Risk Analysis for Construction and Operation of Gas Pipeline Projects in Pakistan

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Abstract

In order to cater for its high energy demand, Pakistan is planning to import natural gas through pipelines from neighboring countries. For fully utilizing the imported gas, providing it to end customers, the infrastructure of gas pipeline needs to be developed. Therefore, huge investment has been done and proposed in this sector in coming future. Considering geological, topographical, geopolitical and climatic conditions of the country, there is added risk of earthquake, landslides and floods. Due to current geopolitical situation there is a persistent threat of unrest and terrorism in the country. Instable Government policies, high rate of inflation, rapid change in material prices are also important risk factors. All these factors make the situation very complex in quantifying the risk especially for a project in which the risk impact factor rises exponentially in case of risk occurrence. In this paper, most appropriate risk classification is made based on technological, organizational, political, natural climatic, security and environmental risk factors. Effort has been made to device a simpler risk management methodology to analyze and manage risks of gas pipeline project. In the proposed risk management model Monte Carlo simulation has been used to identify critical risks.

Keywords: Oil and Gas pipelines; Risk Analysis and Management; Monte Carlo simulation

1. Introduction

Oil and gas sector is considered as back bone of any country's economy. In Pakistan industrialization, agriculture, transportation and even domestic utilization of the energy depends on oil and gas sector. Almost 80 % of power generation is oil and gas based (50% gas and 30% oil) [1]. For efficient energy production there is a need of efficient transportation system (main and distribution network of pipeline) in the country, which is not sufficient to fulfill the country's requirement. As per World Bank Report only 21% of the total population of the country has access on natural gas. Due to the growing demands, pipeline network is expanding vigorously as during the last 10 years the network of main and distribution gas pipeline was expanded by 85% [2].

Currently Pakistan is meeting its gas demand by internal sources but by the year 2011 the difference between country's gas demand and supply will be 1.2 Bcfd which will rise to 3.1 Bcfd by the year 2015 and ultimately to 11.1 Bcfd by the year 2025 [3]. To fill the gap between demands and supply Pakistan is planning to import natural gas through pipeline from neighboring countries. Options of Turkmenistan, Iran and Qatar are available for gas import. Figure 1 shows that route of future cross country pipeline. In Pakistan, expected investment in pipeline construction is within range of 7 to10 billion dollars during the next 5-10 years [4].

Structure and characteristics of risk are different in different mega project such as Iran-Pakistan-India pipeline due to multi-party involvement from different geographic locations and regulatory structure [5]. These mega projects may be termed as international projects defined as those where the owner and/or contractor may be from a country different to that of where the project is situated typically involve a wider range of issues than domestic projects and in effect, moving outside of one's usual business jurisdiction interjects many unknowns. Factors impacting owner investment decisions with international capital facilities can be quite complex and may vary significantly from region to region and project to project [18].

Nature and impact of risk are different in different stages of project life cycle of pipeline projects. For most effective risk management it is recommended to plan, analyze and manage risk in all phases of project life cycle i.e. initializing, concept clearance and feasibility, design, construction and operation. Understanding the relationship between risk

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management and project phases for capital projects can be a difficult task. For instance, some risks are negligible in construction phase but are of vital importance in design phase such as earthquake. While dealing with risk management of international projects, which are often first or one-time efforts and project progress and phasing decisions can be isolated from risk management. For most international projects, different participants are responsible for control of the various phases of a project's life cycle. In many cases, the project owner is largely responsible for program analysis, a third-party is often hired to design (engineering), construct, manage and control to meet the initial constraints set by the owner [6]. Contractor is hired to construct the project, which turns the results over to the owner for operations or production. Structuring projects with distinct phases and responsibilities can increase risk by isolating the project participants in such a manner that minimal attention is given to overarching project concerns. Individual project participants become concerned with only their own project risks and either willingly or unwillingly try to transfer these risks to other project participants. To limit the scope of this paper the discussion is confined to the risks occurring during construction and operation phase.

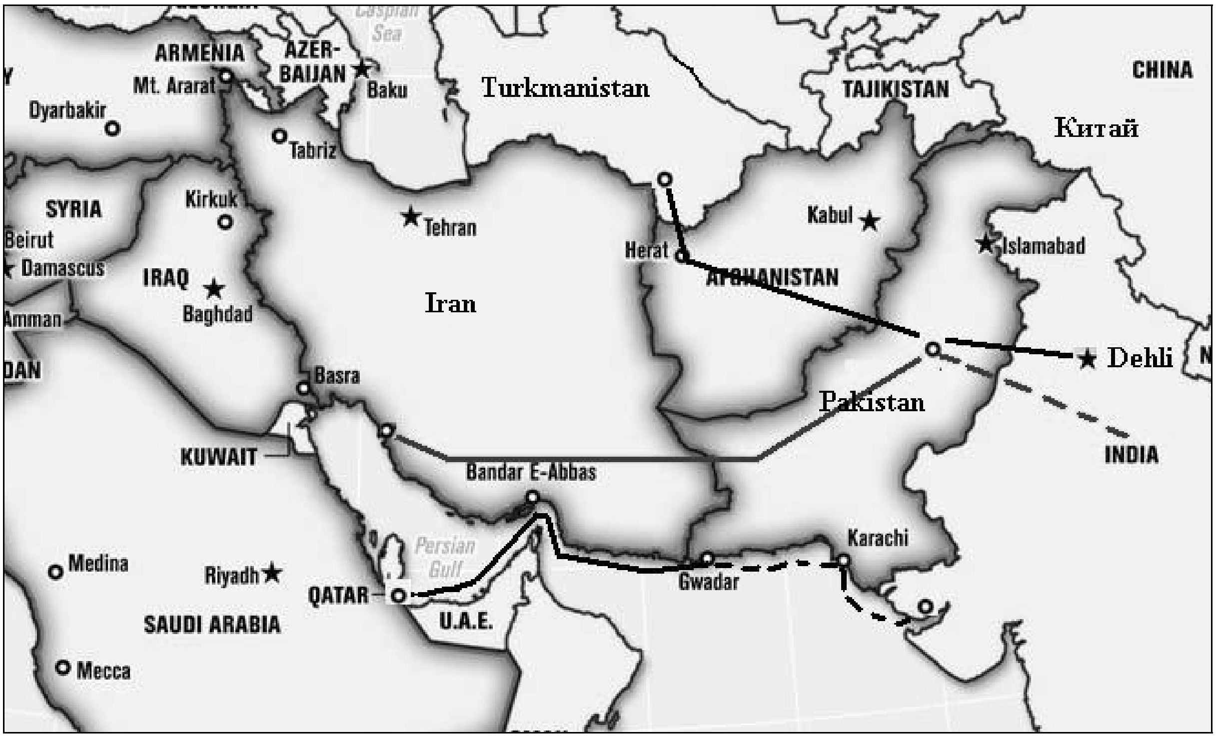

Figure 1: The routes of future gas pipeline project in the region.

