RISK MANAGEMENT IN PROJECT IMPLEMENTATION - DAHEJ URAN PIPELINE PROJECT

A PROJECT WORK

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTERS OF TECHNOLOGY
IN
PIPELINE ENGINEERING

UNDER THE GUIDANCE OF

MR R.P.SRIWAS

COLLEGE OF ENGINEERING
UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

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May, 2007

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This is to certify that Mr. S. ManiKandan, a student of M.Tech (Pipeline Engineering) in University of Petroleum & Energy Studies, Dehradun has done his project on "Risk Management in Project Implementation for Dahej Uran Pipeline Project" for the period Feb28, 2007 to Apr 28, 2007.

His performance in the project was very good.

B. Saravana Kumar,
Sr. Manager (Pipelines).

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CONTENTS

ABSTRACT:
Time, cost and quality achievements on large scale construction projects are uncertain because of technology constraints, long durations, large capital requirements and improper scope definition.

A cross country gas pipeline construction project is characterized by its complexity of its execution with respect to lack of experience in relation to certain design conditions being exceeded. These conditions can include ground condition, pipeline size and water depth. External causes can limit resource availability, including the areas of techniques and technology. Various environmental impacts, State's laws and Regulations, changes in economic and political environment may result in cost and time overrun and the unsatisfactory quality of a project which are the general sources of management disappointment with a pipeline organization.

Projects that are exposed to such an uncertain environment can effectively be managed with the application of risk management throughout the project life cycle. Risk is by nature subjective. However managing risk subjectively poses the danger of non achievement of project goals. Moreover, risk analysis of the overall project also poses the danger of developing inappropriate responses.

This project demonstrates a qualitative and quantitative approach to construction risk management through an Analytic Hierarchy Process (AHP) and Decision Tree Analysis (DTA).

The entire project is classified into various work packages. As all the risk factors are identified, their effects are quantified by determining probability using AHP and severity guess estimate. Various alternative responses are generated, listing the cost implication of mitigating the quantified risks.

Most of the risk analysis methodologies apply quantitative techniques and quantify risk by determining probability and severity of risk factors; without identifying risk responses objectively. It provides an objective basis for additional investment in planning or for engaging superior consultants, contractors, and suppliers for specific work packages. The combined AHP and Decision tree is especially required for large scale projects because there are many uncertainties.

Use of a combined AHP and DTA techniques for risk assessment and thereafter devised methodology for Risk Management did promise completion of project without any time or cost overrun.

CHAPTER - 1

INTRODUCTION TO RISK MANAGEMENT

1.1 RISK AND RISK MANAGEMENT PROCESS

C.B.Chapman and D.F.Cooper define risk as "exposure to the probability of economic or financial loss or gains, physical damage, or injury or delay as a consequence of the uncertainty associated with pursuing a course of actions". Risk management is the systematic process of identifying, analyzing and responding to the project risk. It includes maximizing the probability and consequences of adverse events to project objectives. The following steps provide an overview of the following major processes.

Risk Management Planning- deciding how to approach and plan the risk management activities of the project as illustrated in the figure [1].

Risk Identification-determining which risks might affect the project and documenting the characteristics.

Qualitative Risk Analysis- performing a qualitative analysis of risks and conditions to prioritize their effects on project objectives.

Risk Response Planning- developing procedures and techniques to enhance opportunities and reduce threats to the project objectives.

Risk Monitoring and Control- monitoring residual risks, identifying new risks, executing risk reduction plans, and evaluating their effectiveness throughout the project life cycle.

Project risk is an uncertain event or condition that, if it occurs, has a positive or a negative effect on a project objective. A risk has a cause and, if it occurs, a consequence. For example, a cause may be requiring a permit or having limited personnel assigned to the project. The risk event is that the permit may take longer than planned, or the personnel may not be adequate for the task. If either of these uncertain events occurs,

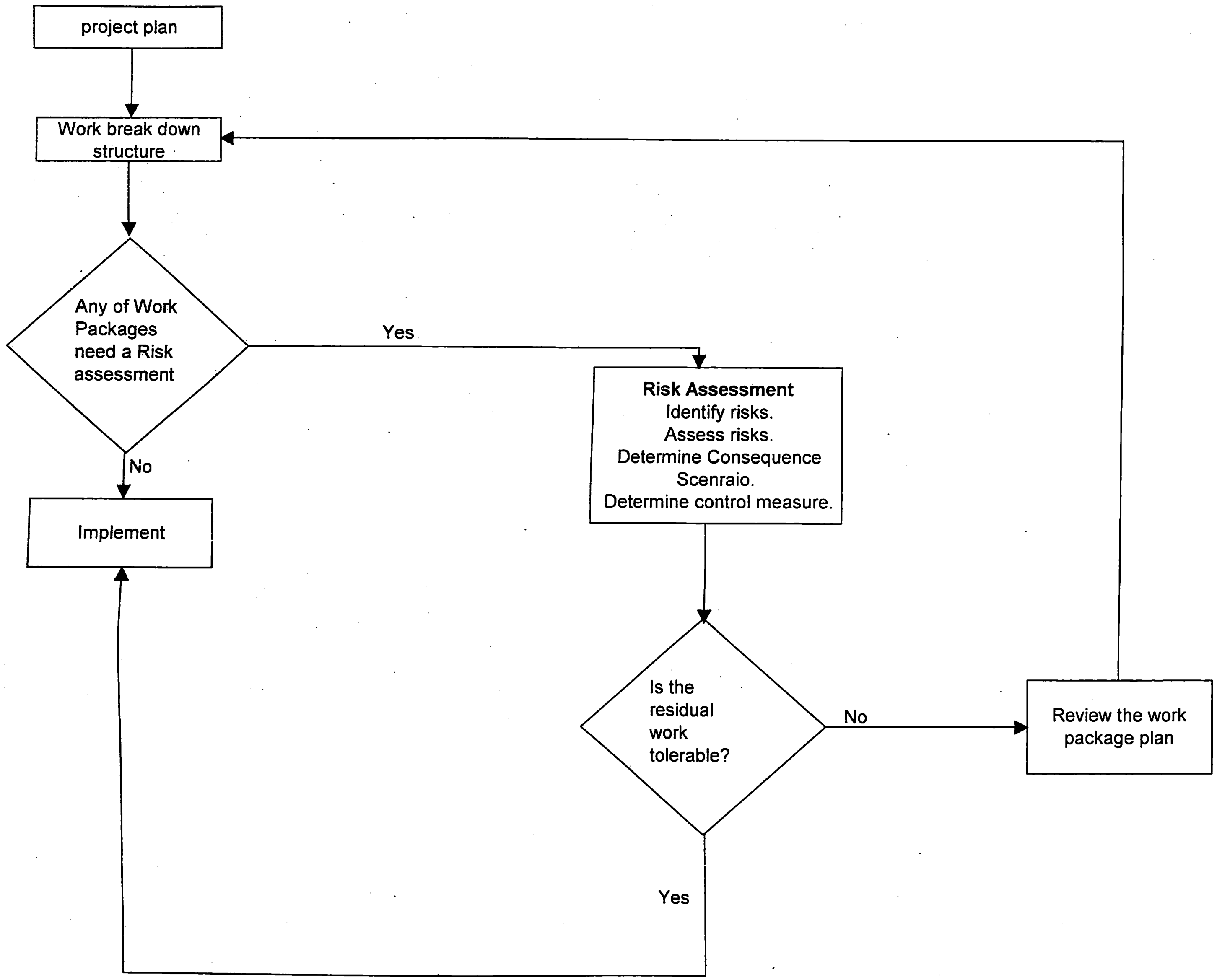


FIG.1 RISK MANAGENEMENT FLOW CHART

there will be the consequence on the project cost, schedule, or quality. Risk conditions could include aspects of the project environment that may contribute to project risk such as poor project management practices, or dependency on external participants that cannot be controlled.

Project risk includes both threats to the project's objectives and opportunities to improve on those objectives. It has its origin in the uncertainty that is present in all projects. Known risks are those that have been identified and analyzed, and it may be possible to plan for them. Unknown risks cannot be managed. Organization perceives risks as it relates to threats to project success. Risks that are threats to the project may be accepted if they are in balance with the reward that may be gained by taking the risk.

To be successful, the organization must be committed to addressing risk management throughout the project. One measure of the organizational commitment is its dedication to gathering high quality data on project risks and their characteristics.

1.1.1 RISK MANAGEMENT PLANNING

Risk management planning is the process of deciding how to approach and plan the risk management activities for a project. It is important to plan for the risk management processes that follow to ensure that the level, type, visibility of risk management is commensurate with both the risk and importance of the project to the organization.

(A). INPUTS TO RISK MANAGEMENT PLANNING

Organization's risk management policies- Some organizations may have predefined approaches to risk analysis and response that have to be tailored to a particular project.

Defined roles and responsibilities- predefined roles, responsibilities, and authority levels for decision-making will influence planning.

Template for the organization's risk management plan: some organizations have developed templates for use of the project team. The organization will continuously improve the template, based on its application and usefulness in the project.

Work breakdown Structure (WBS):

A WBS is a deliverable oriented grouping of project components that organizes and defines the total scope of the project; work not in the WBS is outside the scope of the project. As with the scope of the statement, the WBS is often used to develop or confirm a common understanding of project scope. Each descending level represents an increasingly detailed description of the project deliverables. Each item in the WBS is generally assigned a unique identifier; these identifiers can provide a structure for a hierarchical summation of costs and resources. The items at the lowest level of the WBS may be referred to as work packages, especially in organizations that follow earned value management practices. These work packages may in turn be further decomposed in a subproject work breakdown structure.

(B). TOOLS AND TECHNIQUES FOR RISK MANAGEMENT PLANNING:

Planning meetings: project team hold planning meetings to develop the risk management plan. Attendees include the project manager, the project team leaders, anyone with responsibility to manage the risk planning and execution activities, key stakeholders, and others as needed. They use the risk management templates, and other inputs as appropriate.

(C). OUTPUTS FROM RISK MANAGEMENT PLANNING:

Risk management plan:

The risk management plan describes how risk identification, qualitative and quantitative analysis, resource planning, monitoring and control will be structured and performed during the project life cycle. The risk management plan does not address responses to individual risks. The risk management plan includes the following.

Methodology: defines the approaches, tools and data sources that may be used to perform risk management on this project. Different types of assessments may be appropriate, depending upon the project stage, amount of information available, and flexible remaining in risk management..

Budgeting: establishes a budget for risk management for the project.

Timing: defines how often the risk management process will be performed throughout the project life cycle. Results should be developed early enough to affect decisions. The decisions should be revisited periodically during project execution.

Scoring and interpretation: the scoring and interpretation methods appropriate for the type and timing of the qualitative and quantitative risk analysis being performed. Methods and scoring must be determined in advance to ensure consistency.

1.1.2. RISK IDENTIFICATION:

Risk identification involves determining which risks might affect the project and documenting their characteristics. Risk identification is an iterative process. The first iteration may be performed by a part of the project team, or by the risk management team. The entire project team and primary stakeholders may take a second iteration. To achieve an unbiased analysis, persons who are not involved in the project may perform the final iteration.

(A). INPUTS TO RISK IDENTIFICATION:

Project planning outputs- risk identification requires an understanding of the project's mission, scope, and objectives of the owner, sponsor, or stakeholders. Outputs of other processes should be reviewed to identify possible risks across the entire project.

Risk categories- risks that may affect the project for better or worse can be identified and organized into risk categories. Risks categories should be well defined and should reflect common sources of risk for the industry or application area. Categories include the following.

Technical, quality or performance risks- such as reliance on unproven or complex technology, unrealistic performance goals, change to the technology used or to industry standards during the project.

Project management risks- such as poor allocation of time and resources, adequate quality of the project plan, poor use of project management disciplines.

Organizational risks- such as cost, time, and scope and objectives that are internationally inconsistent, lack of prioritization of projects, inadequacy or interruption of funding, and resource conflicts with other projects in the other organization.

External risks- such as shifting legal or regulatory environment, labor issues, changing owner priorities, country risk, and weather. Force majeure risks such as earthquakes, floods and civil unrest generally require disaster recovery actions rather than risk management.

(B). TOOLS AND TECHNIQUES FOR RISK IDENTIFICATION:

Documentation reviews- performing a structured review of project plans and assumptions, both at the total project and detailed scope levels, prior project files, and other information is generally the initial step taken by project teams.

