MANAGING RISK IN ENGINEERING PROJECTS

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ABSTRACT: *In order to guide management in making better decisions, decorous project decision-making require risk management and risk analysis techniques be applied. As a result of uncertainty as well as hazard there are risks inherent in all engineering projects. Decision making under uncertainty literally encompasses every aspect of engineering projects. No project is risk free. Risk can be managed, minimised, shared, transferred or accepted; it cannot be ignored (Sir Michael Latham, 1994). Risks are assessed against criteria defined before or during risk analysis and ranking. Once ranked, the risks are almost easily displayed on a likelihood impact-matrix that serves as a clear communication tool, allowing everyone to be able to understand the level of risk. Risk management processes described include risk planning, identification, analysis, response and monitoring. If implemented correctly, a successful risk mitigation strategy should reduce negative impacts. The purpose of this paper is to describe the risk management process and why it is important to determine and quantify the risk involved in any project or venture. Such that decisions can be made to counter or mitigate and make allowances for potential detrimental events.*

Keywords: Risk, Risk Management, Opportunity, Threat, Planning, Identification, Analysis, Response, Monitoring, Mitigate.
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INTRODUCTION

Risk assessment provides users with understanding of the causal events and the way they can lead project failures, health, safety and environment in general. Engineering projects are high-stakes games characterized by substantial irreversible commitments, skewed reward structures in case of success, and high probabilities of failure. No project is risk free. Risk can be managed, minimised, shared, transferred or accepted; it cannot be ignored (Sir Michael Latham, 1994). The process becomes risk management if the knowledge is used to decide whether to change the initial assumptions or projections on the project duration to reduce risk, and those decisions are implemented.

The prediction of risk in business is essential to ensure the survival of a business. Predicting risk depends on the information available and the processes involved in manipulating the information (John Dean, 2012). Managers are normally responsible for predicting risk. They acknowledge the process of using their experience and 'gut feeling' to identify and mitigate risk. The purpose of this article is to demonstrate the steps for systematic risk management.

RISK

A myriad of risk and risk-related definitions are applied to construction projects, and no standard definitions or procedures exist for what constitutes a risk assessment. Risks are future events with a probability of occurrence and a potential for loss.

> *Risk: An uncertain event or condition that if it occurs, has a positive or negative effect on a project objective (US project Management Institute, 2000).*

> *Risk: An uncertain event or set of circumstances that, should it occur, will have an effect on the project's objectives (UK Association of Project Management, 1997).*

Risk is also defined as the exposure to the chance of occurrences of events adversely or favourably affecting project objectives as a consequence of uncertainty (Al-Bahar, 1990). Dias and Ioannou (1995) concluded that there are two types of risk:

1) **Pure Risk:** When there is the possibility of financial loss but no possibility of financial gain.

2) **Speculative Risk:** That involves the possibility of both gains and losses.

Uncertainty of the Event

Uncertain event has a positive (opportunity) or negative consequence (threat) on at least one of the project objectives (strategic, project, operational).

Opportunity is a risk that has a positive effect. Project Managers will look for ways to enhance / exploit / share the effects of an opportunity.

Threat is a risk that has a negative effect. Project Managers will look for ways to reduce/eliminate the effects of a threat.

Risk can often be expressed in terms of probability and impact.

$$Risk = f\,(probability, impact)$$

In the construction industry, risk is often referred to as the presence of potential or actual treats or opportunities that

influence the objectives of a project during construction, commissioning, or at time of use (RAMP, 1998).

Risks can be avoided, negated or have their impacts reduced.

RISK MANAGEMENT

Risk Management is a systematic action-oriented process of identifying, analysing, assessing, prioritising, treating and monitoring risk events that may prohibit an organisation from achieving its objectives and may adversely impact of the economic, effective or efficient delivery of its operations.

These risks may have financial implications such as those associated with injuries to staff and other parties, damage and theft of equipment, or matters that expose an organisation to litigation.

- *Risk Management: is the process of balancing the detrimental and favourable events for a given project or venture.*

- *It is the process of determining and quantifying the risk involved in any project or venture. Such that decisions can be made to encounter or mitigate and make allowances for potential detrimental events.*

- *Risk Management: is the process of systematically identifying, analysing and responding to risk events throughout the life of a project to obtain the optimum or acceptable degree of risk control.*

BALANCING RISKS AND OPPORTUNITIES

Generally,

- High risk means – High profit or loss.
- Low risk means – Minimum profit or loss.

