%
88.3%
5.0%
1.3%
83.1%
15.6%
Mean = 3.7558
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.7558
Std Dev 1.2306
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.7558
Std Dev 1.2306
@RISK Course Version
National Institute of Construction Management and Research

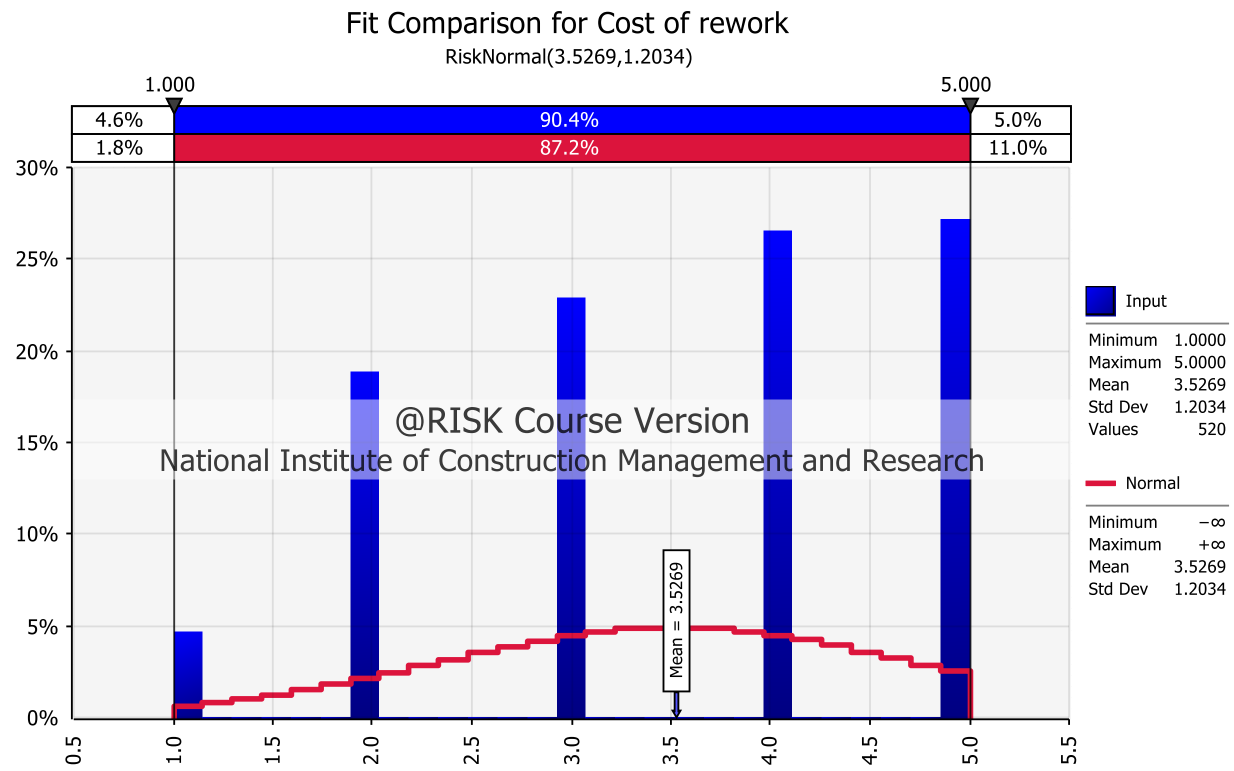


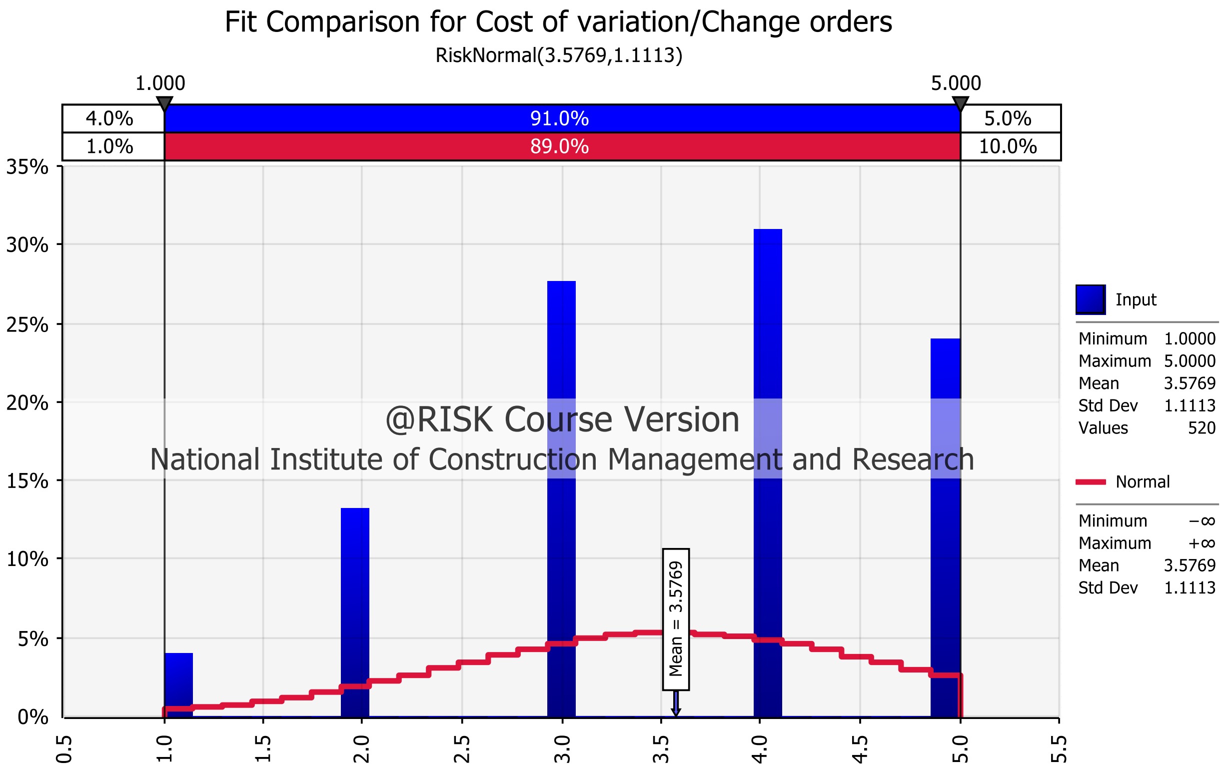
Fit Comparison for Inflation / price fluctuation
RiskNormal(3.2538,1.2137)
1.000
5.000
10.0%
85.0%
5.0%
3.2%
89.3%
7.5%
Mean = 3.2538
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.2538
Std Dev 1.2137
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.2538
Std Dev 1.2137
@RISK Course Version
National Institute of Construction Management and Research

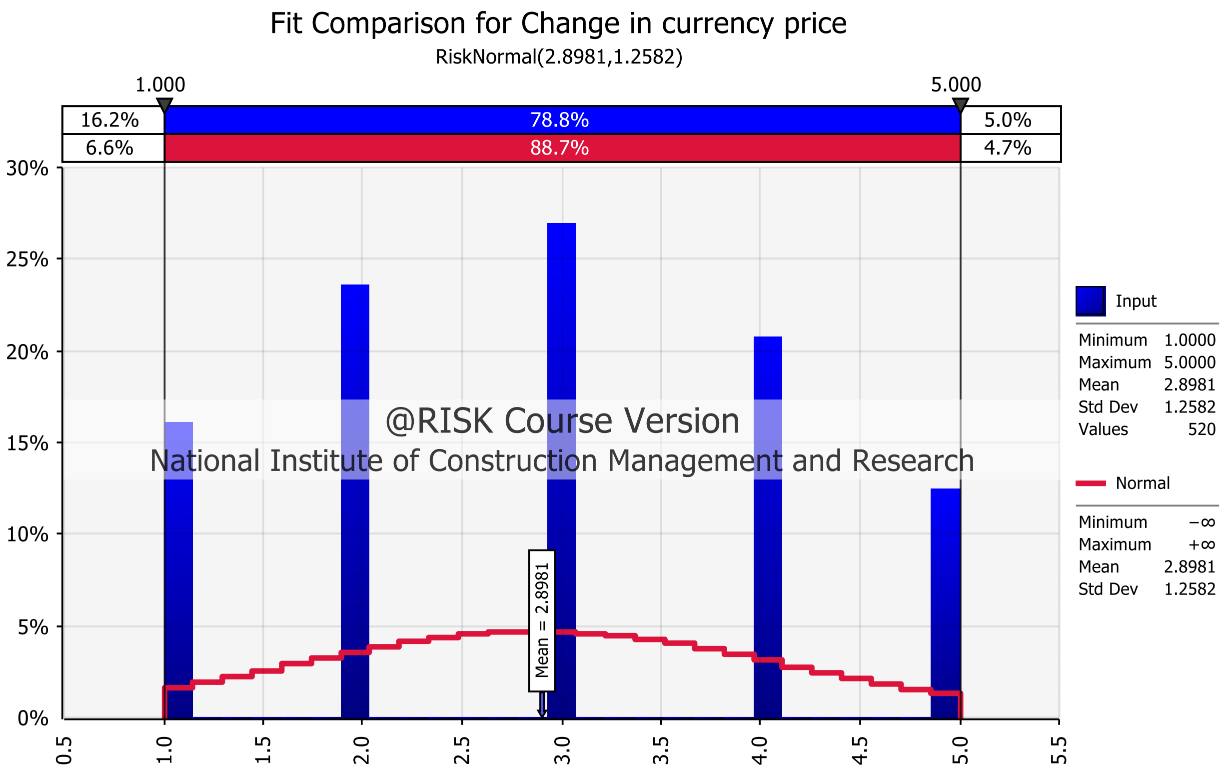

Fit Comparison for Unavailability of incentive clause for early completion
RiskNormal(3.1077,1.1530)
1.000
5.000
10.4%
84.6%
5.0%
3.4%
91.6%
5.0%
Mean = 3.1077
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.1077
Std Dev 1.1530
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.1077
Std Dev 1.1530
@RISK Course Version
National Institute of Construction Management and Research

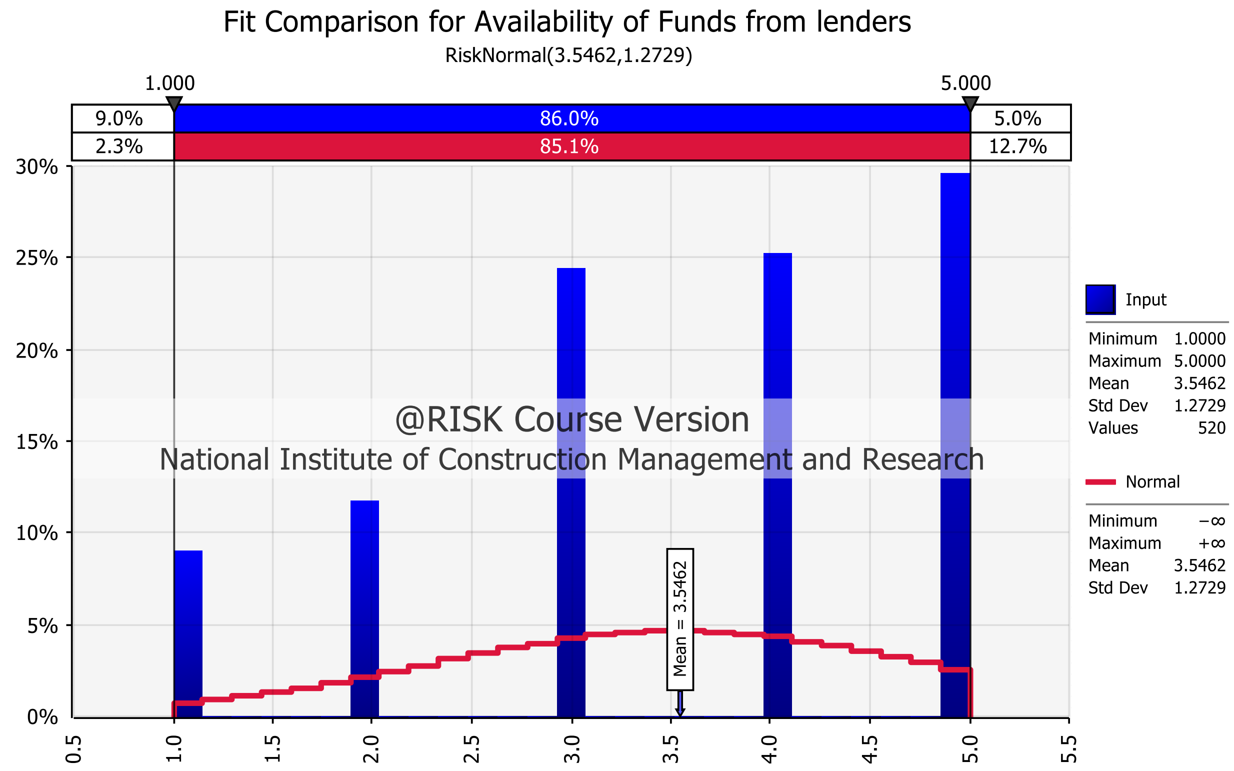

Fit Comparison for Cash flow of project
RiskNormal(3.7788,1.1856)
1.000
5.000
6.3%
88.7%
5.0%
1.0%
83.9%
15.1%
Mean = 3.7788
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.7788
Std Dev 1.1856
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.7788
Std Dev 1.1856
@RISK Course Version
National Institute of Construction Management and Research


Fit Comparison for Profit rate of project
RiskNormal(3.4962,1.1647)
1.000
5.000
7.9%
87.1%
5.0%
1.6%
88.6%
9.8%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.4962
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.4962
Std Dev 1.1647
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.4962
Std Dev 1.1647

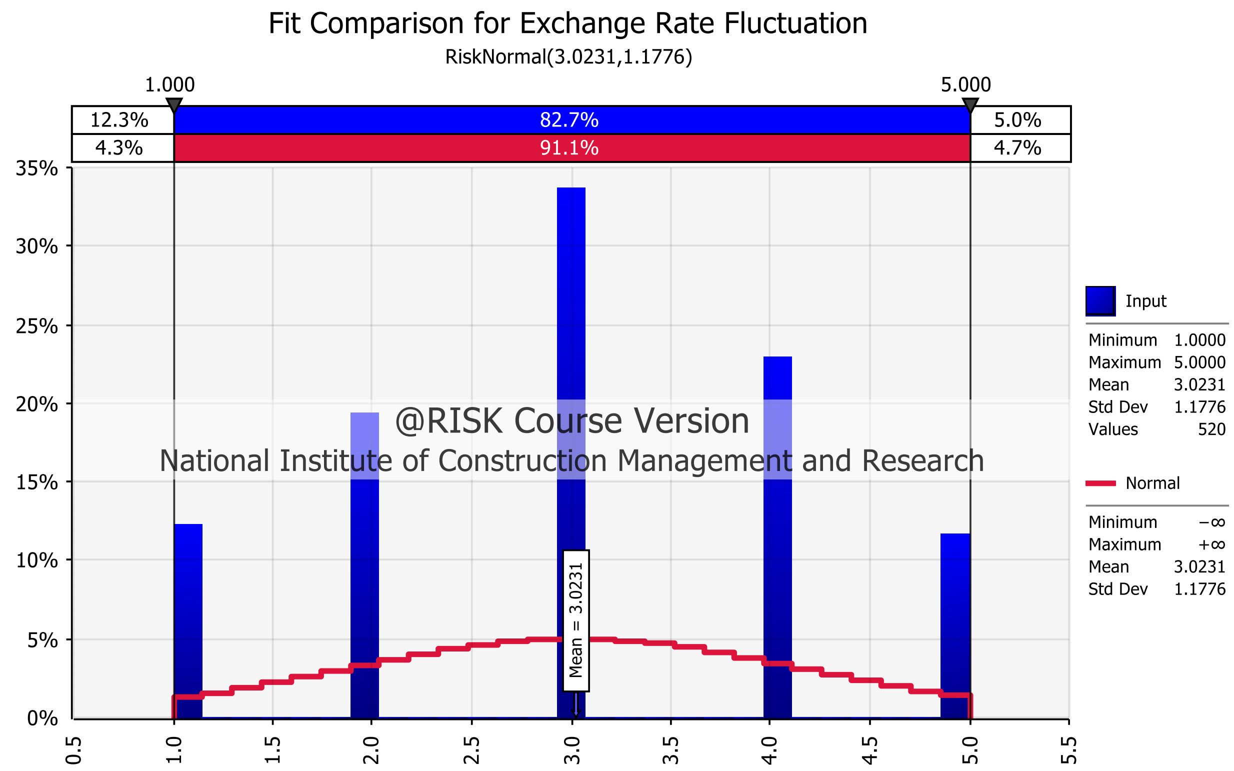

Fit Comparison for Cost of rework
RiskNormal(3.5269,1.2034)
1.000
5.000
4.6%
90.4%
5.0%
1.8%
87.2%
11.0%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.5269
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5269
Std Dev 1.2034
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5269
Std Dev 1.2034


Fit Comparison for Cost of variation/Change orders
RiskNormal(3.5769,1.1113)
1.000
5.000
4.0%
91.0%
5.0%
1.0%
89.0%
10.0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.5769
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5769
Std Dev 1.1113
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5769
Std Dev 1.1113

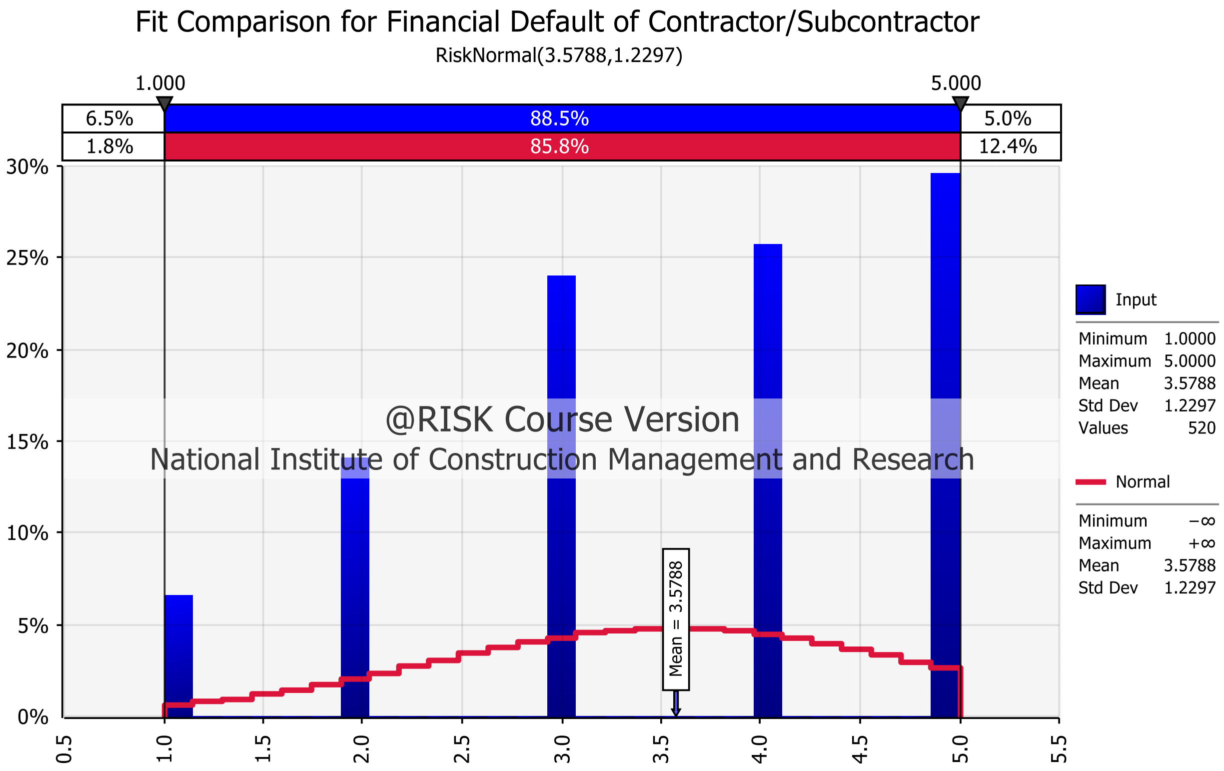

Fit Comparison for Change in currency price
RiskNormal(2.8981,1.2582)
1.000
5.000
16.2%
78.8%
5.0%
6.6%
88.7%
4.7%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 2.8981
Input
Minimum 1.0000
Maximum 5.0000
Mean 2.8981
Std Dev 1.2582
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 2.8981
Std Dev 1.2582

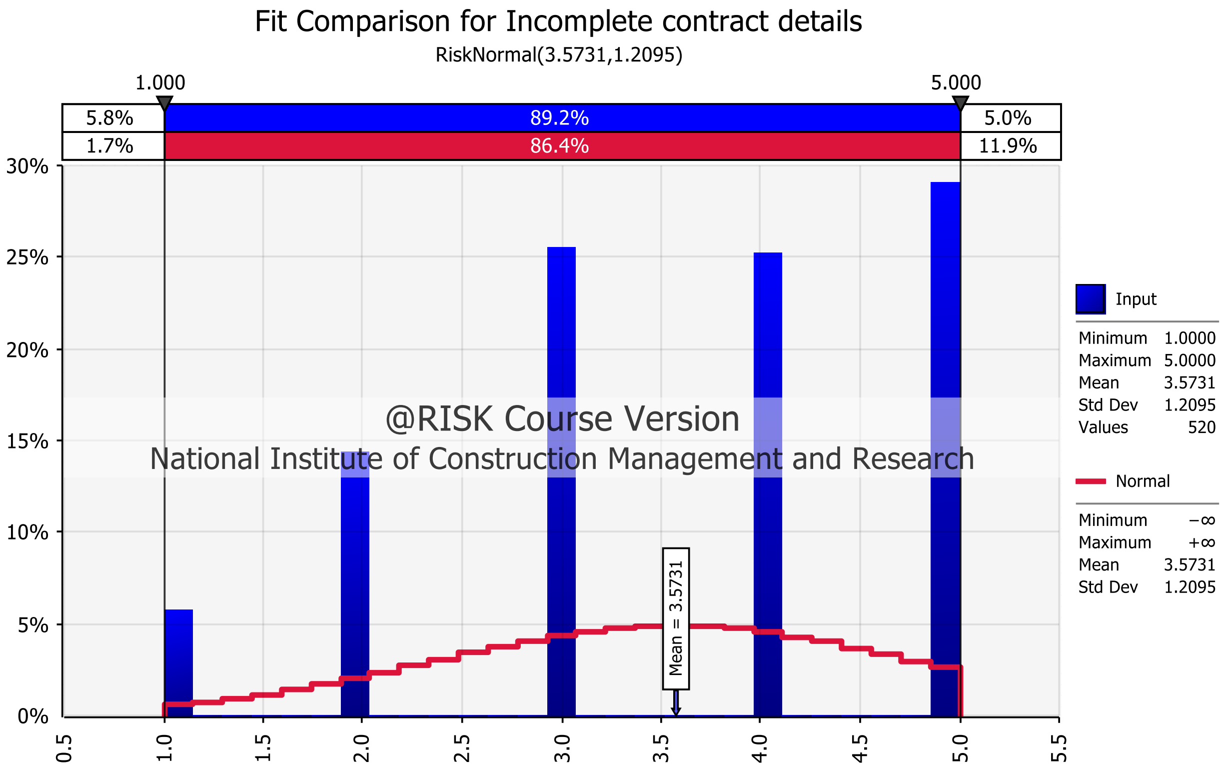


Fit Comparison for Availability of Funds from lenders
RiskNormal(3.5462,1.2729)
1.000
5.000
9.0%
86.0%
5.0%
2.3%
85.1%
12.7%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.5462
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5462
Std Dev 1.2729
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5462
Std Dev 1.2729