Information gathering techniques- examples of information gathering techniques used in risk identification.

Assumption analysis- every project is conceived and developed based on a set of hypotheses, scenarios or assumptions. Assumptions analysis is a technique that explores the assumptions validity. It identifies risks to the project from inaccuracy, inconsistency, or incompletes of assumptions.

(C). OUTPUTS FROM RISK IDENTIFICATION

Risks- A risk is a uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective.

Triggers- triggers, sometimes called risk symptoms or warning signs, are indications that a risk occurred or is about to occur. For example, failure to meet intermediate milestones may be an early warning signal of an impending schedule delay.

1.1.3. QUALITATIVE RISK ANALYSIS:

Qualitative risk analysis is the process of assessing the impact and likelihood of identified risks. This process prioritizes risks according to their potential effect on project objectives. Qualitative risk analysis is one way to determine the importance of addressing specific risks and guiding risk responses. The time criticality of risk related actions might magnify the importance of a risk. An evaluation of the quality of the available information also helps modify the assessment of the risk. Qualitative risk analysis requires that the probability and consequences of the risks be evaluated using established qualitative analysis methods and tools.

(A).INPUTS TO QUALITATIVE RISK ANALYSIS:

Identified Risks- risks discovered during the risk identification process are evaluated along with their potential impacts on the project.

Project status- the uncertainty of a risk often depends on the project's progress through its life cycle. Early in the project, many risks have not surfaced, the design for the project is immature, and changes can occur, making it likely that more risks will be discovered.

Data precision- precision describes the extent to which a risk is known and understood. It measures the extent of data available, as well as the reliability of data. The source of the data that was used to identify the risk must be evaluated.

(B).TOOLS AND TECHNIQUES FOR QUALITATIVE RISK ANALYSIS:

Risk probability and impact- risk probability and risk consequences may be describe in qualitative terms such as very high, high, moderate, low and very low. Risk probability is the likelihood that a risk will occur. Risk consequence is the effect on project objectives if the risk event occurs. These two dimensions of risk are applied to specific risk events, not to the overall project. Analysis of risks using probability and consequences helps identifying those risks that should be managed aggressively.

Probability / impact risk rating matrix:
A matrix may be constructed that assigns risk ratings (very low, low, moderate, high and very high) to risks or conditions based on combining probability and impact scales. Risks with high probability and high impact are likely to require further analysis, including quantification, and aggressive risk management. The risk rating is accomplished using a matrix and risk scales for each risk.

A risk's probability scale naturally falls between 0.0 (no probability) and 1.0 (certainty). Assessing risk probability may be difficult because expert judgment is used, often without benefit or historical data. An ordinal scale, representing relative probability values from very likely to require further analysis, including quantification, and aggressive risk management. The risk rating is accomplished using a matrix and risk scales for each risk.

The risks impact scale reflects the severity of its effect on the project objective. Impact can be ordinal or cardinal, depending upon the culture of the organization conducting the analysis. Ordinal scales are simply rank ordered values, such as very low, low, moderate, high, and very high. Cardinal scales assign values to their impacts. These values are usually linear but are often non linear, reflecting the organization's desire to avoid high impact risks. Well-defined scales, whether ordinal or cardinal, can be developed using definitions agreed upon by the organization. These definitions improve the quality of the data and make the process more repeatable.

(C). OUTPUTS FROM QUALITATIVE RISK ANALYSIS:

Overall risk ranking for the project: risk ranking may indicate the overall risk position of project relative to other projects by comparing the risk scores. It can be used to assign personnel or other resources to projects with different risk rankings; to make a benefit cost analysis decision about the project, or to support a recommendation for project initiation, continuation or cancellation.

List of prioritized risks: risks and conditions can be prioritized by a number of criteria. These include rank or Work Break down structure level. Those that require immediate response and those that can be handled at a later date may also group risks. Risks that affect cost, schedule, functionality and quality may be assessed separately with different ratings. Significant risks should have a description of the basis for the assessed probability impact.

Lists of risks for additional analysis and management- risks classified as high or moderate would be prime candidates for more analysis, including quantitative risk analysis, including quantitative risk analysis, and for risk management action.

1.1.4 DECISION TREE ANALYSIS (DTA)

A decision tree analysis is usually structured as a 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 incorporates probabilities of risk and the costs or rewards of each logical path of events and future decisions. Solving the decision tree indicates which decision yields the greatest expected value to the decision maker when all the uncertain implications, costs, rewards, and subsequent decisions are quantified.

1.1.5 RISK RESPONSE PLANNING

Risk response planning is the process of developing options and determining actions to enhance opportunities and reduce threats to the project's objectives. It includes the identification and assignment of individuals or parties to take responsibility for each agreed risk response. This process ensures that identified risks are properly addressed. The effectiveness of response planning will directly determine whether risk increases or decreases for the project.

Risk response planning must be appropriate to the severity of the risk, cost effective in meeting the challenge, timely to be successful, realistic within the project context, agreed upon by all parties involved, and owned by a responsible person. Selecting the best risk response from several options is often required.

TOOLS AND TECHNIQUES FOR RISK RESPONSE PLANNING:

Several risk response strategies are available. The strategy that is most likely to be effective should be selected for each risk. Then, specific actions should be developed to implement that strategy. Primary and backup strategies may be selected.

Avoidance:

Risk avoidance is changing the project plan to eliminate the risk or condition or to protect the project objectives from its impact. Although the project team can never eliminate all risks events, some specific risks may be avoided.

Some risk events that arise early in the project can be dealt with by clarifying requirements, obtaining information, improving communication, or acquiring expertise. Reducing scope to avoid high-risk activities, adding resources or time, adopting a familiar approach instead of an innovative one, or avoiding an unfamiliar subcontractor may be examples of avoidance.

Transference- risk transfer is seeking to shift the consequence of a risk to a third party together with ownership of the response. Transferring the risk simply gives another party responsibility for its management; it does not eliminate it.

Transferring liability for risk is most effective in dealing with financial risk exposure. Risk transfer nearly always involves payment of a risk premium to the party taking on the risk. It includes the use of insurance, performance bonds, warranties and guarantees. Contracts may be used to transfer liability for specified risks to another party. Use of a fixed price contract may transfer risk to the seller if the project's design is stable. Although a cost- reimbursable contract leaves more of the risk with the customer or sponsor, it may help reduce cost if there are mid project changes.

Mitigation- mitigation seeks to reduce the probability and or consequence of an adverse risk event to an acceptable threshold. Taking early action to reduce the probability of a risks occurring or its impact on the project is more effective than trying to repair the consequences after it has occurred. Mitigation costs should be appropriate, given the likely probability of the risk and its consequence.

Risk mitigation may take the form of implementing a new course of action that will reduce the problem.

Where it is not possible to reduce probability, a mitigation response might address the risk impact by targeting linkages that determine the severity.

Acceptance: this technique indicates that the project team has decided not to change the project plan to deal with a risk or is unable to identify any other suitable response strategy. Active acceptance may include developing a contingency plan to execute, should a risk to occur. Risk triggers, such as missing intermediate milestones, should be defined and tracked. A fallback plan is developed if the risk has a high impact, or if the selected strategy may not be fully effective. This might include allocation of a contingency amount, development of alternative options, or changing scope.

CHAPTER – 2

THE ANALYTIC HIERARCHY PROCESS

2.1 INTRODUCTION TO ANALYTIC HIERARCHY PROCESS (AHP)

Analytic

Analytic is a form of the word analysis, which means the separating of any material or abstract entity into its constituent elements. Analysis is the opposite of synthesis, which involves putting together or combining parts into a whole. AHP should really be called the *Synthesis* Hierarchy Process because at its core, AHP helps us measure and synthesize the multitude of factors involved in complex decisions.

Hierarchy

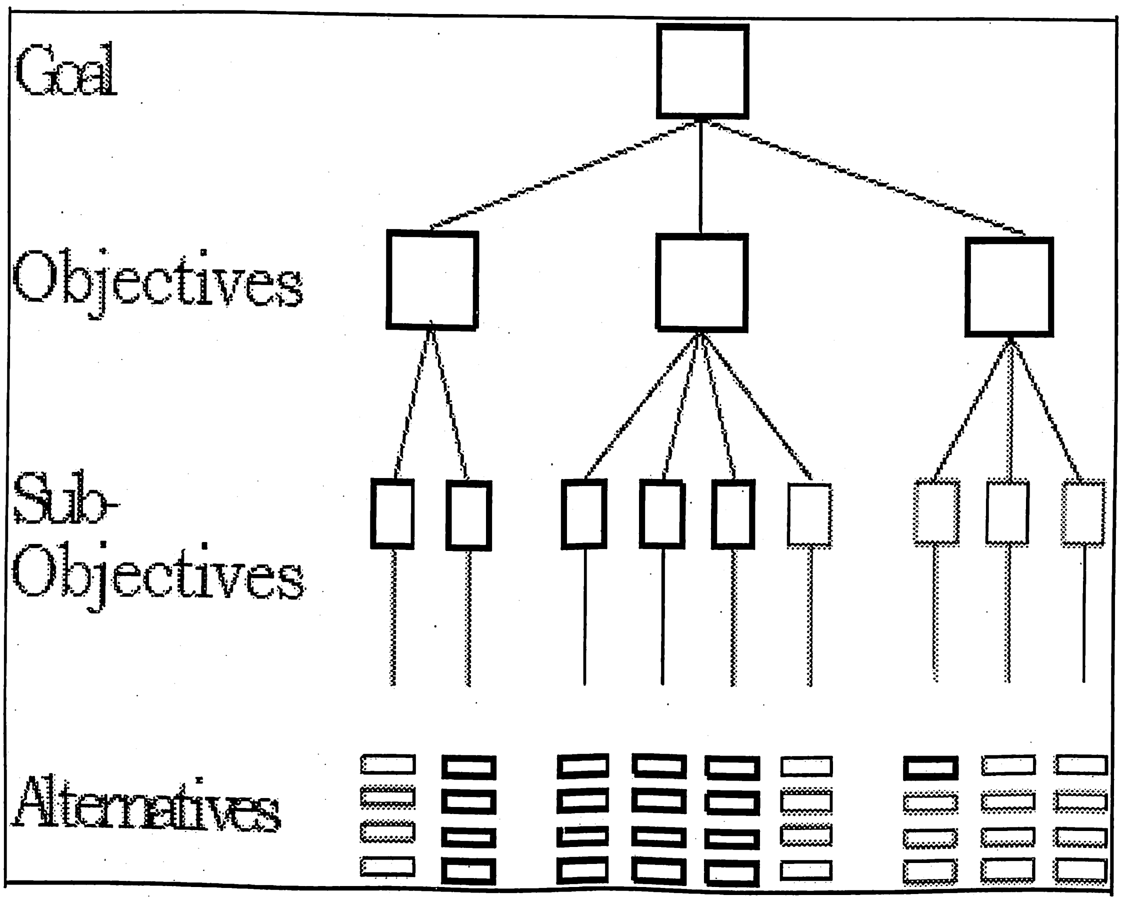
How can human's best deal with complexity? Herbert Simon, father of the field of Artificial Intelligence and Nobel laureate, writes "Large organizations are almost universally hierarchical in structure. That is to say, they are divided into units which are subdivided into smaller units, which are, in turn, subdivided and so on. Hierarchical subdivision is not a characteristic that is peculiar to human organizations. It is common to virtually all-complex systems of which we have knowledge. The near universality of hierarchy in the composition of complex systems suggests that there is something fundamental in this structural principal that goes beyond the peculiarities of human organization. An organization will tend to assume hierarchical form whenever the task environment is complex relative to the problem-solving and communicating powers of the organization members and their tools. Hierarchy is the adaptive form for finite intelligence to assume in the face of complexity." In his book on "Hierarchical Structures" L.L. White expressed this thought as follows: "The immense scope of hierarchical classification is clear. It is the most powerful method of classification used by the human brain-mind in ordering experience, observations, entities and information. The use of hierarchical ordering must be as old as human thought, conscious and unconscious."

Process

A process is a series of actions, changes, or functions that bring about an end or result.

