

Innovative Approach to Risk Analysis and Management of Oil and Gas Sector EPC Contracts from a Contractor's Perspective

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Abstract

Engineering, Procurement and Construction (EPC) is an advanced contracting method in which a single party is responsible to complete all the components of the project and further commission it and handover to the client within a predefined cost and agreed timeline. Failure to which, EPC contractor has to pay heavy penalties. There are many risks for both the parties in this arrangement. Proper risk analysis and management is very important for this type of contract which dominates a project's success or failure. In this research an effort has been made to identify, analyse and quantify rationally risks of oil and gas sector EPC projects. For this purpose a model has been proposed to assess and quantify risks involved in the process. Proper mitigation measures have also been proposed for all the critical risks to successfully complete a project from the contractor's prospective in the oil and gas sector.

Key Words: EPC, FIDIC, Oil and Gas Sector, Risk Analysis and Management

1. Introduction

The operational and fundamental structure of projects has significantly changed in the last ten years as globalization became more prominent, the

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construction industry being multifaceted has especially gone through major changes. In conventional approaches of contracting, it is difficult for the owner to assign responsibility for the delay or cost overrun as a number of stakeholders are involved. To overcome this discrepancy an advanced approach has been introduced known as Engineering, Procurement and Construction (EPC). In EPC projects a single party is obliged to deliver a complete facility to a developer who need to only 'turn a key' to start operating the facility. In addition to delivering a complete facility, the contractor must deliver the facility for a guaranteed price by a guaranteed date and it must perform to the specified level. Failure to comply with any requirements will usually result in the contractor incurring monetary liabilities (Damian M., 2011). In these projects, largest engineering and construction risks are transferred to the contractor. This type of contract requires an excellent project definition, but it ultimately guarantees a well-defined cost and completion time. The EPC type of contracting method is ideal for owners and developers because the capital cost is fixed at the start and the risk is placed onto the EPC contractor. EPC contracts and their use in construction have received bad publicity, particularly in contracting circles. A number of contractors have suffered heavy losses due to improper knowledge of risk identification, assessment and their mitigation, as a result, a number of contractors have now refused to enter into EPC contracts under certain jurisdictions. On the other hand, more the risk the greater is the rate of return for an EPC contractor, if risks are properly addressed. There are a lot of EPC contractors who have almost doubled their turnover in a decade.

Through the EPC contracting method, sponsors and owners expect to get the degree of certainty as to time and costs that they require. Such has been the popularity of this method of procurement that organizations such as International Federation of Consulting Engineers (FIDIC) responded to the need for appropriate standard forms that more closely reflected market conditions by, for example, the introduction of its Conditions of Contract for EPC/Turnkey Contracts (the Silver Book) given by Henchie (2001).

EPC projects are being executed in many fields of engineering and

construction. However, they are more common in oil and gas sector therefore focus has been made to oil and gas sector in this research.

Risk analysis and management is a comprehensive and systematic way of identifying, analyzing and responding to risks to achieve the project objectives (PMBOK, 2007). Construction projects can be extremely complex and fraught with uncertainty. Risk and uncertainty can potentially have damaging consequences for the construction projects (Mills, 2001). Jannadi and Almishari (2003) made attempt to assess risks associated with various construction project activities, defining risk as the potential damage that may affect personnel or property. They modeled risk by probability, severity of impact and 'exposure' to all hazards of an activity and provided software to generate risk scores. However, they did not provide a methodology for aggregating risk ratings.

Similarly, Cagno et al. (2007) adopted the P-I model and quantify the 'risk load' allocated to each project element by identifying sources of uncertainty, activities affected, and risk owners. Risk impact is assessed in monetary terms but collectively as a single figure. They attempt to improve risk modeling by introducing the concept of 'controllability' as a ratio between the expected risk impacts before and after applying mitigation actions. Controllability is dealt with as a tool for justifying mitigation actions economically.

Mubin S. (2007) defined risk as an unwanted but probable event which has negative impact on projects in terms of project targets. Moreover, he also identified various types of risks encompassing technological, financial & investment, natural disaster, environmental, health & safety, contractual and socio-economical. He also described two broader types of risk analysis i.e. quantitative and qualitative.

Therefore, the risk analysis and management is one of the major features of the EPC project management of oil and gas sector in order to efficiently deal with uncertainty and unexpected events to achieve project success. The

benefits of the risk management process include identifying and analyzing risks, and improvement of construction processes and effective use of resources, which ultimately results in completion of projects with in predefined targets of time, cost, quality and health & safety.

