Risk Management in Construction Projects

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Risks are unavoidable in almost every construction project whether it is building projects, civil works, or any other type of construction projects. Risk is inherent in all human endeavors, including construction activities, and the risk factors involved are diverse and varied. Managing construction project risks is considered as compulsory for any project to be successful. Thus, this study aims to identify and classify the types of construction project risks, to evaluate the level of construction project risks and finally, to identify the methods available to reduce or mitigate the construction project risks. This study also demonstrates a quantitative approach to Construction Risk Management through Analytical Hierarchy Process (AHP). The entire methodology is explained through a case study of the Delhi metro bridge collapse and its effectiveness in building a speedy and well judged response is demonstrated.

Keywords: Risk management, Construction, AHP

Risks in Construction Projects

Risks are considered as the probability of an unfavorable outcome arising from a decision (Wood, 1977). It is the chance of something happening as a result of a hazard or threat which will impact on business activity or planned event. Risk arises out of uncertainty. It is measured in terms of the likelihood of it happening and the consequences if it does happen. In the construction management domain, Perry and Hayes (1985) defined risk as an exposure to economic loss or gain arising from involvement in the construction process.

Risk management is a discipline that enables people and organizations to cope with uncertainty by taking steps to protect its vital assets and resources. Risk management is the process which is used to avoid, reduce or control risks. There should be a balance between the cost of managing risk and the benefits expected from taking that risk, systematic risk management is a management tool, which requires practical experience and training in the use of the techniques. According to Anthony (1996), systematic risk management helps to identify, assess, and rank risks, making the risks explicit; focus on the major risks of the project; make informed decision on the provision for adversity, e.g. mitigation measures; minimize potential damage should the worst happen; control the uncertain aspects of construction projects; clarify and formalize the company’s role and the roles of others in the risk management process; identify the opportunities to enhance project performance.

Chavas and Paul (2003) expresses effective risk management is a critical component of any winning management strategy. Properly designed, a risk management program allows an organization to actually take on additional risk while growing more securely. Options for treatment of exposure to loss include avoidance, reduction, contractual transfer, insurance transfer, and retention. The most effective treatment of risk usually involves the application of more than one of these methods. Experienced coordination of the selected methods of treatment is essential to effect real change and to accurately monitor results.

Construction professionals need to know how to balance the contingencies of risk with their specific contractual, financial, operational and organizational requirements. In order to achieve this balance, proper risk identification and risk analysis is required. The risk management process entails identifying construction risks and exposures, and formulating an effective risk management strategy to mitigate the potential for loss.

Successful risk management in a project delivery is one of the best practices in modern construction management. Paying attention to the risk aspects in construction project will direct to profitable outcome. This report gives an overview of construction project risks. Risks in construction project are identified and classified into several groups.
Current situation of construction industry

In India, construction accounts for more than 20% gross national product. The decision by the Government to allow 100% foreign direct investment (FDI) in real estate in 2005 has led to significant additional interest and growth, both in the real estate and construction sectors, and because of its size and diversity one might conclude that the industry would be both stable and profitable. This is hardly the case, however, as the construction business instead is known for its high volatility yet relatively slender profit margins.

The reasons for this are easy to understand: fierce competitive pricing exists at all tiers, sectors, and geographies of the industry; while the technical, managerial, and administrative components that characterize today’s construction process are growing more elaborate and expensive.

In spite of these challenging “macro-dynamics,” it is important to recognize that, from a “micro” perspective, all construction projects begin with the best of intentions. Unfortunately, in a highly competitive and complex climate that is fraught with risk, unfavorable outcomes can often plague these projects and their participants. Such outcomes might include cost overruns, budget shortfalls, compromised quality, schedule delays, third-party meddling, confusion about scope of work, smeared reputations, bruised relationships, severe financial hardship, and increased underwriting expenses Meyer (2003).

Troubling situations frequently surface because owners, contractors, designers, oversight agencies, and vendors cannot reliably predict the future, and so are rarely able to assess the true impacts of their decisions until late in the construction program. By then it is often difficult — if not too late — to recover.

