SYNOPSIS OF THE THESIS

Critical Factors affecting Risk Management Strategy in Selected Brownfield Projects in Steel Plants

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By

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1. Introduction

A project is a temporary endeavour to deliver a unique product or a service or a result or a unique combination of these three, which means a "deliverable" at the end. Thus, it involves certain actions directed to deliver that deliverable (Kliem et al, 1997; PMBoK®, 2017).

Project Management has been defined by PMBoK® (2017) as "*the application of knowledge, skills, tools and techniques to project activities to meet the project requirements."*

Risks are a permanent feature in projects and affect the cost, schedule and quality of the project. While these risks can vary in type and magnitude, their presence can be felt from the very beginning of a project.

Construction project, is a discipline where these challenges and risks are further magnified due to the presence of several features like non-homogeneous character of project and uniqueness of the product, implementation of the project in a dynamic, uncertain and complex environment, different stakeholders having divergent viewpoints or requirements, changing climatic factors, long period of time through which the project develops and division of responsibilities of the involved agencies (De Azevedo et al, 2014).

The steel industry is capital as well as labour intensive industry and any project in steel plant involves a considerable amount of project cost and project time. Most of the steel plants in India have embarked upon expansion / modernisation project to augment their existing capacity at different points of time. These projects can be either "brown-field" or "greenfield" in nature. The projects that are undertaken within the confines of a working steel plant are termed as "brown-field project" (Joy, 1993) while any project

taken up beyond the boundary of the existing plant at a new location is termed as "green-field project"

There are several parties whose interests are linked with the project outcome. These interested parties, termed as "stakeholders" to the project, may include public, project sponsor, project owner, project executor i.e the contractor / subcontractor, suppliers or vendors, statutory agencies and user group or department. Another important agency which has some say in the project is the consultant.

While the operational responsibility of the facility that comes up with the project, lies with the user department, the project planning and management responsibility lies with the project manager and his team from the project department. Thus these two departments constitute the stakeholder - **Project Owner**. Consultant is the advisor to the project owner. Apart from design and engineering that is usually included in their scope of service a consultant also advises the project owner in matters related to project. It is because of this role the consultant is included in the **Project Owner group** in this study in-spite of being an external agency.

The idea of complexity in projects has developed over the years. While Baccarini (1996) defined it in terms of structural complexity involving "differentiation" and "interdependency" of "many varied interrelated parts" there are other authors who added several other attributes of complexity like uncertainty, dynamics, pace and socio-political factors (Shenhar & Dvir, 2007; Geraldi et al., 2011). These research ideas provide useful guidelines for the present study relating to risk and its relationship with project complexity for brown-field construction projects in steel plants.

2. Research Motivation

Several studies have identified number of risks in construction projects over the last few decades. While these studies have identified and assessed risks related to a whole range of construction projects starting from building construction to industrial construction and further to infrastructural construction, there is dearth of documentation with respect to risks in the particular category of steel plant construction. The risks in construction projects are categorized under some broad heads like Market, Political, Economic, Legal, Logistical, Organisational, Construction, Management, Environmental. Possibility exists that the risk or risk events identified in these research studies are applicable to the construction projects in steel plants. However, brownfield construction projects in an operating steel plant may have some risks which are typical of any construction project under such circumstances.

The aspect of project complexity has found gradual recognition in several literatures over the years and brownfield construction projects in steel plants may have some attributes of complexity of their own.

Literatures on project risk management have thrown more light on identifying risk in different construction projects but have not dealt specifically on the relationship between risk and the complexity of project.

Management of risks in project takes place through appropriate risk response like escalate, avoid, transfer, mitigate and accept. Existing literatures have indicated several actions under these response options to respond to the risks. However, these studies have not gone much beyond the actions, thus not throwing much light into the factors affecting these actions and their relationship with criticality of risks and complexity of projects. These limitations of research both in the relationship between the project

complexity and the criticality of risk as well as their relationship with the risk response factors has motivated the Author to take up this topic for research.

3. Review of Literature

Review of literature is carried out related to project especially construction projects and their management. The basic idea of the review is to understand the risks in construction projects and their management. It also focused on the literatures related to project complexity. The different attributes of project complexity and those relevant to brown-field construction projects in steel plants have been reviewed. The tables below indicates some of the important literatures reviewed in connection with the present study.