2. Gaps

There are different risk management models, which are a subset of a larger project management model that attempts to analyze and control risk in a more generalized way for all types and categories of projects and contracts. There are certain models of risk analysis and management that are available specifically for detailed analysis but no particular model is available from the oil and gas perspective and particularly for those projects which are executed under EPC contracts in a very risky environment such as Pakistan. Even though, if a certain general model is adopted for risk analysis and management but no attempt has been made to separate the contractor and client perspective for risk analysis and management, in which mitigation measures are opposite to each other.

3. Research Methodology

In this research an effort has been made to develop an easy approach and model for EPC project and their associated risks from a contractor's perspective in the oil and gas sector. In this regard, a survey based methodology has been developed to identify, assess and analyse the risks involved in EPC oil and gas sector projects and propose mitigation strategies for the critical risks taking into account all functions and peculiarities of EPC projects. Moreover, emphasis has been paid in this research for giving three dimensional risk assessment and quantification.

Through a survey based research, this model has given a way forward for identification of risks with the help of process owners in four internal EPC contractors working in Pakistan. The method developed by the author addresses limitation of Project Management Institute (PMI) as mentioned in the previous section highlight the EPC process of a successful project and to

explore a win-win situation for the both the parties in an EPC contract. Identified risks along with a barometer of probability and impact scale (different from PMI approach) were provided to the four EPC companies. Each company imparted the probability and impact of each risk depending upon its experience and lesson learnt from previous EPC projects. Average of this information is analyzed and quantified and incorporated in the risk register along with suitable management strategies by using FIDIC terms and conditions of EPC projects, internal arrangement of risk mitigation, through transfer or any other measure. Following components are necessary to carry out the risk analysis process as per risk management model developed by the researchers (Mannan, 2009)

3.1 Risk Management Planning

Pakistan Management Institute (PMI) approach of risk management starts with the planning of risk management, which includes a detailed risk management planning. In risk management planning the proposed course of action for risk analysis is set. The process includes the following;

- i. Setting criteria and planning method for risk identification
- ii. Setting criteria for probability and impact of risks
- iii. Selection of analysis method
- iv. Reporting method

A risk management plan should be documented early in the project, during the planning phase. A plan is undertaken prior to its execution phase to ensure that all risks are identified and their most appropriate and realistic assessment has been made. Immediately after the plan has been documented, the risk management process is engaged to monitor and control the likelihood and impact of risks on the project.

3.2 Risk Classification

In the context of EPC projects, risks are broadly classified into the following seven areas keeping in view the structure of EPC companies as

described by Mubin (2008);

- i. Engineering
- ii. Proposal
- iii. Project Management
- iv. Procurement and Contractual
- v. Quality, Health & Safety (QH&S)
- vi. Human Resource (HR)
- vii. Finance and Audit

3.3 Risk Identification

After risk classification, it is essential to identify risk which is an important part of any construction project described by Mubin (2008) following risk identification methods were adopted;

- i. Information Gathering Techniques
- ii. Project Document Review
- iii. Assumption Analysis
- iv. Checklist
- v. Diagraming

Figure 1 shows a complete model for risk identification and analysis process of EPC projects. It shows the essential components of risk analysis process and the steps involved in each component. It is evident from the figure that after completing each risk analysis cycle, lessons learned or conclusions drawn must be addressed in order to carry out the risk analysis process in a better way. By using any or a combination of the aforementioned methods any one or more than one of the following tools may be used;

- i. Individual/ departmental experience
- ii. Historical data of the projects
- iii. Organizational document review
- iv. Brain storming session

- v. Periodic meetings for fact finding
- vi. Questionnaire
- vii. Interviewing

In this research, information gathering techniques have been used in combination with other methods. Firstly, through document review process all probable risks were enlisted followed by enlistment of all probable risks according to the classification with the help of process owners and the concerned line department in four major EPC companies i.e. Presson Descon, Petronas, and SMEC. For accurate and realistic project risk identification all relevant documents of one major project of each EPC company were studied including Information to Bids (ITB) by reviewing technical and commercial terms and conditions, design and construction complexity of a project, safety and security on site, client repute and payment terms, socio-economic and political conditions of site and country, exchange rate fluctuations, performance of sub-contractors and vendors, environmental regulations, requirements of licenses and permits, design error/ omission, human error during construction and installation, natural disaster/ calamity, local unavailability of semi-skilled and skilled workers, quantity/ volume of work and material and rework risk etc.