The extent to which these construction risks can be successfully identified and managed largely determines whether a project meets its schedule, budget, and quality assurance targets. The intent of this chapter is to discuss project risk; once appropriately identified, project personnel can then better monitor and mitigate these risks, and thereby improve project performance.

The 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. The requirements of continued re-evaluation of problems and the lack of definitive criteria which are practical have also resulted in added costs. Public safety regulations have similar effects, which have been most noticeable in the energy field involving nuclear power plants and coal mining. The situation has created constantly shifting guidelines for engineers, constructors and owners as projects move through the stages of planning to construction. These moving targets add a significant new dimension of uncertainty which can make it virtually impossible to schedule and complete work at budgeted cost. Economic conditions of the past decade have 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.

During periods of economic expansion, major capital expenditures are made by industries and bid up the cost of construction. In order to control costs, some owners attempt to use fixed price contracts so that the risks of unforeseen contingencies related to an overheated economy are passed on to contractors. However, contractors will raise their prices to compensate for the additional risks.

Construction Project Delivery Methodologies

Construction project delivery methods are often misunderstood and misapplied and the efficiency of each type can vary due to a range of variables. At the end of the day, however, picking the best construction project delivery method depends largely depend upon two factors

(1) The type of project (new construction, renovation, repair, sustainability), and

(2) The characteristics and requirements of owner

The ultimate success of a deployed project delivery method depends upon the level of collaboration, quality, and experience of the owner and service provider(s) teams and the consistent, comprehensive application of the selected method and associated supporting information technology.
For the purposes of this discussion, a **project delivery method** is the way construction project is conceptualized, planned, designed, bid, procured, managed, built, and completed thru any warranty period. Application of a robust construction delivery method is a process and process is the key to success.

While there are several types of construction delivery methods, the following are representative of five of the most common, and most efficient.

1. **Design-Bid-Build (DBB)**
2. **Design-Build (DB)**
3. **Construction Management At-Risk (CMAR)**
4. **Integrated Project Delivery (IPD)**
5. **Job Order Contracting (JOC)**

**Risk elements in construction projects**

Risks will be apparent at all stages of the life of a construction project: at appraisal, sanction, construction and operation. The effects, relative impact, and opportunity to avoid, transfer, or retain these uncertainties will change throughout the project. The consideration and assessment of risks therefore needs to be undertaken at all stages of the project so that they can be managed constantly Perry and Hayes (1985).

The development of a construction project is fraught with enormous risks. This is due to the uniqueness of every project, the uncertainties introduced by the project stakeholders, statutory or regulatory protocols and other intrinsic and extrinsic constraints. Risks in the construction project development could constrain the achievement of the key project objectives – time, cost and quality targets Cullen (2005).

In managing construction project risks, determining the types of project risks and classifying it into several groups in which it belongs is a fundamental step as it could enable the assessment process to be carried out later on in determining the level of each risks and the severity effects of it in a project undertakings. Early risk identification ensures that team effort is concentrated in critical areas, focusing the project team’s attention on actions and resources where there is a major risk exposure, or where the greatest time and cost savings can be made through streamlined project management.

Managing construction project risks from the beginning will contribute to early risks response where problems are reduced as they are identified differentiated with traditional approach in project management whereby risks are responded only when problem occurs. This is not good as it will incur a lot of time and cost as well as effort. Risk management is the responsibility of every stakeholders involved in a project.

**Key stakeholders in a construction project**

A project is successful when it achieves its objectives and meets or exceeds the expectations of the stakeholders. But who are the stakeholders? Stakeholders are individuals who either care about or have a vested interest in your project. They are the people who are actively involved with the work of the project or have something to either gain or lose as a result of the project. When you manage a project to add lanes to a highway, motorists are stakeholders who are positively affected. However, you negatively affect residents who live near the highway during your project (with construction noise) and after your project with far reaching implications (increased traffic noise and pollution).

**Note:**

Key stakeholders can make or break the success of a project. Even if all the deliverables are met and the objectives are satisfied, if your key stakeholders aren’t happy, nobody’s happy.