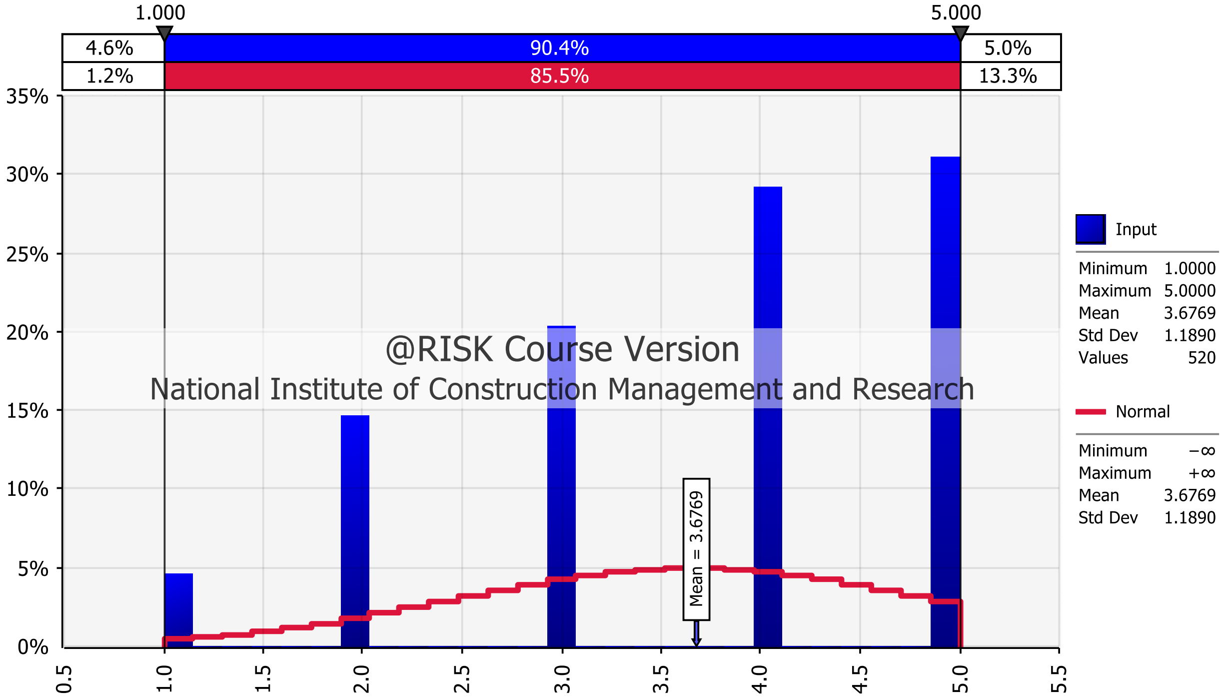


Fit Comparison for Exchange Rate Fluctuation
RiskNormal(3.0231,1.1776)
1.000
5.000
12.3%
82.7%
5.0%
4.3%
91.1%
4.7%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.0231
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.0231
Std Dev 1.1776
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.0231
Std Dev 1.1776

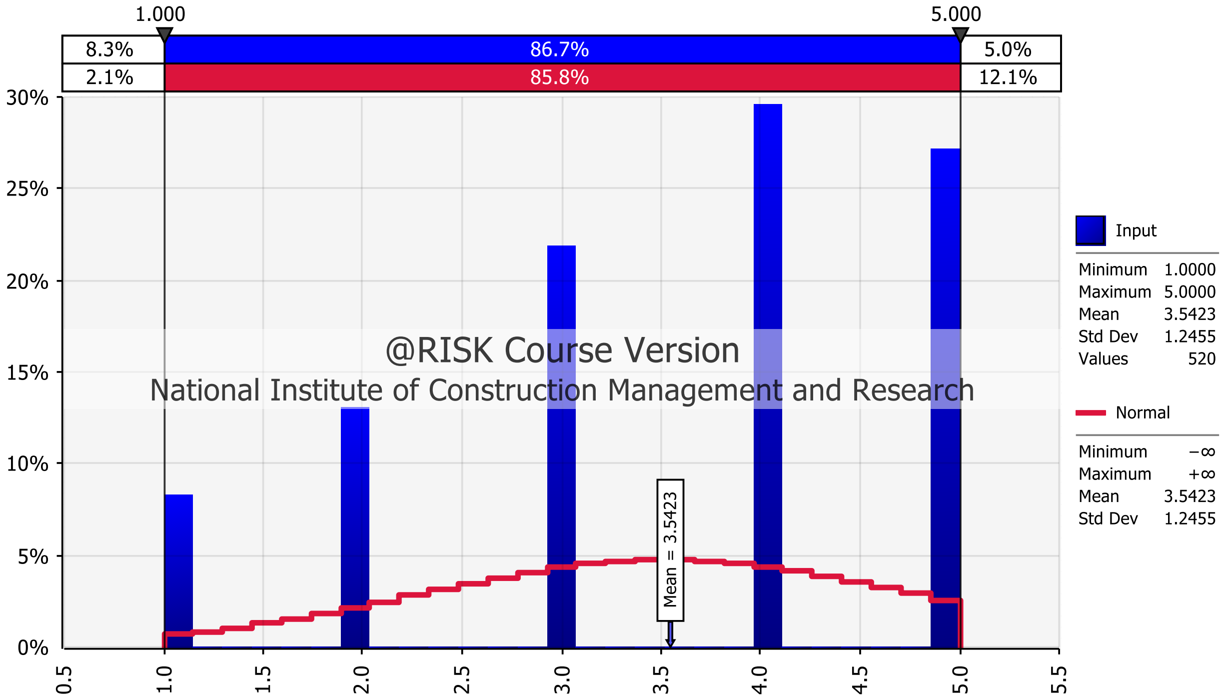

Fit Comparison for Financial Default of Contractor/Subcontractor
RiskNormal(3.5788,1.2297)
1.000
5.000
6.5%
88.5%
5.0%
1.8%
85.8%
12.4%
30%
25%
20%
15%
10%
5%
0%
Mean = 3.5788
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5788
Std Dev 1.2297
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5788
Std Dev 1.2297
@RISK Course Version
National Institute of Construction Management and Research

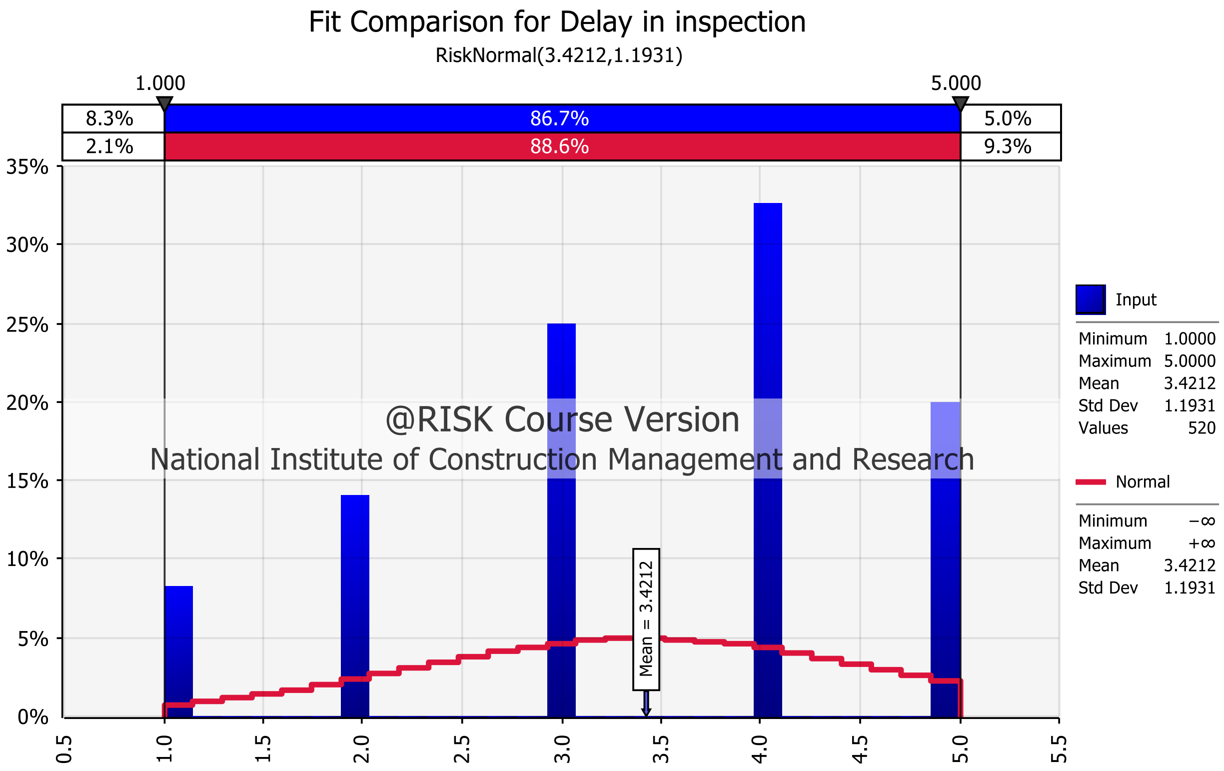

Fit Comparison for Incomplete contract details
RiskNormal(3.5731,1.2095)
1.000
5.000
5.8%
89.2%
5.0%
1.7%
86.4%
11.9%
30%
25%
20%
15%
10%
5%
0%
Mean = 3.5731
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5731
Std Dev 1.2095
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5731
Std Dev 1.2095
@RISK Course Version
National Institute of Construction Management and Research

Fit Comparison for Week design coordination and delay in communication
RiskNormal(3.6769,1.1890)

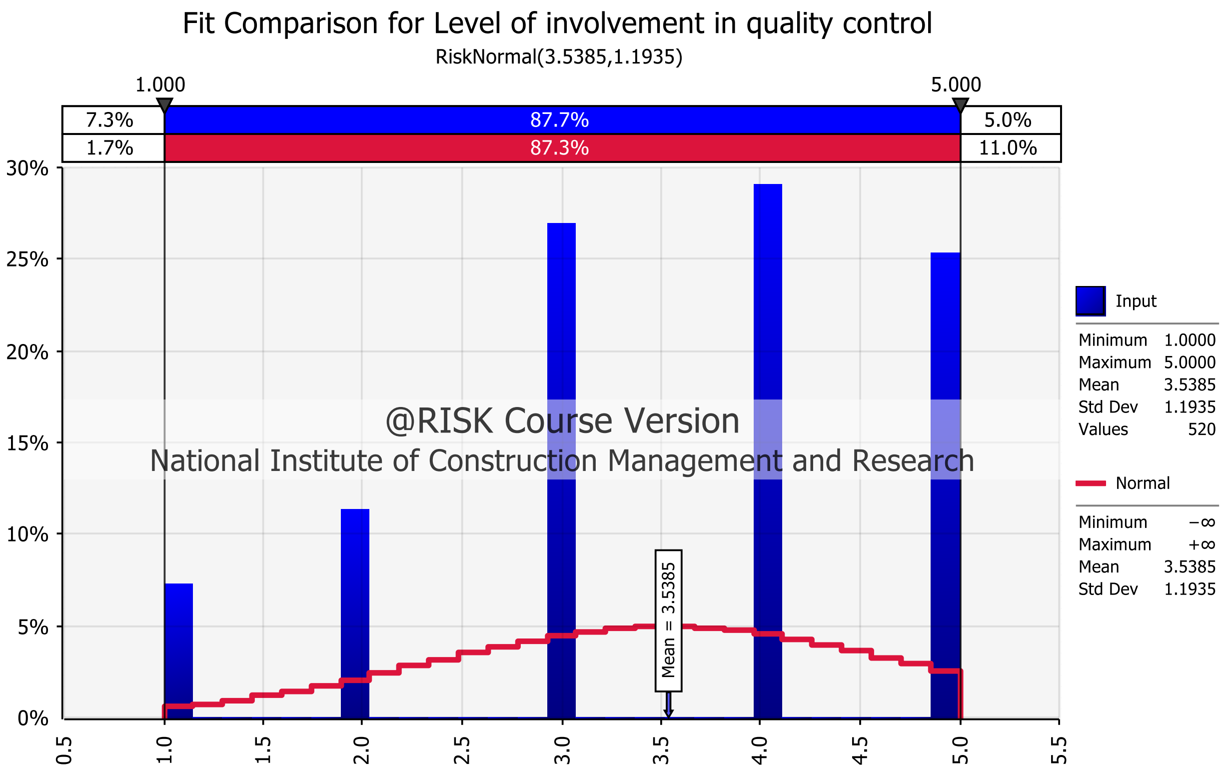


Fit Comparison for Slow response to Request For Information(RFI) or technical quarries
RiskNormal(3.5423,1.2455)

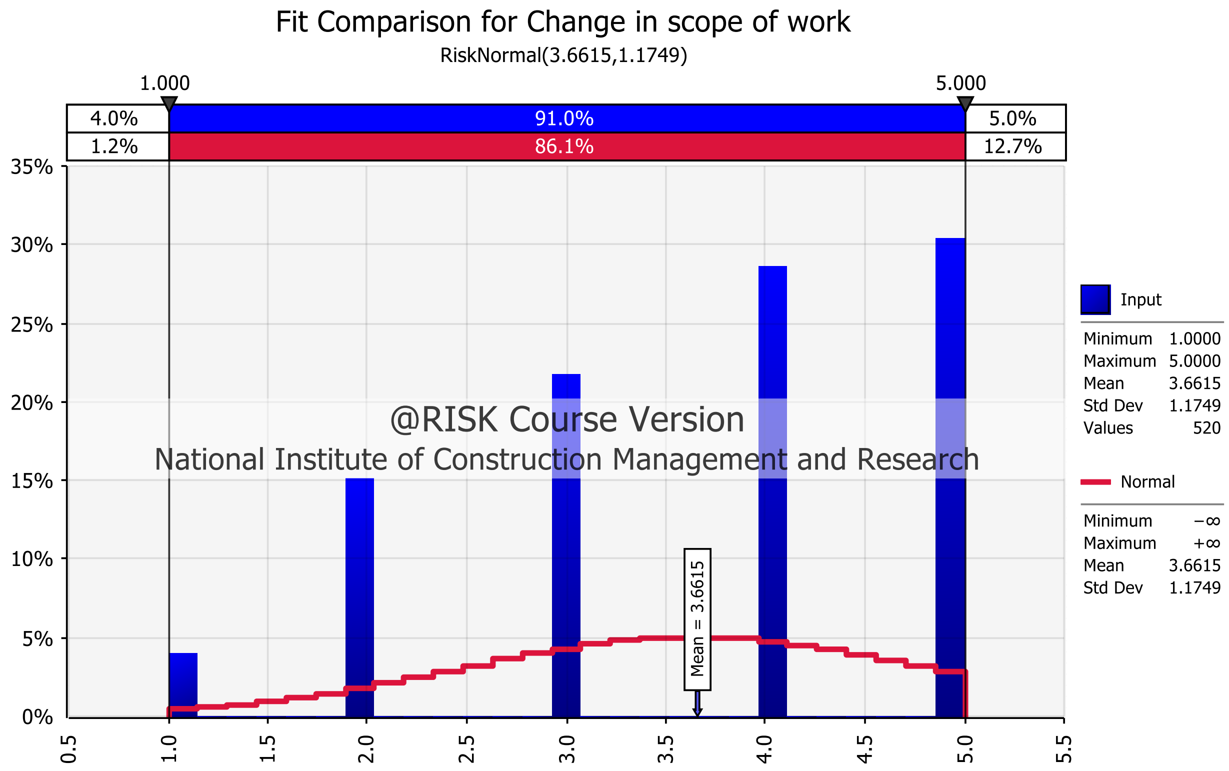


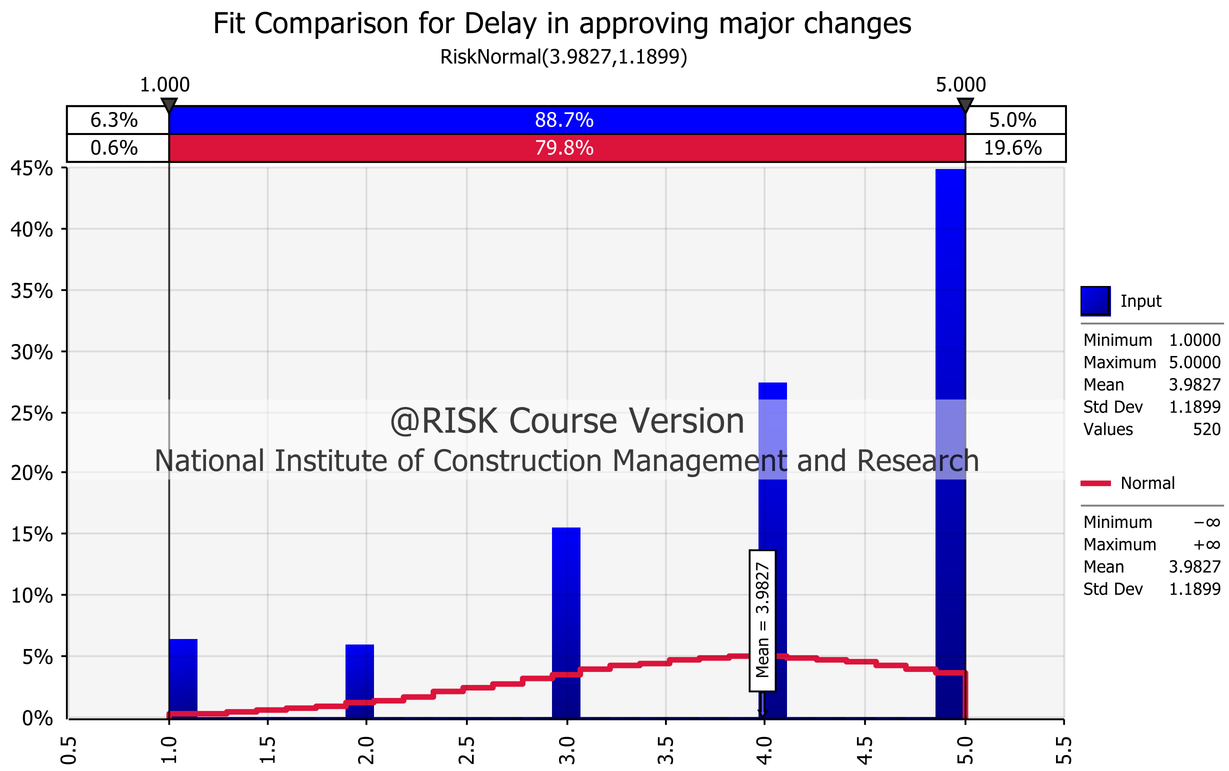


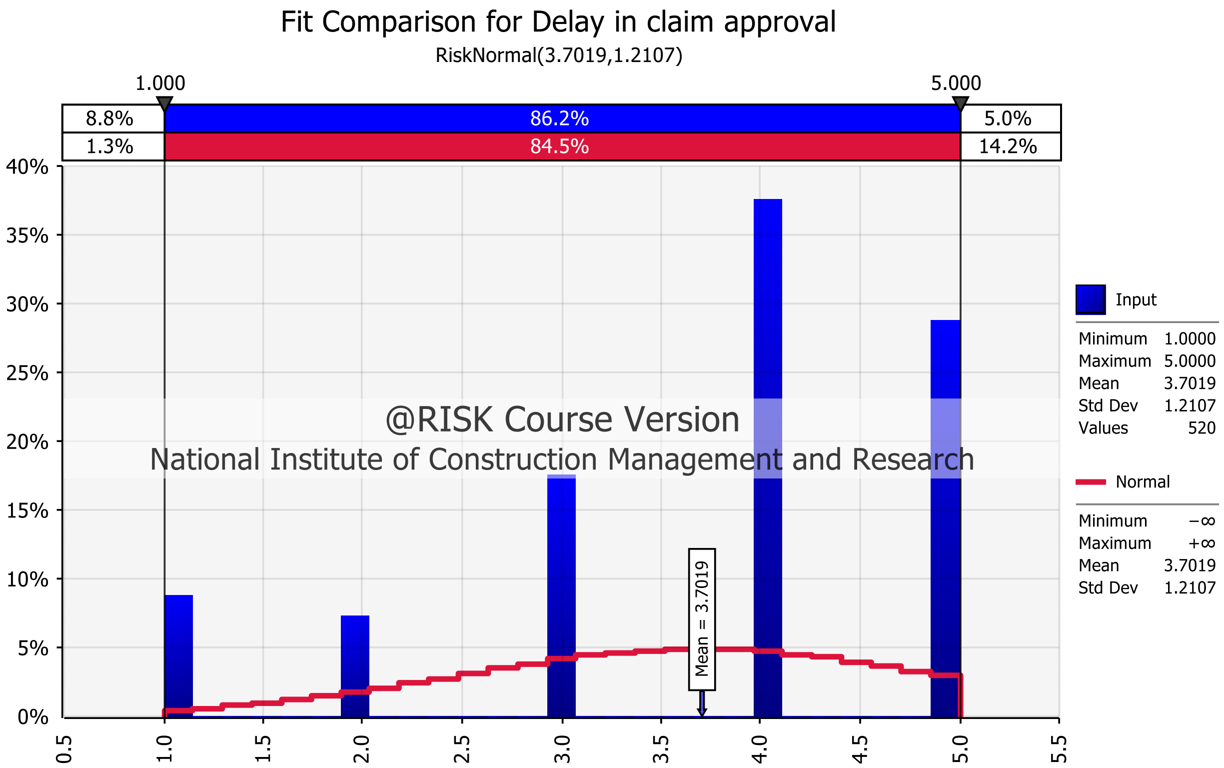
Fit Comparison for Delay in inspection
RiskNormal(3.4212,1.1931)
1.000
5.000
8.3%
86.7%
5.0%
2.1%
88.6%
9.3%
Mean = 3.4212
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.4212
Std Dev 1.1931
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.4212
Std Dev 1.1931
@RISK Course Version
National Institute of Construction Management and Research