2.2 THE ANALYTIC HIERARCHY PROCESS AND EXPERT CHOICE

The analytic hierarchy process (AHP), developed at the Wharton school of business by Thomas saaty, and allows decision makers to model a complex problem in a hierarchical structure. Showing the relationships of the goal, objectives (criteria), sub-objectives, and alternatives. Uncertainties and other influencing factors can also be included.



AHP allows for the application of data, experience, insight, and intuition in a logical and thorough way. AHP enables decision-makers to *derive* ratio scale priorities or weights as opposed to arbitrarily *assigning* them. In so doing, AHP not only supports decision-makers by enabling them to structure complexity and exercise judgment, but allows them to incorporate both objective and subjective considerations in the decision process. AHP is a compensatory decision methodology because alternatives that are deficient with respect to one or more objectives can compensate by their performance with respect to other objectives. AHP is composed of several previously existing but unassociated concepts and techniques such as hierarchical structuring of complexity, pair wise comparisons, redundant judgments, an eigenvector method for deriving weights, and consistency considerations. Although each of these concepts and techniques were useful in and of themselves, Saaty's synergistic combination of the concepts and techniques produced a process whose power is indeed far more than the sum of its parts.

2.3 PRINCIPLES AND AXIOMS OF THE ANALYTIC HIERARCHY PROCESS

AHP is built on a solid yet simple theoretical foundation. The basic 'model' is one that almost every executive is familiar with — a pie chart. If we draw a pie chart, the whole of the chart represents the goal of the decision problem. The pie is organized into wedges, where each wedge represents an objective contributing to the goal. AHP helps determine the relative importance of each wedge of the pie. Each wedge can then be further decomposed into smaller wedges representing sub-objectives. And so on. Finally, wedges corresponding to the lowest level sub-objectives are broken down into alternative wedges, where each alternative wedge represents how much the alternative contributes to that sub-objective. By adding up the priority for the wedges for the alternatives, we determine how much the alternatives contribute to the organization's objectives. AHP is based on three basic principles: decomposition, comparative judgments, and hierarchic composition or synthesis of priorities. The decomposition principle is applied to structure a complex problem into a hierarchy of clusters, sub-clusters, sub-sub clusters and so on. The principle of comparative judgments is applied to construct pair wise comparisons of all combinations of elements in a cluster with respect to the parent of the cluster. These pair wise comparisons are used to derive 'local' priorities of the elements in a cluster with respect to their parent. The principle of hierarchic composition or synthesis is applied to multiply the local priorities of elements in a cluster by the 'global' priority of the parent element, producing global priorities throughout the hierarchy and then adding the global priorities for the lowest level elements (the alternatives). All theories are based on axioms. The simpler and fewer the axioms, the more general and applicable is the theory. Originally AHP was based on three relatively simple axioms. The first axiom, the reciprocal axiom, requires that, if PC(EA,EB) is a paired comparison of elements A and B with respect to their parent, element C, representing how many times more the element A possesses a property than does element B, then PC(EB,EA) = 1/PC(EA,EB). For example, if A is 5 times larger than B, then B is one fifth as large as A. The second, or homogeneity axiom, states that the elements being compared should not differ by too much, else there will tend to be larger errors in judgment. When constructing a hierarchy of objectives, one should attempt to arrange elements in a cluster so that they do not differ by more than an order of magnitude. (The AHP verbal scale ranges from 1 to 9, or about an order of magnitude. The numerical and graphical modes of Expert Choice accommodate almost two orders of magnitude, allowing a relaxation of this axiom. Judgments beyond an order of magnitude generally result in a decrease in accuracy and increase in inconsistency). The third axiom states those judgments about, or the priorities of, the elements in a hierarchy do not depend on lower level elements. This axiom is required for the principle of hierarchic composition to apply. While the first two axioms are always consonant with real world applications, this axiom requires careful examination, as it is not uncommon for it to be violated. Thus, while the preference for alternatives is almost always dependent on higher-level elements, the objectives, the importance of the objectives might or might not be dependent on lower level elements, the alternatives.

2.4 DEVELOPING A DECISION HIERARCHY:

2.4.1 Decompose the problem:

The first step in using AHP and the expert choice software is to develop a hierarchy by breaking the problem down to its components. The three major levels of the hierarchy are the goal, objectives, and alternatives.

Goal: The goal is the statement of the overall objective.

Objectives: What are we trying to achieve the goal?

Alternatives: The feasible alternatives that is available to reach the ultimate goal.

2.4.2 ESTABLISHING PRIORITIES:

After arranging the problem in a hierarchical fashion, the next step is to establish priorities. Each node is evaluated against each of its peers in relation to its parent node. These evaluations are called pair wise comparisons.

2.4.3 PAIR WISE COMPARISONS:

Pair wise comparisons of the elements at each level of an EC model are made in terms of either.

Importance – when comparing objectives with respect to their relative importance.

Preference- when comparing the preference for alternatives with respect to an objective.

Likelihood – when comparing uncertain events or scenarios with respect to the probability of their occurrence.

Pair wise comparisons are basic to the methodology. When comparing a pair of factors, a ratio of relative importance, preference or likelihood of the factors can be established. This ratio need not be based on some standard scale such as feet or meters but merely represents the relationship of the two factors being compared.

Most individuals would question the accuracy of any judgment made without using a standard scale. Yet it has been verified that a number of these pair wise comparisons taken together form a sort of average, the results of which are very accurate. This average is calculated through a complex mathematical process using Eigen values and Eigen vectors. The results of this method have been tested experimentally and have found to be extremely accurate. The method is used in AHP and Expert choice allowing one to use both subjective and objective data in making pair wise comparisons.

2.4.4 EIGEN VALUES AND EIGEN VECTORS:

Suppose the relative weights is known and expressed in a pair wise comparison matrix as follows.

$$\underline{A} = \begin{bmatrix} W_1/W_1 & W_1/W_2 & W_1/W_3 & \cdots & W_1/W_n \\ W_2/W_1 & W_2/W_2 & W_2/W_3 & \cdots & W_2/W_n \\ W_3/W_1 & W_3/W_2 & W_3/W_3 & \cdots & W_3/W_n \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ W_n/W_1 & W_n/W_2 & W_n/W_3 & \cdots & W_n/W_n \end{bmatrix}$$

The vector of weights (W1, W2, W3.... Wn) has given these ratios, the matrix product of the matrix A with the vector w to obtain

$$\begin{bmatrix} w_1/w_1 & w_1/w_2 & w_1/w_3 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & w_2/w_3 & \dots & w_2/w_n \\ w_3/w_1 & w_3/w_2 & w_3/w_3 & \dots & w_3/w_n \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ w_n/w_1 & w_n/w_2 & w_n/w_3 & \dots & w_n/w_n \end{bmatrix} * \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ \dots \\ \dots \\ \dots \\ w_n \end{bmatrix} = \begin{bmatrix} nw_1 \\ nw_2 \\ nw_3 \\ \dots \\ \dots \\ \dots \\ nw_n \end{bmatrix}$$

$$\underline{A} \qquad\qquad * \ \underline{w} = n\,\underline{w}$$

If we knew A, but not w, we could solve the above for w. The problem of solving for a nonzero solution to this set of equations is very common in engineering and physics and is known as an eigenvalue problem:

$$\mathbf{A\,w = \lambda\,w}$$

The solution to this set of equations is, in general found by solving an nth order equation for l. Thus, in general, there can be up to n unique values for l, with an associated w vector for each of the n values. In this case however, the matrix A has a special form since each row is a constant multiple of the first row. For such a matrix, the rank of the matrix is one, and all the eigenvalues of A are zero, except one. Since the sum of the eigenvalues of a positive matrix is equal to the trace of the matrix (the sum of the diagonal elements), the non-zero eigenvalue has a value of n, the size of the matrix. This eigenvalue is referred to as λmax.

Notice that each column of A is a constant multiple of w. Thus, w can be found by normalizing any column of A.

The matrix A is said to be strongly consistent in that
Aikakj = aij for all i, j.

Now let us consider the case where we do *not* know w, and where we have only estimates of the aij's in the matrix A and the strong consistency property most likely does not hold. (This allows for small errors and inconsistencies in judgments). It has been shown that for any matrix, small perturbations in the entries imply similar perturbations in the eigenvalues, thus the eigenvalue problem for the inconsistent case is:

$$\mathbf{A\, w = \lambda_{max}\, w},$$

Where λ_{max} **will** be close to n (actually greater than or equal to n) and the other λ's will be close to zero. The estimates of the weights for the activities can be found by normalizing the eigenvector corresponding to the largest eigenvalue in the above matrix equation. The closer λ_{max} is to n, the more consistent the judgments. Thus, the difference, λ_{max} - n, can be used as a measure of inconsistency (this difference will be zero for perfect consistency). Instead of using this difference directly, Saaty defined a consistency index as:

$$(\lambda_{max} - n)/(n-1)$$

Since it represents the average of the remaining eigenvalues.

In order to derive a meaningful interpretation of either the difference or the consistency index, Saaty simulated random pair wise comparisons for different size matrices, calculating the consistency indices, and arriving at an average consistency index for random judgments for each size matrix.

The consistency ratio is defined as the ratio of the consistency index for a particular set of judgments, to the average consistency index for random comparisons for a matrix of the same size.

Since a set of perfectly consistent judgments produces a consistency index of 0, the consistency ratio will also be zero. A consistency ratio of 1 indicates consistency akin to that, which would be achieved if judgments were not made intelligently, but rather at random. This ratio is called the inconsistency ratio in Expert Choice since the larger the value, the more inconsistent the judgments.

2.4.5 THREE PAIR WISE COMPARISON MODES:

Expert choice allows entering judgments in numerical, graphical or verbal modes. Each judgment expresses the ratio of one element compared to another element. Verbal judgments are easier to make, and for qualitative or value driven comparison modes may be preferred, although it is perfectly acceptable to use the verbal mode.

Numerical judgments:

When comparing properties that lend themselves to a numerical scale, one can use the numerical mode to enter the judgments. In the numerical scale, 1.0 implies that the elements are equally important, 2.0 that one element is twice as important as the other, and 9.0 that one element is nine times as important as the other. If the disparity between elements in the group is so great that they are not of the same "order of magnitude" that is, some elements in the group are more than 9.0 times greater than some other elements in the group, they should be put into clusters of like elements. Alternatively, expert choice allows expansion of the numerical scale to a ratio of 99.9 to 1.

Graphical judgments:

The graphical pair wise comparison scale can be used to express the relationships between two elements as the ratio of the length of two bars. Judgments are entered in the graphical mode by adjusting the relative lengths of the two bars.

Verbal judgments:

The nine point verbal scale used in expert choice is represented in the following table

Table1. Verbal Scale

1.0	Equal importance of both elements	Two elements contribute equally
3.0	Moderate importance of one element over another	Experience and judgment favor one element over another.
5.0	Strong importance of one element over another	An element is strongly favored.
7.0	Very strong importance of one element over another.	An element is very strongly dominant.
9.0	Extreme importance of one element over another	An element is favored by at least an order of magnitude.
2.0, 4.0, 6.0,8.0	Intermediate values	Used to compromise between two judgments.

Whereas numerical and graphical judgments are in and of them ratios and hence process the ratio level of measurement, the same is not true for the verbal scale. The verbal scale is essentially an ordinary scale. The relative (pair wise *verbal* judgments can produce accurate, ratio scale priorities from what are basically imprecise, ordinal judgments, provided that redundant judgments are included in the calculations. Redundancy helps to reduce the average effect of errors in a manner analogous to the way that taking the average of a sample of measurements will produce an estimate of the mean that is likely to be closer to the true mean than only one judgment (i.e., no redundancy.) In addition to reducing the effect of the usual type of errors in measurement, this procedure also reduces the effect of the fuzzy nature of the ordinal scale and different interpretations of the scale by different decision-makers. While relative pair wise judgments can be made numerically or graphically, verbal judgments are important in decision-making because humans have learned to use and are comfortable in using words to measure the intensity of feelings and understanding with respect to the presence of a property. The derivation of ratio scale priorities from verbal judgments makes this possible.

2.3.6 SYNTHESIS:

Once judgments have been entered for each part of the model, the information is synthesized to achieve an overall performance. The synthesis produces a report, which ranks the alternatives in relation to the overall goal. The report includes a detailed ranking showing how each alternative was evaluated with respect to each objective.