With the help of process owner and concerned line departments in four companies in which survey was conducted, total one hundred and sixty two (162) most frequent risks were identified. Risks identified in departmental representatives and process owners of every functional area were w.r.t. time, cost and quality. With collaborative efforts and after extensive brain storming sessions in four identified EPC companies, 162 risks associated with engineering, procurement & contracts, finance and audit, quality health safety environment (QHSE) and human resource (HR) aspects of oil and gas EPC projects were identified with the following breakup as mentioned in Appendix 1 on respective serial numbers:

- i. Engineering (Risk No. 1 to 18), 18 risks
- ii. Proposal (Risk No. 18 to 35), 17 risks

- iii. Project Management (Risk No. 36 to 70), 34 risks
- iv. Procurement and Contractual (Risk No. 71 to 110), 39 risks
- v. Quality, Health & Safety (QH&S) (Risk No. 111 to 124), 13 risks
- vi. Human Recourse (HR) (Risk No. 125 to 140), 15 risks
- vii. Finance and Audit (Risk No. 141 to 162), 21 risks

3.4 Risk Frequency and Impact Factor

Project Management Institute has given an ambiguous criterion to select probability and impact of identified risks as shown in the Table 1 below. However, it has been observed that one standard criterion cannot be adopted to capture different aspects of a risk in a project by using the standard PMI approach. PMI approach also does not help to find a separate impact of a risk in terms of time, cost and quality rather it gives a common impact factor of each risk mentioned in Table 1. Similarly, it is very difficult to categorize the frequency in percentage terms of their frequency of occurrence. It shows that for those professionals involved in risk analysis and quantification, it is difficult to distinguish between “Very High Chance” and “High Chance”. PMI approach also gives a limited choice to select a probability (frequency) from the set criteria.

For this purpose, a mechanism has been developed in consultation with all process owners and stakeholders for selecting probability of each risk. Table 2 gives opportunity to the risk professional to select a frequency with a base frequency of 50 percent. Neutral position of a risk, according to this mechanism will be 50 percent frequency. If there is a positive possibility of occurrence of risks, frequency higher than 50 percent will be selected. More the chances of occurrence, higher will be the frequency or vice versa.

Similarly, the mechanism developed by the author, gives a risk professional the opportunity to assign separately the impact of risk in terms of time, cost or quality. Sometimes, it happens in an EPC project, where cost is not too much implicit, it reduces the impact factor negatively downwards, however, its other indirect impact on time or quality is significant, which is

ignored if we use the PMI approach. Impact of risks in three different aspects will also be judged through experience of process owners or departmental representative with thorough consultation, but the elements of bias, expertise and personal judgments will impact the process of risk analysis, which is one of the limitations of this research.

To avoid the subjectivity of PMI approach to identify, analyse and quantify risks, a quantitative approach has been used and mentioned in Table-4 and will be used for selecting an impact factor to a risk in a three dimensional context of time, cost and quality to have three risk numbers separately.

Table 3 shows the impact factor for risk quantification based on project cost, time and quality. The percentage deviation in cost, time and quality of an EPC project with respect to each impact factor shown in Table 3 was selected in consultation with four EPC companies. The table shows that highest impact factor of 0.9 is assigned when there is an increase of 10 percent of both cost and time with worst quality of work.

3.5 Risk Analysis and Quantification

There are several theories to quantify risks. Numerous different risk formulas exist, but perhaps the most widely accepted formula to analyze and quantify risk requires the following.

- i. The likelihood (frequency/probability) of occurrence of each consequence (risk)
- ii. The magnitude (impact) of the possible adverse consequences (risk).

For risk quantification, likelihood of risk calculated based on the frequency of risks is multiplied by the impact of event equal to the Risk Number, mathematically expressed in equation 1.