Risk management must be initiated early in the project life cycle to achieve full value by minimizing risk at source and optimizing capital investment.

Risk Management (RM) Process

Step 1: Planning for risk Management
Step 2: Risk identification
Step 3: Risk analysis
Step 4: Risk Response planning
Step 5: Risk Monitoring

Step 1: Planning for Risk Management

- Decide on a risk management methodology.
- Define risk management roles and responsibilities.
- Identify risk assumptions.
- Define risk management timeframes.

- Define risk communication strategy.
- Define how risks are to be tracked.
- Define any risk thresholds/tolerance.
- Define ranking/scoring techniques.

Output: Risk Management Plan (RMP)

Step 2: Risk Identification

Objective: to determine the risks that may affect the project and document their characteristics.

Output: Risk Register

Table 1: Risk register

Risk ID	Risk Description	Status (Active, Dormant, Retired)	Project Phase	Date Identified
001	Vendor not meeting deadline - will mean that the budget will be exceeded	Active	Execution	01/09/2014

- **Identification Methods:**
  - Documentation reviews
  - Information-gathering techniques
    - Brainstorming
    - Delphi Technique
    - Interviewing
    - Root Cause Analysis
    - SWOT analysis
  - Checklists
  - Assumptions analysis
  - Diagramming techniques
    - Cause-and-effect diagrams
    - Influence diagrams
    - System or process flow charts

Documentation Reviews:

Performing a structured review of:

Objective sources - Project plans and assumptions
- Lessons learned files
- Current performance data
- Current performance data
- Programme documentations evaluation

Subjective sources - Information gathering techniques (-next point-)

Information-Gathering Methods:

- **Brainstorming:**
  - Probably the most frequently used risk identification technique.
  - Group thinking (multidisciplinary set of experts) rather than individual thinking.
  - Avoid criticism during brainstorming.

• **Outputs:**

A comprehensive list of risks, Understand stakeholders' views about the risks identified.

- **Delphi Technique**
  - A method by which a consensus of experts can be reached on a subject such as project risk. Project risk experts are identified but participate anonymously.
  - Helps reduce bias and minimises the influence of any one person on the outcome.
  - A facilitator uses a questionnaire to solicit ideas about the important project risks.
  - The experts answer the questionnaire in two or more rounds
  - After each round, the facilitator provides an anonymous summary of the experts' forecasts (risks).
  - Risks are then circulated to the experts for further comment.
  - Consensus on the main project risks may be reached after a few rounds of this process.

- **Interviewing**

  - Experienced project managers or with experts in the field.
  - Interviewees identify risks on the project based on their experience, the project information, and any other sources that they find useful.
  - Risk profile with specific questions help stimulate interviewee.

Example of Risks

- **Financial Risks:** Exchange rate may worsen making the project less profitable, inflation.

- **Physical Risks:** Accidents, injuries, unusual ground conditions resulting in the necessity to redesign the foundations.

- **Schedule Risks:** Very optimistic schedule estimates leading to higher actual costs.

- **Act of God:** Unpredictable risks beyond human control e.g. Bad weather resulting in schedule slippage.

- **Political:** Law changes, civil disorder.

- **SWOT analysis**

Table 2: SWOT Analysis Example

Strengths	Weaknesses
Good Leadership and Management	Management Skills
Client Satisfaction	Risk Management
Staff Expertise/Commitment	Repeatable Processes & Methods
Product and Service Mix	Access to Capital
Opportunities	**Threats**
Strategic Alliances	Competitors
New markets opening	Economic Conditions
Product and Service Additions	Government Policies
Injection of Government's funds	Vendor Policies
Competitor in administration	

Checklists:

- In-house lists of risks that have been on previous similar project.
- Useful to ensure that risks identified on previous projects are not overlooked.

Example of Check Lists:

- Personnel shortfall that cause technical failures.
- Unrealistic schedule that results in delays.
- Developing the wrong software functions so the product is rejected by clients.
- Excessive requirement changes that ….
- Shortfalls in externally performed tasks (e.g. sub-contract).

Assumptions Analysis

- Consider the assumptions or scenarios used in the project plan.
- Explores assumptions' accuracy by identifying risks to the project from inaccuracy, inconsistency or incompleteness of assumptions.