Concept of Risk

Sl. No.	Literature Reviewed (Title of the paper, article, etc. along with the source, i.e., the name of the Journal, Magazine, Book, etc.)	Literature Type (Research Paper, Review Paper, Chapter of a Book, etc.)	Author/s	Publishing Year	Gist of Points gained	Linkage to own research
1.	A Disciplinary Perspective on the Epistemological Status of Risk, Risk Analysis, *Society for Risk Analysis, Vol. 25, (No. 3)*, pp 567-588	Research Paper	C. E. Althaus	**2005**	Defined risk from three different perspectives: a) Possibility of loss, damage, injury etc. (exposure) b) A hazardous journey, undertaking, course of action (hazard) **c)** A person or thing that can cause a good or bad outcome (outcome)	It is the outcome related perspective that is relevant for the study of project risk. This necessitates that risk be assessed in terms of two parameters – the likelihood of the risk event occurring and the severity of its impact. outcome

2.	Risk Analysis and management in construction *International Journal of Project Management, Vol. 15, (No. 1),* pp 31-38	Research Paper	Akintoye & MacLeod (1997)	**1997**	Cited several other studies that emphasised on the economic loss or gain as risk due to the construction process.	Economic loss in terms of cost overrun has been considered as risk in the present study. Economic gain , however, has not been considered.
3.	*A Quantitative Risk Management Approach to the Selection of a Construction Contract Provisions*, PhD Thesis, Department of Civil Engineering , Stanford University	PhD Thesis	Mason, 1973	**1973**	Considered negative aspects of loss as risk.	It is the negative consequences of risk that has been considered in the present study.

Project Risk and their Management

Sl. No.	**Literature Reviewed** **(Title of the paper, article, etc. along with the source, i.e., the name of the Journal, Magazine, Book, etc.)**	**Literature Type** **(Book/ Research Paper/ Chapter/ Conference paper)**	**Author /s**	**Publishing Year**	**Gist of Points gained**	**Linkage to own research**
4.	Guide to Project Management Body of Knowledge, 6th edition, Project Management Institute, USA	Book	Project Management Institute, USA	**2017**	Defined project risk as "…any event the occurrence of which impacts the achievements of project objectives"	It is this definition of project risk that has been adopted for the present study.
5.	Identifying and Managing Project Risk – Essential Tools for Failure-Proofing Your Project,	Book	Kendrick,	**2010**	• This book has identified project risks under three major heads of Scope risks, Schedule risks and Resource risks.	Risks are identified for the present study in each of these areas of risks.

	PHI Learning Private Limited, New Delhi				• Aligning itself to PMBoK® Guide the author emphasised that risk management is successful when consistent processes are adopted by the organisation.	The present study followed the risk manage-ment process steps indicated in the book with the exception of the last step of monitoring and control which was outside the scope of the present study.
6.	Developing a risk assessment model for PPP projects in China – A fuzzy synthetic evaluation approach, *Automation in Construction Vol.19*, pp 929-943	Research Paper	Xu, Yelin, Yeung, John F. Y., Chan, Albert P.C., Chan Daniel, W.M , Wang, S Q and Ke Yongji an	**2010**	Identified 37 risks in Public Private Partnership Projects in China. It has calculated the Impact of individual risk as geometric mean of Probability of occurrence and Severity of that risk and finally calculated overall risk of the PPP projects using Fuzzy Synthetic Evaluation Method	Similar method is used to calculate the Risk Potential Score of individual risk event and the overall risk potential score of the construc-tion projects in operating steel plants.
7.	Risk Management in Construction Projects, *Journal of Engineering and Applied Sciences, Vol. 12 ,(No. 20)*, pp 5347-5352, © Medwell Journals, 2017	Research Paper	P. Rehace k	**2017**	Explained risk in terms of "PI Factor" which is equal to the product of the probability of occurrence of risk event and the impact of the risk event in terms of loss.	In the present study risk has been assessed in terms of the probability of occurrence and severity of impact. Both these factors are measured in a scale of 1 to 5.
8.	Assessment Of Risks In Public Private Partnership Highway Projects In India using Fuzzy Synthetic Evaluation, *International Journal of Civil Engineering and Technology (IJCIET) Volume 8, (No. 11)*, pp. 401–413, Article ID: IJCIET_08_11_042	Research Paper	P.Desh pande and S. Rokade	**2017**	Identified risks in highway projects and assessed them in terms of impact of risk event, which is geometric mean of probability of occurrence and severity of the risk event.	Same method has been applied in the present study to assess the Risk Potential Score (RPS) as geometric mean of probability of occurrence and severity of impact. Both are measured in a scale of 1 to 5.
9.	*Risk Management in the Construction*	Conferenc e Paper	B. Y. Renault	2016	The article talked about identifying	In line with this study and