The uncertainty in undertaking construction of a pipeline project comes from many sources and often involves many participants in the project. Since each participant tries to minimize its own risk, the conflicts among various participants can be detrimental to the project. Systematic risk management of project activities is not fully recognized as valuable by practitioners in the construction industry. No common view of risk exists since the owner, investor, designer, and constructor have differing project goals and objectives, and historically adverse relationships are common. In recent years, the concept of "risk sharing/risk assignment" contracts has gained acceptance in pipeline design and construction. The distribution of risk between the client and contractor tends to overshadow effective management strategies and investigations show that contactors and owners give minimal consideration to risks outside the realm of their own concerns. The Fédération Internationale des Ingénieurs Conseils (the International Federation of Consulting Engineers, FIDIC) and the International European Construction Federation (FIEC) publish two well-known and widely-accepted forms of conditions of contract for international construction projects (the Red and Yellow Books) that include provisions on the fair and equitable risk sharing between the owner and the contractor as well as risk responsibilities, liabilities, indemnity, and insurance [7]. Considering technological point of view geographical conditions of Pakistan are very complex for the construction of pipeline projects. Almost 50 % of the total area of Pakistan is mountainous or semi-mountainous and in rest of the area there is wide network of rivers and canals (Figure 2). Therefore, for linear structure like pipelines there are extensive crossings and sometimes extreme site conditions are met, where degree of risk is increased as compare to normal conditions of construction.

On the other hand, risks during operation of pipelines have different characteristics depending upon the strength and weakness of operating organization, topographical, geopolitical and climatic conditions of the country where project is executed. While dealing with natural risks, the geology and geographical characteristics of the regions must be thoroughly studied. For instance, the two continental plates i.e. Indian and Eurasian meet in Pakistan which highly impact on the geodynamics of the region which are the major source of earthquake [8]. In monsoon period there is high probability of floods. Typical topography, steep slopes, high rainfall in a specific period (June-August) and high temperature (melting glaciers) are the dominating factors for intensifying the frequency of floods in a particular year. Considering geopolitics of the regions there is a persistent threat of unrest and terrorism. The economic instability has added the problem due to that there is frequent change in economic parameters. All these are in fact the potential risks for any construction project especially oil and gas pipelines in which risk are multiplied many fold and there is exponential rise in damage in case of occurrence of one or more risks resulting huge human and environmental losses.

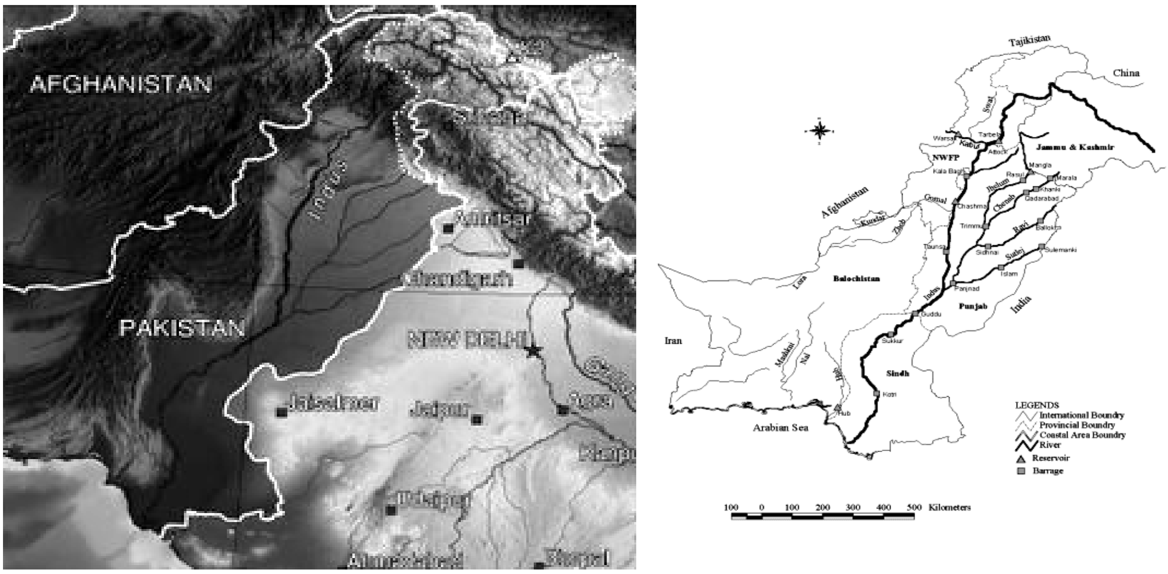

Figure 2: Map of Pakistan showing important geological and geographical features of the country

2. Classification of Risks

For effective Risk Management, risk classification is of prime importance. There are many kinds of classifications have been made so far [10]. In general, risks associated with pipeline projects may be classified as broadly:

- Risk during Construction
- Risk during Operation

The type and causes of risk in each class are different. Risks during construction are time susceptible and the probability of occurrence of different risk are time dependent, more is the duration of project higher are the probabilities. These are generally related to execution of work processes, material availability, manpower, finances (budget), time frame, accidental, legal and environmental. However, in operation, risk are slightly different, in which emphasis is given to avoid those factor with hurdle safe and smooth operation/functioning of pipeline. Usually, in mega projects such as cross country trunk pipelines investment risk are considered most import followed by the security risk. More precisely, risk during construction and operation of oil and gas pipelines can be divided into following categories (Table 1):

i. Political risk
ii. Socio-economical risk
iii. Technical risk
iv. Organizational risk
v. Natural catastrophic risk
vi. Financial risk (investment risk)
vii. Safety and security risk
viii. Environment risk

Table1: Risk Classifications

No	Category Risk	Risk Factors			
1.	Political risks	Unstable Govt. policies	Change in labour policy	Delay in approvals from regulatory bodies	Strikes, lockout, lawlessness
2.	Socio-economical risks	Change in economic parameters	Rise in inflation and material prices	Seasonal unavailability of labour	Change in economic policies and tax system
3.	Organizational risks	Breach in contractual relationship	Loss of venture or partnership	Unrealistic SWOT analysis	Fine or compensation
4.	Investment risk	Unrealistic cost baseline and financial delay	Exchange rate risk and rise in interest rate	Disinvestment from market	Strong credit policy
5.	Technological risk	Inefficient communication	Inefficient and conventional technologies	Insufficient resources and equipment	Quality risk and rework
6.	Security risk	Accident during construction or operation	Not use of HSE policies and standard	Terrorism or war	Human error (Damage or loss of machine or human resource)
7.	Natural and climatic risk	Earthquake	floods	Landslide, hurricanes	Weather conditions e.g. humidity, precipitation
8.	Environmental risk	Damage to natural resources	Damage to surrounding environment	Depletion of hydrocarbon resources	Damage to ecology and wildlife

2.1 Political Risk

The effect of country's policies on the project directly impact on project success or failure. During the policy making process, technical factors are usually ignored and policies may be set in a way that operation of a project may not be economical or trade offing. This factor is also important in unstable governments, where there is more risk of change of economic, petroleum or labor policies, which are directly related to the pipeline projects. Delays can occur due to laborious and detailed procedure for approval from public safety regulation department, environmental regulation agencies and oil and gas regulatory bodies. Public health, safety and environmental concern are more important in the western countries as compare to developing countries like Pakistan.