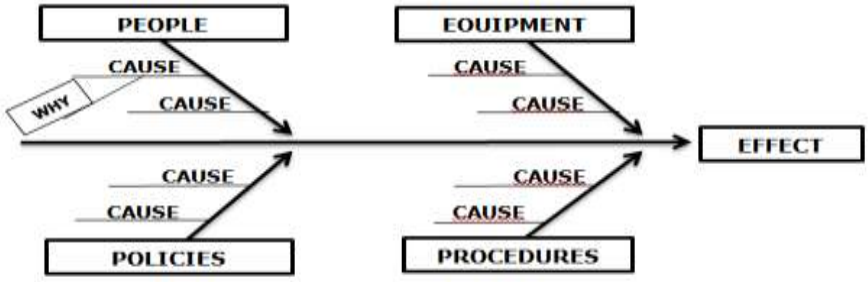
Example of Assumptions:

- Interest rate not greater than 3%.
- Crude oil price not greater than $ 100 / barrel.

Diagramming Methods

- Cause-and-effect diagrams
- Influence diagrams
- System or process flow charts

Cause-and-Effect Diagrams



(FIG. 1 ISHIKAWA OR "FISHBONE" DIAGRAM)

Influence Diagrams

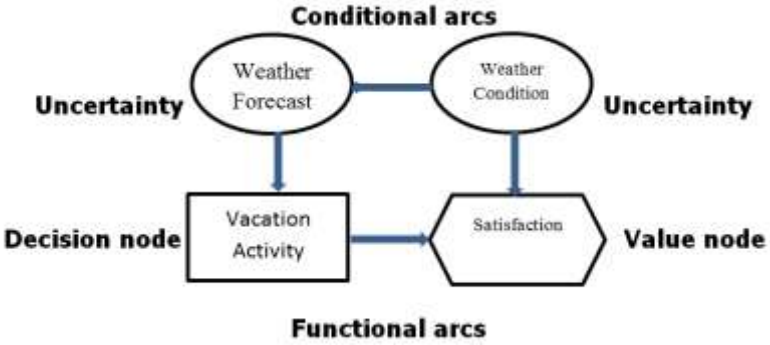


Fig. 2

System or Process Flow Charts:

• Explains how a system works using a diagram.

- Diagrams show the flow of data through a system and how decisions are made to control events.

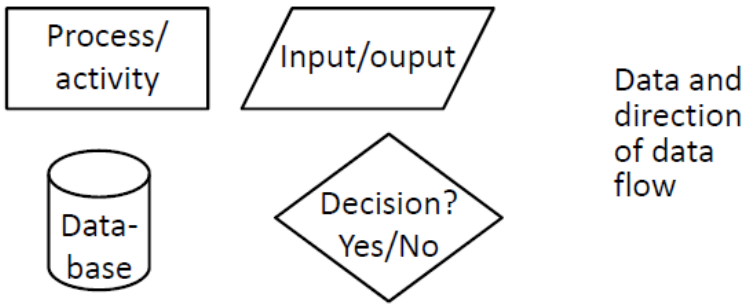


Fig. 3:

Step 3: Risk Analysis

Objective: to examine each identified risk to estimate the probability and predict the impact on the project.

The risk analysis method used in engineering projects is based on qualitative and quantitative analyses and allows determination of the risk of project failure under normal or abnormal executing conditions.

- **Qualitative Risk Analysis:** Prioritising risks for subsequent further analysis or action by assessing and combining their probability of occurrence and impact.

- **Quantitative risk analysis:** analyses numerically the effect a project risk has on a project objective.

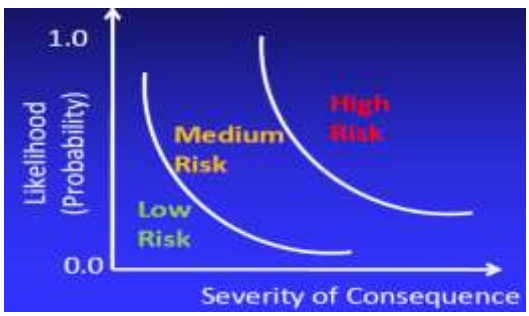
Output: Updated Risk Register

Qualitative Risk Analysis

- **Probability/Impact/Risk Rating Matrix:**
  A common method to determine whether a risk is considered low (L), moderate (M), or high (H) by combining the two dimensions of a risk: its probability of occurrence, and its impact on objectives if it occurs.