	Industry: a new literature review, MATEC Web of Conferences 66, 00008, Creative Commons Attribution License 4.0 (available at http://creative commons.org/licenses/by/4.0/)		& J. N. Agumba		possible risk response options with the objective of reducing the negative effect or threat of the risk event.	supported by PMBoK® Guide, the present study has identified the possible response options as avoid, transfer, mitigate and accept, which can be either active or passive.

Construction Project Risks and their Management

Sl. No.	Literature Reviewed (Title of the paper, article, etc. along with the source, i.e., the name of the Journal, Magazine, Book, etc.)	Literature Type (Book/ Research Paper/ Chapter/ Conference paper)	Author/s	Publishing Year	Gist of Points gained	Linkage to own research
10.	A comparative study of causes of time overruns in Hong Kong construction projects, *International Journal of Project Management, Vol. 15* , (No.1), pp 55-63.	Research Paper	Chan and Kumaraswamy	**1997**	Studied the delay in construction projects in Hong Kong from the perspective of clients, consultants and contractors and found poor site management & supervision, unforeseen ground condition, low speed of decision making, client initiated variations as major risks.	These risks have been considered in the present study with variations in some cases.
11.	Risk management framework for construction projects in developing countries, *Construction Management Economics , Vol.22, (No. 3),* pp 237–252.	Research Paper	Wang S.Q., Dulaimi M.F., Aguria M.Y.	**2004**	The study explained that while internal risks largely remain unchanged for local or international projects, external risks for international projects generate mainly from the unawareness of social condition, economic and political scenar-ios, unknown procedural form-	The present study has tried to incorporate some of the possible ext.l risks in the brownfield project set-ting in steel plants of India.

					alities, regulations etc.	
12.	How Project Manager – Project Owner Interaction can Work within and Influence Project Risk Management, *Project Management Journal, Vol.43, (No.2)* , pp 54-62	Research Paper	Krane, H. P., Olsson, Nils O. E & Rolstadå s A	**2012**	Categorised risks in large construction projects under strategic and operational risks	The present study though has not made such categorisation but has considered some of the strategic and operational risks in the pilot survey.
13.	Risk Management in Construction Projects, Chapter 19, retrieved from http://creativecommons.org/licenses/by/3.0	Book Chapter	Banaitiene, N & Banaitis, A.	**2012**	The study classified risk factors in construction projects under two major groups – internal and external. The internal risks are identified as Construction Risks, Design Risks and Project management risks. External risks, on the other hand are like Natural Forces, Inflation and interest rates, Fiscal policy, Political controls	The risks under both these categories have been considered under the pilot survey
14.	Managing Risks in Complex Projects, *Project Management Journal, Vol. 44, (No. 2)*, pp 20-35	Research Paper	Hans Thamhain	2013	The study considered risk in terms of three variables- Degree of Uncertainty, Project Complexity and Impact of risk on project and enterprise with major constraints of time schedule of project.	Project Complexity has been considered separately in this study with uncertainty being a part of it. Further a study of correlation betn. Impact of risk and Project complexity was carried out.
15.	*An Overview on the Issue of Delayin the Construction Industry*, available at https://www.researchgate.net/publication/300177825	Research Paper	Sunitha V. Doraisamy, Zainal Abidin Akasah and Riduan Yunus	2015	The study dealt with delays in construction projects and suggested that contractor's improper planning, contractor's poor site management, contractor's lack of experience, clients inadequate finance	Most of these risks have been considered in Pilot survey for the present study.