The project sponsor, generally an executive in the organization with the authority to assign resources and enforce decisions regarding the project, is a stakeholder. The customer, subcontractors, suppliers and sometimes even the Government are stakeholders. The project manager, project team members and the managers from other departments in the organization are stakeholders as well. It’s important to identify all the stakeholders in your project upfront. If you leave out an important stakeholder or their department’s function and don’t discover the error until well into the project, it could be a project killer.

Inability to achieve set project objectives has far-reaching implications to all stakeholders in the project (Boyd 2005).
To the client, it could mean added costs over and above those originally agreed upon, and less returns on investment.

To the end-user, the increased costs or poor quality are passed on as higher prices, rental cost, prohibitive running and maintenance costs, etc.

To the professionals, it could result in the loss of confidence reposed in them by clients.

To the contractor, it could mean loss of profit through penalties for non-completion, and negative word of mouth that could jeopardize their chances of getting further jobs, if found to be at fault.

To the construction industry, the prevailing inability to achieve set project objectives due to risks could lead to a perpetuation of the bad reputation of time and cost overruns, inability to procure project finance or procuring at higher costs due to added risks, and clients' disinvestments from the industry to other less risky investment sectors such as shares, bond or foreign investments.

**Risk management activities as applied to project management**

In project management, risk management includes the following activities:

- Planning how risk management will be held in the particular project. Plan should include risk management tasks, responsibilities, activities and budget.
- Assigning a risk officer - a team member other than a project manager who is responsible for foreseeing potential project problems. Typical characteristic of risk officer is a healthy skepticism.
- Maintaining live project risk database. Each risk should have the following attributes: opening date, title, short description, probability and importance. Optionally a risk may have an assigned person responsible for its resolution and a date by which the risk must be resolved.

Figure 1: A sample of the project environment featuring the different kinds of stakeholders involved on a typical project.
• Creating anonymous risk reporting channel. Each team member should have possibility to report risk that he foresees in the project.

• Preparing mitigation plans for risks that are chosen to be mitigated. The purpose of the mitigation plan is to describe how this particular risk will be handled – what, when, by who and how will be done to avoid it or minimize consequences if it becomes a liability.

• Summarizing planned and faced risks, effectiveness of mitigation activities and effort spend for the risk management.

Risk Management Process

Risk management is a discipline that enables people and organizations to cope with uncertainty by taking steps to protect its vital assets and resources. Using a holistic approach in managing construction project risks will facilitate the contractors to accomplish their ultimate goal of producing profitable project by means of achieving the target of good quality, under budget and according to planned schedule. Thus, to manage the construction project risks, definitely there are processes to be followed.

Determining which risks are likely to affect a project and documenting the characteristics of each, constitute a fundamental step in project risk management processes. By identifying and prioritizing potential risk sources at the outset of a project development, pitfalls could be avoided thereby eliminating or minimizing the consequences of adverse events.

The risk management process offers a framework on identifying risks and deciding what to do to cope with the identified risks. All risks are not created with equal weight age. Therefore, risk management is not just about identifying risks, but it is also about deciding and weighing which risks deserves immediate attention and solutions. In general, the risk management process requires identifying construction risks and exposures, analyzing those risks, and formulating an effective risk management strategy to reduce and mitigate the potential risks Ceric (2003). The risk management processes and steps can be detailed as follows:

![Risk Management Process Diagram](image)

**Figure 2: Risk Management Process**

Construction project – Know the risks

There are different types of risks in different stages of a construction project. From the literature reviews, the types of risks in construction projects can be classified broadly into seven groups as shown in figure 2.3 which comprises of physical risks in construction project, construction risks in project undertakings, design risks in construction project, financial risks in construction project, political risks in construction project, legal – contractual risks in construction project, and finally environmental risks in construction project.