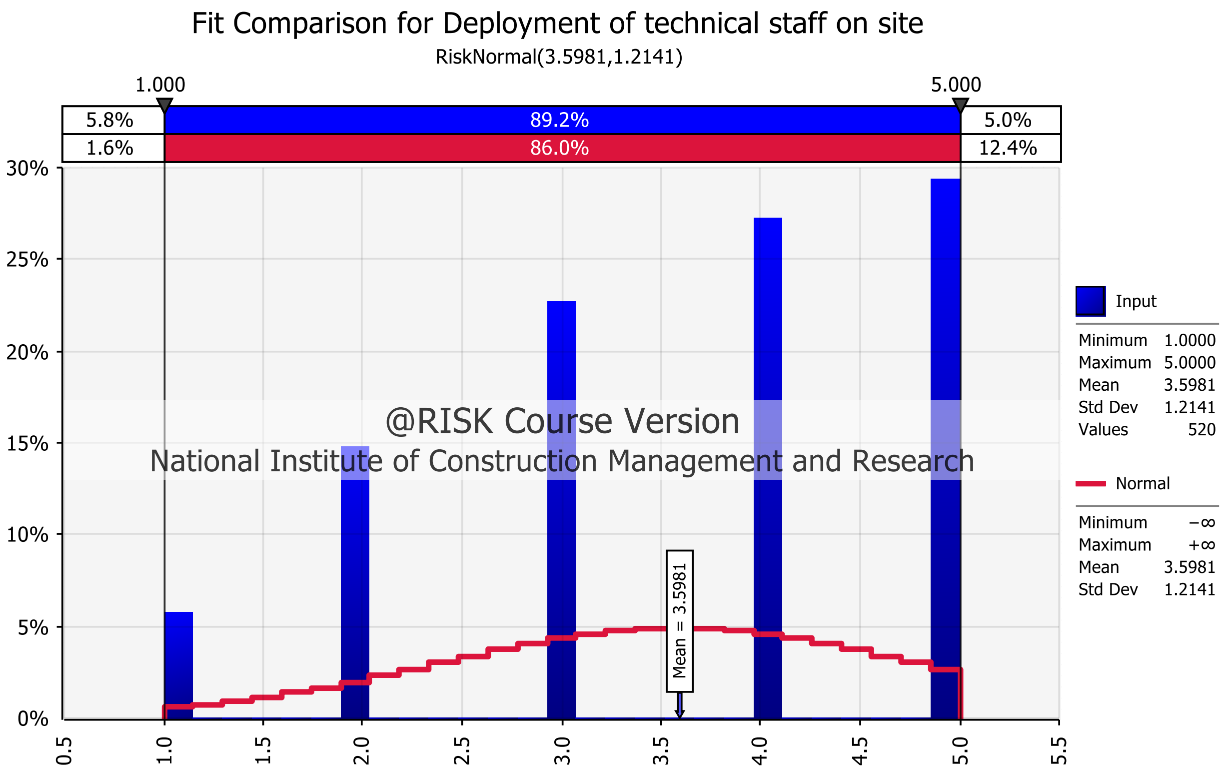


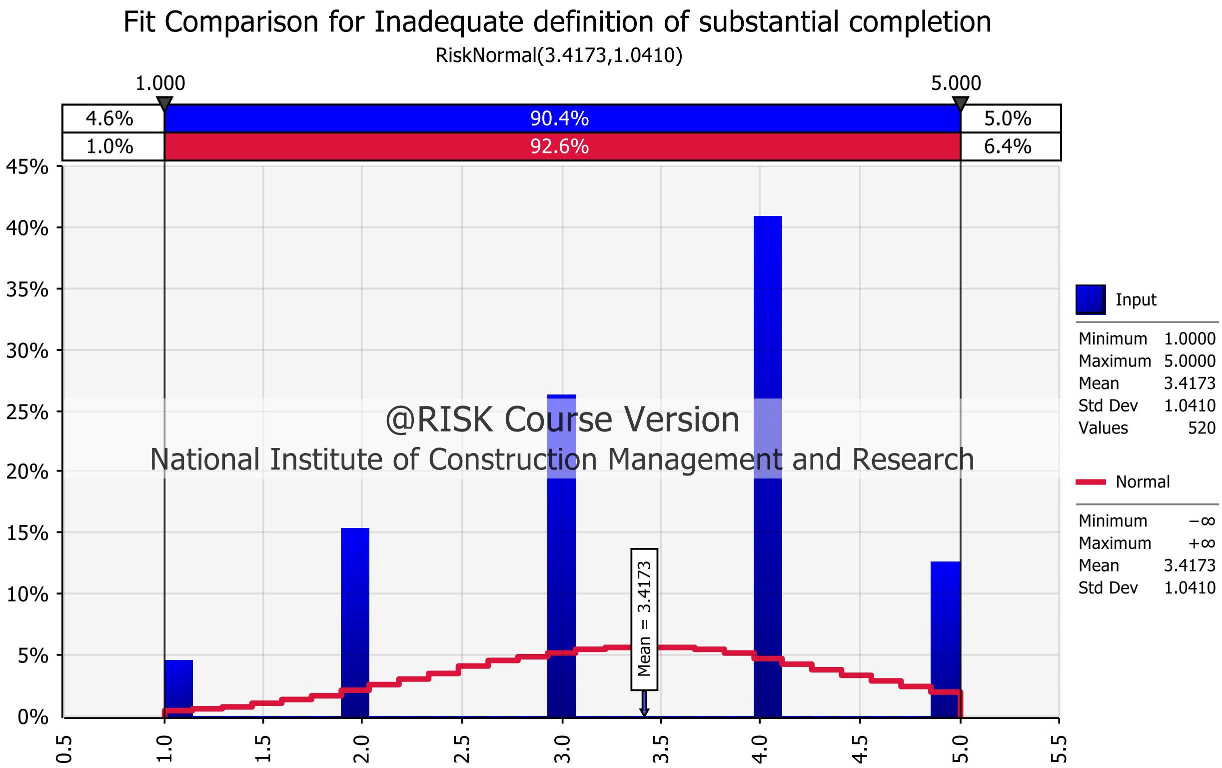
Fit Comparison for Level of involvement in quality control
RiskNormal(3.5385,1.1935)
1.000
5.000
7.3%
87.7%
5.0%
1.7%
87.3%
11.0%
Mean = 3.5385
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5385
Std Dev 1.1935
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5385
Std Dev 1.1935
@RISK Course Version
National Institute of Construction Management and Research

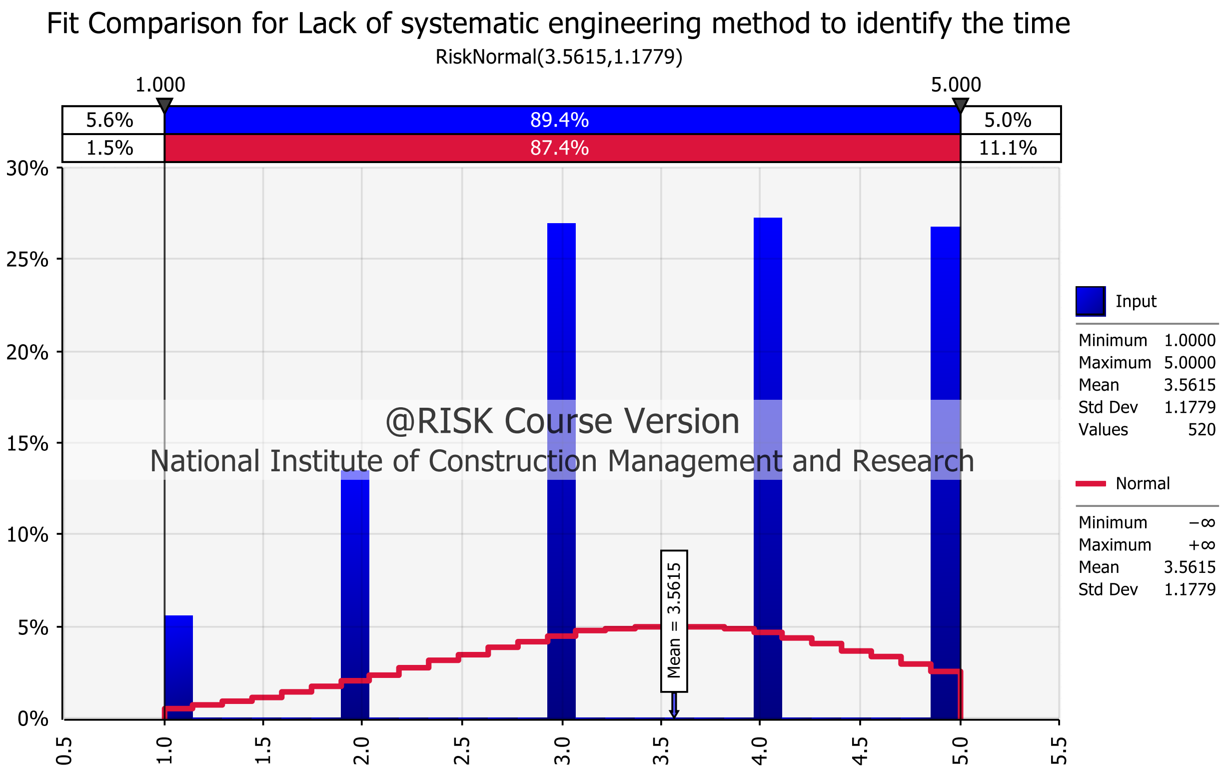

Fit Comparison for Change in scope of work
RiskNormal(3.6615,1.1749)
1.000
5.000
4.0%
91.0%
5.0%
1.2%
86.1%
12.7%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.6615
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6615
Std Dev 1.1749
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6615
Std Dev 1.1749

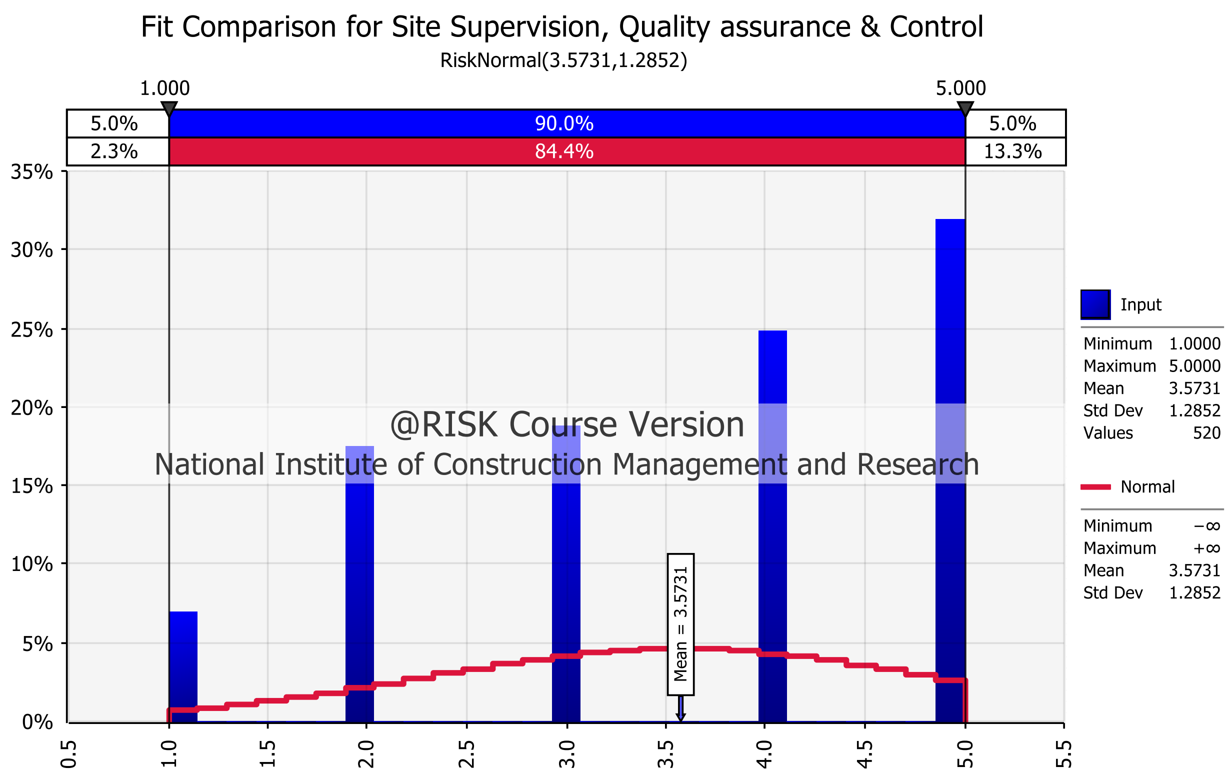

Fit Comparison for Delay in approving major changes
RiskNormal(3.9827,1.1899)
1.000
5.000
6.3%
88.7%
5.0%
0.6%
79.8%
19.6%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.9827
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.9827
Std Dev 1.1899
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.9827
Std Dev 1.1899

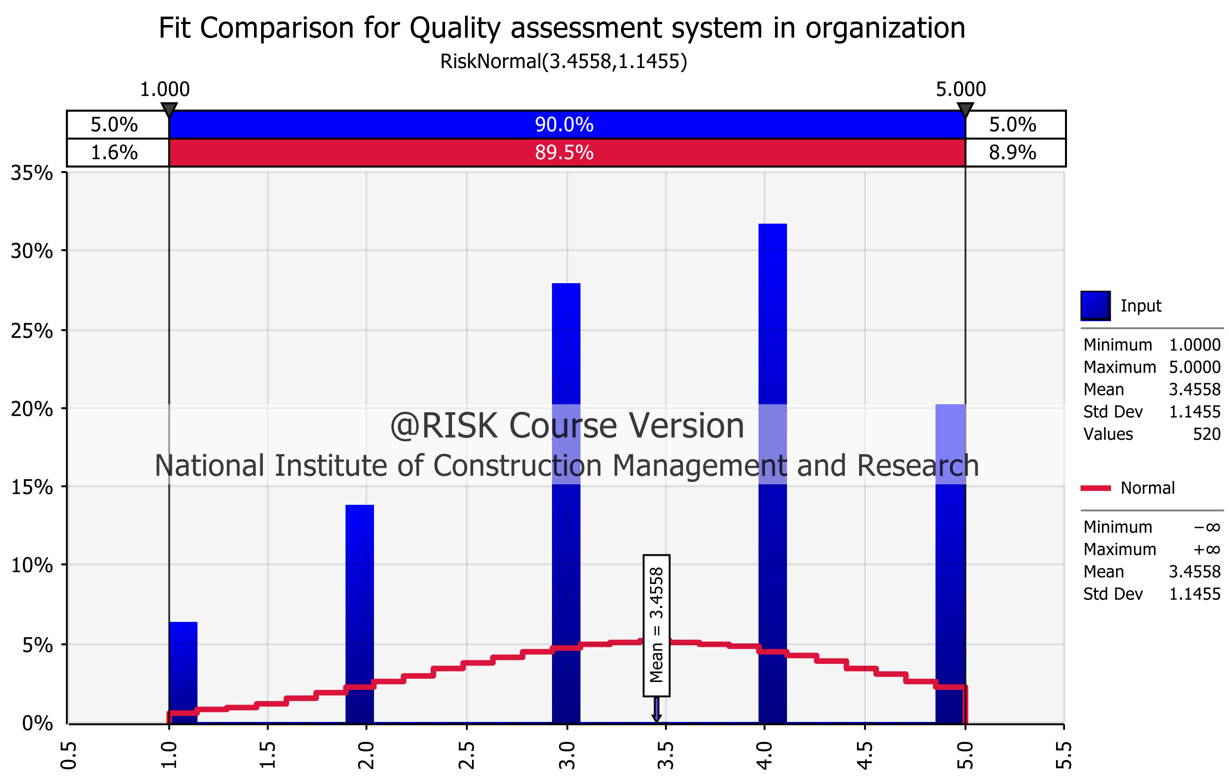

Fit Comparison for Delay in claim approval
RiskNormal(3.7019,1.2107)
1.000
5.000
8.8%
86.2%
5.0%
1.3%
84.5%
14.2%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.7019
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.7019
Std Dev 1.2107
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.7019
Std Dev 1.2107

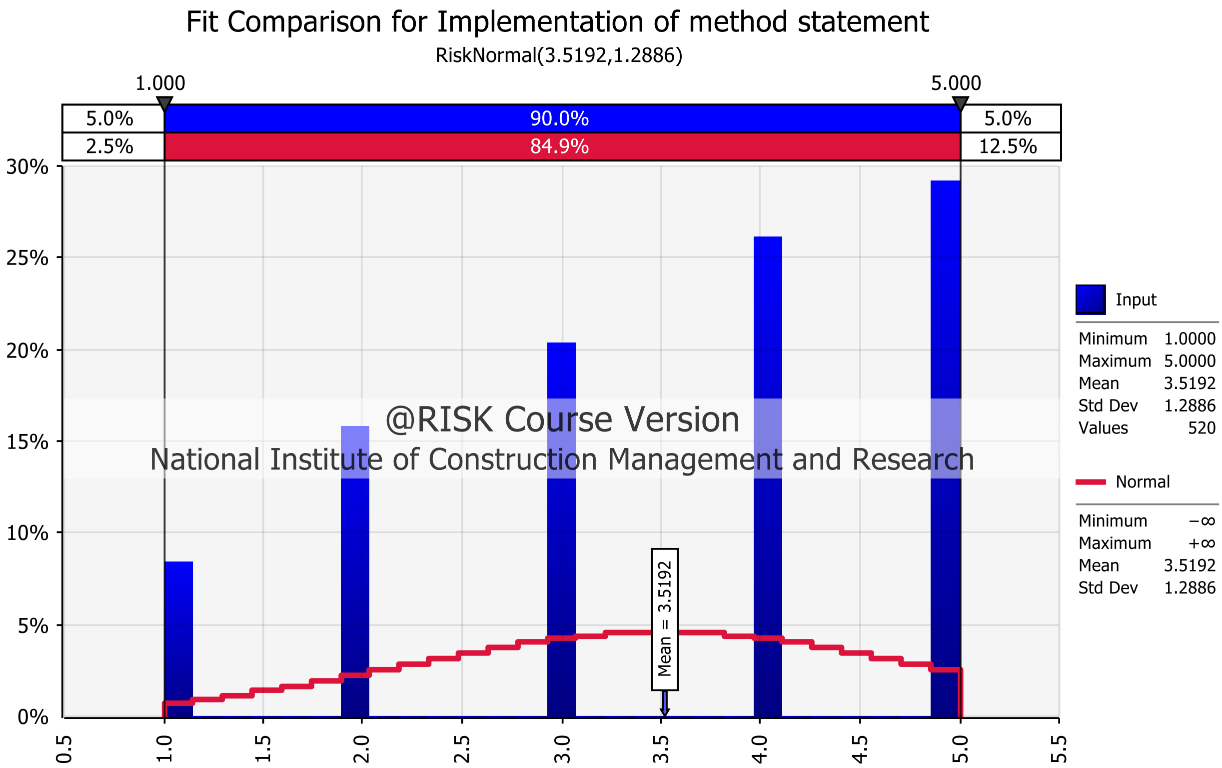

Fit Comparison for Deployment of technical staff on site
RiskNormal(3.5981,1.2141)
1.000
5.000
5.8%
89.2%
5.0%
1.6%
86.0%
12.4%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.5981
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5981
Std Dev 1.2141
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5981
Std Dev 1.2141


Fit Comparison for Inadequate definition of substantial completion
RiskNormal(3.4173,1.0410)
1.000
5.000
4.6%
90.4%
5.0%
1.0%
92.6%
6.4%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.4173
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.4173
Std Dev 1.0410
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.4173
Std Dev 1.0410

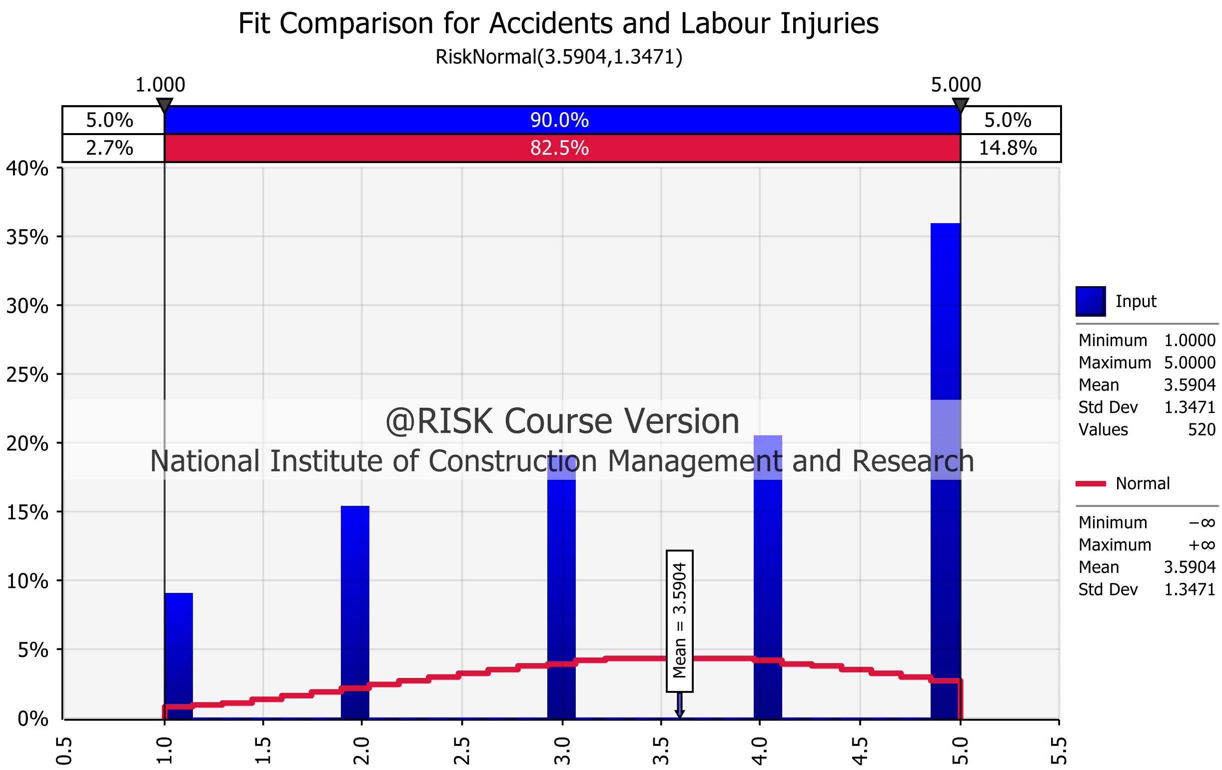

Fit Comparison for Lack of systematic engineering method to identify the time
RiskNormal(3.5615,1.1779)
1.000
5.000
5.6%
89.4%
5.0%
1.5%
87.4%
11.1%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.5615
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5615
Std Dev 1.1779
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5615
Std Dev 1.1779


Fit Comparison for Site Supervision, Quality assurance & Control
RiskNormal(3.5731,1.2852)
1.000
5.000
5.0%
90.0%
5.0%
2.3%
84.4%
13.3%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.5731
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5731
Std Dev 1.2852
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5731
Std Dev 1.2852


Fit Comparison for Quality assessment system in organization
RiskNormal(3.4558,1.1455)
1.000
5.000
5.0%
90.0%
5.0%
1.6%
89.5%
8.9%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.4558
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.4558
Std Dev 1.1455
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.4558
Std Dev 1.1455



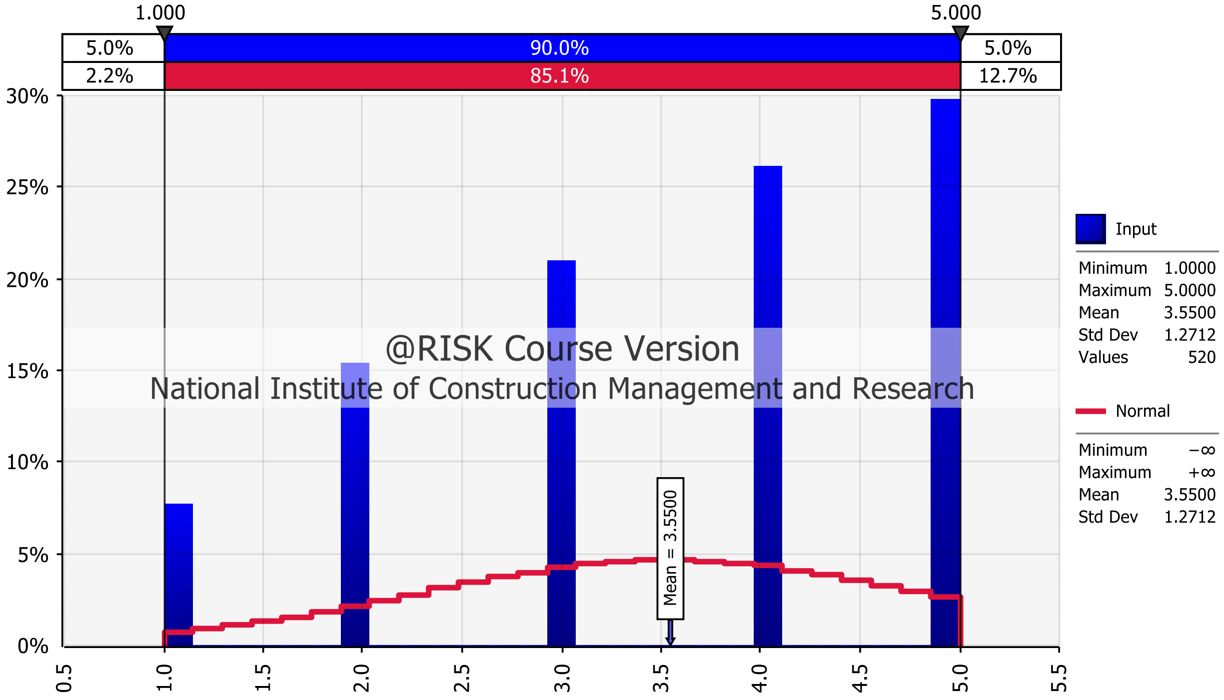
Fit Comparison for Implementation of method statement
RiskNormal(3.5192,1.2886)
1.000
5.000
5.0%
90.0%
5.0%
2.5%
84.9%
12.5%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.5192
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5192
Std Dev 1.2886
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5192
Std Dev 1.2886