2.3.7 SENSITIVITY:

Sensitivity analysis can be performed to see how well the alternatives performed with respect to each of the objectives as well as how sensitive the alternatives are to changes in the importance of the objectives. The performance sensitivity shows the relative importance of each of the objective as bars, and the relative preference for each alternative with respect to each objective as the intersection of the alternative curves with the vertical line for each objective.

CHAPTER – 3

PROJECT WORK DETAILS

OBJECTIVE: To model a decision support system through risk analysis for completing a project on time, within budget, and in line with project objectives, and the organizational policy.

3.1 DAHEJ URAN PIPELINE PROJECT

GAIL India ltd is construction a natural gas pipeline from Dahej to Uran for transporting natural gas to MSEB (Uran), ONGC (Uran), and DFPCL and Trombay areas.

DUPL is a cross-country pipeline project from Dahej to Uran for transportation of natural gas. Being part of GAIL natural gas network in the states of Gujarat and Maharashtra it will also supply gas to GAIL customers.

The pipeline-laying contract is divided into 3 spreads. The spread 3 comes under the Gammon India Ltd scope of work.

The spread III is subdivided into five sections.

SECTION	DIAMETER	LENGTH
I	30" MAINLINE	106.28 KM
II	24" MAINLINE	31.1 KM
III	18" SPURLINE	7.13 KM
IV	18" SPURLINE	8.125 KM
V	24" MAINLINE	39.5 KM

3.2 SOURCE OF INPUTS

The basic inputs are taken from the particular technical specifications and cost estimate for the on going Dahej Uran pipeline project along with looking at other recently completed projects and quotations from vendors and contractors

CROSSING DETAILS

Natural Highway Crossings	**8 Nos**
State Highway Crossings	**5 Nos**
Major River crossings	**21 Nos**
Nala crossings	**20 Nos**
Railway Crossings	**5 Nos**
Station Works	**17 Nos**
Other crossings	**25 Nos**

Table 2- BASIS FOR PROBABILITY FIGURES

Decision Alternatives	Basis for probability figures
Do nothing	Overall likelihood of failure in pipeline construction(output from Expert choice)
Carrying out detailed survey	50 percent of do nothing
Using superior technology	50 percent of do nothing
Engaging expert project team	Same as do nothing
Taking all responses	Assumption: probability of failure is five percent.

(Table 2 values are taken from reference [1].)

3.3 PROJECT MODEL:

The figure [2] illustrates the proposed project model. Project planning, design, and detailed engineering should be taken up in sequence as soon as a project gets approval. Materials procurement and works contract preparation start concurrently with completion of design activities. The availability of funds, materials drawings, specifications, contract document, and other utilities are initiated and implemented at the work site by contractors. Projects are controlled through effective monitoring of various performance parameters that are fixed during the planning phase. Just after project planning, risk management with respect to time achievement and covering all projects phase is carried out. Risk management with respect to cost achievement should be carried out before implementing work.

The Analytic Hierarchy Process developed by T.L.Saaty provides a flexible and easily understood way of analyzing project risks. It is a multi criteria decision-making methodology that allows subjective as well as objective factors to be considered in project risk analysis.

The project adopts Analytic Hierarchy Process for analyzing risk in the project and uses decision tree analysis for selecting specific risk responses for specific work packages from various alternatives.

Decision tree analysis use calculations to measure the attractiveness of alternatives. They also use graphical methods to display several relevant aspects of a decision situation. These graphical models consist of tree like structure with branches to represent the possible action event combinations. A tree gives much the same information as a matrix, but in addition, it can be used to depict multi stage decisions.

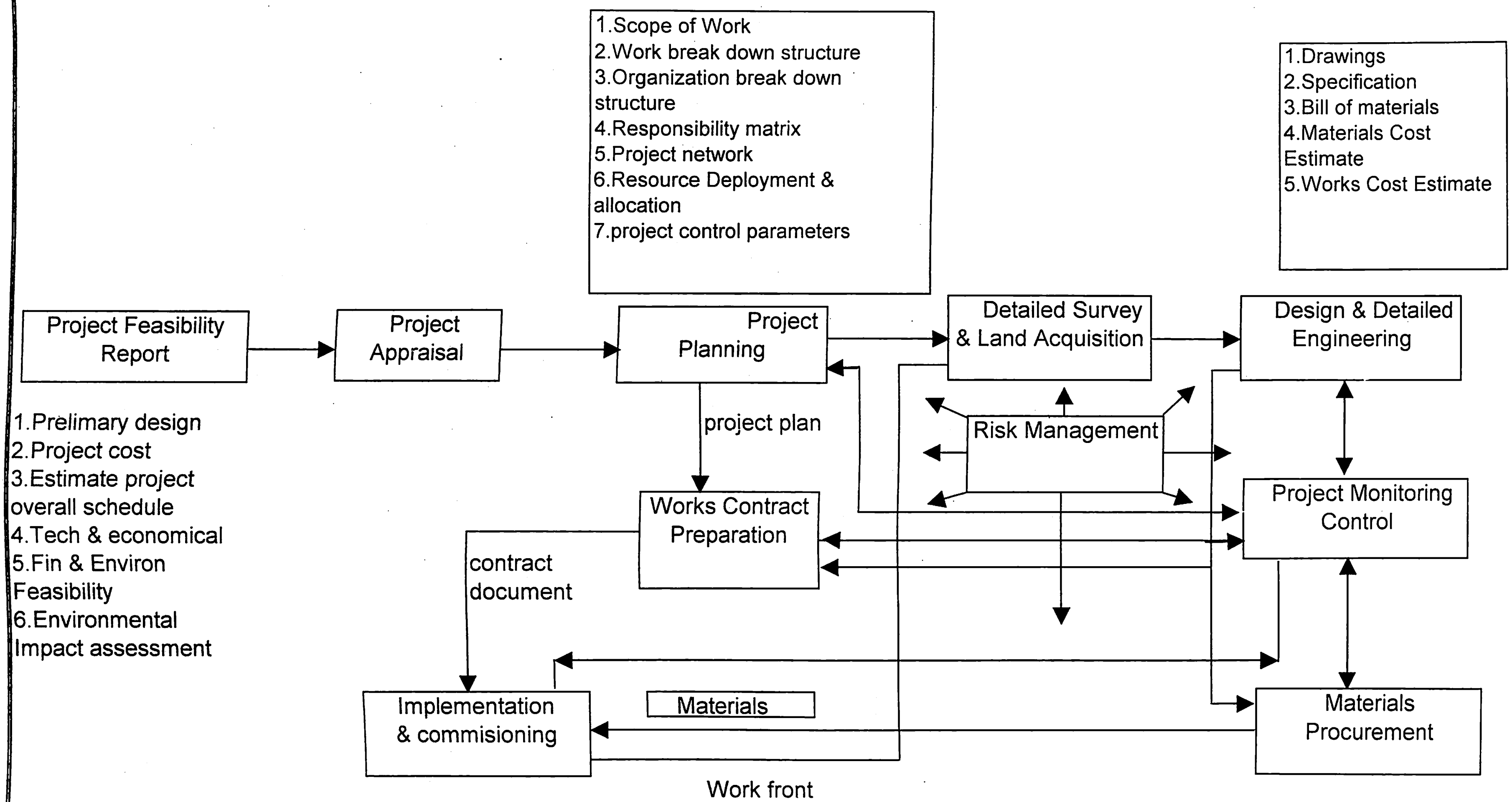


FIG.2 PROJECT MODEL

3.4 IDENTIFICATION OF WORK PACKAGES:

The total project scope was decomposed and classified to form a work break down structure as shown in figure [3]. The first level is project, the second level and third levels are work packages, and the forth level is activities of each work package. Based on the importance of achieving time targets, the following work packages were considered for risk management.

- Pipeline lying
- River crossing
- Station construction
- Telecommunication and cathodic protection

3.5 IDENTIFICATION OF RISK FACTORS:

The risk factors and sub factors were identified and the following are the risk factors and sub factors of the project.

TECHNICAL RISK:

- Scope change
- Technology selection
- Implementation methodology
- Equipment risk
- Material risk
- Engineering and design change

FINANCIAL & ECONOMICAL RISK:

- Inflation risk
- Fund risk
- Changes of local law
- Changes in government policy
- Improper estimation

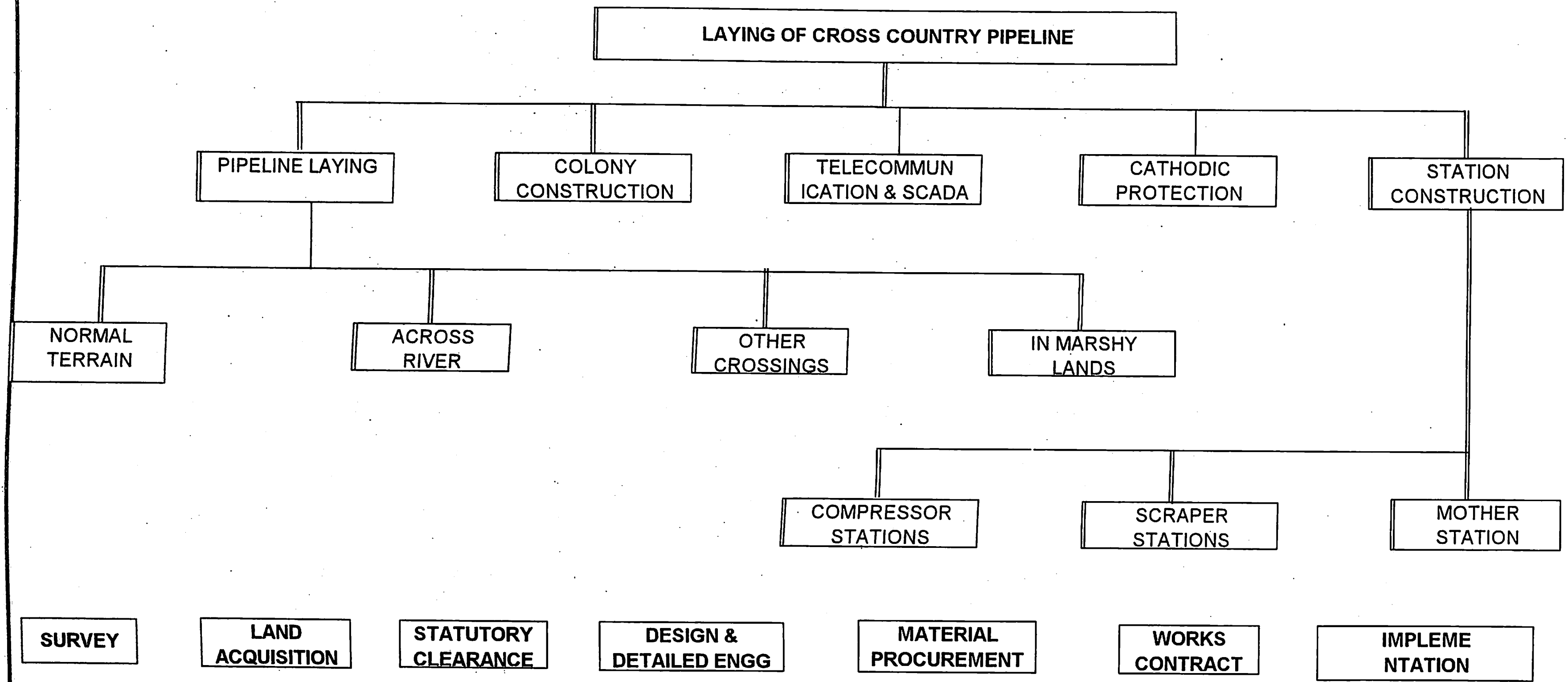


FIG.3 WORK BREAK DOWN STRUCTURE OF CROSS COUNTRY PIPELINE PROJECT

ORGANIZATIONAL RISK:

- Capability of owner/client
- Contractor's failure
- Vendor's failure
- Consultant's failure

ACTS OF GOD:

- Normal natural calamities
- Abnormal natural calamities

STATUTORY CLEARANCE RISK:

- Environmental clearance
- Land acquisition
- Clearance from chief controller of explosives
- Other clearance from government authorities

3.6 PAIR WISE COMPARISON:

The AHP model was made in an expert choice software package developed by E.H.Forman and T.L.Saaty. Pair wise comparisons were made by giving weights and scores table [1]. The outcome of matrix operation in table [3] shows the likelihood of these risks occurring while the project is being executed.