Understanding the project risks and its classification could lead to clear decisions concerning, for example the advantages or disadvantages of an acceleration of the project, the type of contract to be used, types of project funding and so on. Identification of risk in advance can lead to clear response procedures if the risks occur.
Classification and Types of Construction Project Risks

The classification of construction project risks can be grouped into seven categories. The followings are the type of construction project risks described in many literatures:

Physical Risks in Construction Project

Physical risks in construction project are risks that often associated with the physical nature of the project. Most of the types of risks fall under this category are uncontrollable source of risk. The types of risks within this category are such as force majeure (acts of God), i.e. inclement weather, flood, fire, landslip, and etc., pestilence or deadly disease, disease, and unexpected events or unforeseen circumstances, for instance airplane crashed at the construction site.

Construction Risks in Project Undertakings

Construction risks are risks that happen during the construction phase in a project life cycle. The construction phase is one of the critical phases because any changes during this phase will affect to a great extent on cost, time and quality aspects. Due to this fact, it is necessary for the stakeholders especially the contractors to give full concentration on the construction risks elements in carrying out their work.

Types of risks that fall under this category consists of delay in possession of site, possible failure of equipment which will affect the productivity of the
work, unavailability of equipment, spares, fuel, etc., inappropriate equipment, poor inventory management, late ordering of materials and components, poor storage practices weather condition, poor quality, productivity and unavailability of labor for both manual and management, the capability level of professional staff such as incompetence, unreasonableness, etc., poor industrial relations with suppliers that will affect the availability of materials, etc., and supplier’s problem due to inability to fulfill supply obligations as and when needed.

Other than that, laborer’s problem such as sickness and absenteeism, poor supply, suitability and unavailability of materials, poor supply of manufactured items like stop of production, spec failure, etc., poor quality, productivity and unavailability of subcontractors, the use of new technology or method due to its applicability and feasibility, risks on safety issues, negligence, poor management of occupational health, and safety resulting in disruptive and costly accidents and penalties, and frequent and late changes at critical stages of the construction processes resulting in scope modifications and variations.

Other risks that fall under this category are errors or omissions and additions in bills of quantities, insufficient time to prepare bid tenders, inadequate contract documentation and poor communication with the parties involved in the project delivery, delay in retrieving and sending information to the other parties and among the staff and laborers’ in the same organization that will cause delay in decision making, often due to conflicts in multi-stakeholders’ interests or bureaucratic processes, poor design and shop drawings, accessibility to the site, damage of materials or manufactured items during transportation or storage, damage during construction due to negligence of any party, vandalism, accident, etc., and price escalation on materials and equipments.

The construction risks will emerge most probably by reason of unrealistic expectations, for example, requiring the project to be constructed too quickly and defect-free, yet at minimal costs.

**Design Risks in Construction Project**

A design risk is any potential risk in a design process, either in a concept design or a detailed design. Early assessment on design risk will increase the chances of eliminating possible failures and reduce the impact of potential failures. This enables a meticulous and systematic examination in the reliability of the design. Design decisions by various engineering disciplines are coordinated with others with respect to function and cost.

Design risks in construction project comprise of incomplete and poorly defined design scope resulting from inability to comprehensively articulate own and users’ needs and requirements, unavailability of information and incomplete design information; i.e. delay in supplying information required by contractors, innovative application, new technology, level of detail required and accuracy, appropriateness of specification, design errors and frequent changes resulting in variations, claims and cost escalations, interaction of design and constructability, complex designs and shapes presenting ‘build ability’ / ‘constructability’ problems, non standardization of details, non standardization of suppliers, quality control exercised such as inspections and approvals and finally the risk of late confirmation and approval of design.

**Political Risks in Construction Project**

Conducting construction business in emerging markets brings a whole new set of challenges and risks to any company including political risks. Thus, it is necessary for contractors to confront with the political risks of emerging markets. Political risks are risks due to losses resulting from damage or destruction of assets or business interruption caused by political violence such as war, revolution, insurrection, civil unrest, terrorism, sabotage, etc.

For political risks in construction project, it might range from changes in law, war, revolution, and civil disorder, constraints on the availability of labor, customs and export restrictions and procedures, requirement to use local labor or management, requirements on hiring foreign workers, requirement to joint venture with local organization, inconsistency of regulations within country or organization, requirement for permits and the procedures for their approval, i.e. for building codes and planning permits, and finally the risks of embargo.
Financial Risks in Construction Project

In essence, financial risk is any risk associated with money. Financial risks can be expressed as the chance that an investment’s actual return will be different than expected. This includes the possibility of losing some or all of the original investment.