Fit Comparison for Accidents and Labour Injuries
RiskNormal(3.5904,1.3471)
1.000
5.000
5.0%
90.0%
5.0%
2.7%
82.5%
14.8%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.5904
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5904
Std Dev 1.3471
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5904
Std Dev 1.3471

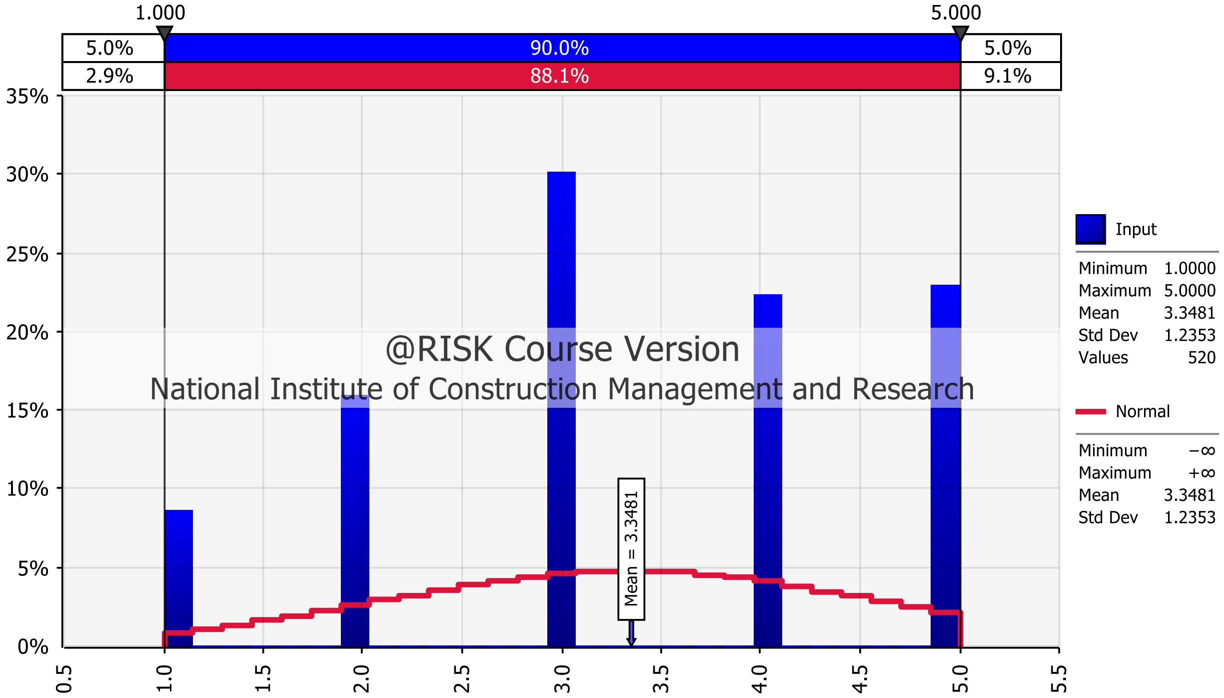
Fit Comparison for Damage to Existing Structure(Utilities beneath ground)

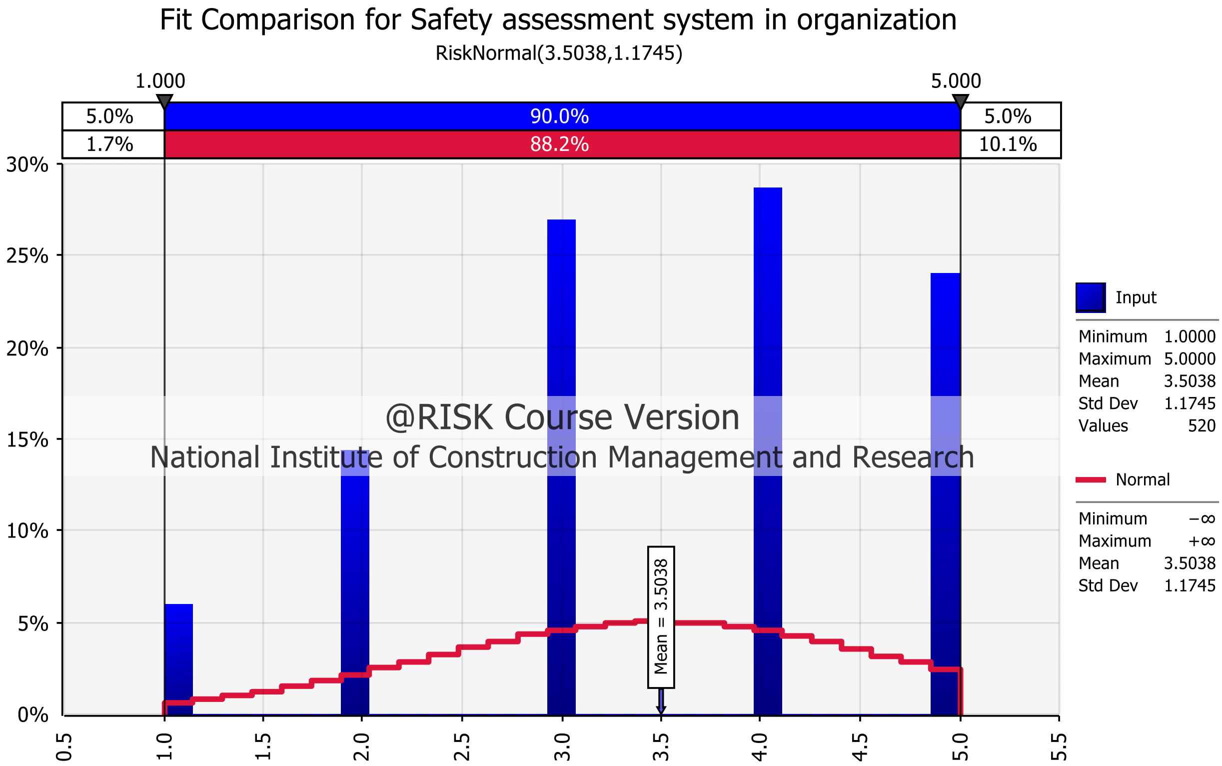
RiskNormal(3.5500,1.2712)

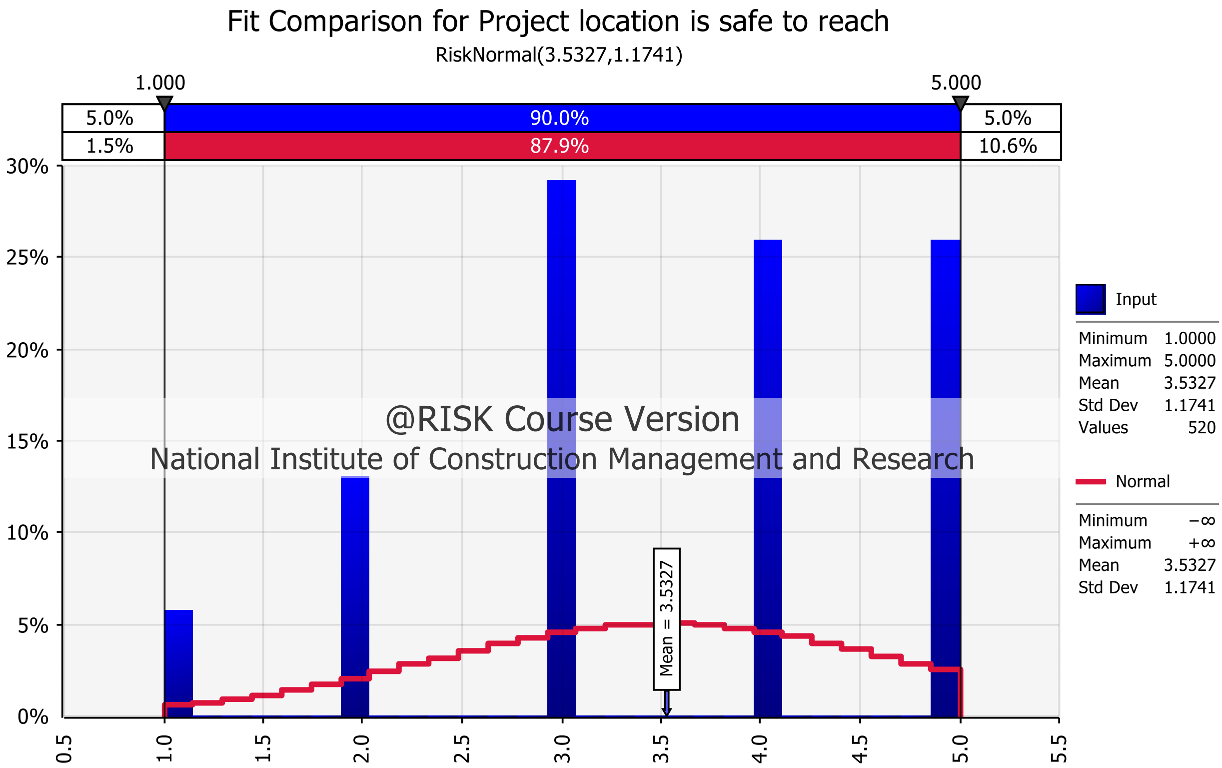


Fit Comparison for Theft of material and equipment's)

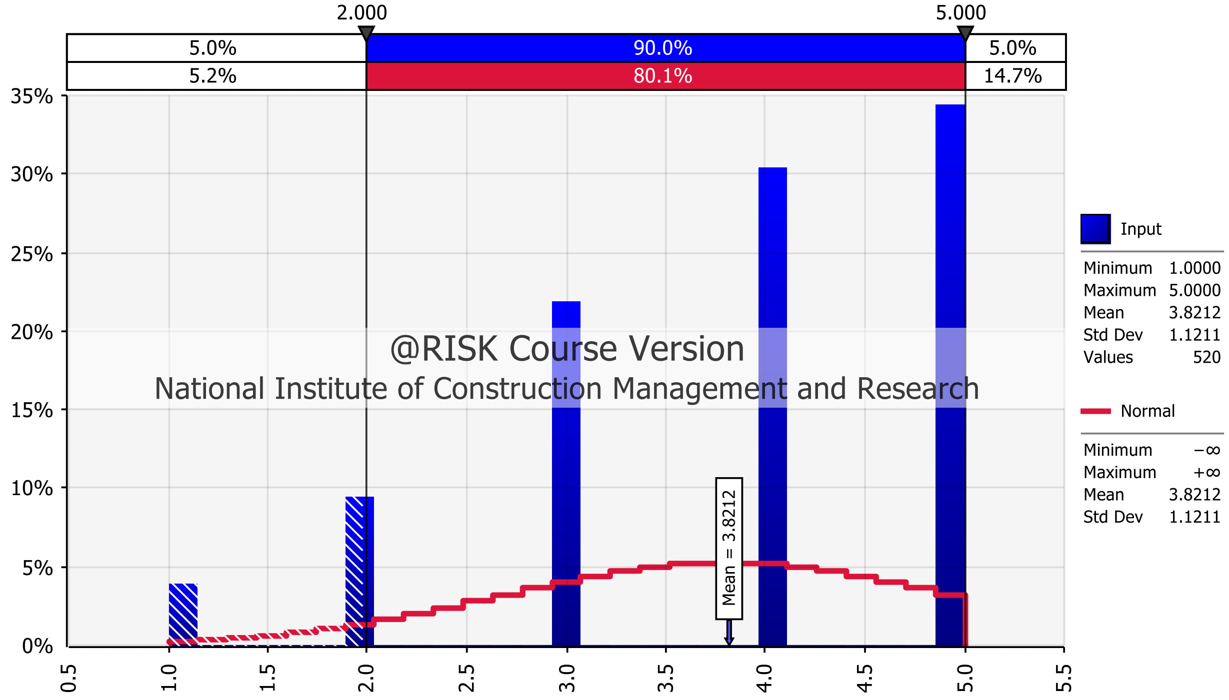
RiskNormal(3.3481,1.2353)



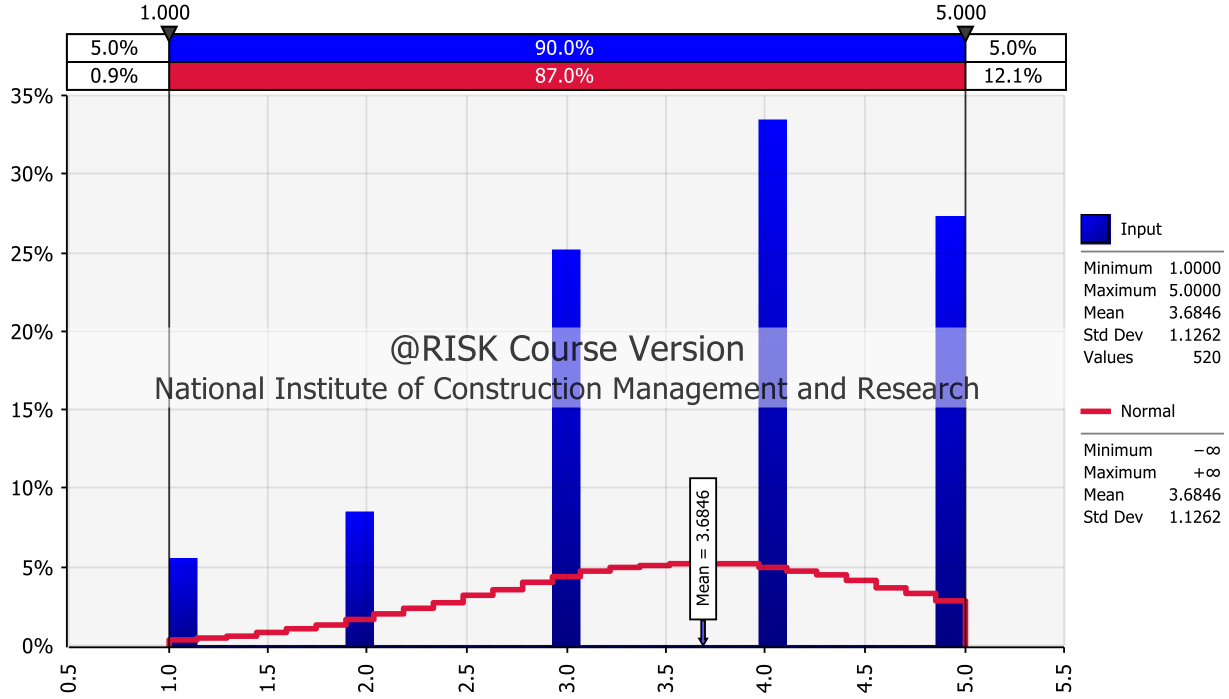

Fit Comparison for Safety assessment system in organization
RiskNormal(3.5038,1.1745)
1.000
5.000
5.0%
90.0%
5.0%
1.7%
88.2%
10.1%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.5038
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5038
Std Dev 1.1745
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5038
Std Dev 1.1745

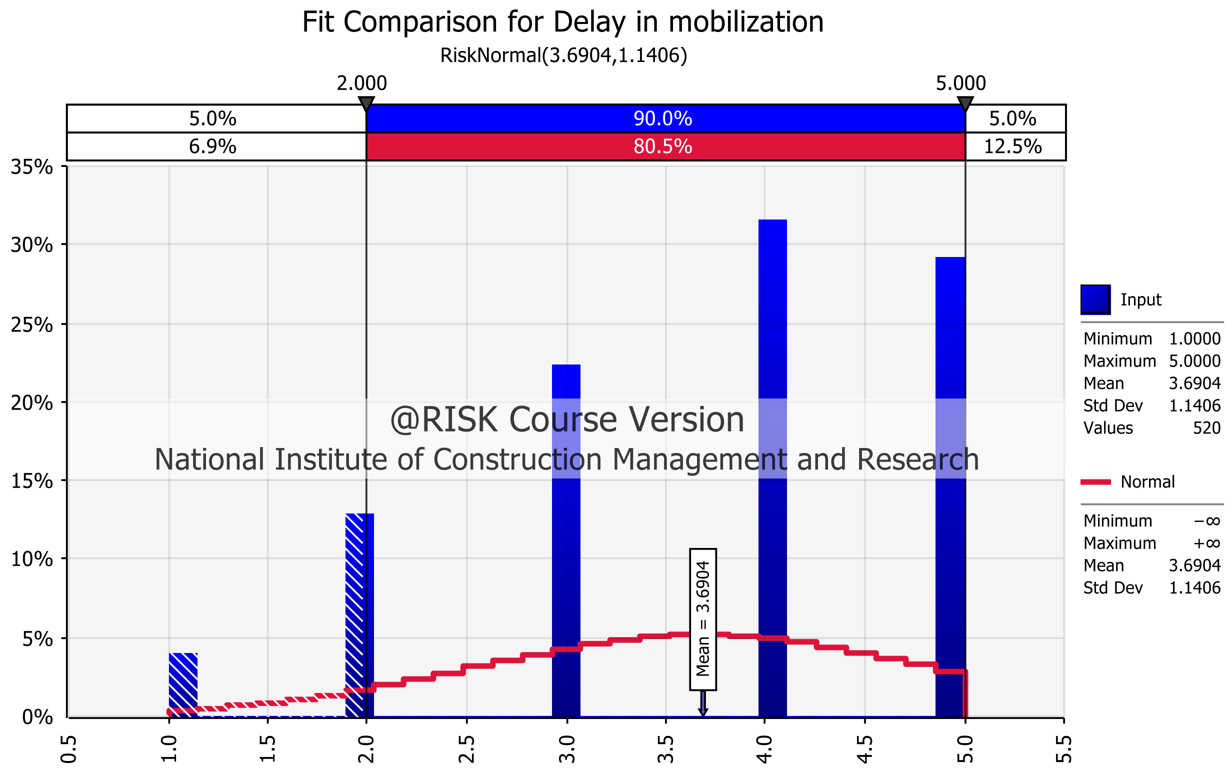

Fit Comparison for Project location is safe to reach
RiskNormal(3.5327,1.1741)
1.000
5.000
5.0%
90.0%
5.0%
1.5%
87.9%
10.6%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.5327
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5327
Std Dev 1.1741
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5327
Std Dev 1.1741

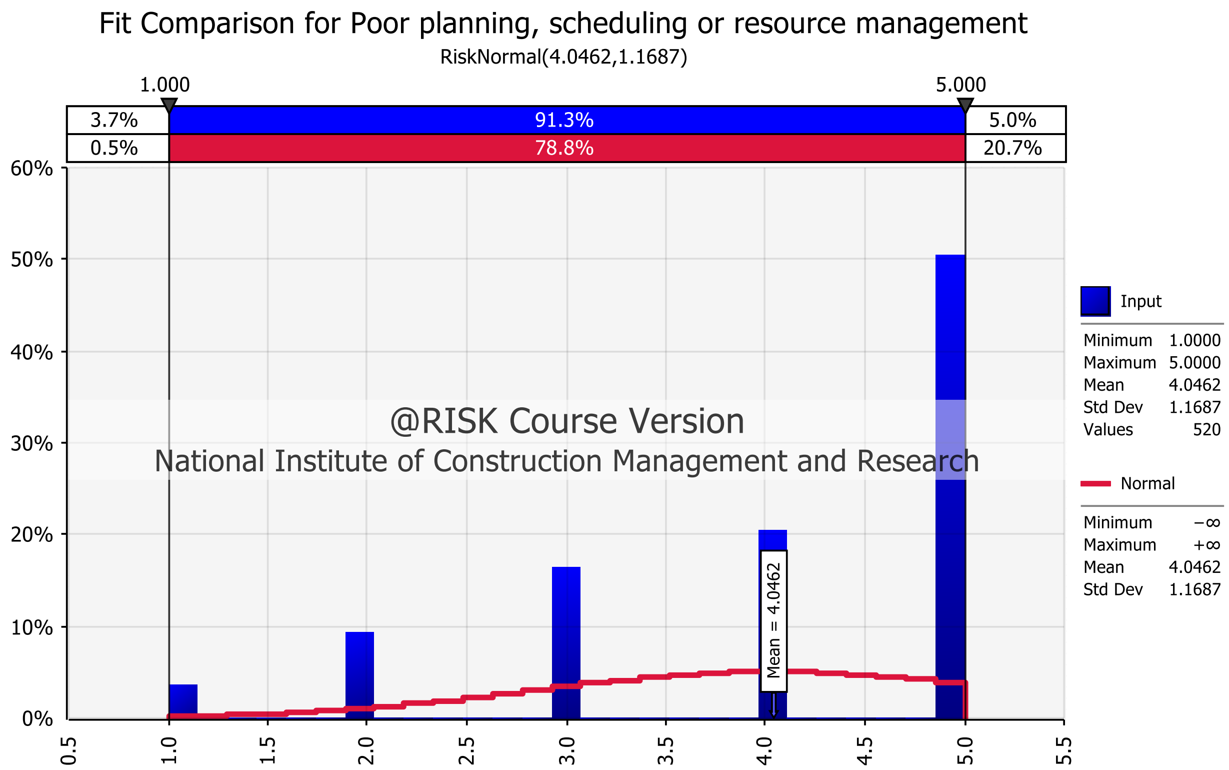
Fit Comparison for Lack of technical professionals
RiskNormal(3.8212,1.1211)