Risk Number (RN) = Likelihood of Risks (Frequency) x Impact (on time,

cost of quality) [1]

After identification and assessment of risk through the procedure discussed above, risks are analyzed and quantified for their overall impact on the organization/ project's time, cost and quality targets/ objectives. The following procedure is developed for risk analysis and quantification:

- i. Probabilities and impact shall be shifted from risk identification form to risk register at their respective position.
- ii. Frequency (chances of occurrence) of each risk will be multiplied with the impact on particular parameter i.e. time, cost or quality to get the respective RN for time, cost and quality. Different RNs will be used to filter different critical risks, impacting on particular parameter i.e. time, cost or quality. To find critical risks impacting quality one may have to find critical RN from quality RN column. Following formulae will be used to find RNs in three dimensions i.e. time, cost and quality. Average risk number and largest risk numbers may also be calculated as shown in equation 5 & 6 and graphically represented in figure 2.

$$\text{Risk Number (RN)}^{\text{Cost}} = \text{Probability of risk} \times \text{Impact on cost} \quad [2]$$

$$\text{Risk Number (RN)}^{\text{Time}} = \text{Probability of risk} \times \text{Impact on duration (schedule)} \quad [3]$$

$$\text{Risk Number (RN)}^{\text{Quality}} = \text{Probability of risk} \times \text{Impact on quality} \quad [4]$$

$$\text{Avg. Risk Number (RN)}^{\text{Avg.}} = (\text{RN}^{\text{Cost}} + \text{RN}^{\text{Time}} + \text{RN}^{\text{Quality}}) / 3 \quad [5]$$

$$\text{Risk Number (RN)}^{\text{C.T.Q}} = \text{Largest RN in Column V, VI, VII} \quad [6]$$

Limitations: For this research, $\text{RN}^{\text{Quality}}$ was not computed, due to operational complexities and assumed to be zero and taking average of RN^{Time} and RN^{Cost} .

3.6 Risk Register

All risks are recorded in the risk register. Certain new columns for RN have been added based on the intervention in the process as mentioned in figure 3;

Risk is ranked in the risk register on continual basis based on three dimensional risk numbers and not on the basis of PMI approach of risk analysis and management. Risks having maximum RN will be critical risks for each category i.e. time, cost or quality. Moreover, average Risk Numbers were also calculated and ranked which may be used when required for decision making as shown in figure 3 below.

Ranking of different risks is shown in figure 2 and 3 (RR). These figures show different risks when ranked at the criteria of “Cost” i.e. risks having largest RN^{Cost} shall be ranked as ‘1’ and will be the critical risk w.r.t. cost of the project. Similarly, all other risks will be ranked in order of severity of their impact on cost, considering RN^{Cost} , given in col-V in figure 2. If a project manager wants to see the critical risks in previous projects of Presson Descon International (Pvt) Limited (PDIL), having significant impact on cost, he will have to check col-X.

If the risks are to be ranked on the criteria of “Time” which means that risks having largest RN^{Time} shall be ranked as ‘1’ and will be designated the critical risk w.r.t. time (duration of the project). Similarly, all other risks will be ranked in order of severity of their impact on duration, by placing them in order according to their RN^{Time} , given in col-VI in figure 2. If a project manager wants to see the critical risks in previous projects of PDIL, which impacted on Duration, he will have to see col-XI.

If a mixed impact of risk is required to be checked, then column XIII will be considered as the criteria i.e. average Risk Number (RN) will be analysed for selection of critical risk in the project.

If the cost impact of any risk is considered to be equal to its time

(duration) impact on project, then column XIV will be considered as the criteria i.e. column XIV will be analysed for the selection of critical risk.

If the cost impact of any risk is considered to be equal to its time (duration) impact on project as well as quality, then column XV will be considered as the criteria i.e. column XIV will be analysed for the selection of critical risk as shown in figure 4.

3.7 Risk Mitigation

This process designates a strategy to mitigate/ manage a particular risk in the most appropriate, economical and safe manner. More emphasis and diligence must be given in selecting a strategy of critical risks. Different risk management strategies have been used conventionally to cater to critical, normal and non-critical risks. Strategy may also be set to a risk depending upon its nature. It may include risk avoidance, risk transfer, risk mitigation and risk retention (acceptance). The ultimate aim of setting any strategy for managing risk is to reduce or regulate the negative impact of risk to its minimum and at the most applicable/ efficient way i.e. minimum cost. It may include a strategy to accept some or all of the risks and their consequences at a certain cost i.e. by incorporating certain allowances for that risk in a proposal, bid or budget.

All the identified risks were analysed and mitigation measures were proposed in the risk register as shown in figure 6. Proper Clause of FIDIC terms and conditions for EPC projects was mentioned in front of each risk which is supposed to be transferred or mitigated the other way.