Many construction projects suffer from preventable financial problems. Underbids ask for too little money to complete the project. Cash flow problems exist when the present amount of funding cannot cover the current costs for labor and materials, and other expenditures. Having sufficient funds at all the time is very important to deliver a successful project. Financial planning for the project is intended to ensure that a solid plan, with adequate safeguards and contingency plans, is in place before the project is started, and is required to ensure that the plan is properly executed over the life of the project.

Financial risks in construction project consists of unavailability of funds, cash flow problems or insolvency due to slow payment and dispute, loss due to default of contractor, supplier, etc., inadequate payment for variations, failure of low bidder to enter construction contract, inflation, exchange rate fluctuation, under pricing, resulting in excessive claims, rivalry and losses, repatriation of funds, local and national taxes, credit worthiness of contractor, cost of legal decision, insufficient insurance, business disruption, bid validity period extension, and finally the bid and construction bonds unfairly called. Large projects can involve highly complex financial plans.

Legal – Contractual Risks in Construction Project

A construction project must fit into the legal – contractual framework governing the property. These include governmental regulations on the use of property, and obligations that are created in the process of construction.

Constructing a project that fails to adhere to legal – contractual obligation will not benefit the project’s stakeholder which in this case, the contractor. A construction project encompasses of a complex net of contracts and other legal obligations, each of which must be carefully considered. A contract is the exchange of a set of obligations between two or more parties, but it is not so simple a matter as trying to get the other side to agree to as much as possible in exchange for as little as possible. Thus, the contracts must be designed to ensure that each side is capable of performing the obligations set out. Contracts that set out clear expectations and clear paths to accomplishing those expectations are far more likely to result in the project flowing smoothly, whereas poorly drafted contracts lead to confusion and collapse.

Legal advisors in the beginning of a construction project seek to identify ambiguities and other potential sources of trouble in the contract structure, and to present options for preventing problems. Throughout the process of the project, they work to avoid and resolve conflicts that arise.

Legal – contractual risks in construction project consists of direct liability, liability to others, local law and codes, legal differences between countries of client, contractors, consultants, suppliers, etc., conditions of contract; i.e. liquidated damages, maintenance, changes to ‘expected risks’, and etc.

Environmental Risks in Construction Project

Environmental risks are a serious and growing issue for the construction industry. Although many construction firms cling to the belief that environmental exposures are associated only with environmental work, in fact, they exist in every facet of a construction firm’s practice Jyne (2003). To succeed in today’s litigious environment, forward-looking contractors are incorporating sound environmental risk management practices throughout their business operations. Environmental risks consideration can significantly reduce minimize or eliminate a contractor’s exposure to environmental liabilities.

Environmental risks in construction projects can consists of ecological damage, pollution, waste treatment, public enquiry, regulations and possible changes, recording and preserving historical finds, environmental constraints: geological / topographic limitations; weather, working space limitations, etc., and finally the minority interests.

Framework for Systematic Risk Management

Analytical hierarchy process

Recently, a number of systematic models have been proposed for use in the risk evaluation phase of
the risk management process. Kangary and Riggs (1989) classified these methods into two categories: classical models (i.e. probability analysis) and conceptual models (i.e. fuzzy set analysis). They noted that probability set models suffered from two major limitations. Some models required detailed quantitative information, which is not normally available at the time of planning, and the applicability of such models to real projects risk analysis is limited, because agencies participating in the project have a problem with making precise decisions. The problems are ill defined and vague and they thus require subjective evaluations, which classical models cannot handle.

There is therefore a need for a subjective approach to project risk assessment, with their being the necessary objectivity in the methodology. The analytical hierarchy process (AHP) developed by Saaty (1980) provides a flexible and easily understandable 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 AHP allows the active participation of decision makers in reaching agreement, and gives managers a rational basis to make decisions.