The pair wise comparisons in other levels also show the likelihood of occurrence of risk sub factors as indicated in table [4]. Synthesizing all of the risk factors and sub factors across hierarchy forms shows the overall likelihood of failure of the work packages.

3.7 DECISION TREE ANALYSIS

- It logically structures risk management by identifying alternative responses in mitigating risk.
- It provides a basis for quantitative risk management.
- It helps to depict multi stage decisions.

Table.3 COMPARISON MATRIXES IN FACTOR LEVEL

FACTORS	TECHNICAL RISK	FINANCIAL & ECONOMICAL RISK	ORGANIZATIONAL RISK	ACTS OF GOD	CLEARANCE RISK	LIKELIHOOD
TECHNICAL RISK	1	3	4	5	5	0.479
FINANCIAL & ECONOMICAL RISK	1/3	1	2	4	3	0.232
ORGANIZATIONAL RISK	1/4	1/2	1	2	3	0.142
ACTS OF GOD RISK	1/5	1/4	1/2	1	2	0.084
CLEARANCE RISK	1/5	1/3	1/3	1/2	1	0.063

(likelihood values are taken from Annexure V)

Table. 4 LIKELIHOOD OF RISK IN PROJECT LEVEL

FACTORS	LIKELIHOOD	SUB FACTORS	LIKELIHOOD LP	LIKELIHOOD GP
TECHNICAL RISK	0.479	Scope Change	0.320	0.153
		Technology selction	0.229	0.110
		Implementation method	0.173	0.083
		Equipment Risk	0.132	0.063
		Material risk	0.086	0.041
		Engg & design Change	0.60	0.029
FINANCIAL RISK	0.232	Inflation Risk	0.355	0.082
		Fund Risk	0.239	0.055
		Changes of Law	0.176	0.041
		Changes in Govt Policies	0.134	0.031
		Improper Estimation	0.096	0.022
ORGANIZATIONAL RISK	0.146	Capability of Owner	0.431	0.061
		Contractor's capability	0.246	0.035
		Vendor's capability	0.189	0.027
		Consultant capability	0.135	0.019
ACTS OF GOD	0.084	Calamity normal	0.667	0.056
		Calamity abnormal	0.333	0.028
CLEARANCE RISK	0.063	Clearance from CE	0.431	0.027
		Environmental Clearance	0.246	0.015
		Land Acquisition	0.189	0.012
		Other Clearance	0.135	0.008

Refer Annexure - V

CHAPTER – 4

OBSERVATIONS FROM RISK ANALYSIS STUDY

4.1 CRITICAL AREAS IDENTIFIED IN THE PROJECT

Technical risk is the major risk factor for time and cost overrun of a project. Within the technical risk category- scope, change, engineering and design change, technology, and implementation methodology selection are the major causes of project failure. The pipeline laying and station construction work packages are vulnerable from scope changes. Technology selection is vital for the river crossing and telecommunication packages. Engineering and design changes are quite likely for the river crossing and pipe laying work packages. A prior selection of implementation methodology is crucial for the river crossings packages, as improper selection could cause major time and cost overruns. The unavailability of pipe materials and delayed delivery of pumping unit sometimes results in a considerable time overrun. Other major risk categories for project achievement are financial, economic, and political risk (F&ER) and organizational risk. Among F&ER, fund flow problems and improper estimates are the major causes of concerns. All the packages are equally vulnerable from fund flow problems. However, the river crossing and pipeline laying packages are prone to problems from improper estimates because there are more uncertainties in the design and implementation methodology selection. Although the organizational risk is less vulnerable for the project under study, consultant and contractor's. The capability of the owner's project group is required for achievement of all the work packages.

Although the project under study is not that vulnerable from statutory clearance risk, care should be taken in getting environmental clearance and explosive clearance on time for a trouble free implementation.

Normal and abnormal calamities are the part and parcel of any pipeline project. Many times these are rated as unimportant and not likely to occur. However, these factors are vulnerable for all work packages with a high probability of failure. The major factors for possible failure are changes in scope, changes in engineering and design, fund availability, vendor capability, abnormal natural calamity and land acquisition. The river crossing work package with the second highest probability. The main contributing factors are scope changes, implementation methodology selection, engineering and design change, and improper estimates.

4.2 RISK MAPPING:

All the factors were organized as per their probability and severity characteristics as indicated in table [5]. The factor scope change has been identified as the most vulnerable for the project under study as it has a high severity. If there is a change in scope of any work packages, there will be considerable implications on design, planning, and implementation of the program. These will cause considerable time and cost overruns in the project. Factors like land acquisition, technology selection, engineering and design changes, contractor capability, vendor capability and abnormal calamity are rated as having medium probability as adequate planning for the project under study prompts the executives to perceive these factors as less vulnerable. However, the project will end up experiencing a major time and cost overrun, if any of the above factors occur during the project implementation. Implementation methodology, fund risk, improper estimate, and material risk are rated as having medium probability of occurrence, as well as severity. The other factors are perceived as either low probability or low severity. The factors, which have, low probability and high severity. The factors that have low probability and high severity should be handled carefully with the development of contingency plans.

4.3 RISK RESPONSES:

- Carrying out a detailed survey with the objective of minimum scope and design change.
- Select technology and implementation methodology on the basis of the ability of owner/consultant expertise, availability of contractors and vendors and life cycle costing.
- Executive design and detailed engineering on the basis of selected technology and implementation methodology and a detailed survey.
- Select superior contractors, consultants and vendors on the basis of past performance.
- Schedule project by accommodating seasonal calamities.

Table.5 RISK MAPPING IN PROJECT LEVEL

Severity	Low	Medium	High
High	Calamity Normal	Land Acquisition Technology Selection Engineering & design Contractors capability Vendors capability Calamity abnormal	Scope Change
Medium	Change in policy Capability of client Consultants ability	Implementation methodology Fund risk Improper Estimate Materials risk	
Low	Inflation risk Environmental clearance CCE clearance Other clearances		

Probability

- Plan contingencies and acquire insurance.
- Ensure the availability of all statutory clearances before doing design and detailed engineering work.

The cost data for each work package against various responses is indicated in table [6]. The decision alternatives are derived based on the cost data of the project.

4.4 DECISION ALTERNATIVES AGAINST RISK RESPONSES

- Do nothing
- Carrying out detailed survey
- Using superior technology
- Engaging an expert project team, and
- Taking all responses

The probability and severity for each decision alternative are derived from the Decision Tree Analysis study of the four packages.

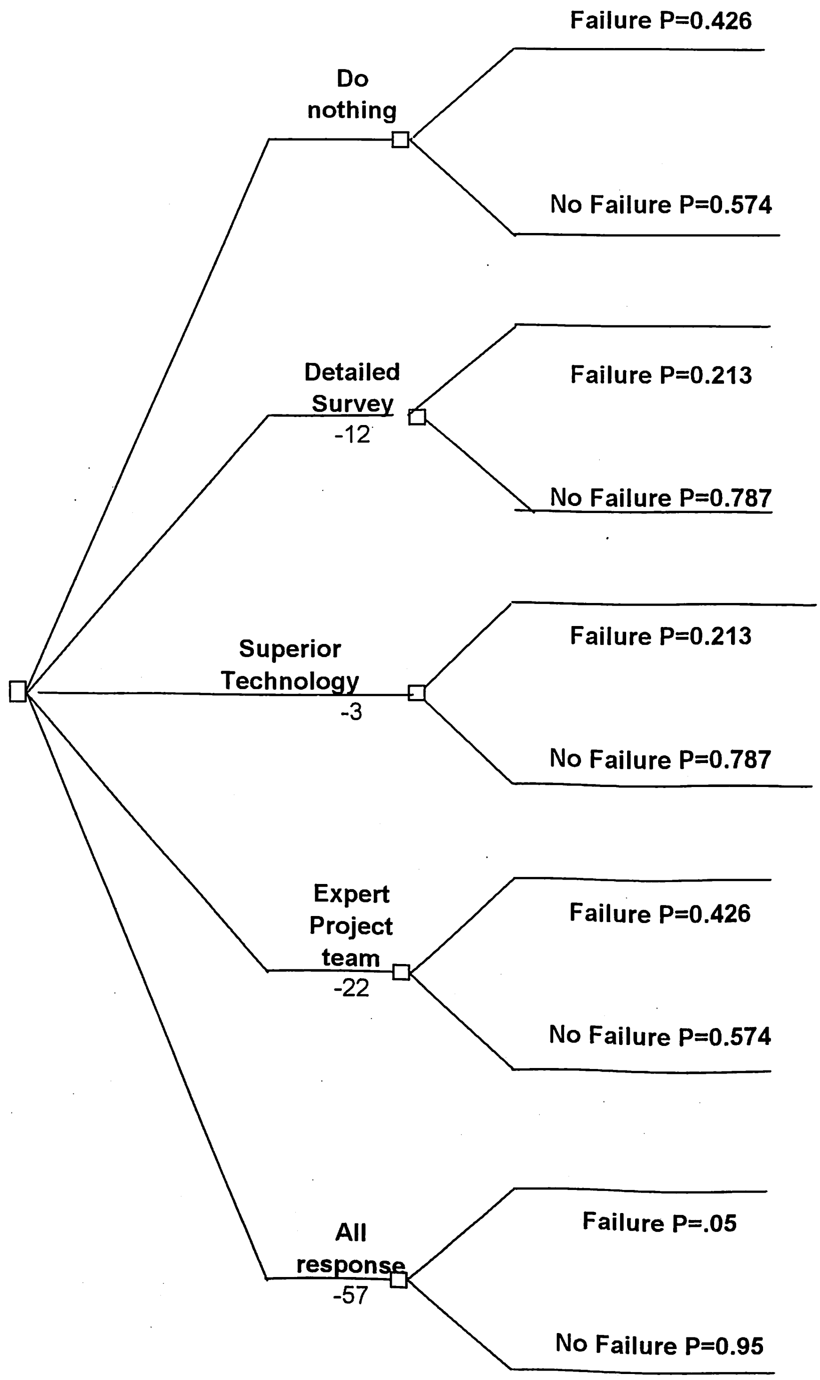
4.5 DECISIONS EMERGE FROM THE DECISION TREE APPROACH FOR EACH WORK PACKAGE:

WORK PACKAGE	RISK RESPONSES
Pipeline Laying	Carrying out detailed survey
Pipeline laying across river	Using detailed survey and superior technology
Station construction	Engaging expert project team
Telecommunication & cathodic protection	All responses
Total cost for risk responses is Rupees Forty Eight Crores, which is much lower than the project estimate amount of Rupees One hundred and forty eight crores.	