Policy and political risks are more concerned in international project risks, such as cross border pipeline projects. In international projects these risks are sometimes overlooked or assessed haphazardly. Such risks include war, civil war, terrorism, expropriation, inability to transfer currency across borders, and trade credit defaults by foreign or domestic customers [6]. Although risks such as civil unrest and economic stability are typically outside the scope, understanding and dealing with these risks are critical for companies working internationally. A 2001 study by AON Trade Credit discovered that, in the Fortune 1000, only about 26 percent of companies had in place systematic and consistent methodologies to assess political risks [6].

2.2 Socio-economical risk

Socio-economical conditions further reinforced the climate of uncertainty with high inflation and interest rates. The deregulation of financial institutions has also generated unanticipated problems related to the financing of construction. These risks can be forecasted and linked with the economic indicators of the country. For instance, In

Pakistan, the economic indicators are tending to grow regardless of the political instability in the country. The GDP of the country was 8.4% prior to 2005 earthquake, which declined down to GDP 5.6 or less currently. Earthquake and floods during the last two year costed government approximately $5.4 B and expected to spend more $3.6bn till 2010. Overall there is growth in the market and potential for foreign investment in construction sector [1].

2.3 Technical risk

The risks related to technological problems are familiar to the design/construct professions which have some degree of control over this category. However, because of rapid advances in new technologies which present new problems to designers and constructors, technological risk has become greater in many instances. Certain design assumptions which have served the professions well in the past may become obsolete in present time. Site conditions, particularly subsurface conditions which always present some degree of uncertainty, can create an even greater degree of uncertainty during construction. Because construction procedures may not have been fully anticipated, the design may have to be modified after construction has begun. An example of facilities which have encountered such uncertainty is the nuclear power plant, and many owners, designers and contractors have suffered for undertaking such projects. There is a need of technological advancement to overcome this risk.

2.4 Organizational risk

The risks related to organization and organizational relationships may appear to be unnecessary but are quite real. Strained relationships may develop between various organizations involved in the design/construct process. When problems occur, discussions often center on responsibilities rather than project needs at a time when the focus should be on solving the problems. Cooperation and communication between the parties are discouraged for fear of the effects of impending litigation. This barrier to communication results from the ill-conceived notion that uncertainties resulting from technological problems can be eliminated by appropriate contract terms. The net result has been an increase in the costs of constructed facilities.

2.5 Natural catastrophic risk

Natural catastrophic risks are those on which there is no control. They are usually the ‘act of God’ and can occur at anytime and anywhere. Earthquake, floods, hurricanes are the common examples of these risks. However, due to the development of the science and technology in the field of simulation and modeling, statistics, geological surveys, sub surface investigation through various method has given rise to the development of such techniques which can not only quantify frequency of occurring of such phenomenon in a particular region but also their impact and destruction. Northern areas of Pakistan are considered in high seismic zone [8] particularly after incidence of 8th Oct. 2005 earthquake, in which more than 86000 people died and one million got injured and 3 million became homeless, this factor is highly considered in planning, feasibility, design and construction of the any construction project in the region [9]. The major reason is the plate tectonic motion in Himalaya, northern part of Pakistan. This plate tectonic motion is due to the uplift of Euro Asian plate by Indian plate (two plates are meeting in Pakistan)

2.6 Investment risk

Pipelines are mega project. A lot of funding is required for the completion and safe operation of pipelines. Investment has been always a prime risk in construction project due to multi party involvement. But especially for the international pipeline project, this is always risk of payback and trade offing, because of the bilateral and diplomatic relationships.

2.7 Safety and security risk

In a broader sense, safety and security risks include factors due to that loss or damage of resources (manpower, machinery and financial resources) or facilities (pipeline, pipeline crossing, gas compressor station) can occur during construction or operation phase of a pipeline. It is very often that loss of work time, machinery and manpower occur due to accident on side because of the negligence of some worker. These risks involve all actions (accident, malfunctioning, terrorism, war etc) due to that loss of resources and production of pipeline can occur. These risks are more likely to occur during operation phase however, these can be occurring in construction stage as well. To cater these risk to occur Health safety policy is strengthen so that to minimize on-site and offsite accidents during construction. It is generally accepted that the pipeline are the target in terrorists’ attacks and wars. For, instance, history prevails that in last five years the total terrorist attacks made on the pipelines in Pakistan were 103. It may be the result of internal political situation of the country but anywhere in the world this factor of risk is considered to be very important. For safe operations, state of the art methodology and technology has been developed which ensure safe exploitation of pipeline, which include remote sensing, Geographical Information System (GIS) and mapping techniques, Light detection and ranging (LIDAR), Global positioning system (GPS), data acquisition (SCADA) and In-line inspection (ILI) etc.

2.8 Environmental risk

Environmental concerns and awareness is increasing everywhere. The worldwide environmental protection movement has contributed to the uncertainty for construction because of the inability to know what will be required and how long it will take to obtain approval from the regulatory agencies. This delay in approval practically influence on total costs of the project. Public safety regulations have similar effects. The situation constantly change guidelines for engineers, constructors and owners, as projects move through the stages of planning to construction due to the change in govt. policies. These moving targets add a significant new dimension of uncertainty which can make it virtually impossible to schedule and complete work at budgeted cost

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3. Risk Management Process

Generally risk analysis and management had not been applied in construction industry and especially in pipeline projects. It is comparatively new area for pipeline projects, which is rapidly advancing due to the involvement of non native client or contractor. However, the concept of risk analysis and management is getting fame in pipeline project due to involvement of multinational contractor/organizations. Basically risk management deals with management of positive and negative events which occurs during realization of projects. Risk management reduces the impact of negative risks and enhances positive risk to make opportunities. However, limiting our scope in this section to negative risks, risk management may be defined as a method to reduce the consequences of negative events (risk) tend to occur during construction and operation of pipeline by developing mechanisms and strategies (risk transfer, risk reduction, risk distribution, avoidance, risk enhancement) compatible to the system environment in which project is executed.

The strategy of risk management is based on risk analysis results for a particular project. According to Project Management Institute (PMI) approach of risk management [11] the process includes:

1. Risk management planning
2. Risk identification
3. Qualitative risk analysis
4. Quantitative risk analysis
5. Risk reduction strategies

3.1 Risk management planning

Risk management process (PMI approach) 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 input, output and process are shown in the table 2.

Table 2: Process showing Risk Management Planning [19]

Input	Process	Out put
Organizational environmental factor Organizational process of assets Project scope management Project management plan	Planning meeting and analysis Planning course of action	Risk Management Plan

3.2 Risk Identification process

For effective risk analysis and management the identification of risk is very important carefully such that no important factor is left which can negatively impact on the project. The risk indemnification process input and output are shown in table 3, which include the following:

Information Gathering Techniques: Examples of information gathering techniques used in identifying risk can include brainstorming, Delphi techniques, interviewing, root cause identification and SWOT (Strengths, weaknesses, opportunities, and threats) analysis. Brainstorming is important data gathering technique for risk identification in which a group of team members or subject-matter experts (design, construction, purchase, finance etc) together identify expected risks. Delphi is another technique of information gathering used as a way to reach a consensus of experts on a subject. Experts on the subject participate in this technique anonymously. A facilitator uses a questionnaire to solicit ideas

Project Documentation Reviews: For risk identification project documentation are reviewed, including plans, assumptions, prior project files, and other information. The quality of the plans, as well as consistency between those plans and with the project requirements and assumptions, can be indicators of risk in the project.