Formulating the decision problem in the form of a hierarchical structure is the first step. In a typical hierarchy, the top level reflects the overall objective (focus) of the decision problem. The elements affecting the decision are represented in intermediate levels. The lowest level comprises the decision options. Once the hierarchy has been constructed, the decision maker begins the prioritization procedure to determine the relative importance of the elements in each level of the hierarchy. The elements in each level are compared pair wise with respect to their importance in making the decision under consideration. The scale used in AHP enables the decision maker to incorporate subjectivity, experience and knowledge in an intuitive and natural way. After the comparison matrices have been created the process moves on to the phase in which relative weights are derived for the various elements? The relative weights of the elements of each level with respect to an element in the adjacent upper level are computed as the components of the normalized eigenvector associated with the largest eigen value of their comparison matrix. The composite weights of the decision alternatives are then determined by aggregating the weights through the hierarchy. Following a path from the top of the hierarchy to each alternative at the lowest level, and multiplying the weights along each segment of the path do this. The outcome of this aggregation is a normalized vector of the overall weights of the options.

**Developing priorities and Synthesizing hierarchy**

Priorities are developed from judgments and are synthesized down the hierarchy by a process of weighting and adding to go from local priorities derived from judgments with respect to a single criterion to global priorities derived from multiplication by the priority of the criterion and overall priorities derived by adding the global priorities of the same element. AHP consistency is also known as the consistency ratio (CR). This consistency ratio simply reflects the consistency of the pair-wise judgments. For example, judgments should be transitive in the sense that if A is considered more important than B, and B more important than C, then A should be more important than C. If, however, the user rates A is as important as C, the comparisons are inconsistent and the user should revisit the assessment. Saaty explains that CR is calculated by using the equation in (1), where \( x \) stands for the maximum eigenvalue of the pair-wise matrix, and \( n \) is the size of the pair-wise matrix, \( RI \) is the random index value recommended by Saaty.

| Intensity of Importance | Definition       | Explanation                                      |
|-------------------------|-----------------|-------------------------------------------------|
| 1                       | Equal Importance| Two activities contribute equally to the objective|
| 3                       | Moderate importance| Experience and judgment slightly favor one activity over another |
| 5                       | Strong importance| Experience and judgment slightly favor one activity over another |
| **7** | Very strong on demonstrated importance | An activity is favored very strongly over another; its dominance demonstrated in practice |
|-------|--------------------------------------|----------------------------------------------------------------------------------|
| 2,4,6,8 | For compromise between the above values | Sometimes one needs to interpolate a compromise judgement numerically because there is no good word to describe it. |
| Reciprocals of above | If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i | A comparison mandated by choosing the smaller element as the unit to estimate the larger one as a multiple of that unit. |
| Rationals | Ratios arising from the scale | If consistency were to be forced by obtaining n numerical values to span the matrix |
| 1.1-1.9 | For tied activities | When elements are close and nearly indistinguishable; moderate is 1.3 and extreme is 1.9. |

| **OBJECTIVE LEVEL** | • Choosing the best contingency plan |
|---------------------|------------------------------------|
| **CRITEREA LEVEL/FACTORS** | • Safety  
• Expenses  
• Process Time |
| **OPTION LEVEL ALTERNATIVES** | • Alternative 1  
• Alternative 2  
• Alternative 3 |

Table 1: The AHP Scale (Satty, 1980)

Figure 4: A typical AHP tree

Case study using AHP framework: Delhi metro bridge collapse

The Delhi Metro (DMRC) column and bridge collapse accident shook South Delhi in the month of July 2009. The metro rail track supporting bridge was being erected at the East of Kailash area stretch on the Central Secretariat to Badarpur corridor of the Delhi Metro when one the piers (huge bridge supporting columns) gave way resulting in loss of life, property, time, money and DMRC’s face and grace of being a top-class engineering division of the country. The initial fact-finding study reports and subsequent testing of samples and engineering design checks pointed fingers at the design flaws which had been found as the prime reason of failure in the design details of the cantilever pier-caps (the one-side...
overhung column caps to support the pre-cast rail bridge pieces), together with ill-quality material and workmanship standards followed for the fast-tracked construction activities that were being pushed to the limit to meet the target of making the Delhi Metro rail network functional in all desired stretches of Delhi and suburbs like Noida, Gurgaon and Faridabad that comprise of the National Capital Region (NCR).