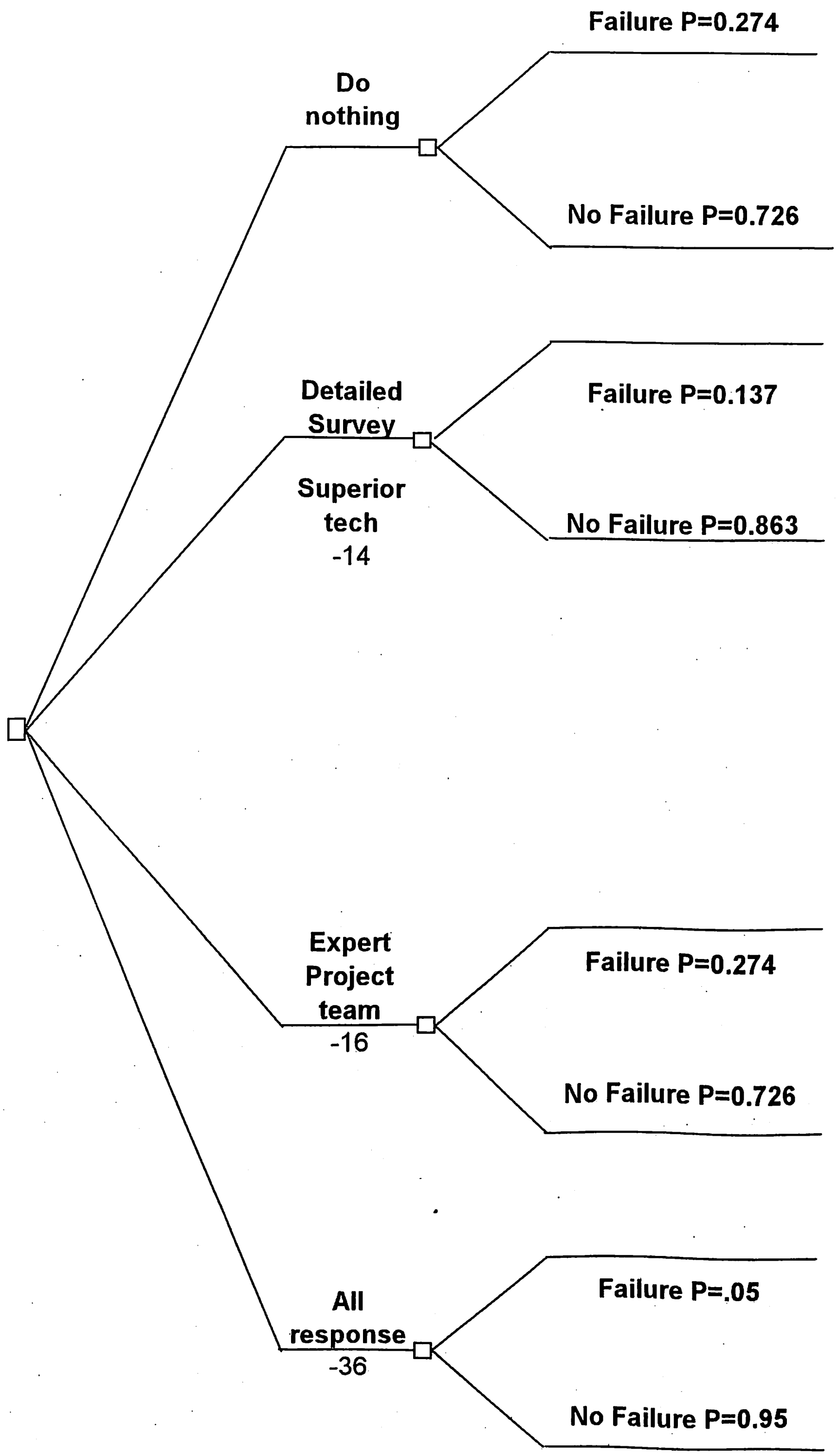
Table 6.THE COST DATA (in crores) FOR EACH PACKAGE AGAINST VARIOUS RESPONSES

Responses	Pipeline Laying	River crossing	station construction	Telecommunication & CP	Building & colony construction
Carrying out detailed survey with minimum scope change	12	8	6	3	3
Selecting technology and implementation methodology	3	6	4	2	2
Executing design and detailed engineering	1	2	3	1	1
Selecting contractors, consultants and vendors on the basis of best performance	22	16	10	2	2
Scheduling projects by accomadating seasonal calamities	6	-	4	-	-
Planning contingencies and acquiring insurance	11	2	6	1	1
Acquiring statutory clearance before design and detailed engineering	2	2	2	1	1
Total	57	36	35	10	10
Grand Total	148				

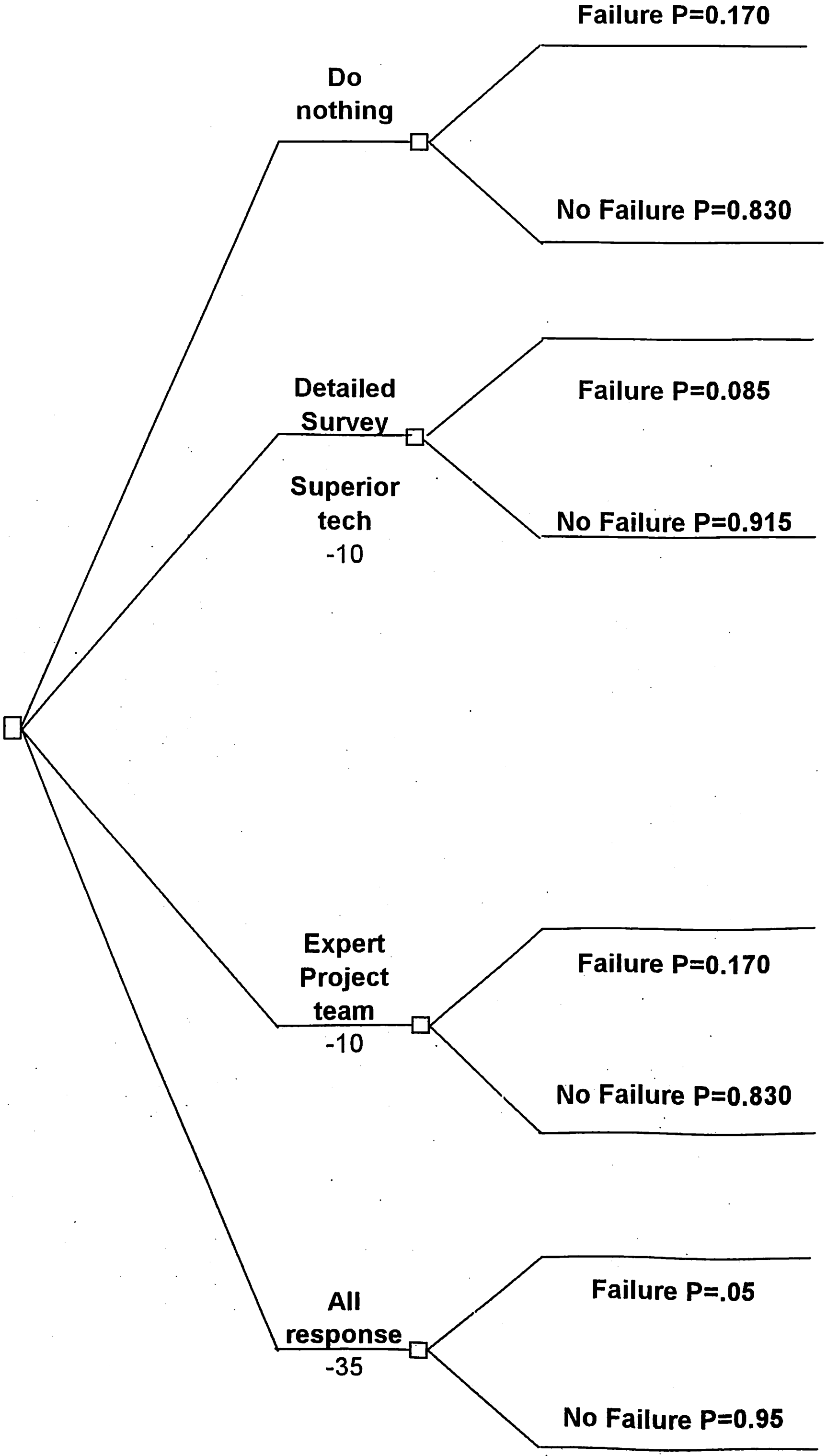
Source : Gammon India ltd



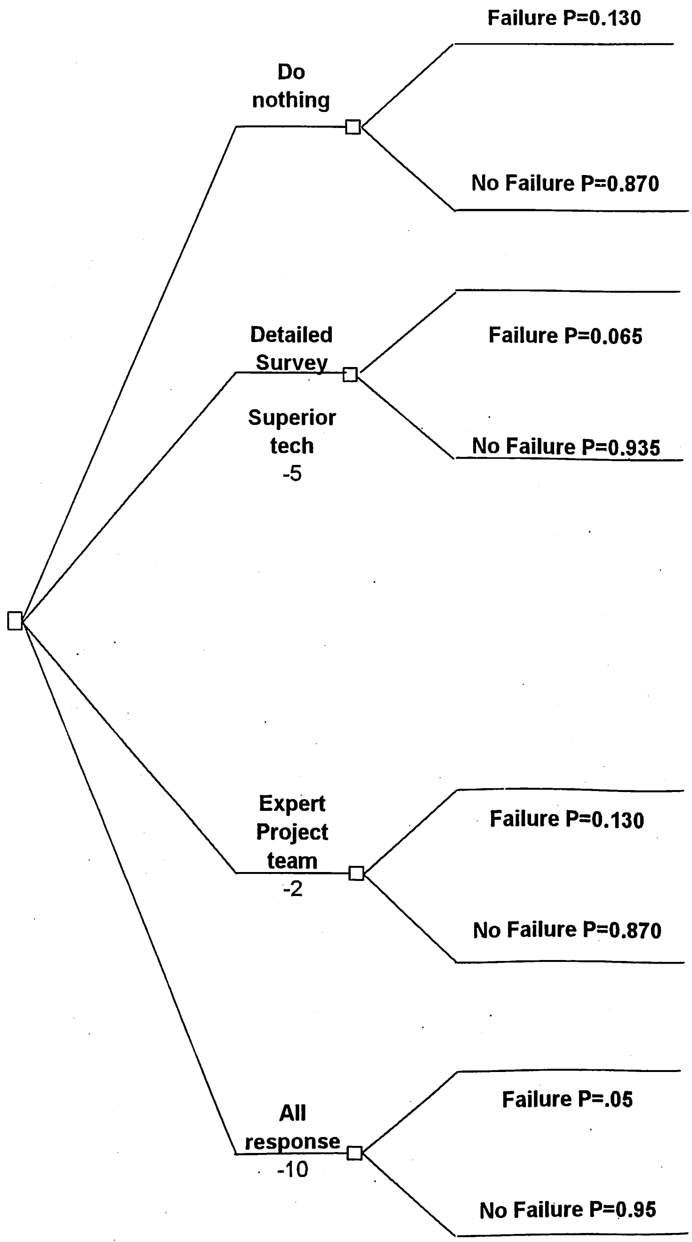
Decision Tree for Pipeline Laying Work Package



Decision Tree for River Crossing Work Package



Decision Tree for Station Construction Work Package



Decision Tree for Telecommunication & Cathodic Protection Work Package

CHAPTER – 5
CONCLUSION

Conventional risk analysis quantifies risk by determining exclusively the probability of occurrences and severity of scenario. It does not deal with Cost spent and Time involved in the Pipeline laying project.

By using the combined Analytic Hierarchy Process (AHP) and Decision Tree Analysis (DTA), approach not only determines probability and severity of risk factors, but also identifies risk responses for each work package like pipeline laying, river crossing, station construction and telecommunication & cathodic protection.

The results of this study on every work package of the pipeline-laying project implies the success rate of the project can be enhanced from 0.75 to 0.858 (88.24% increase in success rate)

By adopting this methodology, the result states that the elimination of time and cost overrun in the pipeline project is achievable.