Assumptions Analysis: Every pipeline project is conceived and developed based on a set of hypotheses, scenarios, or assumptions. Assumptions analysis is a tool that explores the validity of assumptions as they apply to the project. It identifies risks to the project from inaccuracy, inconsistency, or incompleteness of assumptions.

Checklist Analysis: Risk identification checklists can be developed based on historical information and knowledge that has been accumulated from previous similar projects and from other sources of information. The lowest level of the RBS can also be used as a risk checklist.

Diagramming techniques: Some Risk diagramming techniques may also be used for risk identification which includes cause-and-effect diagrams, system or process flow charts and influence diagrams.

Table 3: Process of Risk Identification

Input	Process	Out put
Organizational environmental factor	Information collection	
Organizational process of assets	Documentation review	
Project scope management	Assumption analysis	Risk Register
Project management plan	Checklist analysis	
Risk Management plan	Diagramming techniques	

3.3 Qualitative risk analysis

There are several theories to quantify risks [12, 17]. Numerous different risk formulae exist, but perhaps the most widely accepted formula for risk quantification is: Rate of Occurrence i.e., probability multiplied by the Impact of event equal to Risk Number, mathematically expressed in equation 7. The inputs and output of qualitative risk analysis process is shown in table-4.

PMI defined values of probability and impact factor can be used in risk analysis given in Table 5. However, the selection of one of the value of P for a particle risk from table 5, is based on expert judgment which may produce controversial results.

The objective is to prioritize risk based on their probability and impact assessment. Probability and Impact matrix is used to visualize the impact of risk from least to maximum possibility. Another method called *Risk Data Quality Assessment* is used which requires accurate and unbiased data Analysis of the quality of risk data is a technique to evaluate the degree to which the data about risks is useful for risk management. It involves examining the degree to which the risk is understood.

Risks to the project can be categorized by sources of risk (e.g., using the RBS), the area of the project affected (e.g., using the Work Breakdown Structure), or other useful category (e.g., project phase) to determine areas of the project most exposed to the effects of uncertainty.

Table - 4 Process showing Qualitative risk analysis [19]

Input	Process	Out put
Organizational process of assets	Risk probability and impact assessment	
Project scope management	Probability and Impact matrix	
Project management plan	Risk data quality assessment	Risk Register (updates)
Risk Management plan	Risk categorization	
Risk Register		

Table 5: Standard values of frequency of occurrence and Impact factors [11]

Possibility of occurrence	Probability (P)	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
Greater chance	60%		
Possible	45%	High impact on time, medium impact on scope and lesser impact on cost	0.3
Likely	30%		
Unlikely	15%	When high impact on cost of the project, medium impact on time and lesser impact on scope	0.1

3.4 Quantitative risk analysis

For quantitative risk analysis any of the following method may be used as illustrated in Table 6.

Sensitivity analysis: Sensitivity analysis helps to determine which risks have the most potential impact on the project. It examines the extent to which the uncertainty of each project element affects the objective being examined when all other uncertain elements are held at their baseline value. One typical display of sensitivity analysis is tornado diagram, which is useful for comparing relative importance of variables that have a high degree of uncertainty to those that are more stable.

Expected Monetary Value (EMV) Analysis: It is a statistical technique that calculates the expected outcome of future scenarios in monetary form that may or may not happen.

Decision Tree: The decision tree is a diagram that describes a decision under consideration and the implications of choosing one or another of the available alternatives. It is used when some future scenarios or outcomes of actions are uncertain. It incorporates probabilities and the costs or rewards of each logical path of events and future decisions, and uses expected monetary value analysis to help the organization identify the relative values of alternate actions. See also expected monetary value analysis.

Modeling and simulation: Modeling and simulation is recommended for cost and schedule risk analysis because it is more powerful and less subject to misapplication than expected monetary value analysis. Simulation uses a model that translates the uncertainties specified at a detailed level of the project into their potential impact on project objectives.

3.5 Risk reduction strategies

Risk register may be obtained from risk management procedure defined by Project Management Institute (PMI) [11], which is a document containing the results of the qualitative risk analysis and quantitative risk analysis. On the basis of risk analysis risk reducing strategy is set which is also given in risk register. The risk register in that way, presents all related information of identified risks including description, category, cause, probability of occurring, impact(s), risk number and the possible strategy set for each risk.

Table 6: Process showing Quantitative risk analysis [19]

Input	Process	Out put
Organizational process of assets	Quantitative risk analysis	
Project scope management	(Sensitivity analysis,	Risk Register
Project management plan	Decision Tree, Modeling and	
Risk Management plan	Simulation, Expected	(updates)
Risk Register	Monetary Value, EMV)	

The common course of action of the any organization or participant (consultant, contractor, client or owner) participating in the construction process of oil and gas pipeline can adopt one or combination of course of action given below, depending upon the type of project, location and circumstances. Distribution of risk between participants of the project can be made by:

1. Risk Transfer (insurance, contracts)
2. Contingency Budget
3. Risk mitigation (problem solving and root cause analysis)
4. Risk avoidance

4. Development of Risk Management Model for Pipeline Construction Projects

Project Management Institute (PMI) approach of risk analysis and management may be complicated and laborious for construction project like pipeline. Therefore a model of risk analysis and management is developed which simplifies the process and produce more probable results with the implementation of Monte Carlo simulation (Figure 3).