					and pay-ments for completed work, problems with sub - contractors, shortage of mat-erials, shortage of labour supply, unavailability of equipment and its failure, comm-unication barrier between parties and mis-takes during construction work.	
16.	A Study of Various Factors Affecting Risk Management Techniques in Construction Project: A Case Study Of India, *International Journal of Research in Engineering and Technology, Vol.04, (No. 03),* eISSN:2319-1163/pISSN: 2321-7308 retrieved from http://www.ijret.org	Research Paper	Saminu Shuaibu, Prasad Raj & Thamilarasu, V.,	2015	The study found out that inadequate planning, poor site safety adoption, supply and use of defective material and poor resour-ces management have contributed towards risk in construction projects	These risks have been considered in the pilot survey.
17.	*Risk Management in Construction Projects using Statistical Analysis*, 4th International Conference on Science , Technology and Management (ICSTM-16), May 2016, ISBN: 978-81-932074-8-2	Conference Paper	Jayasudha, K and Vidivelli B,	2016	The paper identified inade-quate planning, poor adoption of site safety, supply and use of defective mat-erials and poor resources man-agement as the key risk factors affecting the construction projects	All these risks have been identified for pilot study.
18.	Ex-Post Risk Management in Public-Private Partnership Infrastructure Projects, *Project Management Journal, Vol. 48, (No.3),* pp 76 – 89, Project Management Institute, USA	Research Paper	Xiong, Wei, Zhao, Xianbo, Yuan Jing-Feng, Luo Sai,	2017	The study discussed about ex-ante and ex-post risk management in PPP infrastructure projects. The risks categorised by them are systematic risks and specific proj-ect risks. Political risks, economic risks, legal risks , social risks coming under systematic risk and construction risk, operation risk, market risk,	Most of these risks have been cons-idered in the pilot study.

					relationship risk under specific project risk.	
19.	"An Innovative Framework for Risk Management in Construction Projects in Developing Countries: Evidence from Pakistan," *Risks, MDPI, Open Access Journal, vol. 7(No.1),* pp 1-10	Research Paper	Nawaz, Ahsan & Waqar Ahsan & Shah, Syyed Adnan Raheel & Sajid, Muhammad & Khalid, Muhammad Irslan	2019	The study suggested a framework for risk management in construction projects in Developing countries. It suggested addressing the risks under three main heads of Risk Identification, Risk Assessment and Risk Response and finally Risk Treatment	The risk addressal methods suggested in the study has been considered except for risk treatment which has been kept out of scope of the present study.
20.	Developing a Risk Management Matrix for Effective Project Planning- An Empirical Study, *Project Management Journal, Project management Institute, Vol.32, (No.2),* pp 45-57,	Research Paper	Datta, S. and Mukherjee, S. K	2001	in their study drawn a risk management matrix based on the levels of external and immediate project risks and suggested the risk response actions corresponding to combinations of low, medium and high level of both these risks.	These actions are considered in determining the types of factors influencing the risk response options for the present study.
21.	Project risk management using multiple criteria decision-making technique and decision tree analysis: a case study of Indian oil refinery, *Production Planning & Control, Vol.23, (No.12),* pp 903-921, DOI: 10.1080/09537287.2011.586379	Research Paper	Dey, Dr P	2012	The study suggested a framework which is an extension of his earlier works in 2001 and 2010 wherein risk identification, analysis and response development using risk map and selecting mitigating measures using decision tree analysis. For risk responses in line with the principles related to avoid, transfer, reduce and absorb, several actions were suggested in the study	The risk response actions are considered to identify the response factors influencing these actions

Project Complexity

Sl. No.	Literature Reviewed (Title of the paper, article, etc. along with the source, i.e., the name of the Journal, Magazine, Book, etc.)	Literature Type (Book/ Research Paper/ Chapter/ Conference paper)	Author/s	Publishing Year	Gist of Points gained	Linkage to own research
22.	The concept of project complexity - a review. *International Journal of Construction Management. Vol.14*, pp 201-204	Research Paper	Baccarini	1996	deals with two types of complexity – organizational complexity and technological complexity on the basis of differentiation and interdependency.	This concept has been adopted partially.
23.	Project complexity: The focal point of construction production planning. *Construction Management and Economics. Vol.14*, pp 213-225	Research Paper	Gidado	1996	In this study construction project activities were analogised with complex production process where the activities are linked in a work flow to be completed within a stipulated time , cost and quality requirement.	The basic idea complexity of projects with its constraints of time , cost and quality has been considered.
24.	Enhancing the prime contractors pre construction planning .*Journal of Construction Research.,Vol. 5*, pp 87-106.	Research Paper	Gidado	2004	In this study the author has identified six main components of complexity like inherent complexity, uncertainty, No. of technologies, rigidity of sequence, overlapping of phases, organizational complexity	Inherent complexity and uncertainty have been considered**.**
25.	*Complexity of Megaprojects*, CIB World Building Congress, pp 219-230	Conference Paper	Brockmann & Girmscheid	2007	The authors defined complexity as manifoldness, interrelatedness and consequential	The aspect of manifoldness and interrelatedness have been con-