3.8 Risk Monitoring

Risk analysis and management is an ongoing process in projects. Risks are closed with appropriate mitigation whereas new risks are coming in the process, recorded in the risk register. Risk monitoring process has the potential of further improvement based on the lesson learned and continuous improvement approach.

4. Conclusion

Based on the analysis of risk given in Risk Register four critical risks for EPC Projects impacting cost and schedule are respectively as follows;

a) Cost

- i. Cost overrun due to change/ variation in quantity and price of goods and services.
- ii. Exchange rate of currency and currency fluctuation.
- iii. Error in estimation and omissions at proposal or execution stage.
- iv. Change in the laws of the country (taxes, interest rate, inflation etc).
- v. Problems in finding 100% technical compliance of Product/supplies.
- vi. Error in FEED, (not compatible to site conditions) and omissions resulting rework.
- vii. Increase in the rate of mark up on guarantees at various stages of the project execution.
- viii. Vendor Service Men (VSM) overstay.
- ix. Poor claim identification, preparation and follow-up.
- x. Incomplete data is provided by procurement at proposal stage.
- xi. Noncompliance of quality requirements from Sub-contractor.

b) Time (Duration)

- i. Error in estimation and omissions at proposal or execution stage.
- ii. Timely vendor information for detail designing.
- iii. Problems in finding 100 percent technical compliance of supplies and services.
- iv. Errors in FEED, resulting in rework.
- v. Increase in supply time requested by a vender.
- vi. Vendor's delay in delivery of goods and services.
- vii. Stoppage of work on site due to various reasons (Client, Sub-Contractors, Locals and Regulations).
- viii. Unavailability of complete data from engineering for preparation of

RFQ.

- ix. Inadequate project planning i.e. not well in time engineering workflow.
- x. (a) Change Order issued to supplier/manufacturer for change in specification by contractor.
(b) Dispute with the supplier/ vender for late supply and under performance.
(c) Delays on letter of credits (LCs) issuance

c) Average of Critical Time and Cost Risk Numbers

- i. Error in estimation and omissions at proposal or execution stage.
- ii. Problems in finding 100% technical compliance of the Product/ supplies.
- iii. Error in FEED, and omissions resulting in rework.
- iv. Impact of exchange rate fluctuation.
- v. Cost overrun due to change/ variation in quantity and price of goods and services.
- vi. Unavailability of complete data from engineering for preparation of RFQ.
- vii. Timely vendor information for detail designing is unavailable.
- viii. Arrangement of Advance Payment Guarantee & Performance Bond.
- ix. Increase in supply time requested by vender.
- x. Incomplete data is provided by procurement at proposal stage.

There are total 162 risks identified for oil and gas sector EPC projects executed in Pakistan from a contractor's perspective given in Appendix A. Maximum number of risks were identified in the procurement process followed by project management and finance & audit risk respectively. Three critical risks noted in each identified broad category are mentioned below;

a) Engineering (Risk No. 1 to 18), 18 risks

- i. Design and estimation error.

- ii. Delayed vendor information for detail designing is unavailable.
- iii. Incomplete data is provided by procurement department at proposal stage.

b) Proposal (Risk No. 19 to 35), 17 risks

- i. Price validation.
- ii. Currency fluctuation and change in exchange rate.
- iii. Change in policies and government taxes.

c) Project Management (Risk No. 36 to 70), 34 risks

- i. Planning and scheduling risks, unrealistic and over stressed schedule.
- ii. Poor claim identification, preparation and follow-up.
- iii. Disputation or litigation with the client or sub-contractor.

d) Procurement and Contractual (Risk No. 71 to 110), 39 risks

- i. Dispute with a supplier/ vender for late supply and under performance.
- ii. Delays by vendors.
- iii. Exchange rate and currency fluctuation.

e) Quality, Health & Safety (QH&S) (Risk No. 111 to 124), 13 risks

- i. Quality and quantity issue and change in specification by vendors.
- ii. Accident and third party damage on project site.
- iii. Non Compliance and poor enforcement of HSE requirements during construction by a contractor or sub- contractor.

f) Human Recourse (HR) (Risk No. 125 to 140), 15 risks

- i. Human error in designing, execution.
- ii. Fraudulence, leakage of information at proposal stage.
- iii. Over stress burden on employees.

g) Finance and Audit (Risk No. 141 to 162), 21 risks

- i. Timely arrangement of advance payment guarantee & performance Bond.
- ii. Increase in the rate of mark up on guarantees at various stages of the project execution.
- iii. Delayed payment by the client and cost overrun due to change/variation in quantity and price of goods and services.