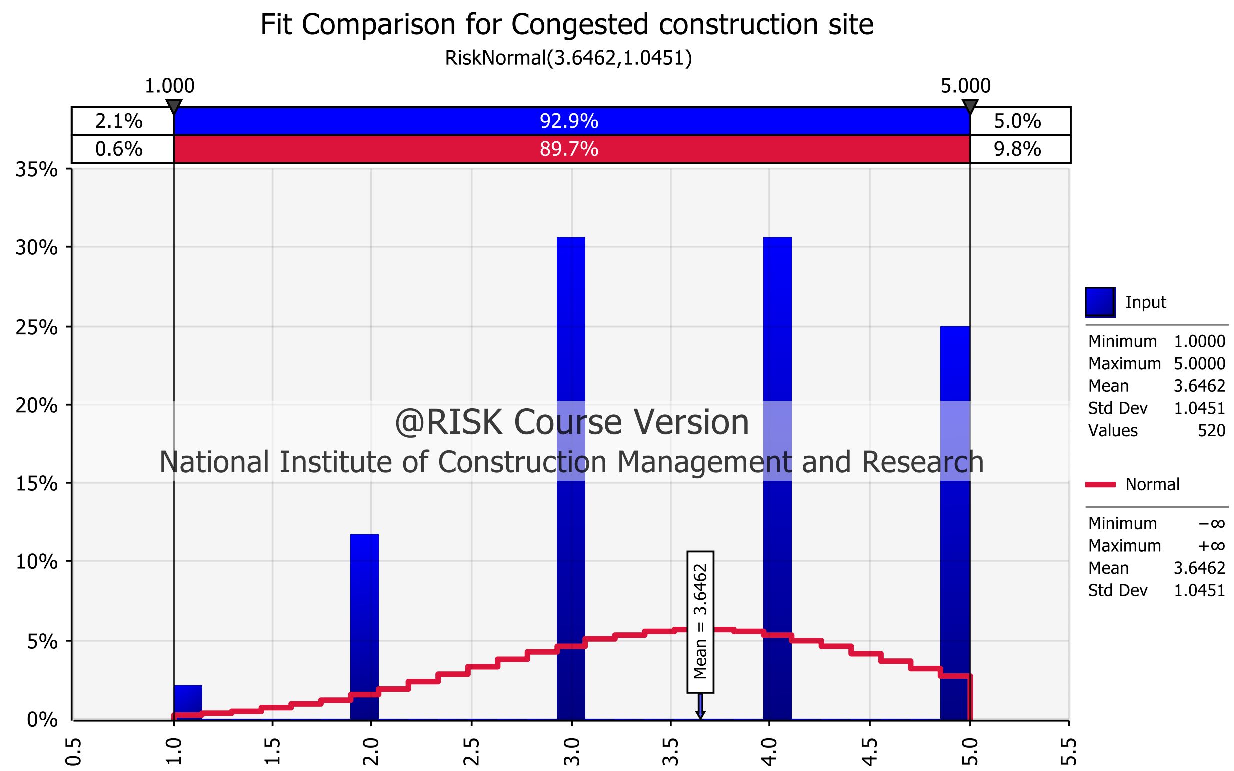


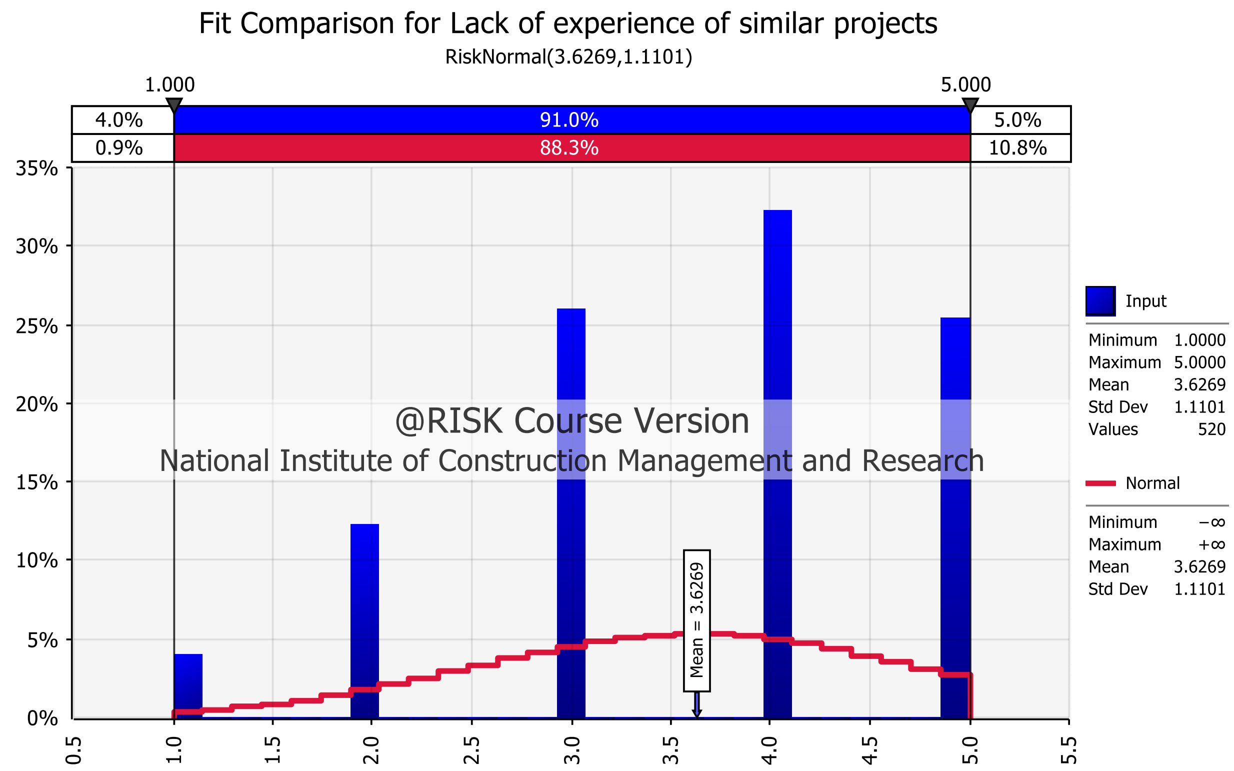
Fit Comparison for Lack of coordination with subcontractors
RiskNormal(3.6846,1.1262)

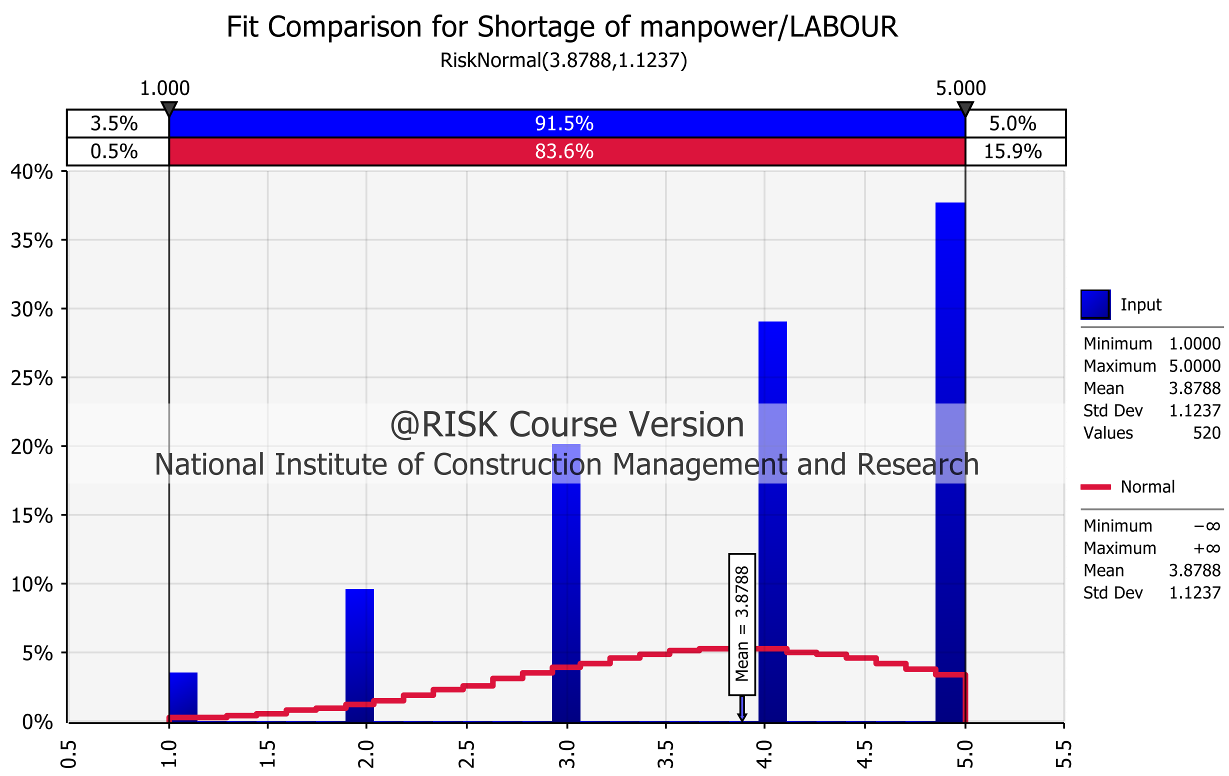


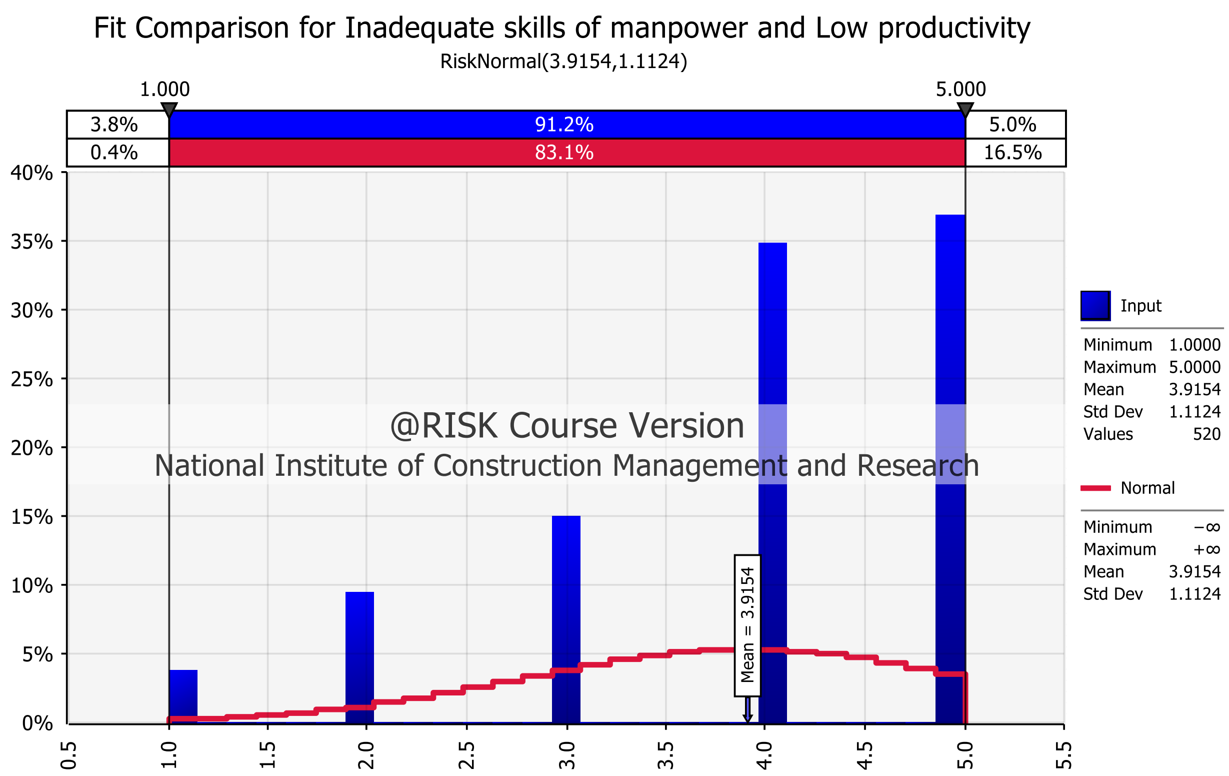

Fit Comparison for Delay in mobilization
RiskNormal(3.6904,1.1406)
2.000
5.000
5.0%
90.0%
5.0%
6.9%
80.5%
12.5%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.6904
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6904
Std Dev 1.1406
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6904
Std Dev 1.1406

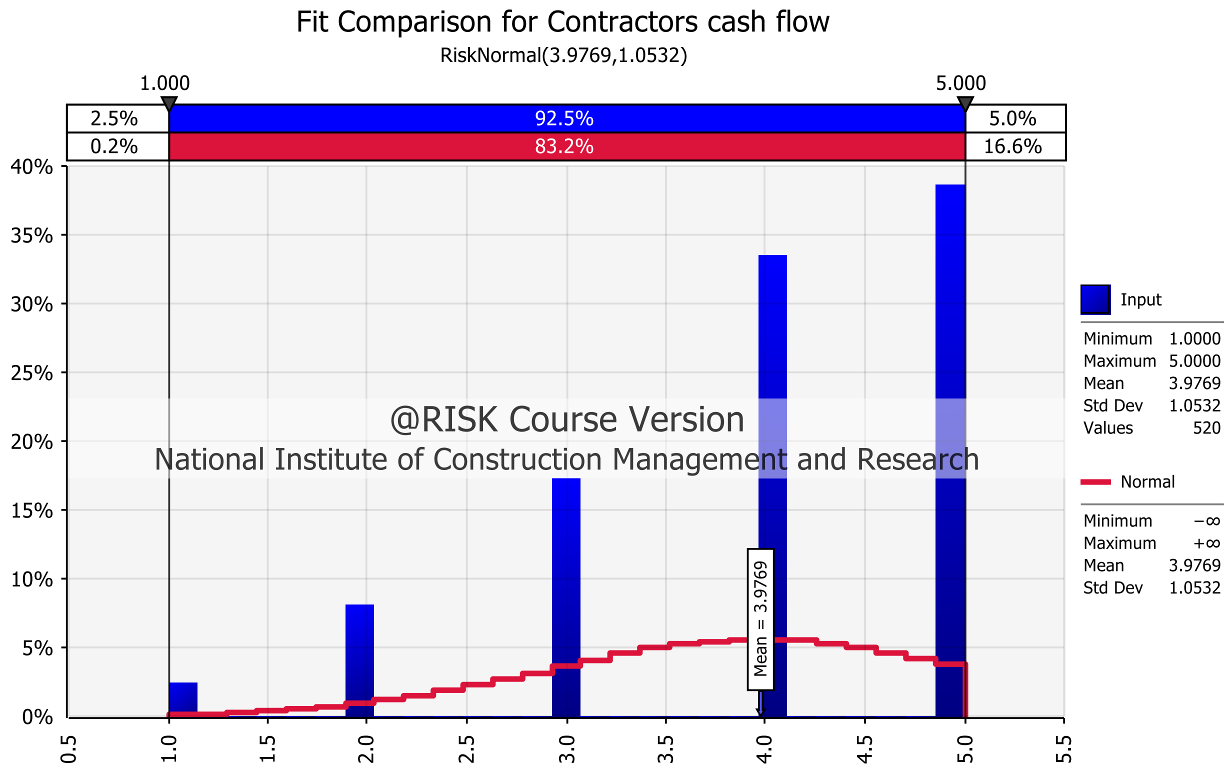

Fit Comparison for Poor planning, scheduling or resource management
RiskNormal(4.0462,1.1687)
1.000
5.000
3.7%
91.3%
5.0%
0.5%
78.8%
20.7%
60%
50%
40%
30%
20%
10%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 4.0462
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 4.0462
Std Dev 1.1687
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 4.0462
Std Dev 1.1687

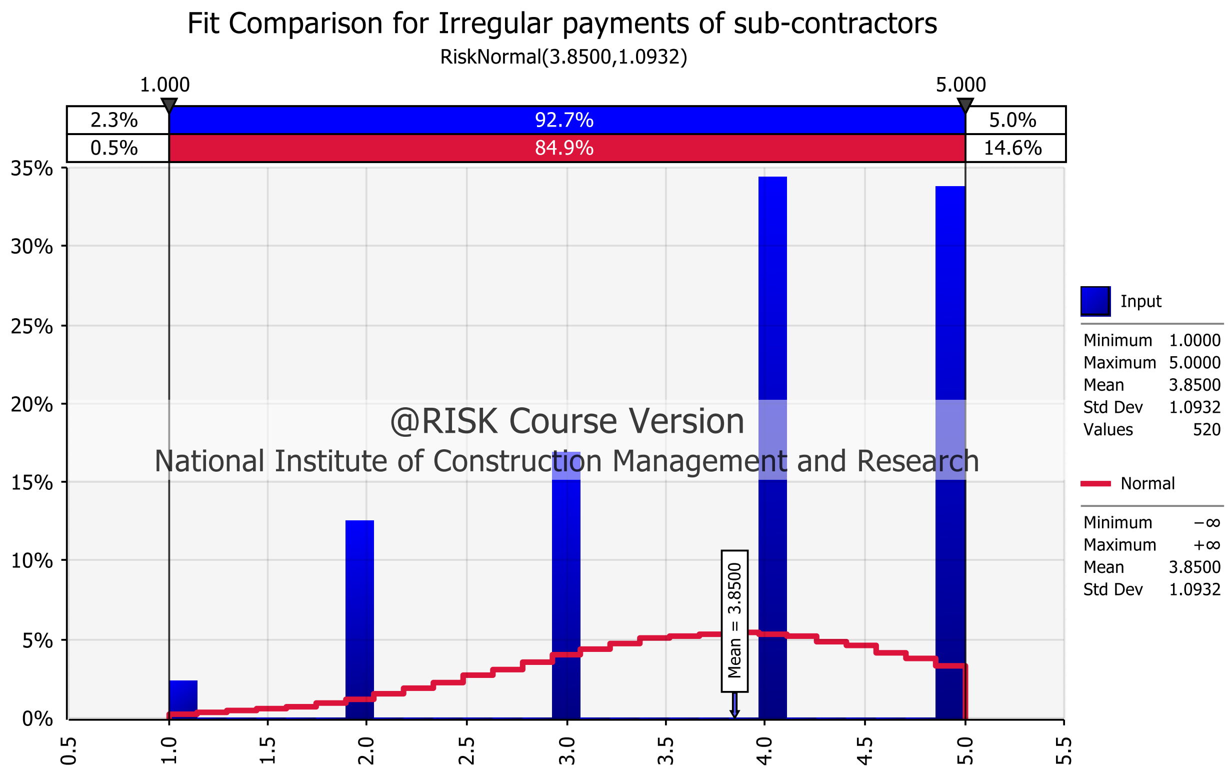

Fit Comparison for Congested construction site
RiskNormal(3.6462,1.0451)
1.000
5.000
2.1%
92.9%
5.0%
0.6%
89.7%
9.8%
35%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.6462
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6462
Std Dev 1.0451
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6462
Std Dev 1.0451


Fit Comparison for Lack of experience of similar projects
RiskNormal(3.6269,1.1101)
1.000
5.000
4.0%
91.0%
5.0%
0.9%
88.3%
10.8%
35%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.6269
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6269
Std Dev 1.1101
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6269
Std Dev 1.1101


Fit Comparison for Shortage of manpower/LABOUR
RiskNormal(3.8788,1.1237)
1.000
5.000
3.5%
91.5%
5.0%
0.5%
83.6%
15.9%
Mean = 3.8788
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.8788
Std Dev 1.1237
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.8788
Std Dev 1.1237

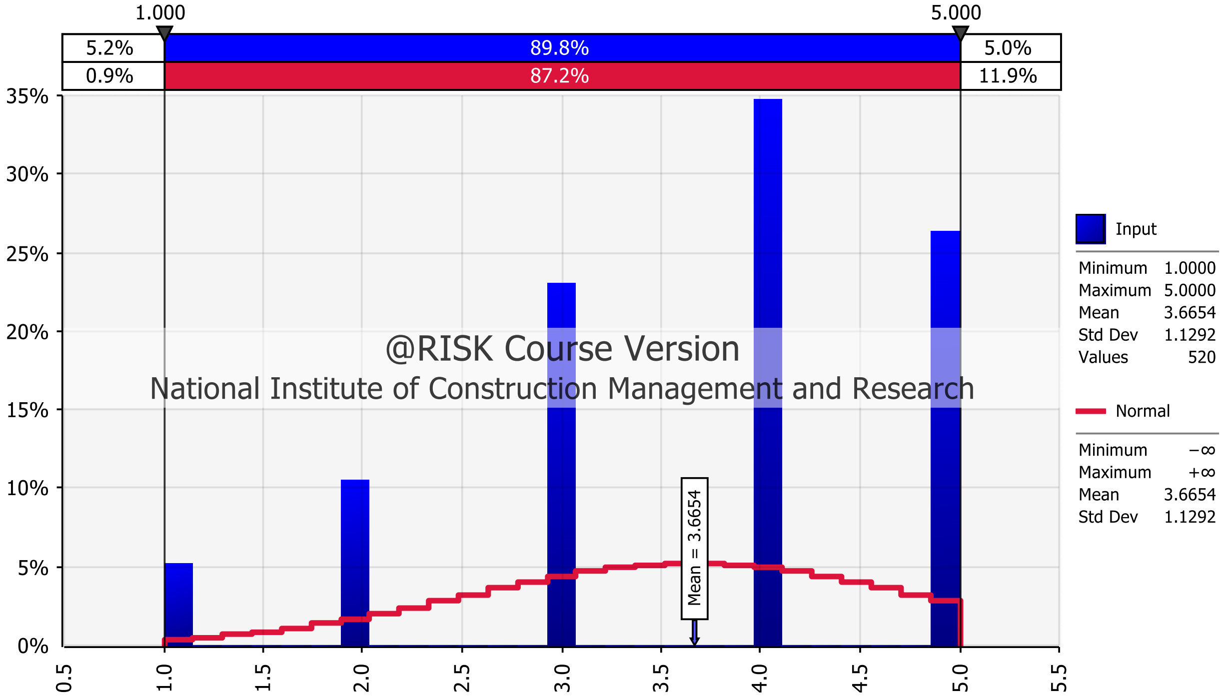

Fit Comparison for Inadequate skills of manpower and Low productivity
RiskNormal(3.9154,1.1124)
1.000
5.000
3.8%
91.2%
5.0%
0.4%
83.1%
16.5%
Mean = 3.9154
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.9154
Std Dev 1.1124
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.9154
Std Dev 1.1124


Fit Comparison for Contractors cash flow
RiskNormal(3.9769,1.0532)
1.000
5.000
2.5%
92.5%
5.0%
0.2%
83.2%
16.6%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.9769
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.9769
Std Dev 1.0532
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.9769
Std Dev 1.0532


Fit Comparison for Irregular payments of sub-contractors
RiskNormal(3.8500,1.0932)
1.000
5.000
2.3%
92.7%
5.0%
0.5%
84.9%
14.6%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.8500
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.8500
Std Dev 1.0932
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.8500
Std Dev 1.0932

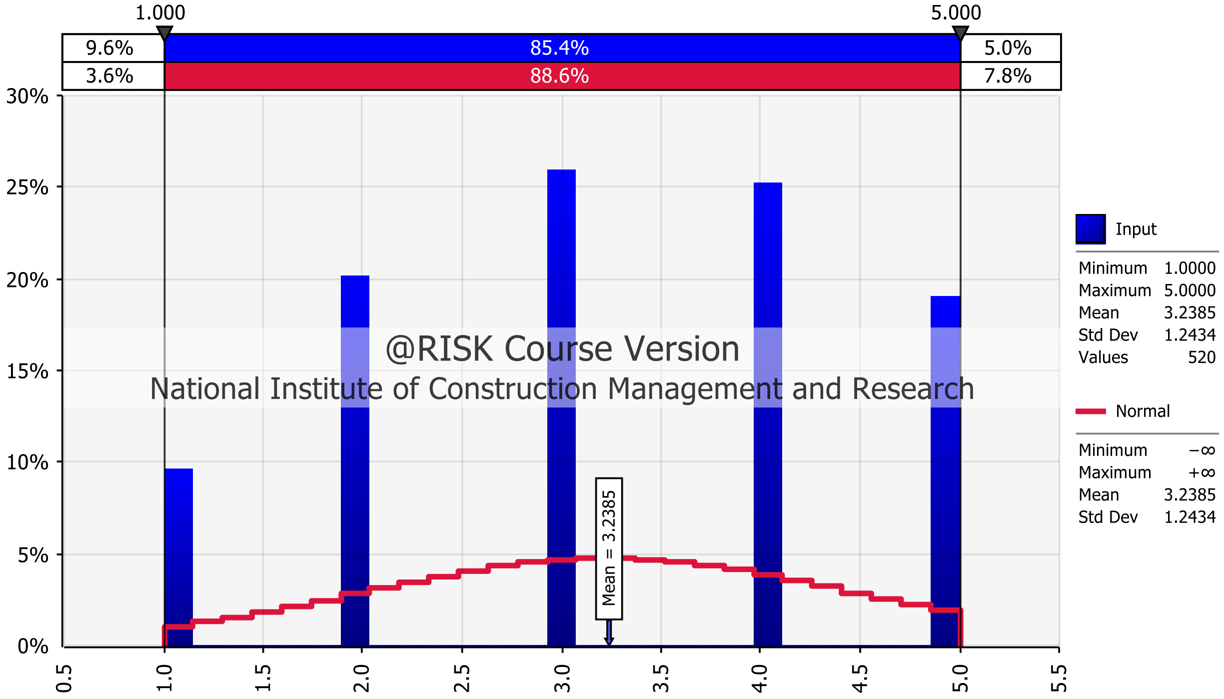
Fit Comparison for Construction Work Permits