In qualitative risk analysis method, risks are assessed for likelihood and impact to establish a ranking for each, even when a specific value is not possible or appropriate. Once ranked, the risks are most easily displayed on a likelihood-impact matrix that serves as a clear communication tool, allowing anyone to be able to understand the level of associated risk.

The matrix can be coloured to highlight the most important risks as shown in figure 4 and 5.



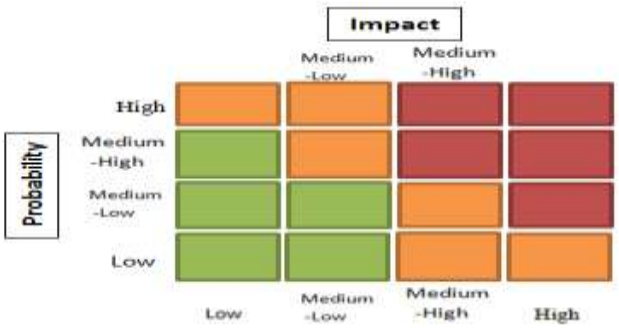


Fig. 4 & 5 Relative Raking of Project Risk
(Dawood and Kaseem, 2012 and Royal Academic of Eng., 1992)

Quantitative Risk Analysis

The quantitative risk analysis helps in:

- Identification of hazards.
- Quantifying the financial consequences if the hazard occurs.
- Determination of the probability of occurrence.
- Calculating the risk and prioritising in order of importance.

The above processes are presented in figure form as shown in fig. 6.

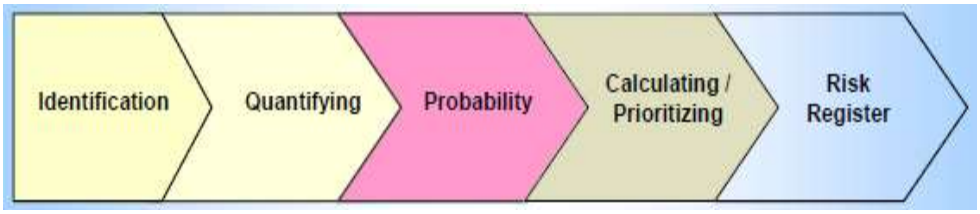


Fig. 6: Quantitative Risk Analysis Process.

Quantitative risk analysis assigns a projected value (usually this value is stated in terms of cost or time) to the risks that have already being ranked in qualitative risk analyses.

Table 3: Example of Quantitative Analysis Ranking

Risk ID	Potential Loss	Probability	Risk Value	Rank
1	N150,000	1 in 50	N3, 500	3
2	N1,500,000	1 in 100	N25,000	2
3	N200,000	1 in 5	N50,000	1

Quantitative risk analysis techniques can be performed using the following methods:

- Interviewing and expert judgment
- Payoff matrices
- Decision analysis (i.e. Decisions Tree)
- Sensitivity Analysis
- Expected monetary value analysis,
- Network Analysis (e.g. PERT)
- Simulations (Monte Carlo analysis).

Payoff Matrices/ Tables (Example)

Decision Alternatives	State of Nature		
	S1	S2	S3
d1	C11	C12	C13
d2	C21	C22	C23
d3	C31	C32	C33

Conditional Outcomes

- Minimax regret
- Maximin Criterion
- Maximax Criterion
- Expected Monetary Value
- Utility Function

Table 4: Payoff matrices table

- Consider the 3 decision alternatives in table 4:

  d1 = make investment A

  d2 = make investment B

  d3 = do not invest

Decision Alternative	State of Nature		
d1	S1	S2	S3
d2			
d3			

Table 5: Payoff table example

- The states of nature are:

  S1 = prices go up ..... P (s1) = 0.3
  S2 = prices remain stable ..... P (s2) = 0.5
  S3 = prices go down ..... P (s3) = 0.2

Decision Alternatives	State of Nature		
	S1 (prices go up)	S2 (prices go up)	S3 (prices go up)
d1 (make investment	30,000	20,000	-50,000
d2 (make investment	50,000	-20,000	-30,000
d3 (make investment	0	0	0
	P(S1) = 0.30	P(S2) = 0.50	P(S3) = 0.20

(Table 6)

Based on **Expected Monetary Value**

EV (d1) = C11 * P(S1) + C12 * P(S2) + C13 * P(S3)
EV (d1) = 0.3(30,000) + 0.5(20,000) + 0.2(-50,000) = 9,000
EV (d2) = 0.3(50,000) + 0.5(-20,000) + 0.2(-30,000) = -1,000
EV (d3) = 0.3(0) + 0.5(0) + 0.2(0) = 0

According to the expected value, **project d1** should be selected.