					impact of a decision field in projects	sidered in the present study.
26.	On faith, fact, and interaction in projects. *Project Management Journal, Vol 38, (No. 1*), pp 32 –43	Research Paper	Geraldi and Adlbrecht	2007	The authors defined project complexity in terms of three factors-faith, fact and interaction. Complexity of faith involves dealing with uncertainty, solving new problems while complexity of fact involves large volume of information in project that are interdependent. Complexity of interaction involves politics, ambiguity, multi-culturity as contributing factors.	Some of the factors of faith, fact and interaction considered in the present study.
27.	*Reinventing Project Management- The Diamond Approach to successful growth and innovation*, Boston, Massachusetts: Harvard Business School Press	Book	Shenhar and Dvir	2007	This study has proposed a Diamond model of Project Management that has identified that uncertainty in projects has four dimensions – novelty, technology, complexity and pace.	The present study has considered project complexity as composed of pace, uncertainty, technology as dimensions contributing to it apart from other dimensions.
28.	Now, let's make it really complex (complicated) - A systematic review of the complexities of projects, *International Journal of Operations & Production Management, Vol. 31 (No. 9)*, pp. 966-	Research Paper	Geraldi, Maylor and Williams	2011	The study suggested an integrated framework for assessing project complexity. This includes structural complexity, uncertainty, dynamics, pace and socio-	This frame work has been adopted by the present study to assess the project complexity. These factors have been termed as "attributes" with some

	990, published by Emerald Group Publishing Limited				political complexity as factors.	other factors termed as "indicators" contributing to some of them.
29.	*Taxonomy of project complexity indicators in energy megaprojects*, Paper presented at International Scientific Conference People, Buildings and Environment 2014, Kromíž, Czech Republic.	Conference Paper	Kian and Sun	2014	The authors identified 76 indicators in the category of internal and external and their sub-categories to assess a composite project complexity.	The idea of calculating composite project complexity has been adopted in the present study though the constituent factors are based on the study by Geraldi, Maylor and Williams.
30.	Identifying and measuring project complexity, *Procedia Engineering 145(2016)* , pp 476-482, Published by Elsevier Ltd.., This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)	Research Paper	Dao et al.	2016	The study identified 37 complexity indicators under 23 complexity attributes which they categorized under eleven heads.	The present study is influenced by the idea of indicators under the attributes.
31.	Research Focuses, Trends, and Major Findings on Project Complexity: A Bibliometric Network Analysis of 50 years of Project Complexity Research, *Project Management Journal, Vol. 49, (No.1),* pp 42-56, Project Management Institute, USA.	Research Paper	De Rezende et al	2018	In their study of trends and focuses of complexity research over a twenty year period the authors observed that the complexity study has basically focused on structural, uncertainty, novelty, dynamics, pace, socio-political and regulative complexity.	The findings of the study strengthened the concept of project complexity as considered in the present study.

4. Research Gap

In the available literatures, the authors have identified project risks in some of the specific area of construction projects but have not specifically addressed any risk pertaining to brownfield construction projects in steel plants, which may have some constraints of their own. The present study, therefore, has tried to address this gap in identification of critical risks which are typical of the construction projects in an operating steel plant apart from the general risks which are characteristic of any construction project. Further this study has attempted to assess the overall risk potential of brownfield construction project in steel plants based on these critical risks.

Literatures have identified several attributes that can contribute to the complexity of a project. In the present study an attempt has been made to put these attributes in the context of brownfield projects and assess them to arrive at the overall project complexity. Further this study focused on the gap in the earlier studies regarding the relationship between the project complexity and criticality of risk or the risk potential of the project.