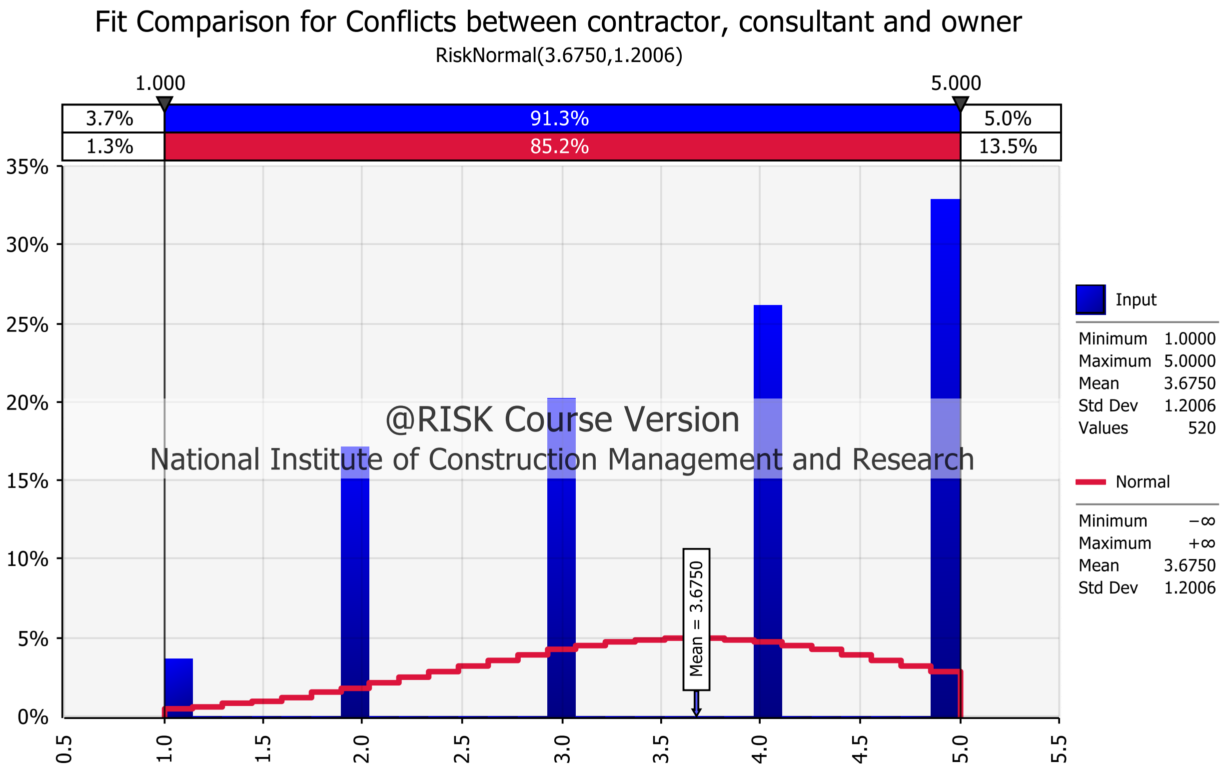
RiskNormal(3.6654,1.1292)

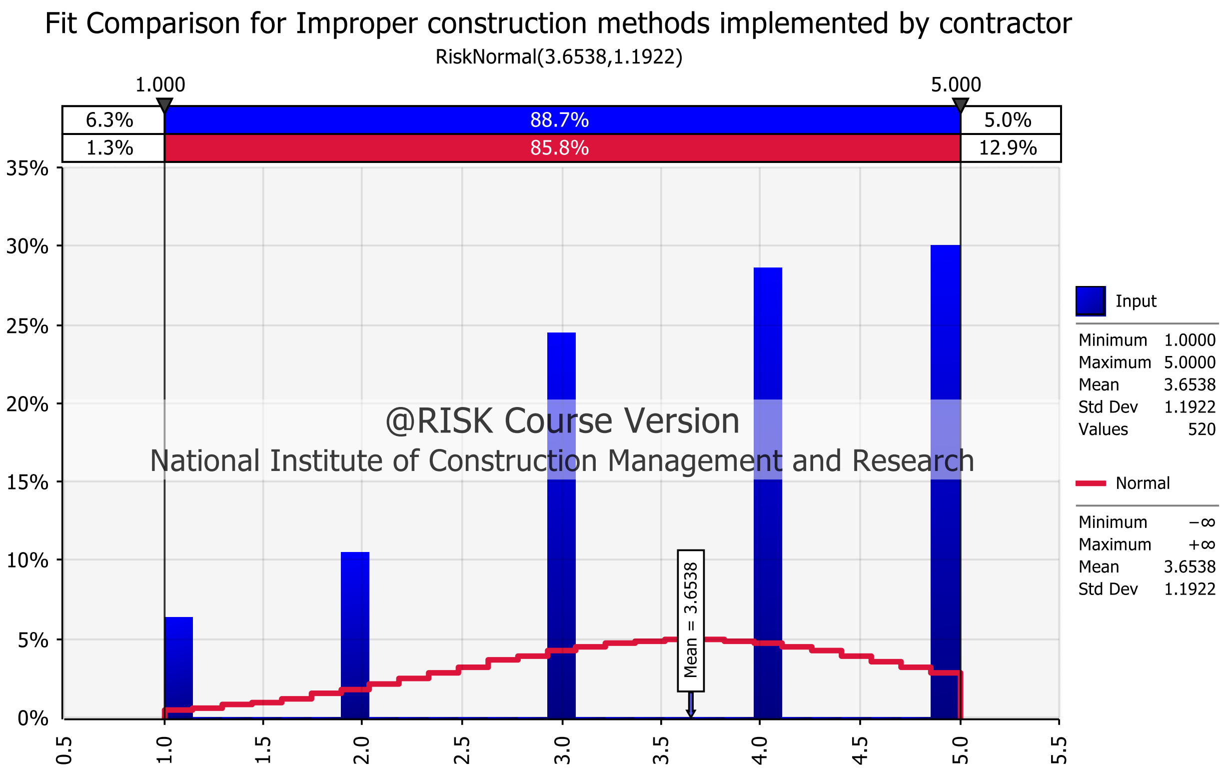


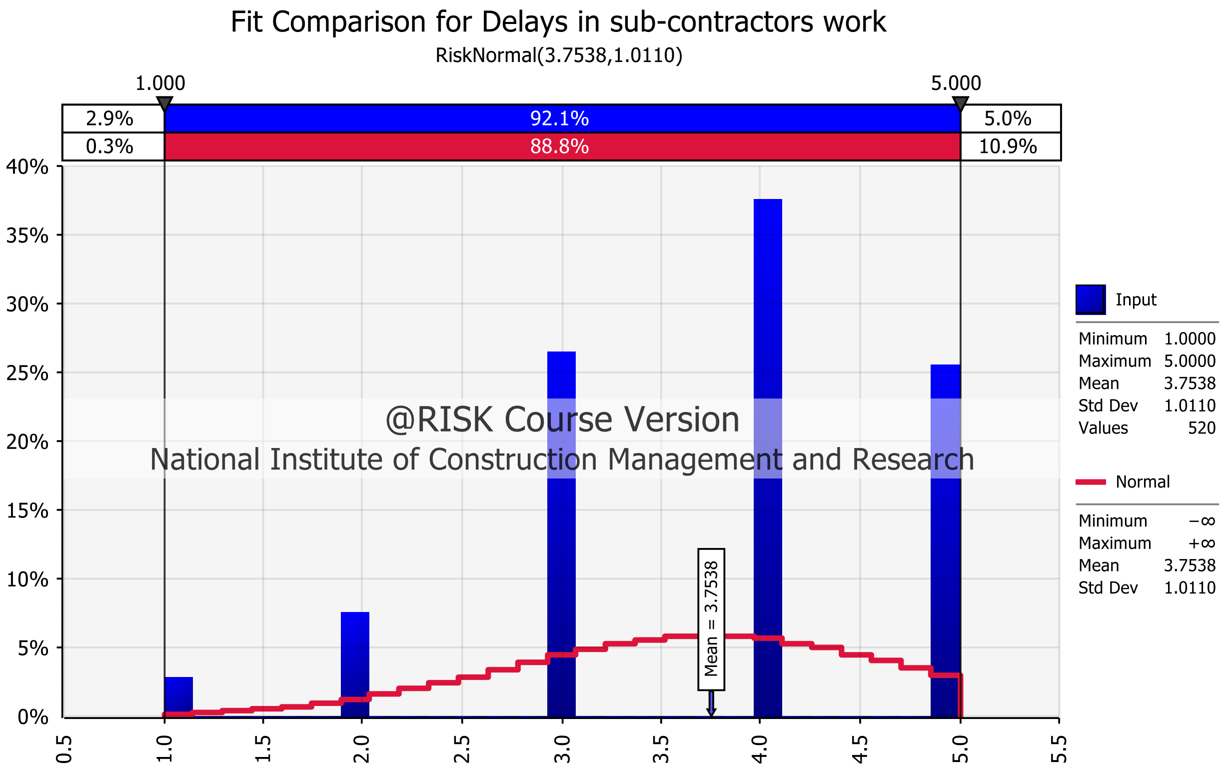
Fit Comparison for Strike

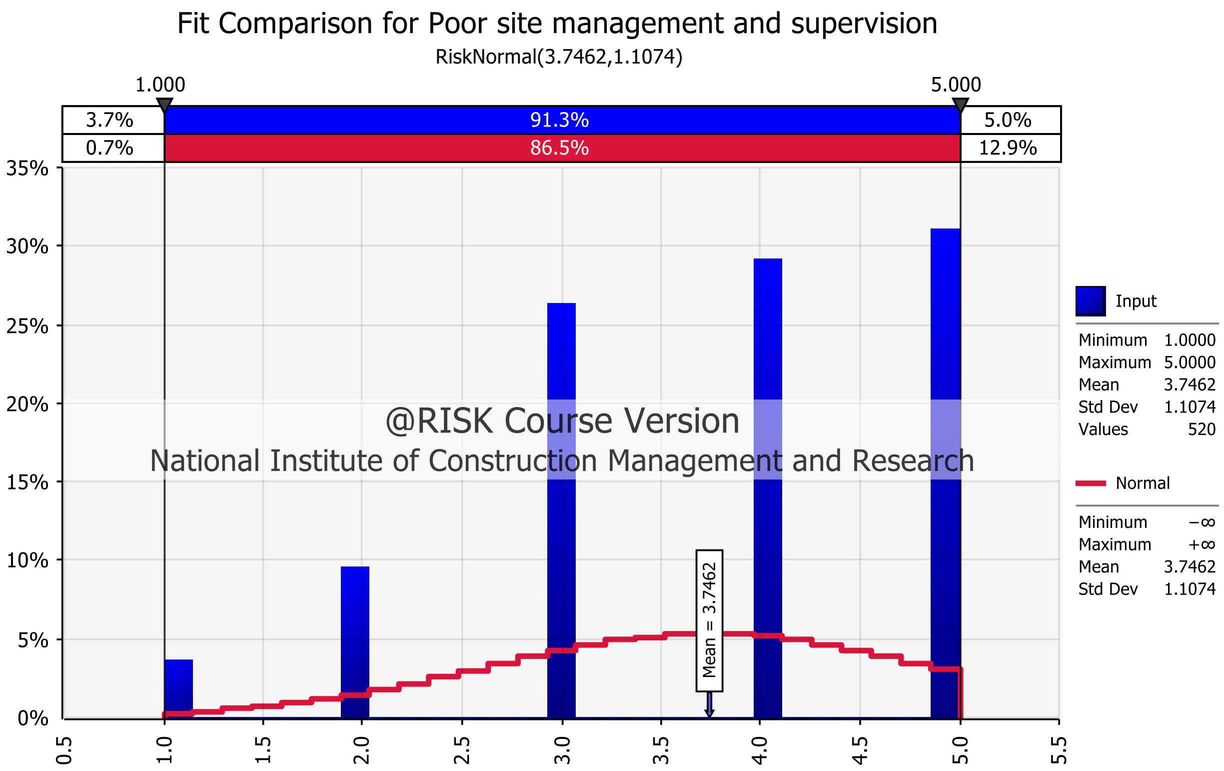
RiskNormal(3.2385,1.2434)

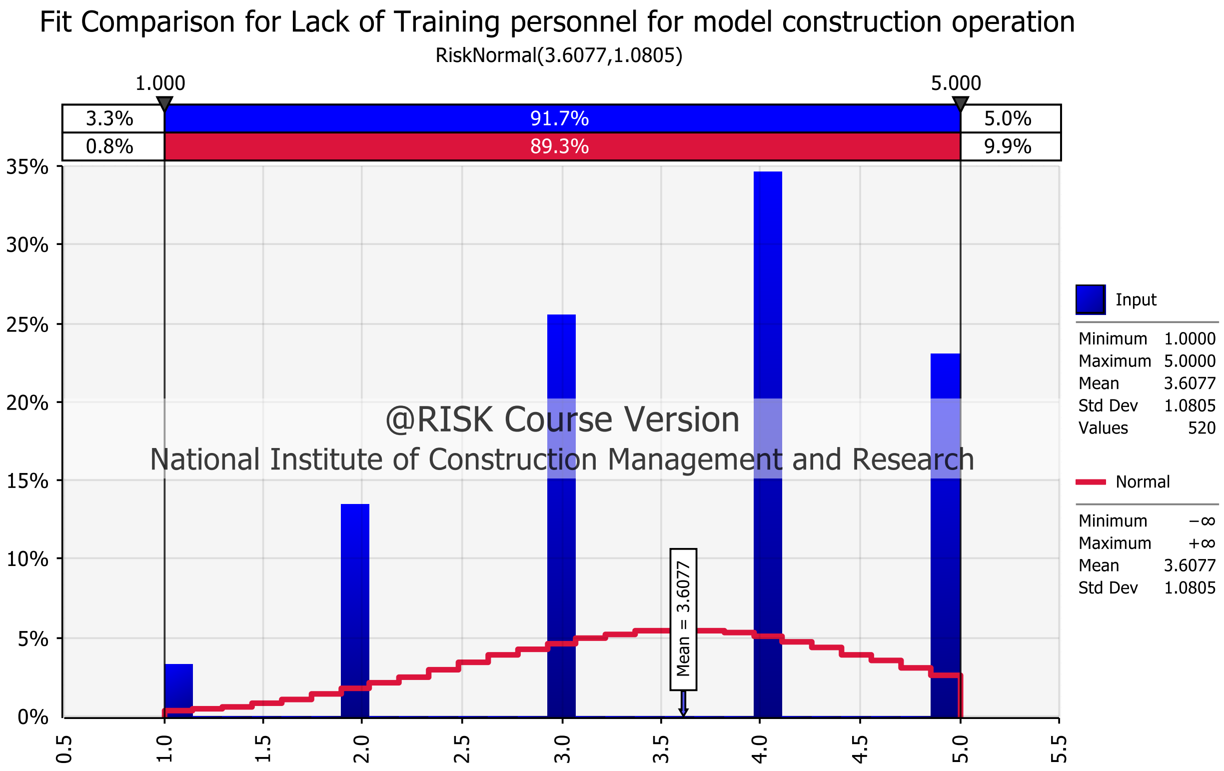


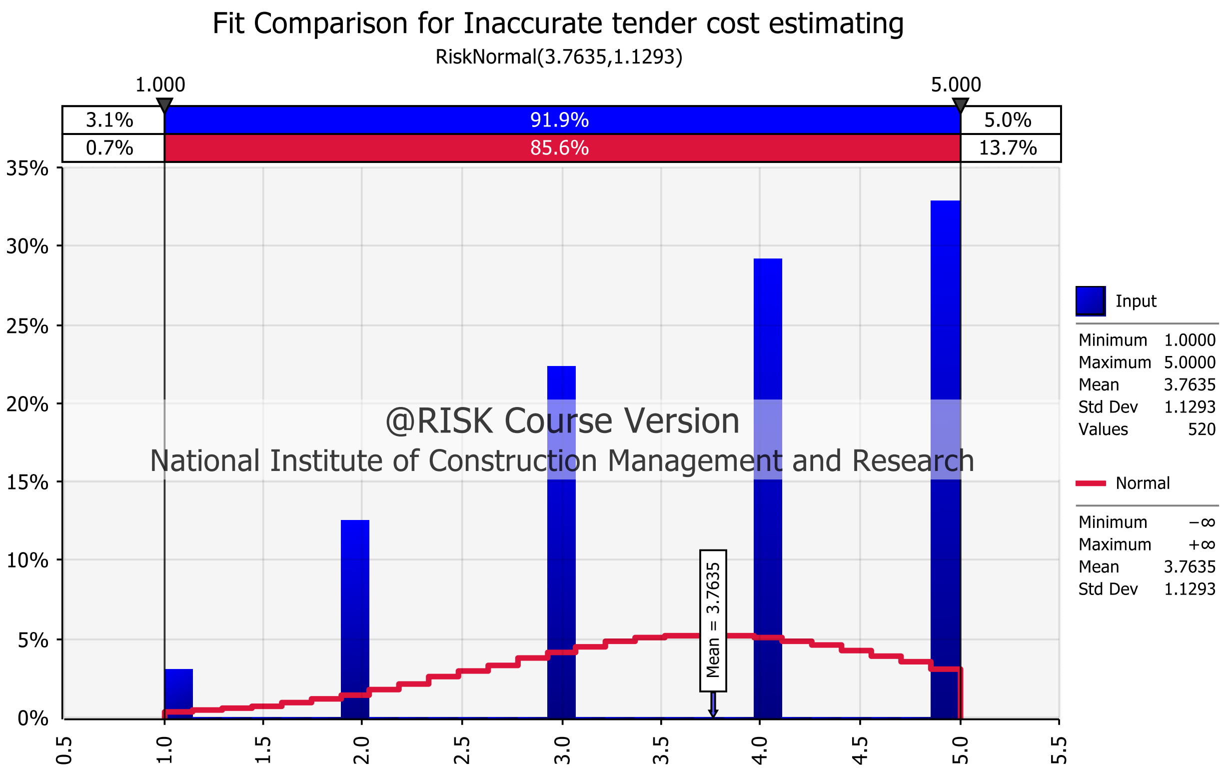

Fit Comparison for Conflicts between contractor, consultant and owner
RiskNormal(3.6750,1.2006)
1.000
5.000
3.7%
91.3%
5.0%
1.3%
85.2%
13.5%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.6750
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6750
Std Dev 1.2006
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6750
Std Dev 1.2006

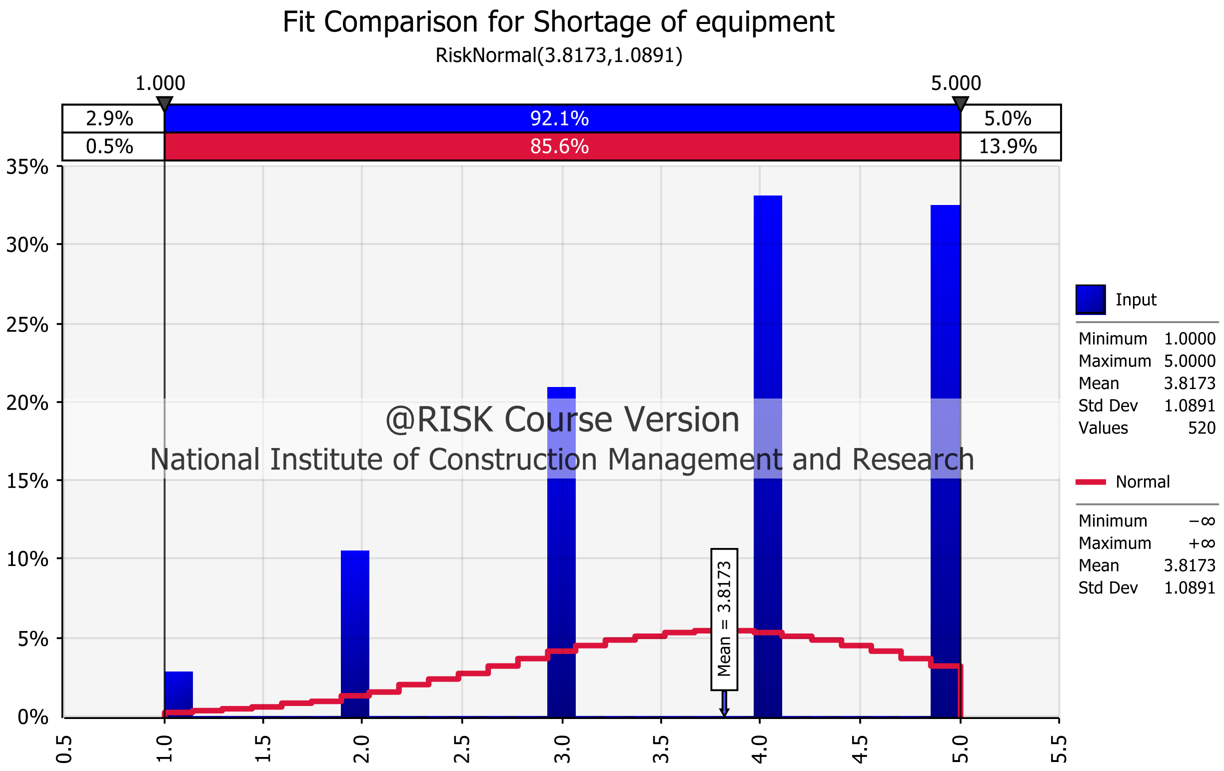

Fit Comparison for Improper construction methods implemented by contractor
RiskNormal(3.6538,1.1922)
1.000
5.000
6.3%
88.7%
5.0%
1.3%
85.8%
12.9%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.6538
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6538
Std Dev 1.1922
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6538
Std Dev 1.1922

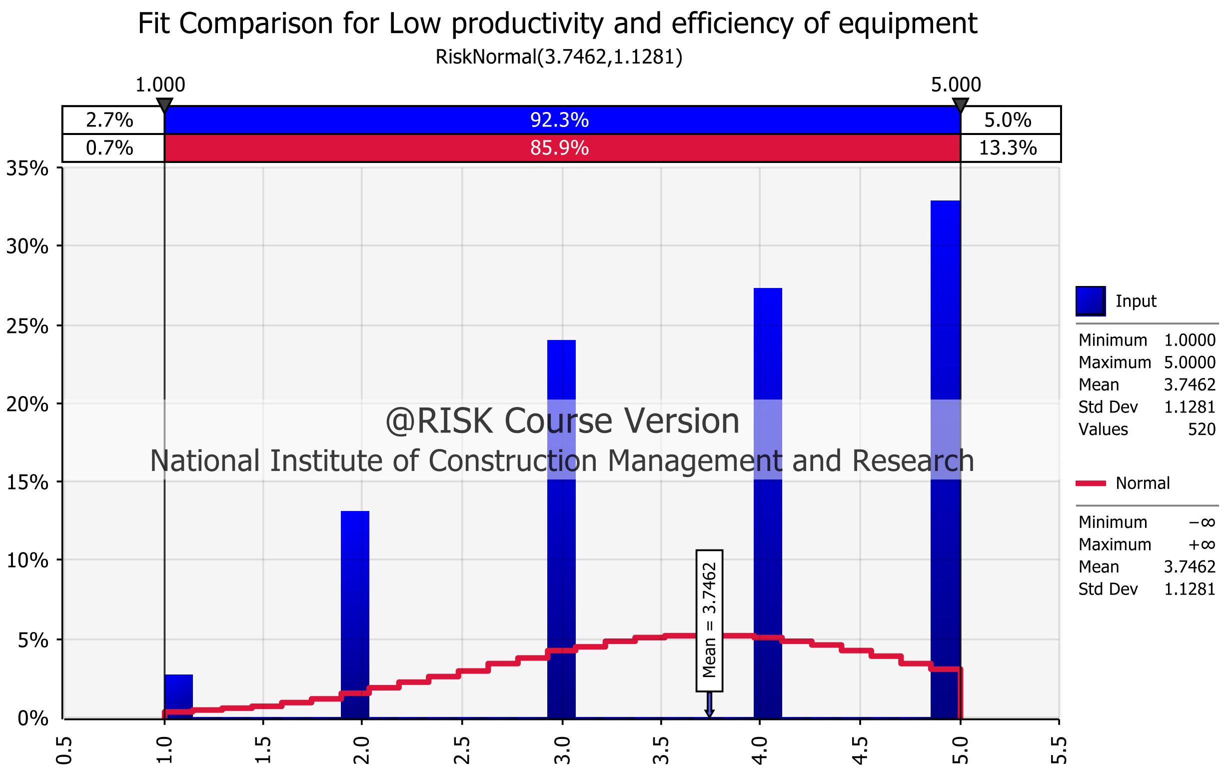

Fit Comparison for Delays in sub-contractors work
RiskNormal(3.7538,1.0110)
1.000
5.000
2.9%
92.1%
5.0%
0.3%
88.8%
10.9%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.7538
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.7538
Std Dev 1.0110
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.7538
Std Dev 1.0110