5. Recommendations

Simulation and risk based planning, scheduling, estimating and controlling of EPC projects is recommended to have most probable duration and most probable cost of the project to avoid the unexpected delays and cost overrun in EPC Projects.

References

Cagno, E., Caron, F., and Mancini, M. (2007). A Multi-Dimensional Analysis of Major Risks in Complex Projects. *Risk Management*, 9, 1-18.

Damian M. (2011). EPC Contracts in Process Power Sector. Retrieved n.d. from <http://www.dlapiper.com/~media/Files/Insights/Publications/2012/03/EPC%20contracts%20in%20the%20process%20plant%20sector/Files/epc%20contractsprocessplantsector/FileAttachment/epccontractsprocessplantsector.pdf>

Henche N. (2001). *FIDIC Conditions of Contract for EPC Projects -The Silver Book, Problems in Store, ICLR*, 47-48. Geneva, Switzerland: World Trade Center II.

International Federation of Consulting Engineers (FIDIC). (1999). *Condition of Contract for EPC Turnkey Projects (Silver Book) (1st Ed.)*. Geneva,

Switzerland: World Trade Center II.

Jannadi, O.A., and Almishari, S. (2003). Risk Assessment in Construction, *Journal of Construction Engineering and Management*, 129(5), 492-500.

Mannad, A. (2009). *Risk Assessment and Management of EPC Projects in Pakistan* (M.Sc. thesis, University of Engineering and Technology, Lahore).

Mills, A. (2001). A Systematic Approach to Risk Management for Construction. *Journal of Structural Survey*, 19(5), 245-252.

Mubin, S., & Mubin, G. (2008), Risk Analysis for Construction and Operation of Gas Pipeline Projects in Pakistan. *Pakistan Journal of Engineering & Applied Sciences*, 2, 23-37.

Project Management Institute. (2007). *Construction Extension to the PMBOK® Guide* (3rd Ed.). Newtown Square, PA: Project Management Institute.

Appendix

Table 1
Standard Values of Frequency of Occurrence and Impact Factors

Frequency of Occurrence	Frequency (F)	Type and Level of Risk Impact	Impact Factor (I)
Very high chance	90 %	When maximum impact on scope, time and cost	0.9
High chance	75%	High impact on scope, medium impact on time and lesser impact on cost	0.6
Possible	45%	High impact on time, medium impact on scope and lesser impact on cost	0.3
Likely	30%	When high impact on cost of the project, medium impact on time and lesser impact on scope	0.1

Table 2
Frequency of Occurrence of Risks in EPC Projects

Sr. No	Chances of Occurrence	Frequency
1	Almost sure that risk will occur in next project	91% - 99%
2	Extremely high chances of occurrence	81% - 90%
3	High chances of risk occurrence	71% - 80%
4	Fair chances of risk occurrence	61% - 70%
5	May occur with some chances of occurrence	51%-60%
6	50 - 50 (May or may not occur)	50%
7	May not occur but some chances are still there	41%-49%
8	Poor chances of occurrence	31% - 40%
9	Extremely poor chances of occurrence	21% - 30%
10	No chances of occurrence but still it is a risk	11% - 20%
11	Almost sure that risk will not occur in the next	1% - 10%

Table 3
Impact Factor for Risk Quantification

Sr. No	Type and level of risk Impact	Impact Factor (I)
i.	Scope (maximum impact and major areas are affected)	0.9
ii.	Worst Impact on Cost (> 10% cost increase)	
iii.	Worst Impact on Time (> 10% time increase)	
iv.	Worst impact on Quality (unaccepted to the Client)	
i.	Scope (normal impact and some areas are affected)	0.6
ii.	High Impact on Cost (5-10 % cost increase)	
iii.	High impact on Time (5-10 % time increase)	
iv.	High impact on Quality (accepted by the Client with major changes)	
i.	Scope (minimum impact)	0.3
ii.	Medium impact on Cost (2-5 % cost increase)	
iii.	Medium impact on Time (2-5 % time increase)	
iv.	Medium impact on Quality (accepted by the Client with minimum changes)	
i.	Scope (insignificant impact)	0.1
ii.	Low impact on Cost (<2 % cost increase)	
iii.	Low impact on Time (<2 % time increase)	
iv.	Low impact on Quality (insignificant)	