CHAPTER – 6

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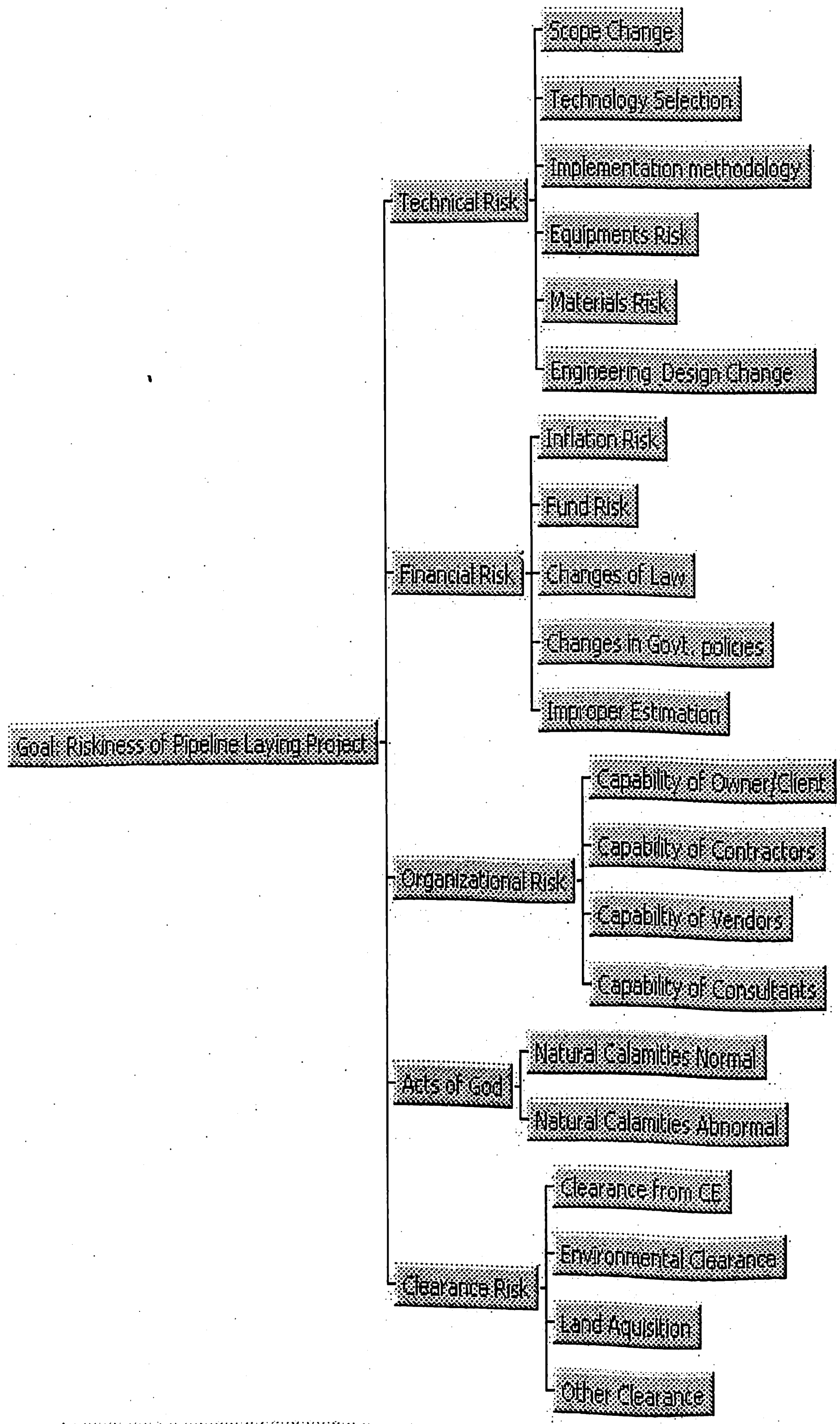
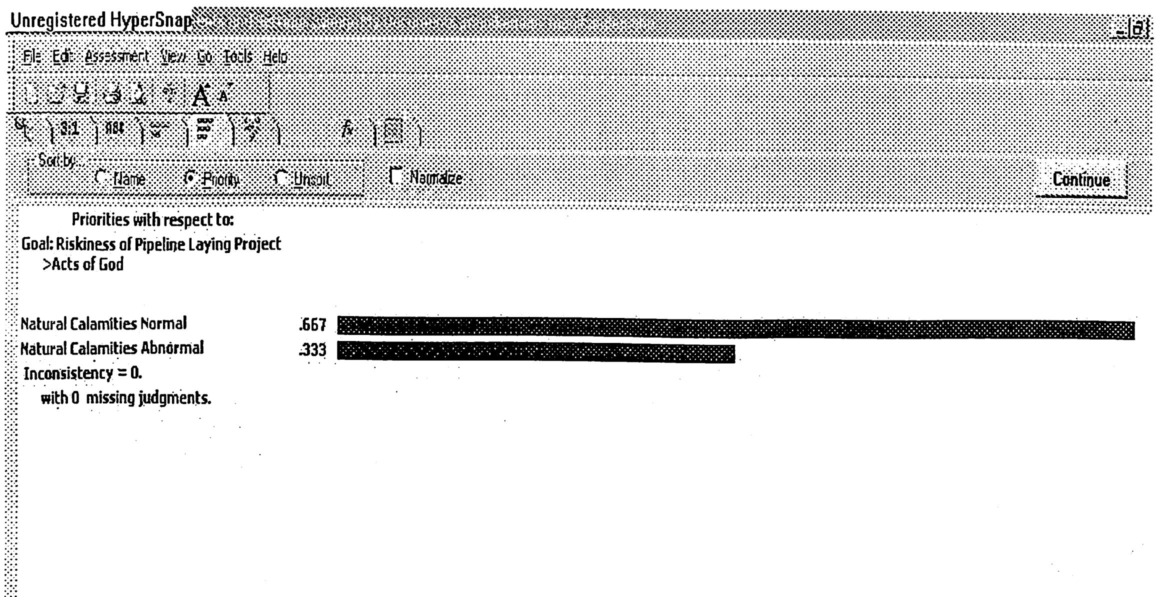
ANNEXURE I