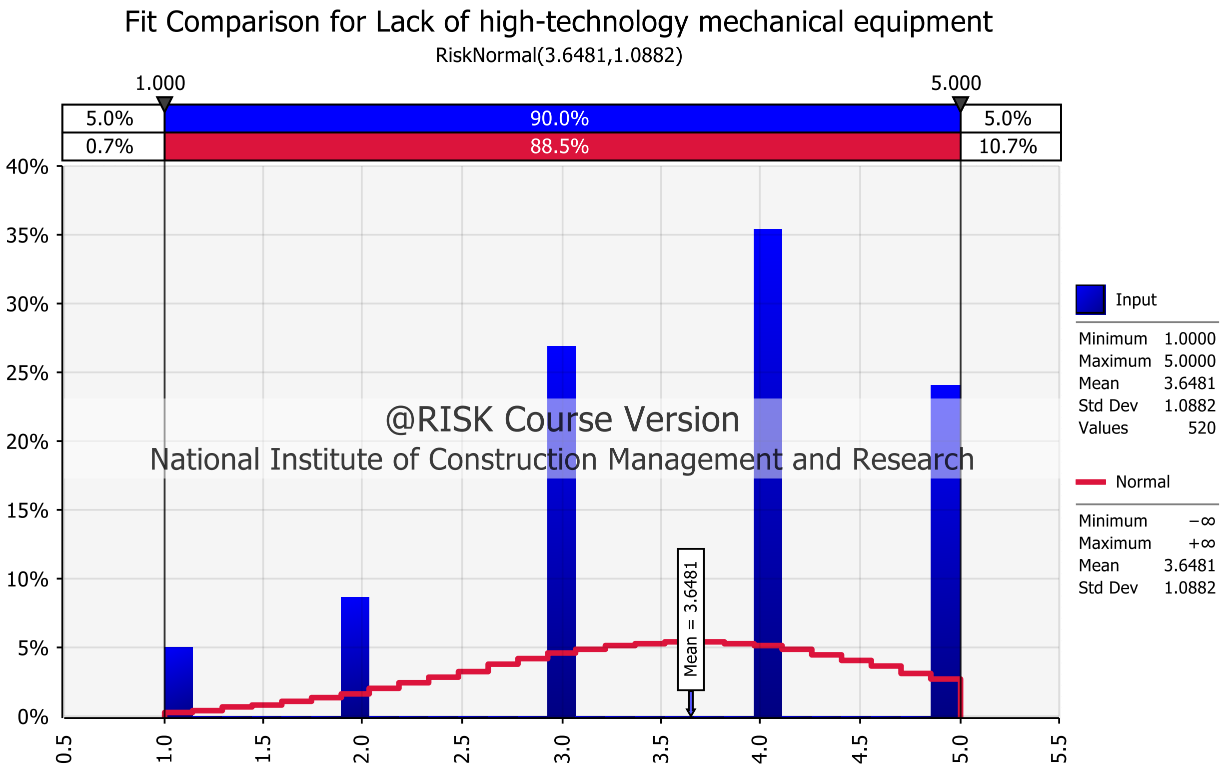

Fit Comparison for Poor site management and supervision
RiskNormal(3.7462,1.1074)
1.000
5.000
3.7%
91.3%
5.0%
0.7%
86.5%
12.9%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.7462
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.7462
Std Dev 1.1074
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.7462
Std Dev 1.1074

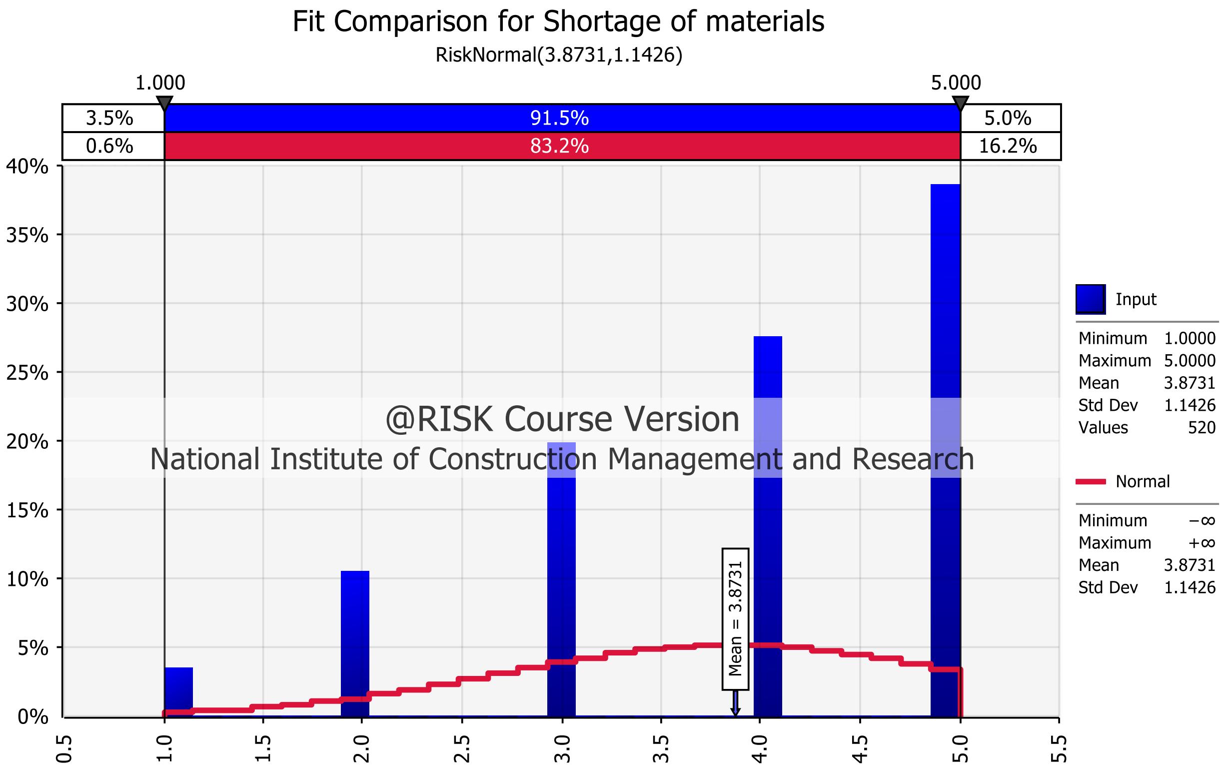

Fit Comparison for Lack of Training personnel for model construction operation
RiskNormal(3.6077,1.0805)
1.000
5.000
3.3%
91.7%
5.0%
0.8%
89.3%
9.9%
35%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.6077
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6077
Std Dev 1.0805
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6077
Std Dev 1.0805

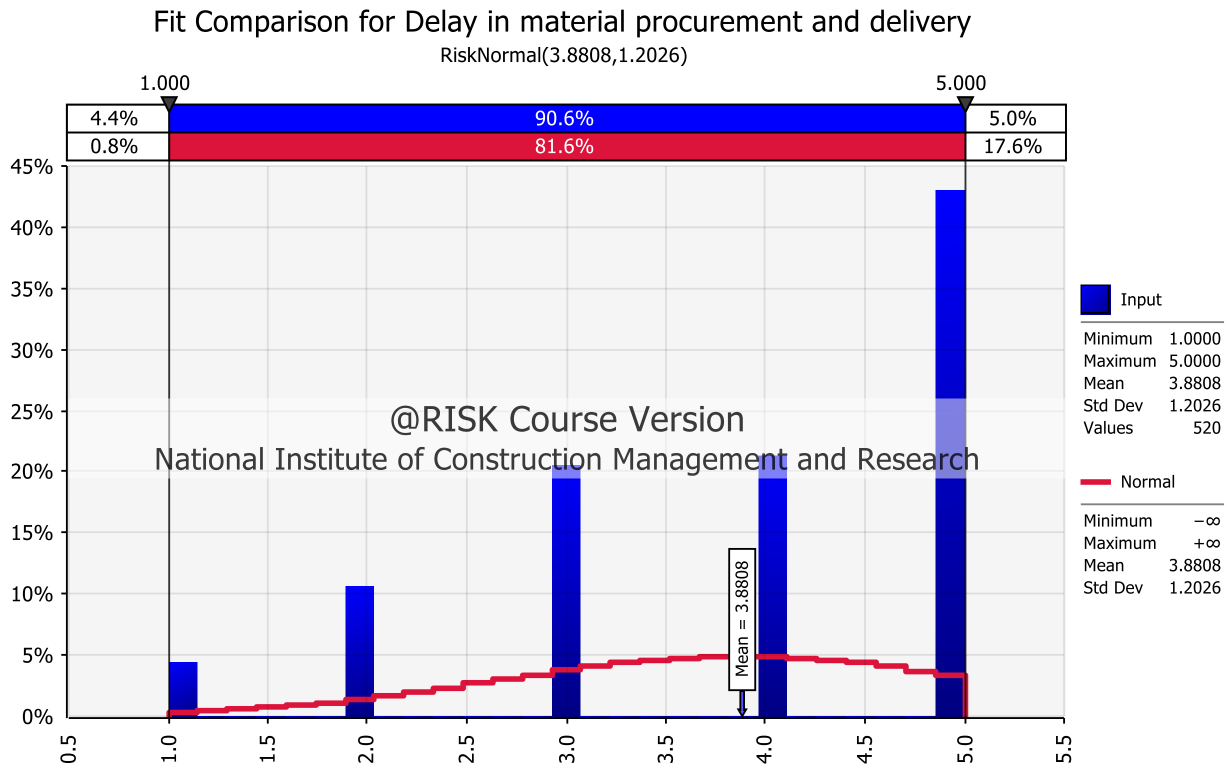

Fit Comparison for Inaccurate tender cost estimating
RiskNormal(3.7635,1.1293)
1.000
5.000
3.1%
91.9%
5.0%
0.7%
85.6%
13.7%
35%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.7635
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.7635
Std Dev 1.1293
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.7635
Std Dev 1.1293

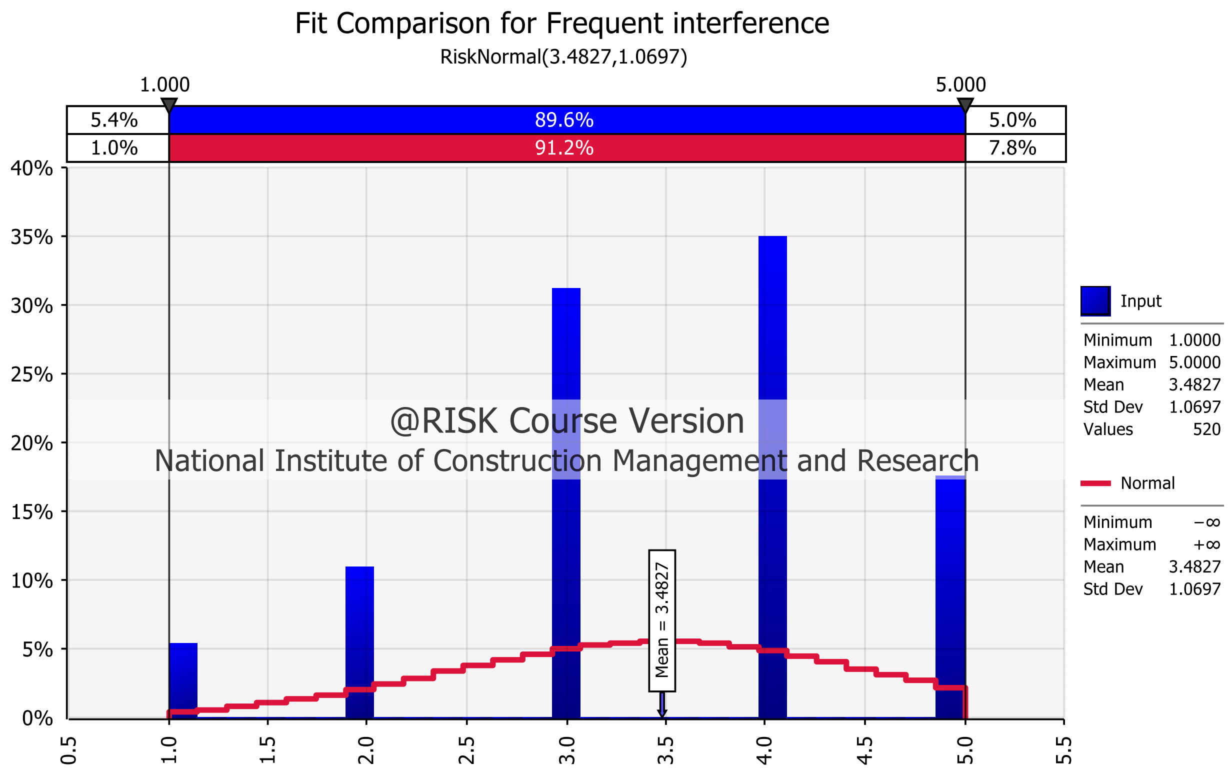

Fit Comparison for Shortage of equipment
RiskNormal(3.8173,1.0891)
1.000
5.000
2.9%
92.1%
5.0%
0.5%
85.6%
13.9%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.8173
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.8173
Std Dev 1.0891
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.8173
Std Dev 1.0891


Fit Comparison for Low productivity and efficiency of equipment
RiskNormal(3.7462,1.1281)
1.000
5.000
2.7%
92.3%
5.0%
0.7%
85.9%
13.3%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.7462
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.7462
Std Dev 1.1281
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.7462
Std Dev 1.1281


Fit Comparison for Lack of high-technology mechanical equipment
RiskNormal(3.6481,1.0882)
1.000
5.000
5.0%
90.0%
5.0%
0.7%
88.5%
10.7%
Mean = 3.6481
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.6481
Std Dev 1.0882
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.6481
Std Dev 1.0882
@RISK Course Version
National Institute of Construction Management and Research

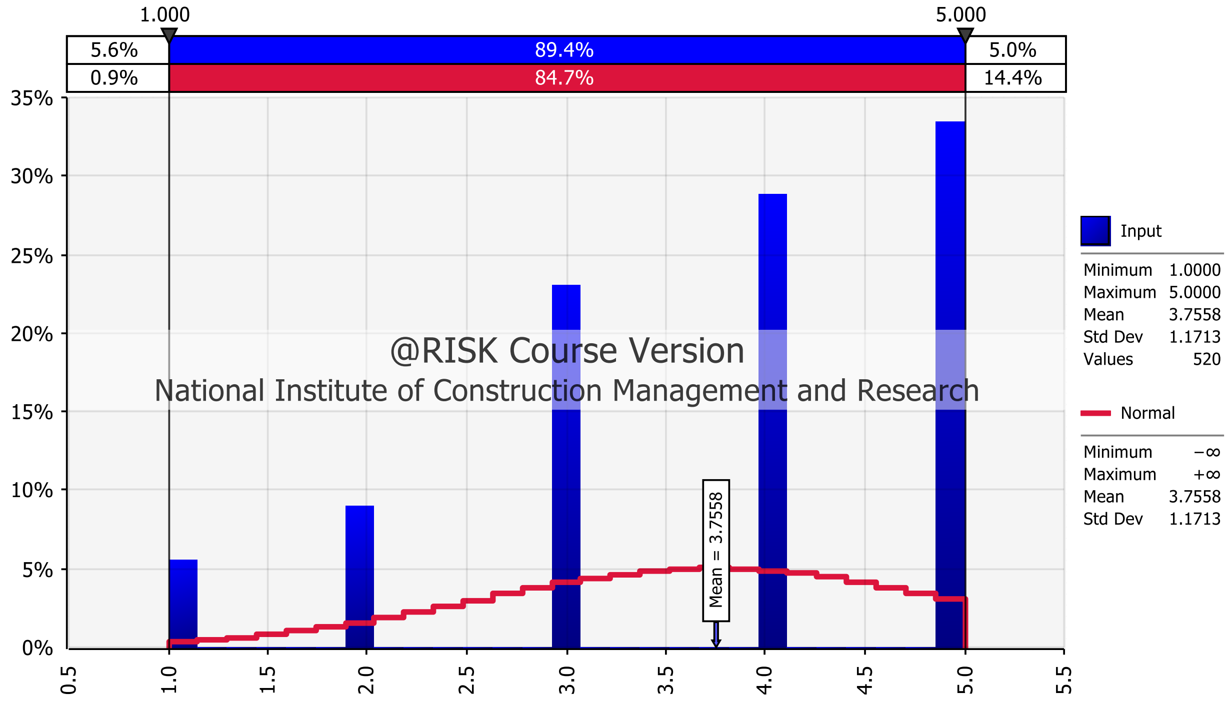

Fit Comparison for Shortage of materials
RiskNormal(3.8731,1.1426)
1.000
5.000
3.5%
91.5%
5.0%
0.6%
83.2%
16.2%
Mean = 3.8731
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.8731
Std Dev 1.1426
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.8731
Std Dev 1.1426
@RISK Course Version
National Institute of Construction Management and Research


Fit Comparison for Delay in material procurement and delivery
RiskNormal(3.8808,1.2026)
1.000
5.000
4.4%
90.6%
5.0%
0.8%
81.6%
17.6%
Mean = 3.8808
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.8808
Std Dev 1.2026
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.8808
Std Dev 1.2026
@RISK Course Version
National Institute of Construction Management and Research


Fit Comparison for Frequent interference
RiskNormal(3.4827,1.0697)
1.000
5.000
5.4%
89.6%
5.0%
1.0%
91.2%
7.8%
Mean = 3.4827
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.4827
Std Dev 1.0697
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.4827
Std Dev 1.0697
@RISK Course Version
National Institute of Construction Management and Research

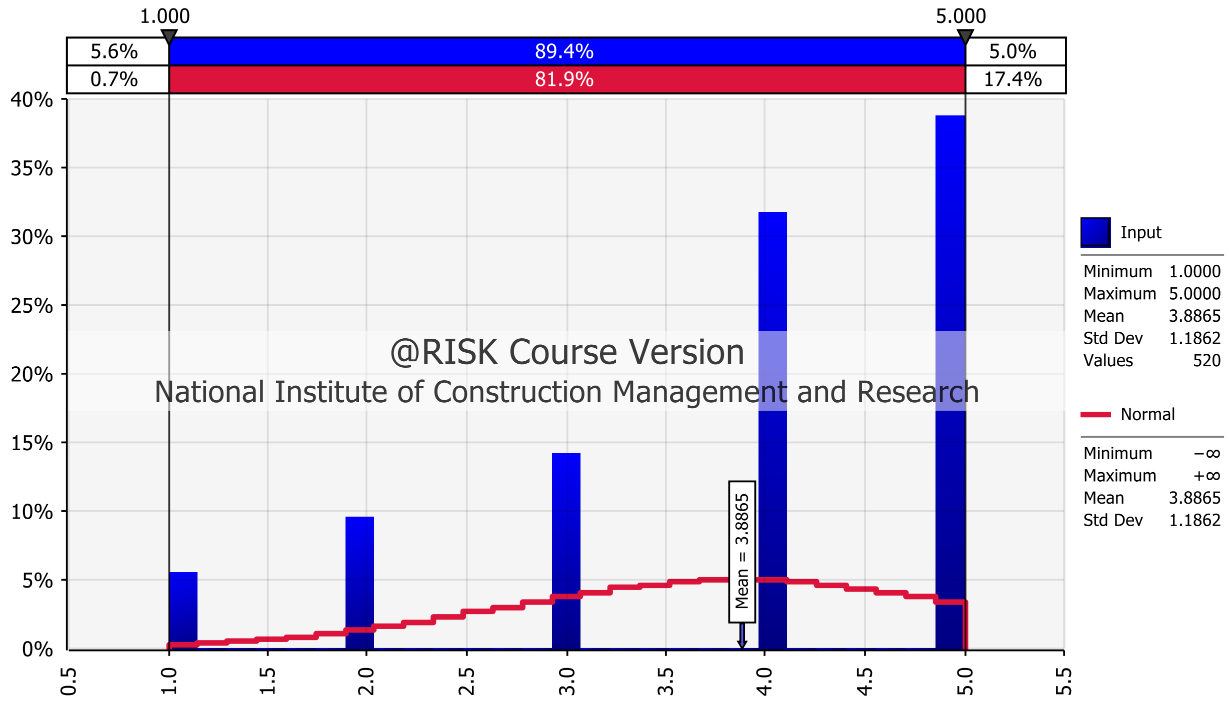
Fit Comparison for Unrealistic contract duration imposed by client

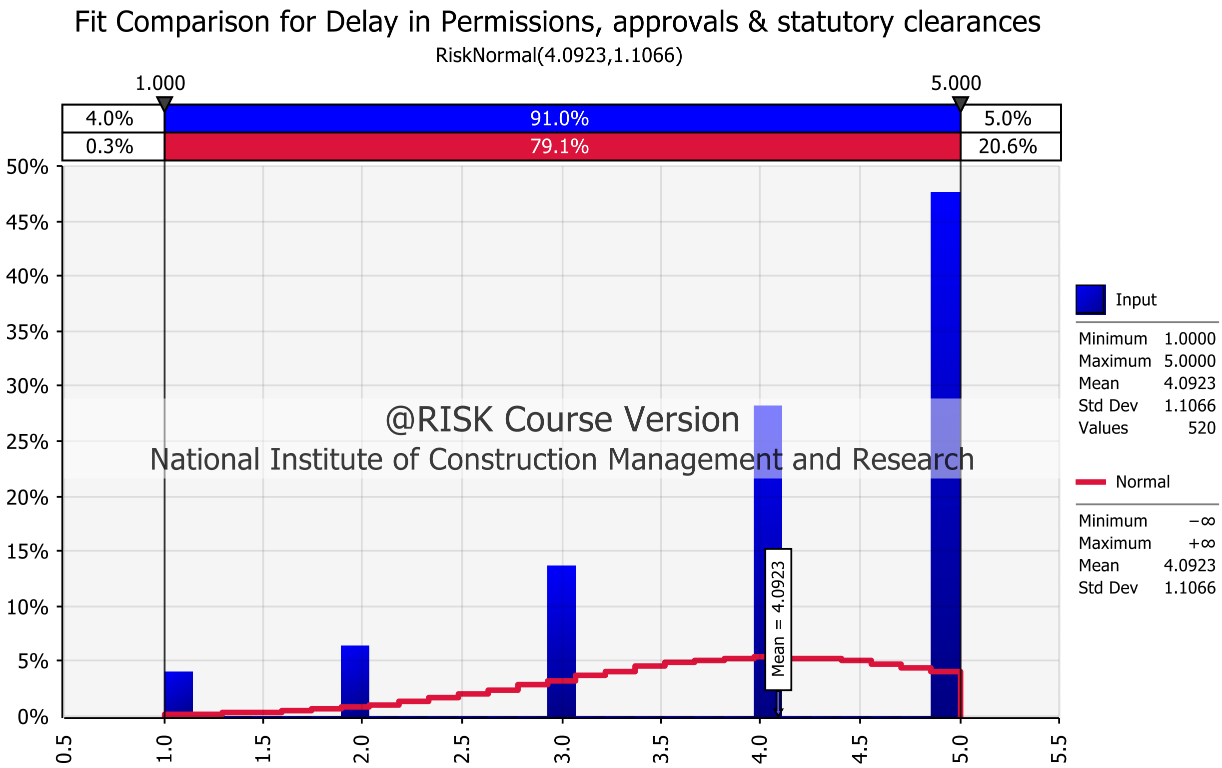
RiskNormal(3.7558,1.1713)