The incident took place between pillars 66 and 67 when the pillar cap was affected. Ten segments were to be erected on the stretch of which five had been completed. When the sixth segment was being erected, the launching girder collapsed due to misbalance causing a portion of the bridge to fall.

Constructing AHP model for the Case

Goal:
Choosing the best contingency plan to tackle the collapse

Alternatives:
A1. Extra concreting along the height of the existing piers to support the faulty cantilever
A2. Redesigning
A3. Change labor and source of material procurement

Criteria/factors:
1. Safety
   • Users’ safety
   • Workmen safety
   • Safety of neighboring structures
2. Expenses
   • Materials
   • Workmanship
3. Process Time
   • Time for material procurement
   • Execution time

Calculation of priority vector and C.R.

Step 1: For any comparison matrix, add up the column and divide the each column value with column total, thus we get the standardized matrix.

Step 2: Take out the average of the each row that is called as priority vector.

Step 3: for calculating C.R. multiply the priority vector to standardized matrix and then sum the all values of column matrix and take the average of this sum. Thus we get the \( \lambda_{\text{max}} \).

Step 4: Then C.I. is calculated with following formula:

\[
C.I. = \frac{(\lambda_{\text{max}}-n)}{(n-1)}
\]

\[
C.R. = \frac{C.I.}{R.I \text{ corresponding value of } n \text{ value of R.I. can be found in tables}}
\]

| Table: 2.2.2 Comparison Matrices |
|----------------------------------|
| **factors** | safety | expenses | process time | priority |
| safety       | 1      | 3        | 3            | 0.6      |
| expenses     | 1/3    | 1        | 1            | 0.2      |
| process time | 1/3    | 1        | 1            |          |

C.R. = 0.026

| safety | users’ | workmen | neighboring | priority |
|--------|--------|---------|-------------|----------|
| users’ | 1      | 5       | 3           | 0.64     |
| workmen| (1/5)  | 1       | (1/3)       | 0.1      |
| neighboring | (1/3) | 3       | 1           | 0.23     |

C.R. = 0.033
| expenses | material | workmanship | priority |
|----------|----------|-------------|----------|
| material | 1        | 3           | 0.75     |
| workmanship | 1/3    | 1           | 0.25     |
|          |          |             | C.R.= 0  |

| process time | procurement | execution | priority |
|--------------|-------------|------------|----------|
| procurement  | 1           | 0.2        | 0.17     |
| Execution    | 5           | 1          | 0.83     |
|              |             |            | C.R.= 0  |

| users’ safety | A1 | A2 | A3 | priority |
|---------------|----|----|----|----------|
| A1            | 1  | 6  | 4  | 0.71     |
| A2            | 1/6| 1  | 4  | 0.12     |
| A3            | 1/4| 1/4| 1  | 0.18     |

| workmen safety | A1 | A2 | A3 | priority |
|----------------|----|----|----|----------|
| A1             | 1  | (1/3)| (1/5)| 0.1      |
| A2             | 3  | 1  | (1/3)| 0.23     |
| A3             | 5  | 3  | 1   | 0.64     |

| neighboring safety | A1 | A2 | A3 | priority |
|--------------------|----|----|----|----------|
| A1                 | 1  | 4  | 4  | 0.66     |
| A2                 | (1/4)| 1  | 1  | 0.17     |
| A3                 | (1/4)| 1  | 1  | 0.17     |

| material expenses | A1 | A2 | A3 | priority |
|-------------------|----|----|----|----------|
| A1                | 1  | 1/3| 1/7| 0.09     |
| A2                | 3  | 1  | 1/3| 0.26     |
| A3                | 7  | 3  | 1  | 0.65     |