Sensitivity Analysis

- Used to determine how changes in the probability of an uncertain event affect the decision alternatives (output).
- Done by changing the value of one of the uncertainties (input) while maintaining the others constant.
- Help the decision maker to understand which of these inputs are critical to the choice of the best decision alternative.

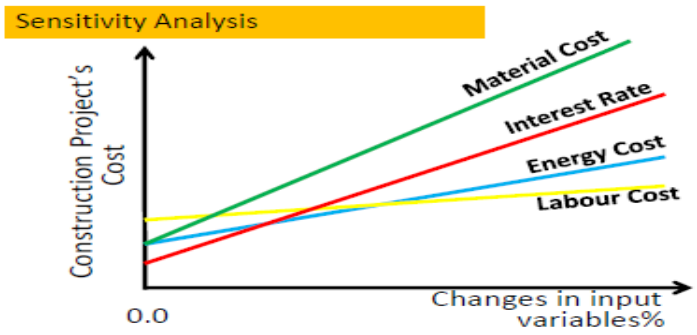


Fig. 7: Showing the Risk Factors

The project is most sensitive to one of the risk factors shown in fig. 7.

Step 4: Risk Response planning

Is the process of developing options and actions to enhance opportunities and to reduce threats to the project objectives.

Risk Response should be:

- Proactive, not reactive
- Appropriate to significance of risk
- Timely and Cost effective
- Realistic within project context
- Agreed upon by project team and all parties involved
- Assigned to / owned by a responsible person

- **Avoid Risks:** Eliminate risk by accepting another alternative (e.g. change design, change a requirement).

- **Mitigate Risk:** Reducing the probability or Impact of an adverse risk event (threat) to an acceptable threshold.

- **Transfer Risk:** Reducing the probability or Impact by transferring ownership of all or part of the risk to another party.

- **Exploit Opportunity:** Seizing an opportunity to ensure that the opportunity will happen and that the impact will happen.

- **Share Risk/Opportunity:** Share with another party who can increase / decrease the probability and impact of opportunities / risks.

- **Enhance Opportunity:** Enhance probability and impact that the event happens.

Step 5: Risk Monitoring & Control

- Risk responses have been implemented as planned.
- Risk response actions are as effective as expected or if new responses should be developed.
- Project assumptions are still valid.

- Risk exposure has changed from its prior state, with analysis of trends.
- A risk trigger has occurred.
- New risks have occurred that were not previously identified.

- Tools and technique used
  - **Risk Reassessment:** Risk ratings and prioritization may change during the life of the project. Changes may require additional qualitative or quantitative risk analysis (review at all team meetings or at major milestones).

  - **Risk Audits:** Examine and document the effectiveness of the risk response planning in controlling risk and the effectiveness of the risk owner.
- Recognise the probability and impact of risk events may change during the life of the project.

- Also recognising that additional risks events can be identified during the "work the Plan".

- Track risk event status:
  - Active/Dormant: risk is currently being monitored and analysed.
  - Retired: risk event (trigger) no longer poses a threat to the project.

CONCLUSION

The engineering project risk management can be applied in many different settings. Risk is inherent in the development of any project (construction, manufacturing, services etc.). No project is risk free. Risk can be manage, minimised, shared, transferred or accepted. It cannot be ignored. With the development and implementation of the risk management processes, different aspects of the project can be examined from a number of perspectives and at appropriate point in the project life cycle.

Risk Management must be proactive, continuous and realistic within the project context. However, if it is not done properly, the results can be disastrous as the analysis can severely understate risk and lead to unsatisfactory conclusions about project viability.

ACKNOWLEDGEMENT

This paper work has tried to describe the risk management process in engineering project. Risk analysis is most effective when deployed at the early stage project. Though risk assessment and management is not a substitute for pre-project

planning, project controls or other technical requirement, its deployment will optimise the portfolio of project risk across the entire project risk cycle.

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