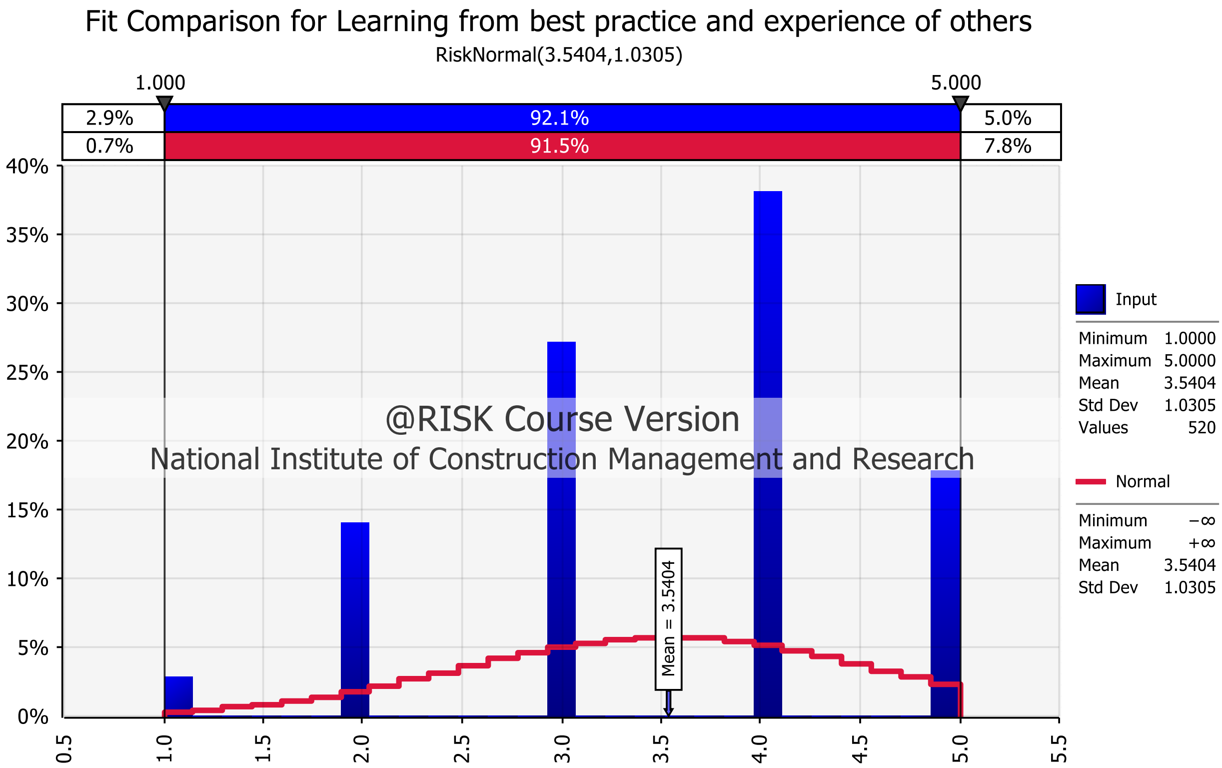
Fit Comparison for Financial difficulties & Irregular payments of work-done

RiskNormal(3.8865,1.1862)

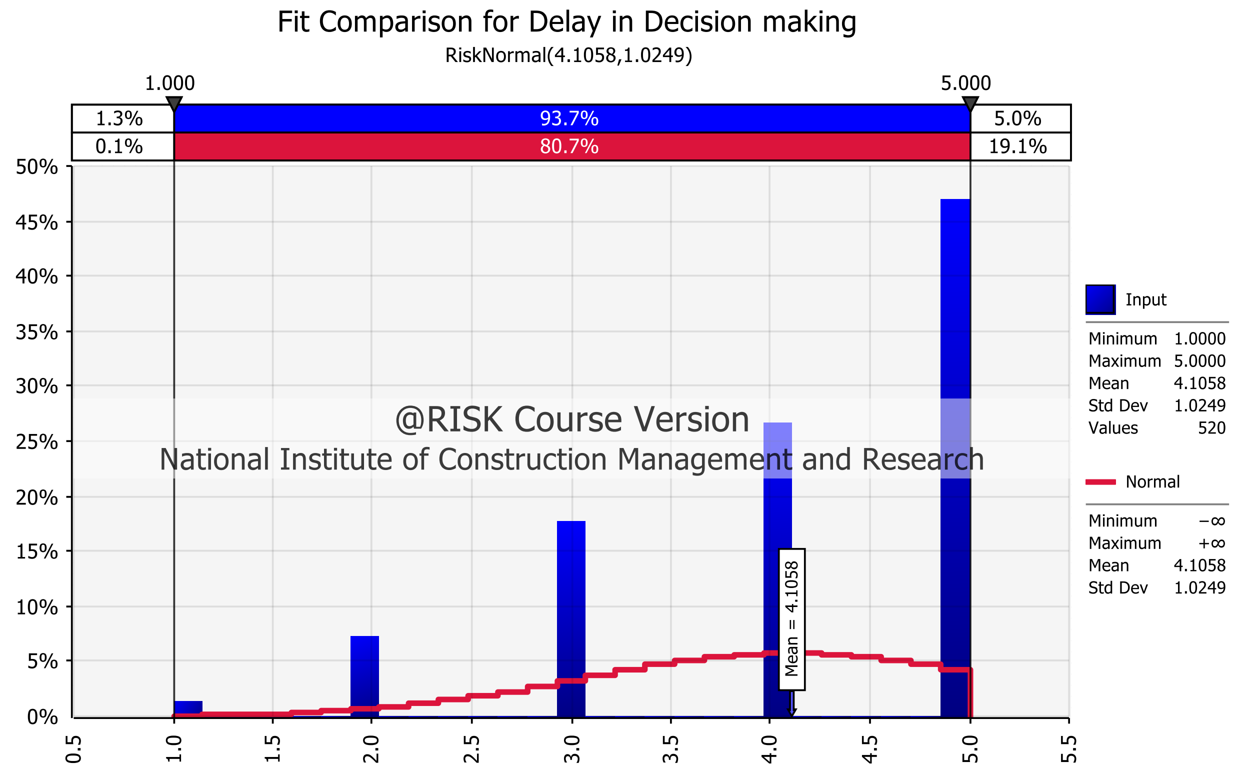


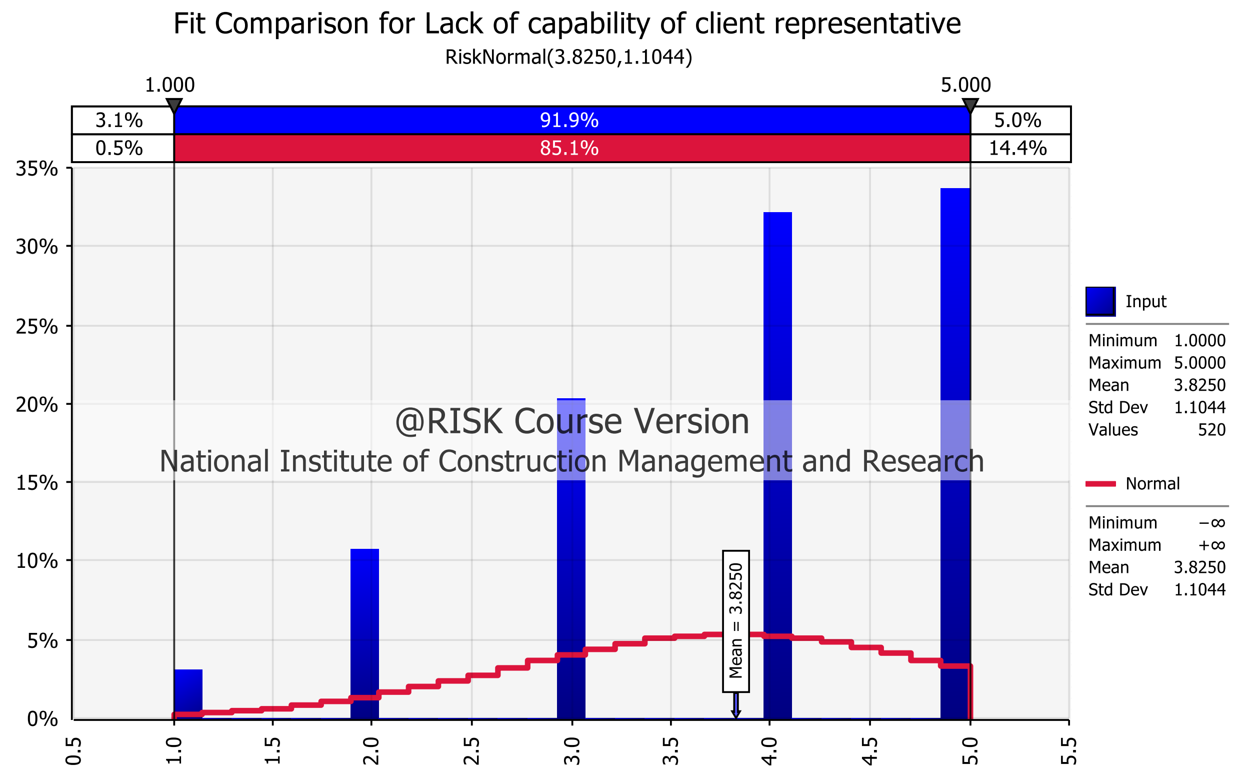


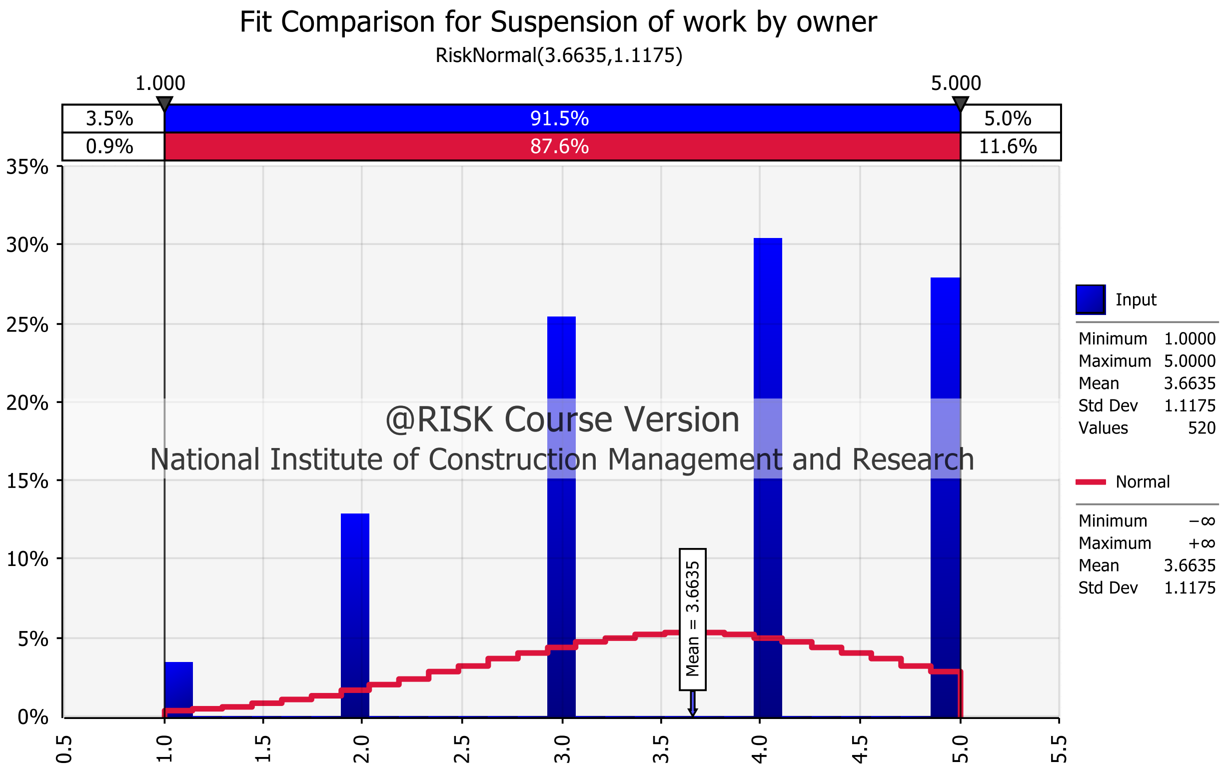
Fit Comparison for Delay in Permissions, approvals & statutory clearances
RiskNormal(4.0923,1.1066)
1.000
5.000
4.0%
91.0%
5.0%
0.3%
79.1%
20.6%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 4.0923
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 4.0923
Std Dev 1.1066
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 4.0923
Std Dev 1.1066



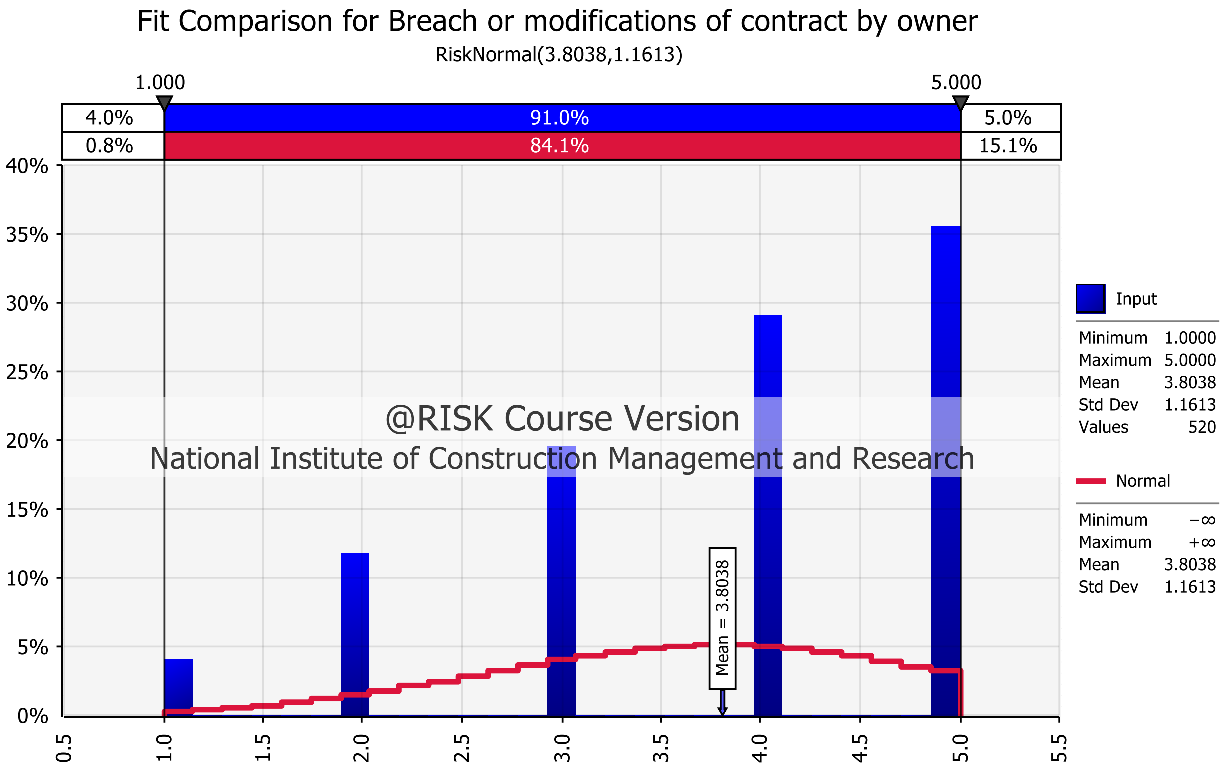
Fit Comparison for Learning from best practice and experience of others
RiskNormal(3.5404,1.0305)
1.000
5.000
2.9%
92.1%
5.0%
0.7%
91.5%
7.8%
40%
35%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.5404
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.5404
Std Dev 1.0305
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.5404
Std Dev 1.0305


Fit Comparison for Delay in Decision making
RiskNormal(4.1058,1.0249)
1.000
5.000
1.3%
93.7%
5.0%
0.1%
80.7%
19.1%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 4.1058
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 4.1058
Std Dev 1.0249
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 4.1058
Std Dev 1.0249

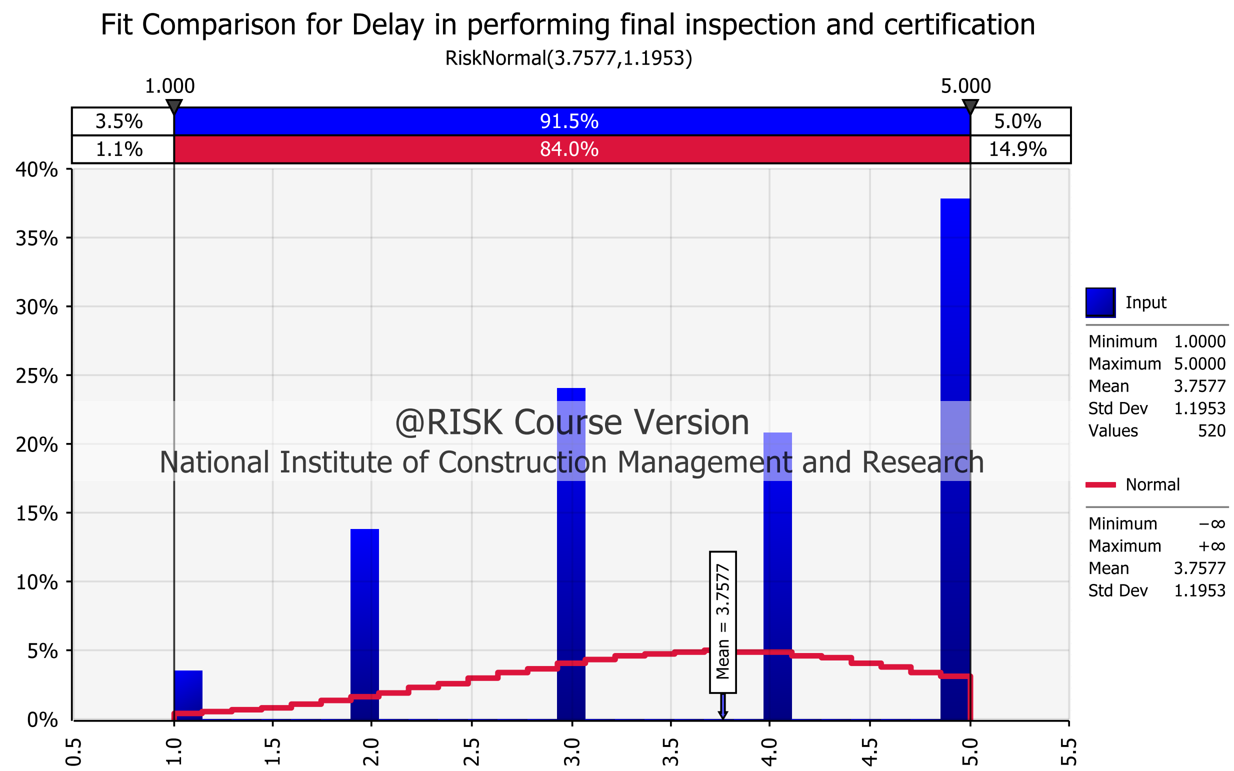

Fit Comparison for Lack of capability of client representative
RiskNormal(3.8250,1.1044)
1.000
5.000
3.1%
91.9%
5.0%
0.5%
85.1%
14.4%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Mean = 3.8250
@RISK Course Version
National Institute of Construction Management and Research
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.8250
Std Dev 1.1044
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.8250
Std Dev 1.1044



@RISK Course Version
National Institute of Construction Management and Research



@RISK Course Version
National Institute of Construction Management and Research



Fit Comparison for Delay in performing final inspection and certification
RiskNormal(3.7577,1.1953)
1.000
5.000
3.5%
91.5%
5.0%
1.1%
84.0%
14.9%
40%
35%
30%
25%
20%
15%
10%
5%
0%
@RISK Course Version
National Institute of Construction Management and Research
Mean = 3.7577
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Input
Minimum 1.0000
Maximum 5.0000
Mean 3.7577
Std Dev 1.1953
Values 520
Normal
Minimum −∞
Maximum +∞
Mean 3.7577
Std Dev 1.1953

CURRICULUM VITAE

I, Ravindra Shrivastava, a research scholar at UPES and Assistant Professor at National Institute of Construction Management and research, Delhi NCR Campus, Bahadurgarh campus.

I am M. Tech. in Construction Management from Veermata Jijabai Technological Institute, Mumbai (University Of Mumbai) and Bachelor of Engineering from Govt. Engineering College, Ujjain (R.G.P.V. Bhopal)

I have total 12 years of work experience in academic and industry. In the past, I had associated with Tata consulting engineers Ltd, Pune, University of Petroleum and energy studies, Dehradun and currently working with National Institute of Construction Management and research, Delhi NCR. My area of teaching includes Construction Project Management, Project Risk management, Quantity Surveying, Tendering, Bidding and Contracting, Infrastructure Development Projects, Management of Public Private Partnerships and project planning software Primavera.

The following are the publications associated with my PhD research work are,

1. R. Shrivastava, S. Gupta, A. Mittal, B. Saxena (2019) A Review on Critical Risk Factors for Infrastructure Projects in Asian Countries, Indian Journal of Economics & Business, Vol. 18, No.1 (2019) : 343-364
2. R. Shrivastava, S. Gupta, A. Mittal, B. Saxena (2019) Critical risk factors causing the time and Cost Overruns of Indian Railway Projects in India", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-9 Issue-1, October 2019

Accepted for Publication

1. R. Shrivastava & S. Gupta "Identification of significant risk attributes causing the overruns of railway construction projects in India" accepted for publication in "International Journal of Advanced Science and Technology"

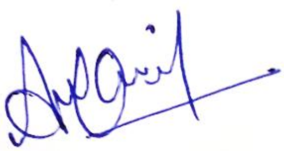
ORIGINALITY REPORT

9%	4%	4%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to University of Petroleum and Energy Studies Student Paper	<1%
2	vcenter.iima.ac.in Internet Source	<1%
3	Swarupa Deshpande, Hiranmoy Roy, Tarun Dhingra, Sumeet Gupta. "Sustainable procurement for improving project performance for oil and gas projects", International Journal of Procurement Management, 2020 Publication	<1%
4	es.scribd.com Internet Source	<1%
5	Homayoun Khamooshi, Hamed Golafshani. "EDM: Earned Duration Management, a new approach to schedule performance management and measurement", International Journal of Project Management, 2014 Publication	<1%

www.spiedigitallibrary.org


Dr Sumeet Gupta | **Dr Ankur Mittal** | **Dr. B K Saxena**