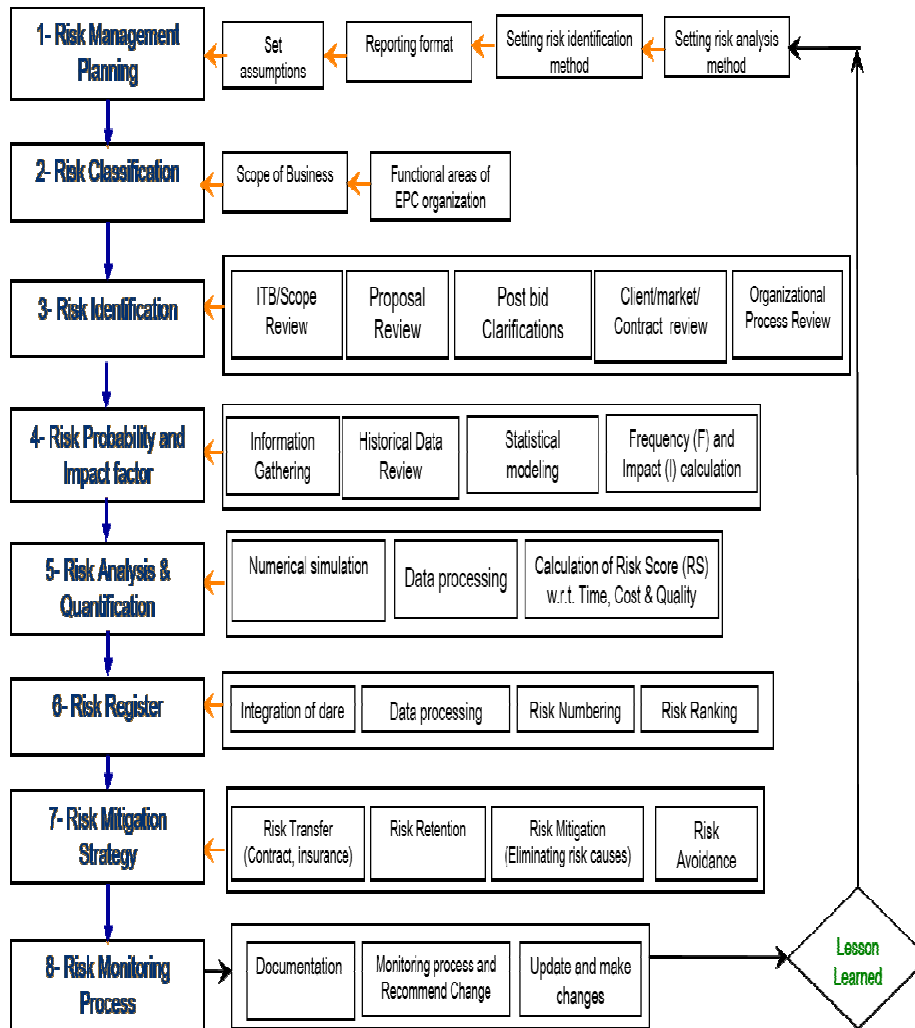


Fig. 1 Risk Analysis and Management Model for EPC Projects

Table 4
Risk Analysis and Quantification

Frequency (F)	Impact on Cost	Impact on Duration	Impact on Quality	Risk Number (RN) ^{Cost}	Risk Number (RN) ^{Time}	Risk Number (RN) ^{Quality}	Avg. Risk Number (RN) ^{Avg.}	Risk Number (RN) ^{C.T.Q}
Col-I	Col-II	Col-III	Col-IV	Col-V	Col-VI	Col-VII	Col-VIII	Col-IX

