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# Identification and Analysis of Risk Factors in Water Supply Projects in Kaski District

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**Abstract**
Risks are the inherent occurrence of infrastructure projects because of their complex nature. Risk management is an important part of planning which comprises various stages such as identification, analysis, and response. The main objective of the study is to identify and qualitatively analyze the major risk factors focusing specifically on water supply projects implemented in Kaski District under the provincial government. Failure mode and effect analysis (FMEA) a structured technique was used to analyze the risk factors. In FMEA risks are prioritized based on Risk Priority Number (RPN). The risk factor with higher RPN requires more prioritization. Brainstorming, article study and consultation with practitioners of water supply projects were done to identify the risk factors and classify them into different categories. 40 risk factors under 10 categories were identified. A questionnaire was further developed and distributed to the client, user committee, and consultant involved in the construction of the sampled project to elicit the occurrence, consequence, and detectability of each risk factor. Based on the assessment supplied by RPN, it was determined that the economic and financial categories presented the greatest risk and that the main risk factor for the water supply project was the inability to ensure the source of funds according to the project estimated amount.

**Keywords**
Risk Management, FMEA, Qualitative analysis

## 1. Introduction

### 1.1 Background of study

Infrastructure projects are complicated strategic projects with different dimensions, including organizational, financial, and social, as well as complex technical and financial ones. The most important objectives of any project is to finish the project within given schedule, stipulated budget and with specific quality standards. In recent years, there has been both an increase in the complexity of the projects delivered and an improvement in the techniques and technologies available, which has led to a focus on research related to risk management [1]. Study of various articles and reports show that project cost and time overrun has been a major issue in successful completion of infrastructure projects. According to a report published by Commission for Investigation Abuse of Authority in 2075 B.S. , 1848 construction projects worth Rs. 118 billion dollars were delayed. As per a report by National Management Information Project of Department of Water Supply and Sewerage out of total number of completed project scheme 35 percent of the water supply schemes were nonfunctional. The average time overrun of the overall projects are found 15.83 months and 10.68 percent increment in cost after variation. Risk and uncertainties are associated with different aspects of the project and not addressing them properly in planning stage has been a major reason for time and cost overrun in context of Nepal. Water supply projects in Gandaki province are implemented majorly by Water Supply Users Committee (WSUC) under supervision of Ministry of Energy Resources, Water Supply and Irrigation and its divisional office. These projects are being implemented haphazardly and without enough planning, which has exacerbated the impact of risk factors. Therefore, it is essential to include effective risk management during the project planning process. There are many various small- and medium-sized project risk management methodologies or models, but the core risk management process consists of four steps: identifying and categorizing risk sources, analyzing risk assessments, developing a risk management response, and monitoring and controlling [2].

### 1.2 Research objectives

This research aims at identifying risk factors associated with water supply projects being constructed in Kaski district at provincial level and analyzing the risk factors qualitatively using Failure Mode and Effect Analysis (FMEA) in order to prioritize these projects during different phases of the project.

## 2. Literature Review

### 2.1 Worldwide Risk Management Practice

Petrovic (2017) as cited by Gain et al. (2022) in his paper “Risk Management in Construction Projects–A KnowledgeManagement Perspective from Swedish Contractors” concluded that Swedish construction industry was largely unknown about the process of risk management [3]. Similarly, a study by Singh and Hong, 2020 as cited by Alsaadi N. and Norhayatizakuan in article ”The Impact of Risk Management Practices of Performance of Construction Projects” risk management practices were found informal and unsystematic. Assessment of risk in projects majorly rely on intuition, judgment and practitioner’s experience [4].

### 2.2 Risk Management Practice in Nepal

Various qualitative and quantitative methods have been introduced for risk management worldwide but in the context of Nepal, risk factors are still addressed in a haphazard way. According to a risk maturity model introduced by Hilson made up of four stages: Naive, Novice, Normalized, and Natural, Nepal is considered at the naive stage. Naive means that an organization has not yet captured the need for managing risks and no structured approach is in place for this purpose. Malik and Mishra's (2017) study on "Factors and Impact of Risk Management Practice on Success of Construction Project on Housing Developer, Kathmandu, Nepal" showed the status of housing developers of Kathmandu valley regarding the practice of risk management. The study showed that though risk management had a significant impact on the successful completion of projects only a few of the organizations included risk management in project planning [5]. A similar study was conducted by Adhikari and Mishra (2020) to study the risk management practice in urban road construction projects in Nepal which showed the risk management practice from the perspective of both clients and contractors. The study results showed the limited implementation of formal and informal practices of risk management both from a client and contractors perspective [6]. These studies show that even though the project managers were aware of the risk management concept, practice is taken in an informal way without any orderly process. According to Koirala (2017) in his study on "Contribution of Risk Factors for Infrastructure Development in Nepal" suggested that time and cost overrun in infrastructure projects were a result of improper planning and negligence towards the contributing risk factors. The study also concluded that despite the significant impact of risk factors on infrastructure projects neither the government level nor public are taking these factor seriously yet [7]. Thus a structured risk management process is necessary for success of infrastructure construction projects.