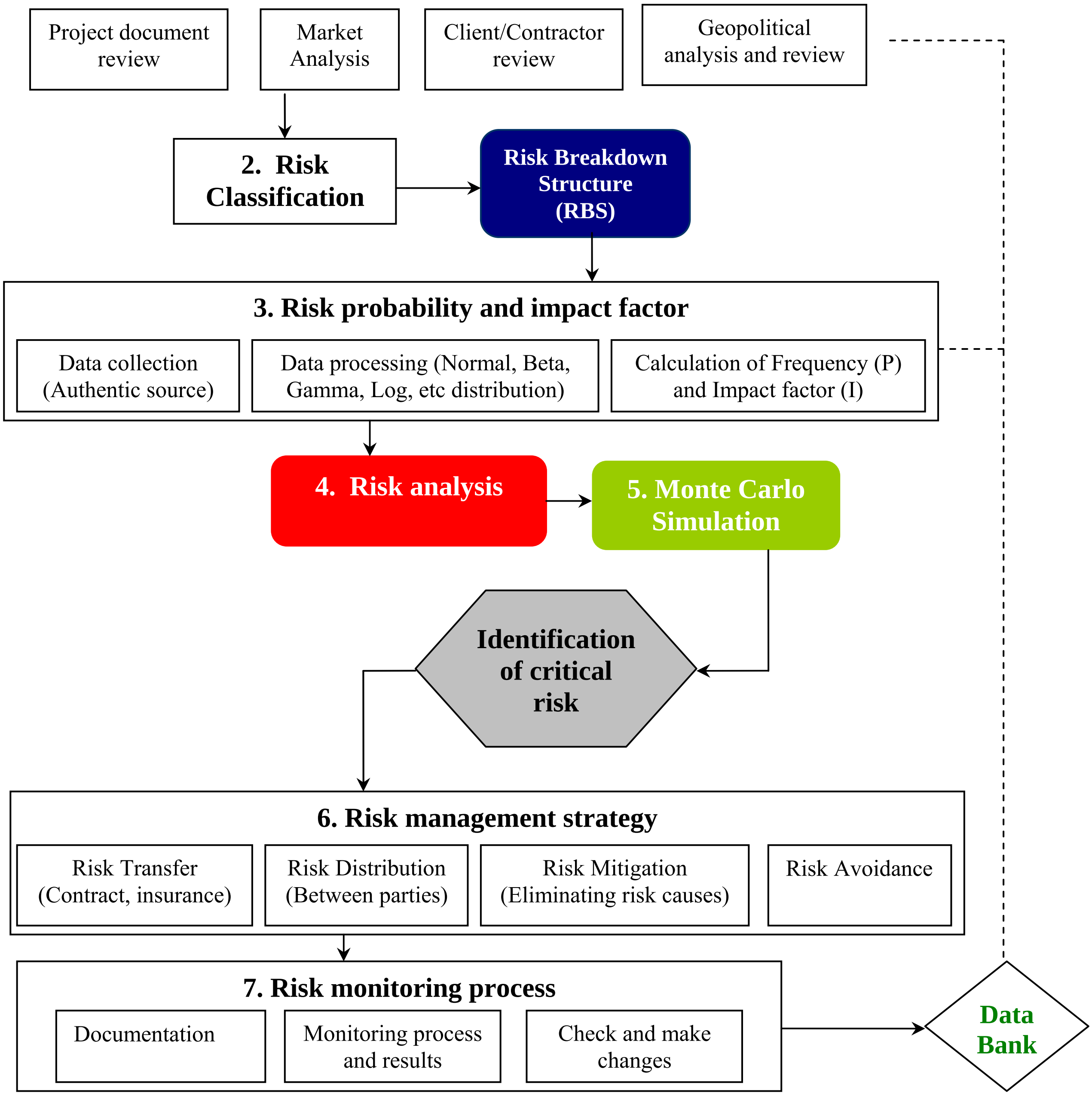


Figure3: Risk Management Model for pipelines construction project.

STEP-1: Model starts with identification and classification of risks considering the type of construction project. Degree and frequency of risk varies from trunk pipeline to distribution line. Similarly it gives suitable approach for both the major parties i.e. Owner (client) and the Contractor. Before identifying the risk the market review, client/contractor capability and geopolitical conditions of the region are analyzed where project is expected to be executed. The types of risk are also depending upon the type of contractual relationship between the owner and constructing firm. In different types of contract (Build-Operate and Transfer, Engineering-Purchase and Construction, Figure, Turnkey contracts, Labour contract, etc) between the owner and constructing body the level and intensity of risk differs [13].

STEP-2: On the basis of risk identification risk are categorized and Risk Breakdown Structure (RBS) is made as shown in Figure 4. Risk identification is the most important thing followed by the probability and impact calculations in whole risk analysis process.

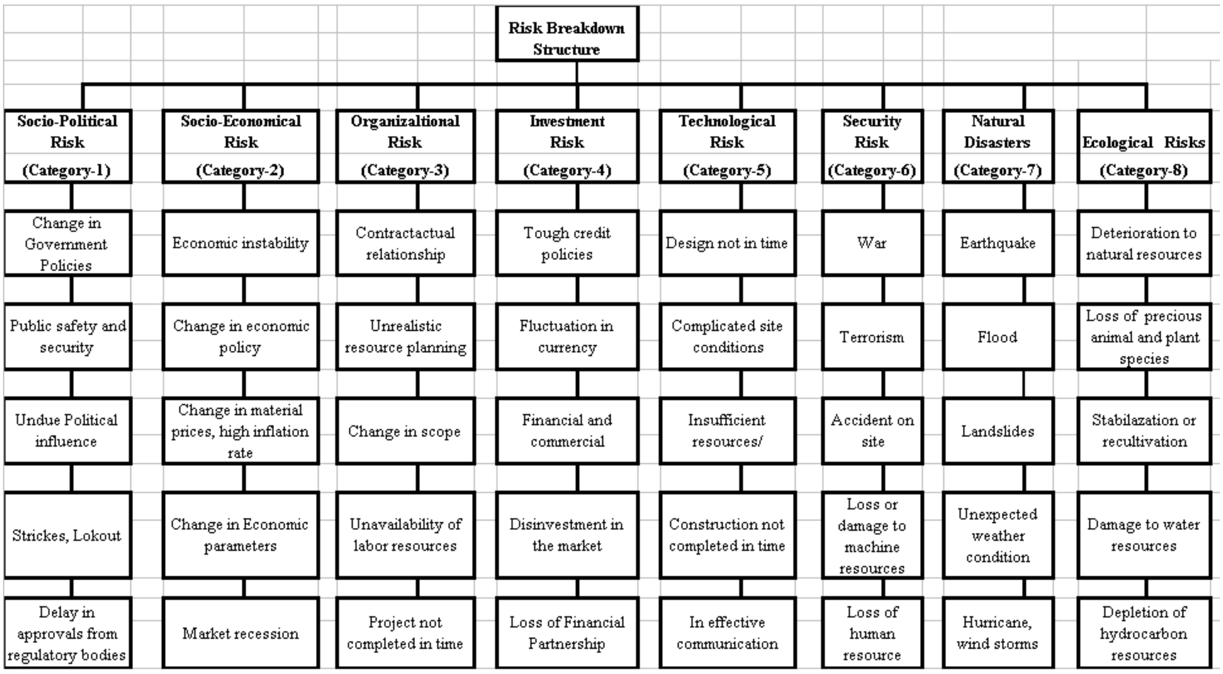


Figure 4: Risk Breakdown Structure of gas pipeline project

STEP-3: Risk probability assessment investigates the likelihood that each specific risk will occur. Risk impact assessment investigates the potential effect on a project objective such as time, cost, scope, or quality. The selection of PMI defined the values of probability and impact factor given in Table 5 is based on expert judgment which may produce controversial results. For instance, it may be difficult some time to distinguish the possibility from “Higher Chance” to “Greater Chance” for that an expert can use 60% probability value however, another use 45%. In that way some negligible risk may be superseded to other important risk. Risk impact factor defined by Project Management Institute (PMI) are used in this study which range from 0,1 to 0.9 depending upon the type and impact of event to the project. For risk Monte Carlo Simulation the precise value of probabilities are required. Therefore, probability and impact of each risk may be calculated based on historic data. In this case we the values of probability of different risks are calculated by using different probability distribution curves, however, when the historical data is not available, the probability is judged by experts opinion (from SNGPL) or the direct value of probability for that particular risk published by the related government agency. It is very important to define the probability distribution of a risk on the basis of that the frequency of occurrence is calculated. It is observed that the probability distribution of different risk appearing in different stages of project life cycle is different. Therefore, during calculation of probability of each risk the characteristic of risk must be considered to find the appropriate distribution to get the more precise results. For example, figure 5 shows the 10 year data of flood [21] depicts that the a normal curve is best suited to find the probability of a given volume/time called as the flood flow may be calculated using Equation 1,2 and 3 [14].