The other gap areas which the present study has attempted to cover are the risk response option and risk response factors. Several literatures have discussed about the risk response options like avoid, transfer, mitigate and accept and actions under those options. A study into those actions suggests that the choice of these options and the actions taken under that option are influenced by two distinct type of factors – human response factors and systemic response factors. This study has tried to investigate the relative influence of these response factors on the risk response options and the relationship of these response factors with the criticality of risk and the project complexity.

5. Research Objectives

This research study was undertaken to understand the critical risks in brownfield construction projects in steel plants, their relationship with project complexity, response options to those risks, factors that influence those risk options and the relationship of these response factors with the criticality of risk and complexity of project. The objectives of the research study, thus, have been formulated as below:

1. To ascertain overall risk potential of brown-field construction projects in steel plants.
2. To investigate the relationship of criticality of risk with complexity of the project.
3. To explore the influence of Risk Response Factors on the Risk Response Options selected for each risk.
4. To determine the relationship of the Risk Response Factors with the complexity of project and criticality of risk.

6. Research Hypothesis

In order to fulfill the objectives of this research the following null hypotheses were formulated and tested.

H_{01}: There is no significant level of risk in brownfield construction projects in steel plants.

H_{02}: There is no significant relationship between the criticality of risk events and the complexity of project

H_{03}: There is no difference in the influence of Risk Response Factors (RRF) on the Risk Response Options (RRO) for each Risk.

H_{04}: For risks of non-availability of work-fronts / shutdown of existing facility both the response factors have same level of influence on the risk response options.

H_{05}: For the risk of unforeseen ground condition both the response factors have same level of influence on the risk response option.

H_{06}: For Safety related risk, both the risk response option have the same level of influence on the risk response options.

H_{07}: There is no significant relationship between the Risk Response Factors and the Complexity of the brownfield project.

H_{08}: There is no significant relationship between the Risk Response Factors and the Criticality of Risk for a brownfield project.

7. Scope of Research

This research study is focused on the brown-field construction projects in steel plants. Thus, it will concentrate on the study of criticality of risk, complexity of projects, risk response options, risk response factors and their mutual relationship on the basis of brown-field construction projects in steel plants from the perspective of project owner-group.

8. Research Methodology

The methodology followed in this study included both qualitative and quantitative approach as has been pointed out by different researchers regarding the pitfalls in following any one approaches.

The risks in construction projects were initially obtained from the secondary data sources like the available literatures on project risks and construction project risks. Further a method of content analysis followed by discussion with experts in a focus group were applied to identify risks for the pilot survey.

Pilot survey was carried out among project executives and executives from plant operation who were directly associated with projects. The pilot survey responses were analysed to assess the risks in terms of their risk potential score and their subsequent prioritization based on the score. These are the major risks in construction projects in an operating steel plant.

The major risks along with some additional risks, which were finalized in a second focus group discussion were put for the main survey. The additional risks included risks suggested by the respondents in the pilot survey and risks of economic nature which are prevalent in projects. The main survey responses were analysed and assessed in terms of risk potential score of each risk. Sixteen (16) critical risks from out of the thirty six (36) major risks were identified based on set criteria. The main survey also attempted to gather information about the risk management framework in organization and the different indicators of project complexity. Simultaneous to the main survey, another survey was conducted among group of project experts to ascertain the weights of attributes and indicators of project complexity in order to determine the overall complexity of project. Finally, the results derived from the main survey responses were further validated from a select group of project experts.

The study followed a convenience and purposive sampling method to determine the samples for the main survey. While 64 responses were obtained during the pilot survey, there were 166 responses in the main survey. The respondents were project executives, executives from plants associated with projects and executives from consultant organization. The pilot survey data was collected in the later half of 2016. The data for main survey was collected during 2017 and first half of 2018.

9. Data Analysis

Following the collection of data from the main survey responses, they were subjected to various analysis including statistical analysis using SPSS 25 package. Initially, the responses on probability of occurrence and severity of impact of each risk event were used to calculate the risk potential score using the following formula used by Xu et.al, 2010 and Deshpande and Rokade, 2017:

$$\text{Risk Potential Score} = \sqrt{(\text{Probability of occurrence} \times \text{Severity of consequences})}$$

Using the risk potential score of each risk event and thereafter applying normalization factor of 0.5 or above as the cut-off 16 critical risks (CR) were identified.