Unregistered HyperSnap

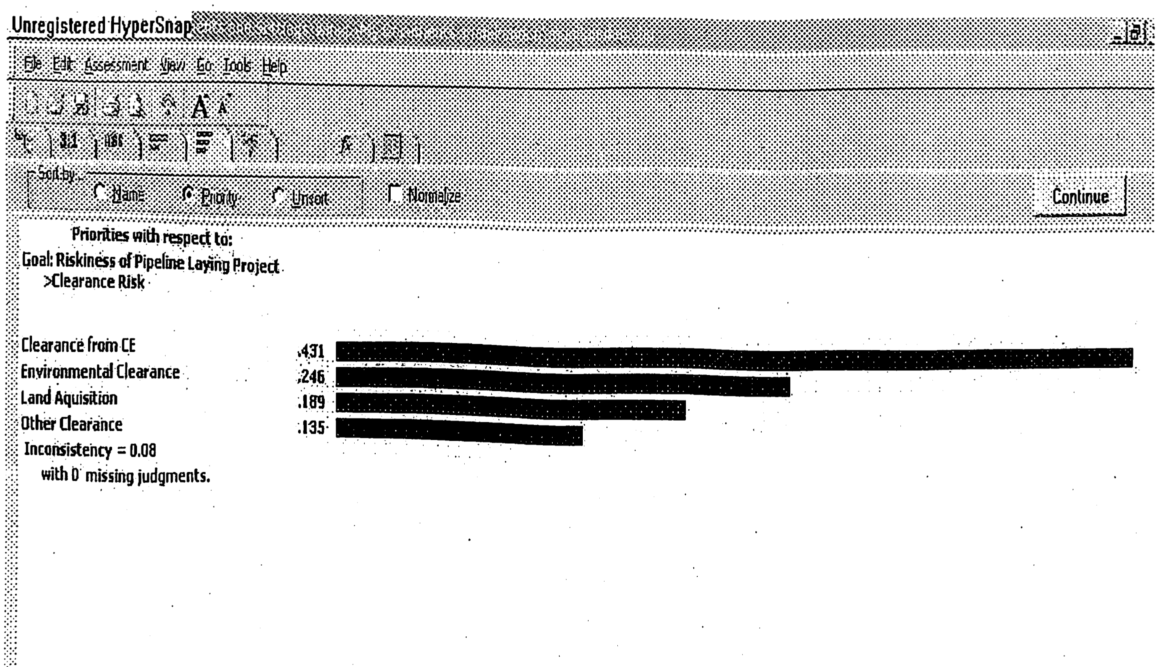


ANALYTICAL HIERARCHY PROCESS (AHP) MODEL FOR RISK DETERMINATION IN PIPELINE LAYING PROJECTS

ANNEXURE II

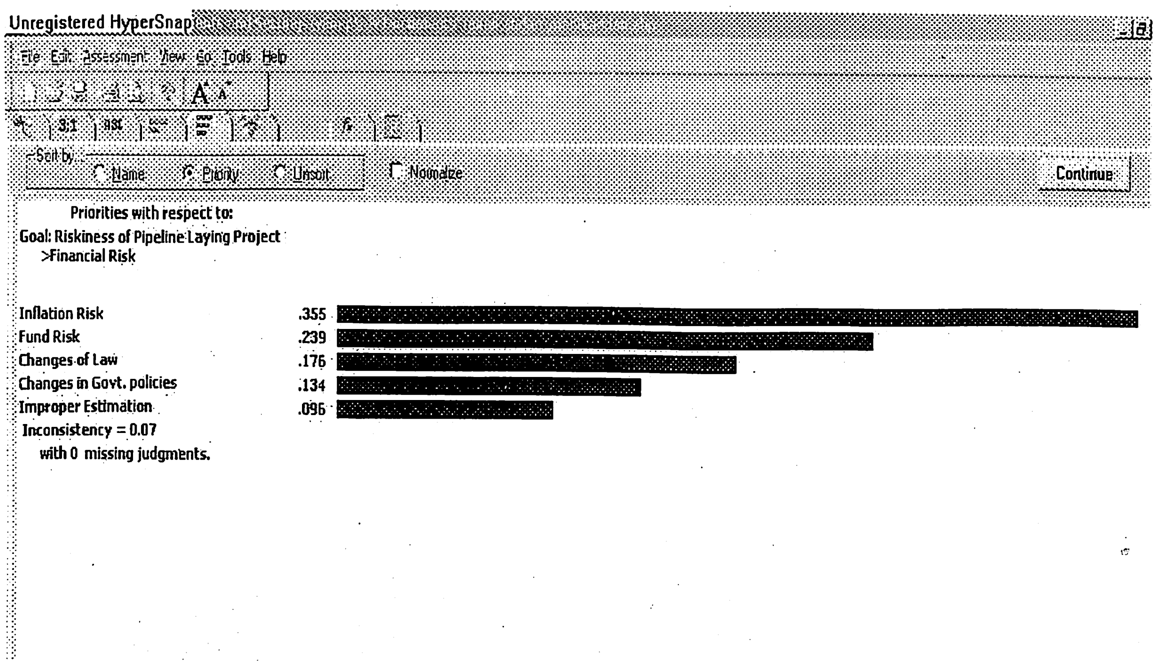


PRIORITIES WITH RESPECT TO: RISK OF PIPELINE LAYING PROJECT Vs ACTS OF GOD

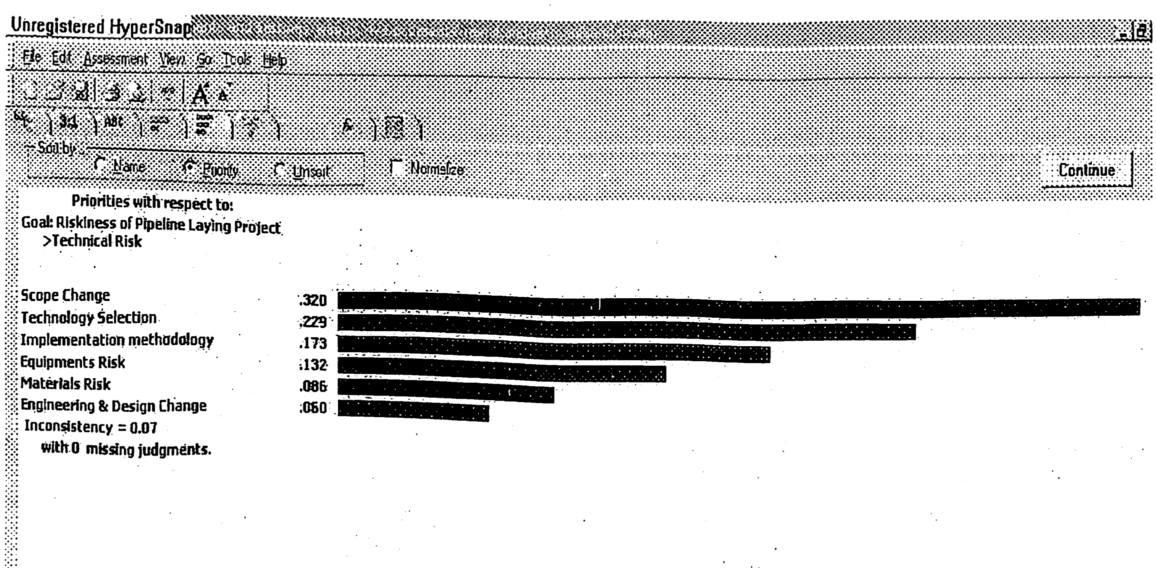


PRIORITIES WITH RESPECT TO: RISK OF PIPELINE LAYING PROJECT Vs CLEARANCE RISK

ANNEXURE III

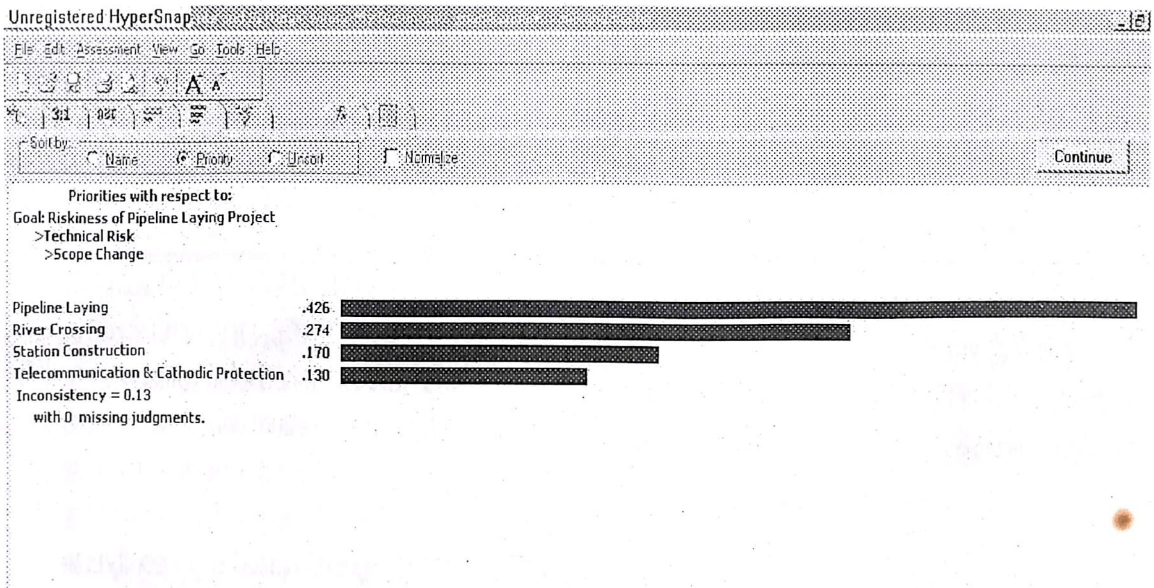


PRIORITIES WITH RESPECT TO: RISK OF PIPELINE LAYING PROJECT Vs FINANCIAL RISK

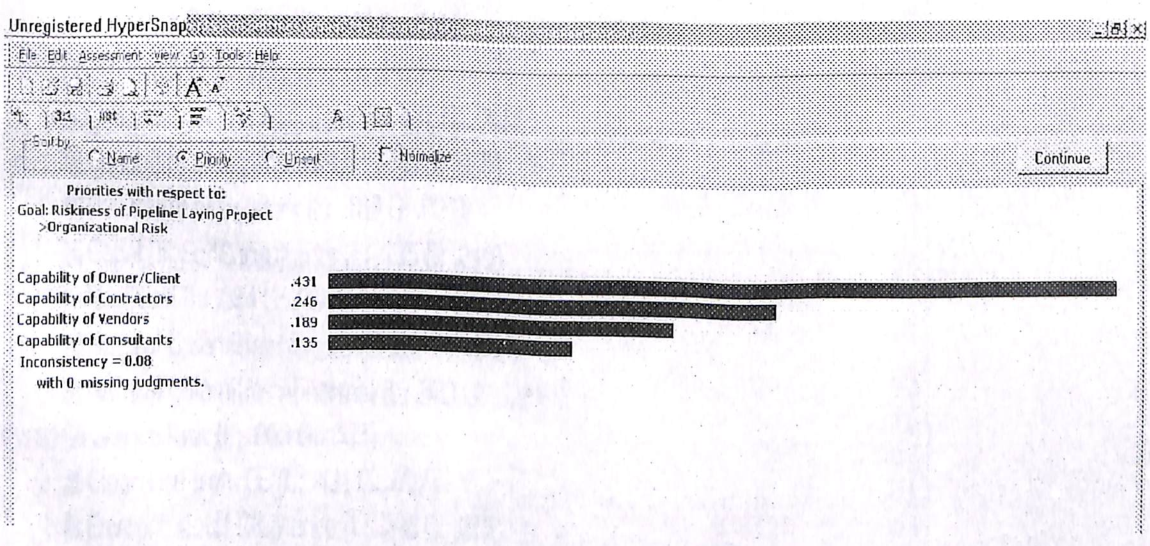


PRIORITIES WITH RESPECT TO: RISK OF PIPELINE LAYING PROJECT VS TECHNICAL RISK

ANNEXURE IV

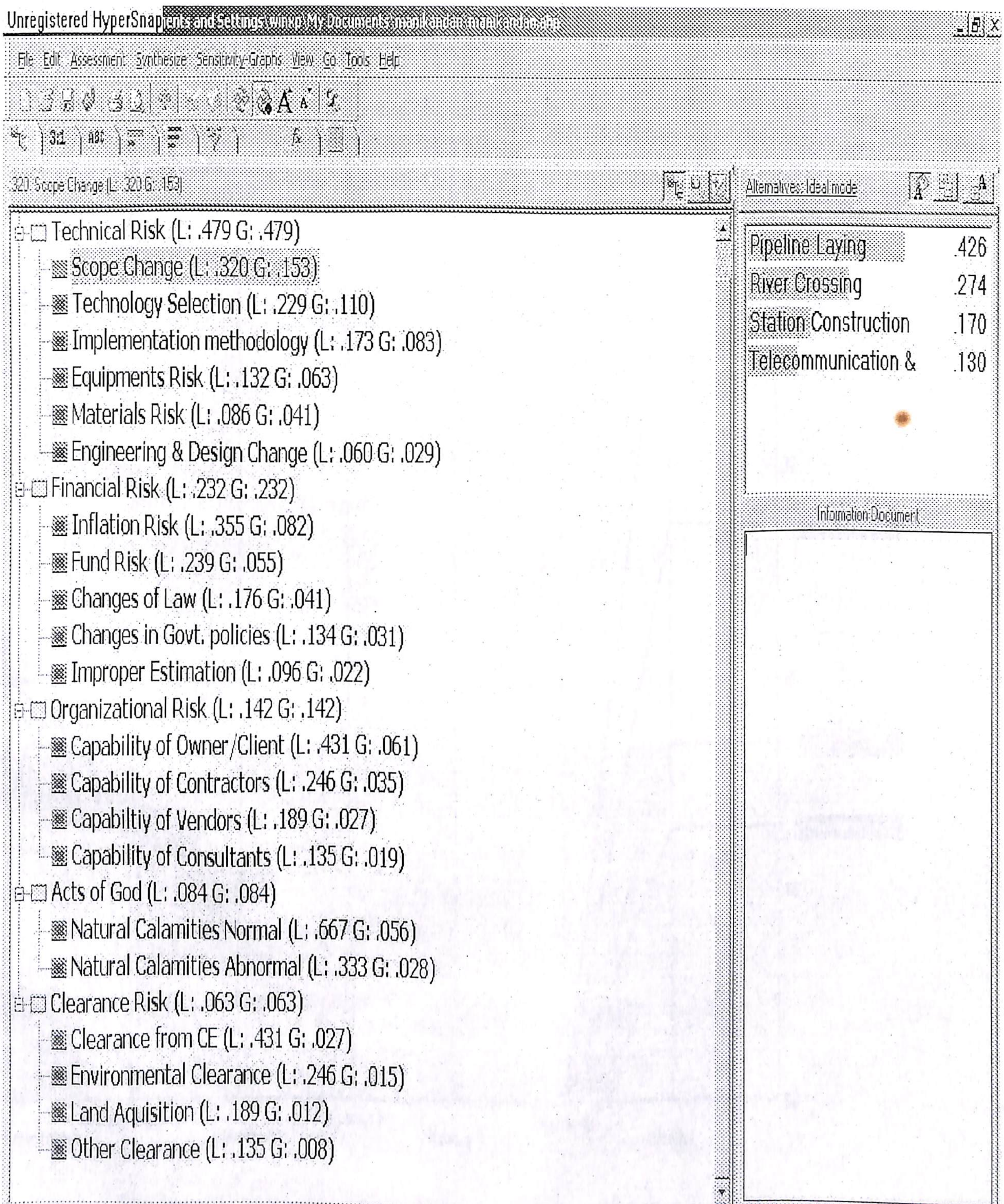


PRIORITIES WITH RESPECT TO: RISK OF PIPELINE LAYING PROJECT Vs SUB FACTORS



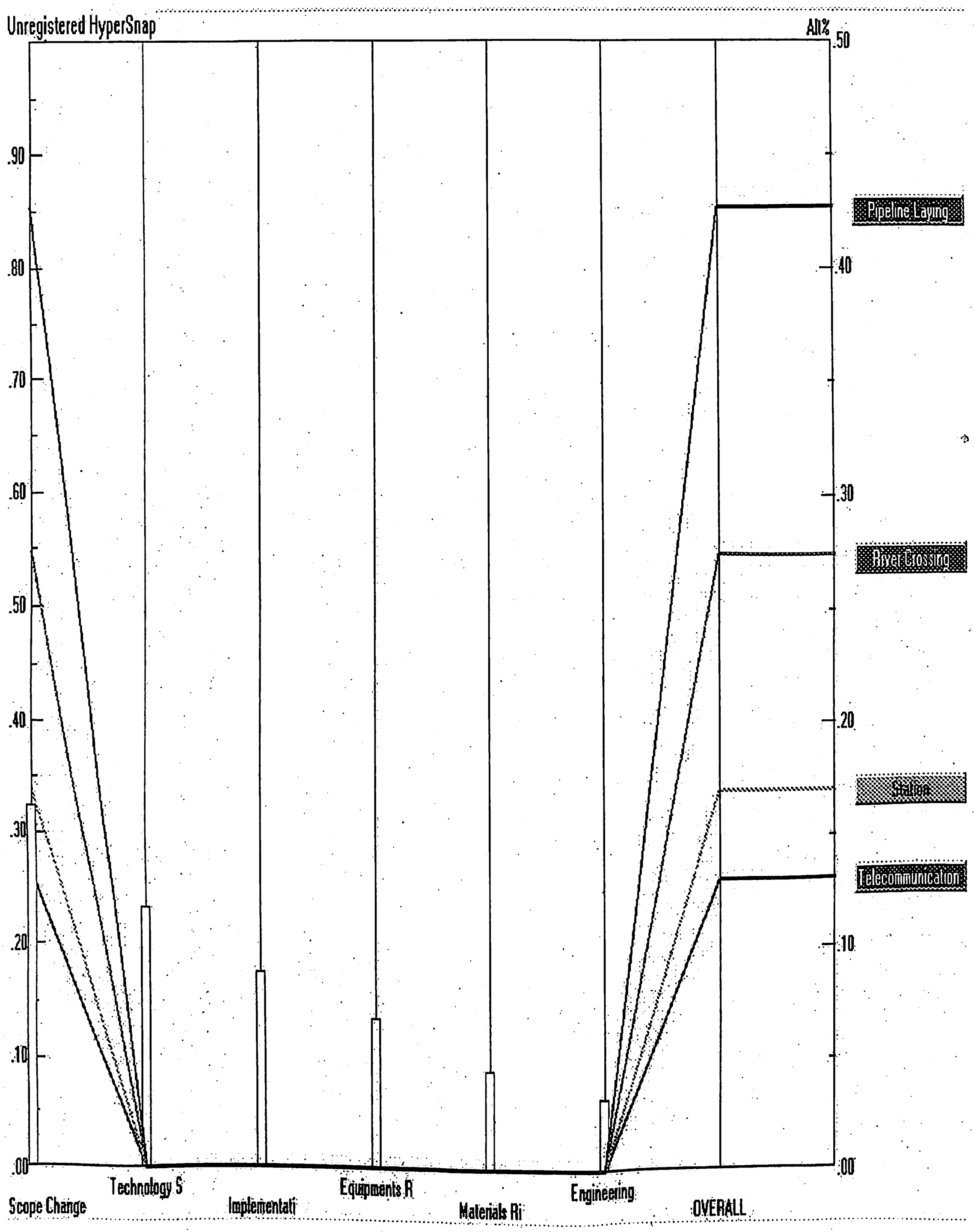
PRIORITIES WITH RESPECT TO: RISK OF PIPELINE LAYING PROJECT Vs ORGANIZATIONAL RISK.

ANNEXURE V



OVERALL LIKELIHOOD OF RISK IN THE PROJECT

ANNEXURE VI



PERFORMANCE SENSITIVITY ANALYSIS