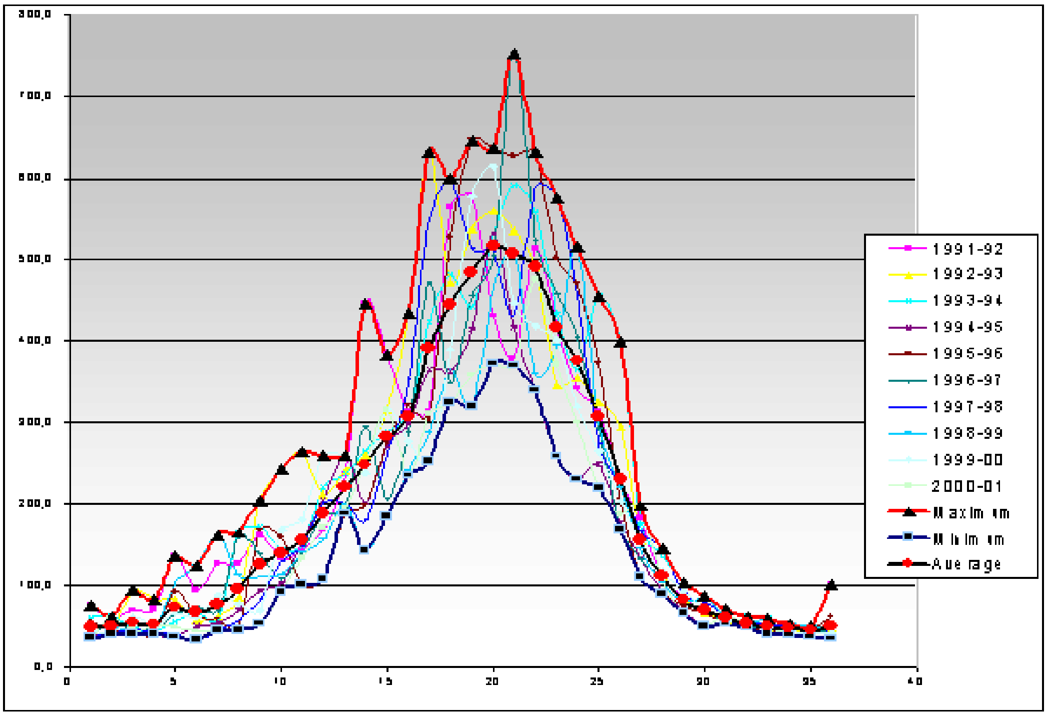


Figure 5: Graphical representation of flood data 1990-2001

$$P(x;\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \quad (1)$$

$$\varphi(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2} \quad (2)$$

$$Z = \frac{X-\mu}{\sigma} \quad (3)$$

where

P – probability of occurrence
Z – area under normal curves for a given value X (the probability of that area can be found out from charts)
μ – mean value of the 10 year data of river flows.
σ – standard deviation of the mean data.

On the basis of historical data, obtained from IRSA, the probability of river flow more than 400 (MAF) (which is termed as flood flow) through river system of Pakistan (sum of river flow at a time on Mangla and Terbela) is calculated by using measured.

Similarly other risks are also quantified based on the characteristic of data distribution curve. For instance, for earthquakes we are interested to find the probability of occurrence earthquake more than 5.5 Richer Scale. According to construction codes, the earthquake between 3.5-5.4 Richer Scale is often felt, but rarely causes damage. A value of 5.5 Richer Scale is selected to calculate probability of occurrence under assumption that almost slight damage to well designed buildings can caused major damage to poorly constructed buildings over small regions. Pipelines can go under slight damage of residual. For a random variable X (x > 0 and elsewhere i.e. x < 0 the value of probability is zero) have an exponential distribution with parameter λ then probability distribution is defined as in equation (4), (5) and (6) [14]. Therefore either exponential or gamma distribution (with m =1) may be used for probability calculation of earthquake at a given value (in Richer Scale) using the historical data [9], as shown in the Figure 6.

$$P(x;\lambda) = \begin{cases} \lambda e^{-\lambda x} & , \; x \geq 0, \\ 0 & , \; x < 0. \end{cases} \quad (4)$$

$$\sigma[X] = \frac{1}{\lambda} \quad (5)$$

$$\mathrm{Var}[X] = \frac{1}{\lambda^2} \quad (6)$$

where

P – probability of occurrence
λ – mean value of historic data
σ – standard deviation of the historic data
e – 2.718282

VAR is the variance at any value X. For 5.5 Richer Scale earthquake λ = 1

$$P(X > 5.5) = \int_{5.5}^{\infty} 1.\, e^{-1*5.5} = 0.000408$$

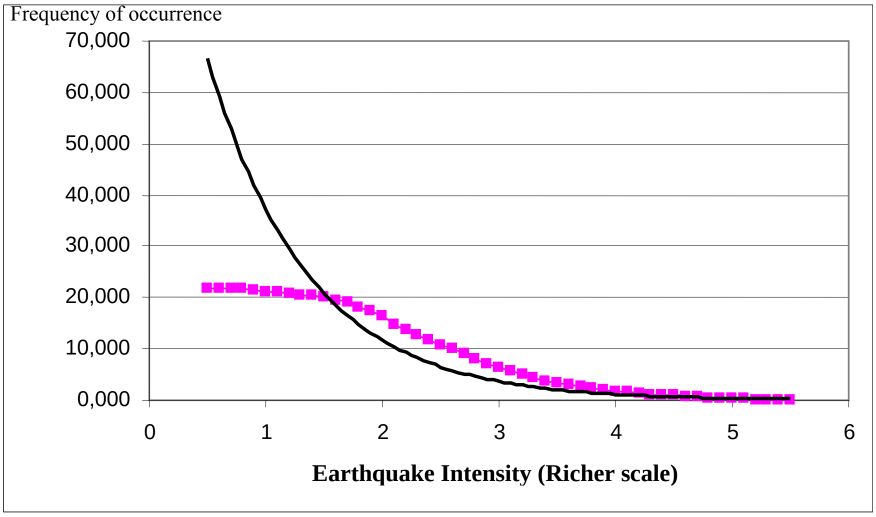


Figure 6: Graphical representation 45 year earthquake data

STEP-4: On the basis of probability values for each risk a risk register (table 7) may be made which presents quantitative risk analysis for each risk. PMI defined impact factor can be used which clear cut defines the type and condition of risk impact. On the basis of this formula below qualitative risk analysis is made. The following relationship is used for risk analysis [11]:

$$RN = P \times I \quad (7)$$

RN – Risk Number
P – Probability of occurrence
I – Impact factor of risk

For parameters the data is not available expert judgment can be used for probability assessment. Risk Number (RN) can be found for all risk identified in Risk Breakdown Structure (RBS). Manually it can be identified critical risk having larger risk number, RN based on the one point calculation. However, the more authentic way to identify the critical risks associated to pipeline project is Monte Carlo Simulation approach which is discussed in next step.

STEP 5: Monte Carlo simulation is a widely used computational method for generating probability distributions of variables that depend on other variables or parameters represented as probability distributions. Although Monte Carlo simulation has been used since the 1940s, development of computer technology has made it accessible and attractive for many new applications [15]. That availability has coincided with increasing dissatisfaction with the deterministic or point estimate calculations typically used in quantitative risk assessment; as a result, Monte Carlo simulation is rapidly gaining popularity.