Assessment of project complexity was done on the basis of attributes and indicators with their relative weights being considered as contributing to overall complexity of each project on the basis of which the respondents have assessed the risks. The relative weights of each attributes and indicators was calculated using Analytic Hierarchy Process (AHP) developed by Saaty (1980).

After assessment of complexity, using AHP, for each of the project, correlation analysis was carried out to assess the relationship between criticality of risk, which is measured by the risk potential score and the overall project complexity. At an individual risk level

the highest correlation coefficient was 0.413 in case of “Inadequate Safety leading to accidents”. On the other side the lowest value was 0.209 in case of risk related to “Inexperienced Contractor”. At an overall level total risk in a project showed greater correlation with project complexity with correlation coefficient of 0.434.

Exploratory Factor Analysis (EFA) was carried out on the main survey data to find out the inherent factors or critical risk groups (CRG). Before carrying out EFA, test for reliability of data was examined through SPSS. The Cronbach alpha value was obtained as 0.901 indicating a highly reliable data. The data was also checked for suitability with Kaiser-Meyer-Olkin (KMO) measure which was found out to be 0.91 suggesting suitable data for EFA. The EFA identified five (5) critical risk groups which explained 65.323% of the variation.

Based on the probability of occurrence and severity of impact of the 16 critical risks and 5 critical risk groups as identified in EFA, Fuzzy Synthetic Analysis was carried out on the data to assess the overall risk potential score of the brownfield projects in operating steel plant. The overall risk potential score of 3.09 signified that the criticality of risk of brownfield project in an operating steel plant is in between medium and high.

The risk response option and the corresponding risk response factors (both human and systemic) were assessed by the respondents in the main survey. The two sets of scores for each of the risk response options were subjected to Wilcoxon Signed Ranks Test. While for most of the options the scores suggested that there is statistically no significant difference between the influence of both the factors on the response option.

The risk response factors were further analysed for their correlation with project complexity and the criticality of risk. While the response factors have shown weak

correlation with project complexity, they exhibited stronger correlation with criticality of risk.

In the last phase of analysis, a select group of project experts were interviewed for their views on the results obtained thus validating the findings.

10. Findings and Conclusions

This research study has got its findings corresponding to the different research areas dealt in the study. The area-wise findings are as below:

a) Risk Management Framework in Organisation

   Though this area has not been covered through any specific hypothesis but the data from the main survey revealed that the respondents have identified some risks in their projects, but a less number of them have infact assessed them in terms of their risk potential and further lesser number of them agreed that they have a proper plan for responding to the risk. Very few of the respondents indicated that they have a proper documentation of such response and its follow-up.

b) Major risk events in brownfield construction projects in steel plants

   In this study 16 critical risks were identified for brownfield construction projects in steel plants. The highest level of risk based on risk potential score considering overall responses was "*Unrealistic Time estimates of activities …"* followed by "*Delayed Supply of equipment…..*". Two risks which were typical of the brownfield project scenario also could find place among the list of the critical risks. These risks - "*Work Fronts/ shutdown not being made available in time….*" and "*Unforeseen ground condition …*" have severely affected the outcome of many construction projects in

steel plants in recent times. The overall risk potential score for brownfield projects in operating steel plants turned out to be in between medium and high.

c) Relationship of Project Complexity and Criticality of risk

On the basis of statistical analysis most of the individual risks have shown quite significant correlation with project complexity with "*Inadequate Safety provisions….*" topping the list. Further, the correlation coefficient between overall risk in a project and project complexity have indicated higher level of correlation.

d) Influence of Risk Response Factors on Risk Response Option

Apart from risks like Inexperienced Contractor causing delay, "*Contractor having inadequate workmen…*", "*Inadequate Project planning …*", "*Increase in scope…*", "*Unrealistic time estimates…", "Delay in supply of equipment….*", "*Delay in approval of drawings and documents…*", "*Inadequate safety provision…*", "*Poor subcontractor performance…*", "*Not adequate skilled Manpower…*", "*Inadequate checking of interface…*" all other risks have shown that statistically there is no difference between the human and systemic response factor influence on the risk response. For two typical brownfield risks i.e "*Work Fronts/ shutdown not being made available in time….*" and "*Unforeseen ground condition …*" the results have shown that both the risk response factors have same level of influence on response options.

e) Relationship of Risk Response factors and Criticality of Risks

The risk response factor have shown significant level of correlation with the criticality of risks. At an overall level both the factors have shown higher level of correlation. However, the human response factors have shown higher level of correlation than systemic response factors.

f) Relationship of Risk Response factors and Project Complexity

While the response factors have shown significant level of correlation with criticality of risk but their correlation with project complexity is very insignificant. The experts also suggested that various factors contributing to complexity have very limited dependence on the risk response factors. Hence is the reason for low correlation level.