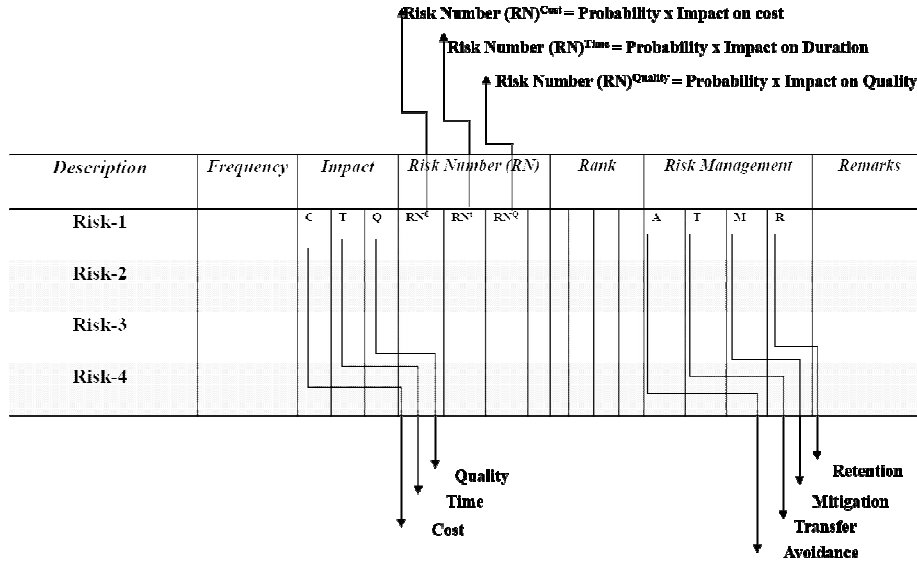


Fig. 2 Risk analysis for risks of EPC projects considering Time, Cost and Quality

Table 5
Mechanism for Risk Ranking Based on Risk Number Based on Time, Cost and Quality

RISK	RANK ^{Cost} Col-X	RANK ^{Time} Col-XI	RANK ^{Quality} Col-XII	RANK ^{Average} Col-XIII	RANK ^{Cost+Average} Col-XIV
RISK-1	14	5	1	6	8
RISK-2	162	153	95	167	169
RISK-3	5	152	15	19	6
RISK-4	1	6	4	1	2
RISK-5	1	1	91	4	1
RISK-6	141	162	41	160	156

Risk 5 is Critical Risk when Cost=Time
 Risk 4 is Critical Risk with respect to mixed (avg.) approach
 Risk 1 is Critical Risk with respect to Quality
 Risk 5 is critical risk with respect to Duration
 Risk 4 is Critical Risk with respect to cost

Table 6
Risk Ranking Based on Average RN

RISK	RANK ^{Cost}	RANK ^{Time}	RANK ^{Quality}	RANK ^{Avg.}	RANK ^{Cost+Time}
	Col-X	Col-XI	Col-XII	Col-XIII	Col-XIV
RISK-1	14	5	1	6	8
RISK-2	162	153	95	167	169
RISK-3	5	152	15	19	6
RISK-4	1	6	4	①	2
RISK-5	1	1	91	4	①
RISK-6	141	162	41	160	156

Risk-5 is Critical Risk when Cost =Time
Risk-4 is Critical Risk with mixed (avg.) approach

Table 6
Risk Mitigation through Transferring of Risk by Standard EPC FIDIC T&Cs

Risk Identification & Categorization		Risk Register	TOOL
		Remarks	
SR. No	Risk		Contractor's EPC T & Cs
Engineering			
1	Incomplete design information in ITB	Some margin in a proposal must be kept for incompleteness of design information. Risk may also be transferred to design Sub-Contractors by revision of sub-contractor T&Cs, provision and by deduction from performance guarantee to improve sub-contractor's performance. Engineering scope must be very much clear and finalize/frozen at the negotiation stage.	4.10
8	Inefficient time is allocated to engineering for making proposal	System improvement	Internal
9	Incomplete data is provided by procurement at proposal stage	Risk may be mitigated by system improvement and by developing closer relation with reliable vendors. Moreover, a contractor needs to improve the system such that more incentives are given to the vendors' to take part in	Internal

		providing bidding information at the proposal stage.	
10	Insufficient engineering resource is available	System improvement, more engineers can be hired. Efficiency of engineers may be enhanced by offering different motivation packages	Internal
11	Timely vendor information for detail designing is unavailable	Good vendor relationship and management is required to mitigate this risk. Incentives must be given to vendors for sending, picking and accurate information to be incorporated in a bid	P.O. Terms (Internal)
12	Inadequate project planning i.e. not well in time engineering work flow		Internal
13	Sub-contractors delay in providing timely information/design drafts to a contractor (PDIL)	Risk transferred to an engineering Sub-contractor through contracted T & Cs	T & C of Sub-contractor