| workmanship expenses | A1 | A2 | A3 | priority |
|----------------------|----|----|----|----------|
| A1                   | 1  | 4  | 7  | 0.68     |
| A2                   | 1/4| 1  | 3  | 0.24     |
| A3                   | 1/7| 1/3| 1  | 0.08     |

| procurement time | A1 | A2 | A3 | priority |
|------------------|----|----|----|----------|
| A1               | 1  | 7  | 3  | 0.65     |
| A2               | 1/7| 1  | 1/3| 0.09     |
| A3               | 1/3| 3  | 1  | 0.26     |
| execution time | A1 | A2 | A3 | priority |
|----------------|----|----|----|----------|
| A1             | 1  | 1  | 1/3| 0.2      |
| A2             | 1  | 1  | 1/3| 0.2      |
| A3             | 3  | 3  | 1  | 0.6      |

Table: 2.2.3 Choosing the best alternative using AHP

| Factors               | 1 | Sub factors | Likelihood | Alternative 1 | Alternative 2 | Alternative 3 |
|-----------------------|---|-------------|------------|---------------|---------------|---------------|
|                       |   |             | LP         | GP1           | GP2           | GP3           |
| Safety                | 0.60 | Users’       | 0.64       | 0.38          | 0.75          | 0.29          | 0.07          | 0.03          | 0.17          | 0.07          |
|                       |   | Workmen     | 0.10       | 0.06          | 0.10          | 0.01          | 0.23          | 0.01          | 0.64          | 0.04          |
|                       |   | Neighboring structures’ | 0.23 | 0.14 | 0.66 | 0.09 | 0.17 | 0.02 | 0.17 | 0.02 |
| Expenses              | 0.20 | Material    | 0.75       | 0.15          | 0.09          | 0.01          | 0.26          | 0.04          | 0.65          | 0.10          |
|                       |   | Workmanship | 0.25       | 0.05          | 0.68          | 0.03          | 0.24          | 0.01          | 0.08          | 0.00          |
| Process time          | 0.20 | Procurement | 0.17       | 0.03          | 0.65          | 0.02          | 0.09          | 0.00          | 0.26          | 0.01          |
|                       |   | execution   | 0.83       | 0.17          | 0.20          | 0.03          | 0.20          | 0.03          | 0.60          | 0.10          |
| Overall priority of the alternative |       |             |            |               |               |               |               | 0.49          | 0.15          | 0.34          |
| RANK                  |     |             | 1          |               | 2             | 3             |

NOTE: l= Likelihood; LP= Local Priority; GP= Global Priority
GP= LP*l
GP1= LP1*GP
GP2= LP2*GP
GP3= LP3*GP
Result: As per the AHP analysis alternative 1 is the best suited. Extra concreting along the height of the existing piers to support the faulty cantilever should be the response to the bridge collapse.

Conclusion

The need to identify and manage risks in a project delivery became crucial as the concepts of project management had evolved into a new dimension in which the project teams are constantly looking forward to establish ways and methods to deliver a project by focusing into customers’ and end users expectation and satisfaction. In order to do so, the common problem in construction projects such as delays in completing the project, over budget, unsatisfactory product quality, unsafe working environment and so on needs to be eliminated as far as possible. The only way to achieve this is by managing risks throughout the production of a project.

Many construction professionals look at risks individually with a myopic lens and do not realize the potential impact that other associated risks may have on their business operations. Using a holistic risk management approach will enable a firm to identify all of the organization’s business risks. This will increase the probability of risk mitigation, with the ultimate goal of total risk elimination. Hence, the contractors should give sufficient thoughtfulness to the risks elements in their project and manage it according to the priority order as indicated by the level of risk.

The decision-making process described in this paper, analytic hierarchy process (AHP) is about breaking a problem down and then aggregating the solutions of all the sub problems into a conclusion. It facilitates decision making by organizing perceptions, feelings, judgments, and memories into a framework that exhibits the forces that influence a decision. In the simple and most common case, the forces are arranged from the more general and less controllable to the more specific and controllable. The AHP is based on the innate human ability to make sound judgments about small problems.

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