Based on the research findings and the opinion of experts the following may be concluded:

a) The overall risk potential of the construction projects in operating steel plants is in between medium and heavy.
b) Criticality of risk has a positive correlation with project complexity both at individual and overall level. This signifies that same risk for a project of higher complexity will have higher level of criticality.
c) There is statistically no difference in the relative influence of risk response factors on the risk response options. Thus for the selection of a choice of response both the factors are significant and need to be considered on equal basis.
d) The high level of correlation between risk response factors and the criticality of risk signifies that these factors become more important as the criticality of risks goes up. Further the results suggest the dominance of human response factors over systemic response factors with increasing criticality.
e) The weak correlation between project complexity and the risk response factors suggest that the risk response factors are more sensitive to the criticality of risks than the complexity of projects.

11. Contributions of the research

The contribution of this research study has been mapped from three different aspects of Theoretical, Practical and Social.

As far as theoretical contributions are concerned the study has identified some critical risks for construction projects in an operating steel plant. Significant among these are the risks which are typical of the brownfield setting.

"*Workfronts / Shutdown not being made available in time…*"

"*Unforeseen ground condition …*"

Over and above the above two risks the respondents felt that the risk of "*Inadequate checking of interface….*"is equally applicable and relevant to the brownfield projects in steel plants.

The study has also tried to draw a connection between two important concepts of criticality of risk and complexity of project.

The study has also highlighted the influence of risk response factors on the choice of risk response which was largely absent in the available literatures. The relationship between these risk response factors and project complexity as well as criticality of risk has also been an added dimension which has been investigated in this study.

At a practical level, the study, pointed out the lack of planning and documentation of risk response in case of project risks in the organization. This highlights the need for a proper risk management framework in the organization as part of managing projects.

The similar importance of human and systemic response factors in responding to risks led to put thrust in two major areas:

a) Skill Development

b) System Development

The skill development encompasses the area of technical skill development of project manager and his team, managerial skill development and leadership skill development. System development includes development of systems for monitoring, vendor selection, changes, approvals, payments etc., having proper provisions in contract/ specifications/ terms and conditions as well as developing and making available proper information system which shall include documentation of lessons learnt in a project with all risks encountered and actions taken to respond to the risks.

From a social angle the study has got relevance in the sense that as per National Steel Policy India has to achieve a production level of 300 million tonnes of crude steel by 2030. This will be only possible through the route of brownfield construction projects because of acute crisis of land resources. Further the technology will be more sophisticated in future with more agencies coming in. The findings of the present study in terms of human and systemic response factor influence is a significant indicator of the skill development and system development need for the organization in future.

12. Limitations of the research

The present study has some limitations in-spite of its contributions. These are as given below:

a) First limitation that was experienced was the general reluctance of executives of private sector projects in responding to the questionnaire survey. Had the responses

been more from the private sector it could possibly have contributed more positively towards the research findings.

b) The study has also restricted itself to the brownfield construction projects in steel plants. Greenfield projects which are also coming up remain outside the focus of the present study.

c) The study has been conducted from the perspective of the project owner group of the steel plant projects only. The perspective of other stakeholders could have added further dimensions to risk management in brown-field steel plant construction projects.

13. Scope of future research

The present study has been limited in its perspective but possibility exists that the study can be extended in the areas mentioned below:

The study can be extended in other types of construction projects to ascertain the validity of the findings in these areas.

The study has made comprehensive analysis based on Human Response factors and systemic response factors at macro level. Further study can be carried out on each of the components of these factors which can be of specific help to the organization.

More attributes and indicators of project complexity may be determined for other types of construction projects to have a better understanding of the relationships in other construction projects.

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