Monte Carlo simulation, which is a mathematical method used in risk analysis to approximate the distribution of potential results based on probabilistic inputs would involve many calculations of the intake rate rather than a single calculation; for each calculation, the computation would use a value for each input parameter randomly selected from the probability density function for that variable [16]. Each simulation is generated by randomly pulling a sample value for each input variable from its defined probability distribution, e.g. uniform, normal, lognormal, triangular, beta, etc. These input sample values are then used to calculate the results, i.e. total project duration, total project cost, project finish time. The inputs can be task duration, cost, start and finish time, etc. This procedure is then repeated until the probability distributions are sufficiently well represented to achieve the desired level of accuracy. They are used to calculate the critical path, slack values, etc. Monte Carlo simulations have been proven an effective methodology for the analysis of project schedule with uncertainties. In Monte Carlo simulation any desired level of mathematical accuracy can be achieved by increasing the number of iterations. Risks are probable entities, it is possible that all the risk accrued at the same time during project execution and may be no identified risk appears. Therefore, it is desired to use Monte Carlo simulation technique to find the most critical and probable risk which can appear in the pipeline project. Risk analysis has been made by using program Riskyproject 1.3.3 [20] which is an advanced project management software with integrated risk analysis. RiskyProject is used for planning, scheduling, quantitative risk analysis, and performance measurement of projects with multiple risks and uncertainties. RiskyProject determines which parameters will have the most effect on the project: duration, cost, and finish time with and without risks, crucial tasks, critical risks, and success rate. RiskyProject helps to optimize the course of the project: track project performance and risk together and analyze the affect of mitigation efforts [22]. On the basis of Monte Carlo simulation critical risks are

Table 7: Risk input in risk register and their quantitative analysis for pre-defined risks

Risk Identification and Categorization		Risk Register							
		Risk Analysis				Risk reducing Strategy			Remarks
Cat. Risk	Risk	Freq. (P)	Impact (I)	Risk Number	Ranking	Risk Avoidance	Risk Transfer	Risk Mitigation	
1	Delay in approvals from regulatory bodies	5,15%	0,3[2]	1,55%	27				EO[5]
1	Unstable Government policies	8%	0,6[3]	4,80%	3				EO
1	Change in regulations	2,10%	0,9[4]	1,89%	23				EO
1	Change in labor policy	2,90%	0,6	1,74%	25				GO[6]
1	Change in petroleum policy	5%	0,6	3,00%	8				EO
1	Political instability	4%	0,6	2,40%	14				EO
1	Lawlessness, strikes, lockouts	4,50%	0,3	1,35%	29				EO
2	Change in economic parameters	8,10%	0,9	7,29%	1				GO, EO
2	Hike in material prices	8,03%	0,3	2,41%	12				SA[7]
2	Unavailability of skilled laborers	6,80%	0,3	2,04%	21				GO
3	Change in project scope	3,9 %	0,6	2,34%	16				EO
3	Insufficient technology	10%	0,3	3,00%	8				EO
3	Completion of construction not on time	9,50%	0,3	2,88%	9				EO
3	Not realistic planning of resources and volume of work	8,10%	0,3	2,43%	12				EO
3	Request for increase in project budget	13,13 %	0,3	3,94%	4				SA
3	In sufficient specialist and engineers	6,50%	0,6	3,90%	5				GO
3	Strains in contractual relationships	5,30%	0,9	4,77%	3				SA
4	Financial delays	6.1 %	0,9	5,49%	2				EO
4	Disinvestment from the market	4,40%	0,1[1]	0,44%	24				EO
4	Loss of Partnership	3,01%	0,6	1,81%	18				SA
4	Change in credit policy (increase interest rate)	5,10%	0,3	1,53%	19				EO
5	Design not completed in time	7,80%	0,3	2,34%	11				SA
5	Unexpected obstacle on site (dewatering, rock excavation)	7,80%	0,3	2,34%	10				EO
5	Slow communication between team members	5,90%	0,6	3,54%	5				EO
6	War	0,10%	0,9	0,09%	20				EO
6	Terrorism	2,20%	0,9	1,98%	11				SA
6	Accident on site during construction	2%	0,9	1,80%	12				SA
6	Loss of human life	3,90%	0,6	2,34%	5				SA
7	Earthquake	0,04%	0,9	0,12%	15				SA
7	Flood	3,07%	0,9	2,76%	3				SA
7	Landslides	2,1 %	0,3	0,63%	12				SA
7	Unexpended weather condition, precipitation wind storms	4,72%	0,6	2,82%	2				SA
8	Damage to environment	3,75%	0,6	2,25%	6				GO
8	Degradation of natural resources	1,10%	0,6	0,66%	8				GO

1. 0.1- When high impact on cost of the project, medium impact on time and lesser impact on scope.
2. 0.3- High impact on time, medium impact on scope and lesser impact on cost.
3. 0.6- High impact on scope, medium impact on time and lesser impact on cost.
4. 0.9- When maximum impact on scope, time and cost.
5. EO- Frequency of risk is based on expert's opinion.
6. GO- Frequency of risk is based on statistic available by relevant Government organization.
7. SA- Frequency of risk is based on statistical analysis.

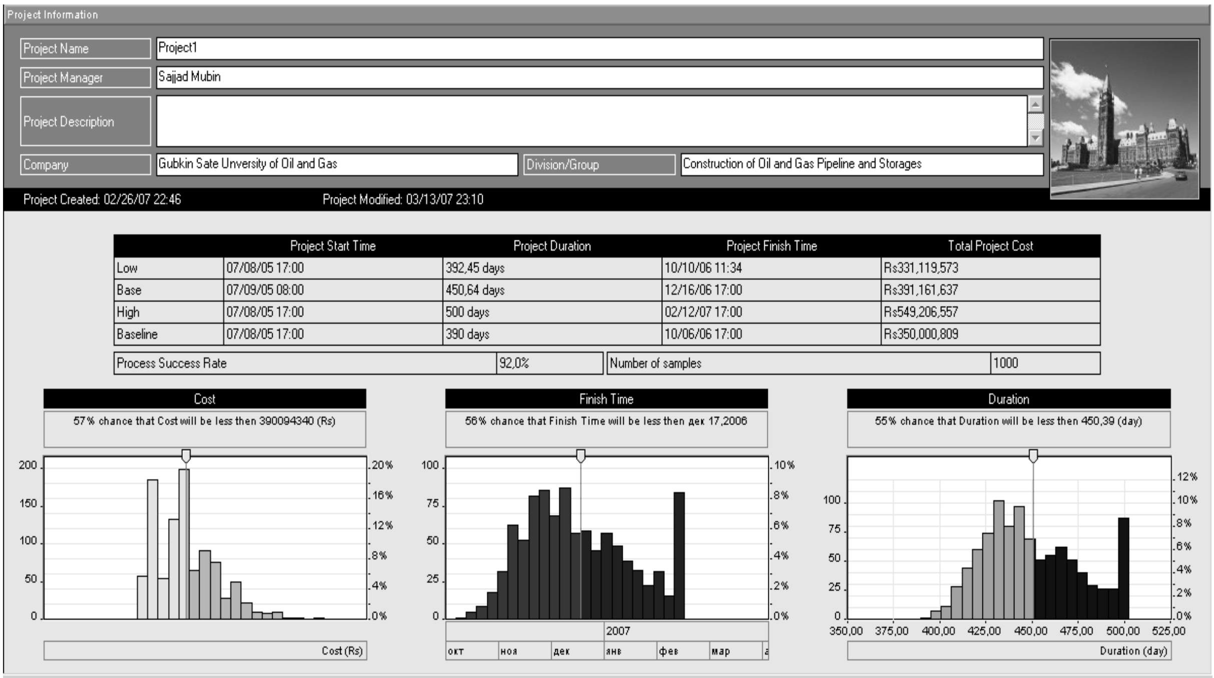
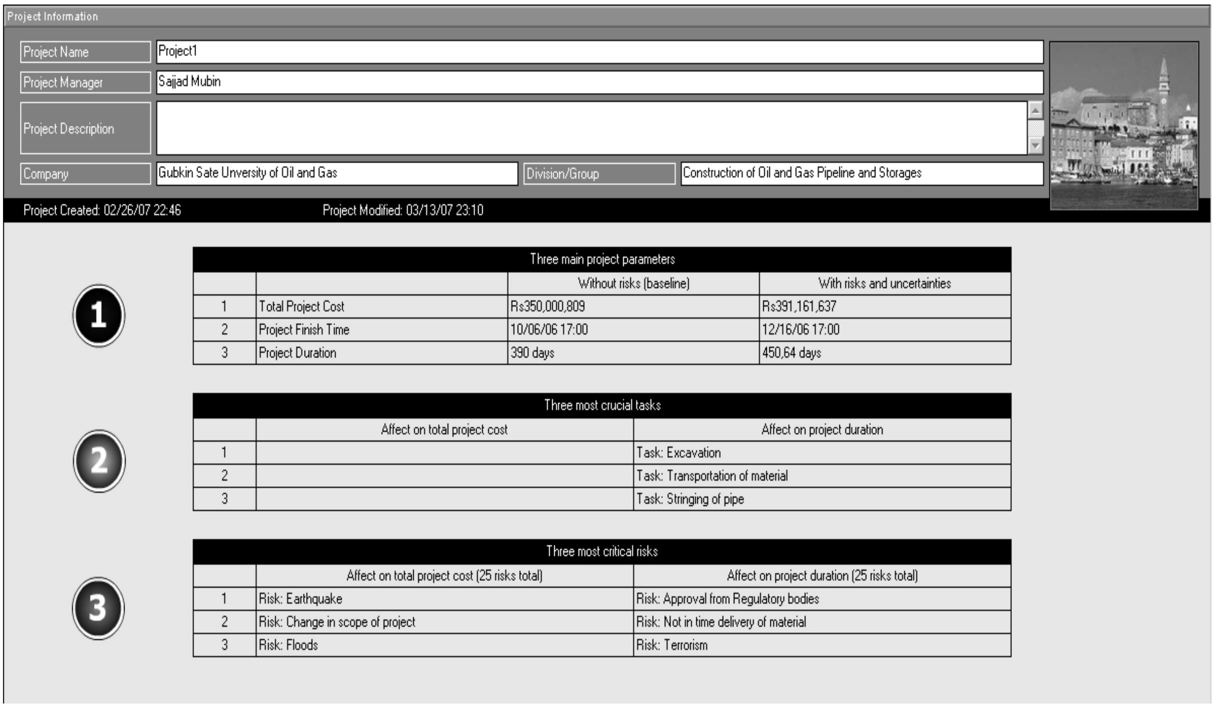


Figure-7(a): Monte Carlo Simulation conducted for risk analysis of Muree Rawat gas pipeline project presents most probable cost and duration to complete project. It also presents most probable date of completion of the project considering all identified risks.



Three main project parameters			
		Without risks (baseline)	With risks and uncertainties
1	Total Project Cost	Rs350,000,809	Rs391,161,637
2	Project Finish Time	10/06/06 17:00	12/16/06 17:00
3	Project Duration	390 days	450,64 days

Three most crucial tasks		
	Affect on total project cost	Affect on project duration
1		Task: Excavation
2		Task: Transportation of material
3		Task: Stringing of pipe

Three most critical risks		
	Affect on total project cost (25 risks total)	Affect on project duration (25 risks total)
1	Risk: Earthquake	Risk: Approval from Regulatory bodies
2	Risk: Change in scope of project	Risk: Not in time delivery of material
3	Risk: Floods	Risk: Terrorism

Figure-7(b): Result obtained from simulation identifying most critical risk impacting scope, duration and cost Muree Rawat gas pipeline project

identified impacting on scope, cost and duration of project [Figure 7 (a) and (b)]. Strategy for risk management is set accordingly. The following analysis and results was produced by the programme:

- ✓ Sensitivity analysis
- ✓ Success rate of completion
- ✓ Critical risks affecting cost
- ✓ Critical risks affecting duration of project

- ✓ Critical activities.
- ✓ Most probable duration
- ✓ Most probable cost of the project
- ✓ Most probable date of completion of project.

STEP 6: On the basis of critical risk identification by Monte Carlo simulation, risk reduction strategy is set, which may be risk transfer, mitigation, avoidance, distribution and etc. During construction process the impact of risk can be lowered by changing the schedule of construction for example 95% of probability of flood occurrence is in period from June to August. In flood, the area comes under water and may not be possible to continue the construction process. Therefore, schedule may be set in a way that ground related activities should be set accordingly to avoid the occurrence.

STEP 7: The results or set methodology for risk management must be periodically monitored and checked for improvement. Lesson learned and recommendation should be send to "Data Bank" which may be useful for risk analysis and management of another pipeline project of similar nature.

5. Conclusion and Recommendations

- Probability of risk occurrence "P" comes out to be the function of project duration "T" both during construction and operation phase. However Intensity of destruction or Impact is a function of enterprise internal and external environment.

- Three most critical tasks calculated by Risky Project are Excavation, Transportation of Material and Stringing of pipelines. The most critical risks come out to be change in economic parameters, Change in design and scope, earthquake and terrorism during construction and operation of gas pipelines.

- Considering all risks the probable values to project completion calculated by Risky project is 460 days however the base project duration is 390 days. Similarly the project cost without risks is 350,00,000 however, with risks it is 391,00,000. On the basis of that contingency budget of project can be formulated to cater the risk.

- The secondary risks like change in material prices, construction not finished in time or budget and design not in time can be reduced or transferred to the other party or organization by contract. However SNGPL is designing, constructing and operating gas pipelines so risk can be eliminated by strengthening the internal organizational capacity for design, construction and operation.

- Organizational or technological risk like insufficient resource planning or project management, change in scope etc can be eliminated by improving the process or application of new technologies available in this field. New state of the art technologies are helpful in managing change at any stage of the project.

- Historical data of river flows shows that the flood has probability of 95% of occurrence between June and August. This risk can be minimized during construction phase by rearranging the construction schedule. Other risks like landslides are associated with floods, rain fall or earthquakes.

- Earthquake risk during construction phase depends on the length of execution of project and only impact on the construction cost of the project. As the duration of the execution increases probability of occurrence of risk also increase. However, in operation phase this risk must be eliminated by practicing design based on earthquake/horizontal forces.

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