### 2.3 Failure Mode and Effect Analysis

Failure Mode and Effective Analysis (FMEA), also known as Failure Mode, Effects and Criticality analysis (FMECA), is a risk assessment tool used to explore, analyze, delve into the causes of, and evaluate probable failures in a system, process, service, or design. The technique was initially developed by reliability engineers of U.S.A for their army works. At present it is used in several industrial and research fields. In this method each risk is considered as failure mode. A traditional FMEA comprises three main objectives, identification possible failure modes, evaluation of causes, impacts and the effects of different component failure mode, and determine the suitable actions to eliminate or to reduce the impact of each failure mode. Risk Priority Number is a numerical value used for prioritization of risk factors. Generally, the RPN is calculated as the product of the severity (S), occurrence (O), and detection level (D) of a failure mode. A numerical scale ranging from 1 and 10 or Likert Scale is used to represent the occurrence (O), severity (S), and detection (D). Risk Prioirity Number was further calculated using equation 1.

$$\text{RPN} = O \times S \times D \tag{1}$$

### 2.4 Risk Related Studies

The section shows various studies related to risk assessment using different methods. In order to identify risk factors in community-based infrastructure projects in Zambia, Manelele and Muya [8] conducted a study. Critical risk categories include project initiation, community involvement, budget and finance, skilled labor, material procurement and technical supervision, and quality control. The article comes to the conclusion that there are significant risks associated with community-based construction projects that call for planning ahead, assessing them, and mitigating them [8].

Nguyan et al. [9] carried out a similar study to evaluate the risk associated with Water Supply project building in Hanoi, Vietnam. 51 risk factors were initially discovered and evaluated using questionnaire survey. To quantify risk and identify the most important and moderate risk elements, a risk matrix was developed. Seven risk categories and 27 primary risk factors that cause the construction schedule to delay were identified based on the analysis [9].

Sokhakian and Moeni's (2011) as cited in Y. Kheradmand et al. [10] identified 63 risk affecting water supply and sewerage projects after consultation with expert. Risk variables affecting project time and cost were introduced, an FMEA-based survey was developed, the risk factors that affected project time and cost were incorporated, and the impact severity and detection rate were then determined. The numbers assigned varied from 0 to 10, and a higher RPN value denoted a more potent and risky component. The risk priority number (RPN) was derived by multiplying these numbers [10].

Sharma & Trivedi [11] identified 48 risk factors where 39 respondents were given a questionnaire survey as part of the risk assessment process. The majority of the questionnaire consists of rating risk variables on a Likert scale from 1 to 5 for their likelihood of occurrence, consequences, and detectability. The response was combined using the Relative Importance Index, and the Risk Occurrence Index (ROI), Risk Consequence Index (RCI), and Risk Detectability Index (RDI) were found and Risk Priority Number, was further computed. Based on the ranking insufficient availability of funds, uncertainty in land acquisition cost and schedule, lack of resources, insufficient availability of funds, issues related to obtaining railway and government permit, delay in payment, poor soil condition were considered the major risk factors. The FMEA table was also further modified to determine allocation of risk factors to parties involved in the construction project. It was concluded that most the risk were allocated to contractors, so contractors were the most risks affected among project related parties [**?**].

Mishra and Gain [12] used FMEA to identify and prioritize the major risk factors in road construction projects in various areas of Sindhupalchowk district, Bagmati Province. Major risk factors based on risk priority number were time overrun risk, Safety Health and Environmental risk, cost overrun risk, financial and economic risk, force majeure and ecological risk, political legal and social risk, organizational risk, contractual risk, quality risk and design and specification risk in descending order of risk severity [3].

Shakya and Mishra [13] conducted a study to evaluate risk factors during construction Gautam Buddha International

Airport. On basis of literature review and consultation with experts 14 risk categories and 96 risk factors were listed. Each risk factor was given score for severity and frequent of occurrence followed by calculation of risk score using Risk Matrix. Risk factors associated with design, specification, and estimation and scheduling were found to be highly significant [13].

## 3. Research Methodology

### 3.1 Research Design

Selection of an appropriate methodology is as per research objective is necessary to obtain reliable and valid data. In order to obtain the objective of the project the methodology was divided into two stages. In the first stage risk were identified based on literature review and consultation with practitioners. Based on the identified risk questionnaire was developed for rating of risk by respondents. In the second stage the response of the participants were analyzed qualitatively using FMEA Approach.

### 3.2 Study population and sample size

For the study risk factors affecting construction of water supply project in Kaski District which were funded by Provincial Government having estimated amount of more than 2 crore which are constructed by User Committee (i.e. 32 water supply projects) were taken under consideration. Initially the risk factors were identified using literature review and relevance of the risk factors was confirmed from consultation with the practitioners. Based on the identified risk the questionnaire is prepared which was distributed to the client, User Committee and consultant involved in construction of these sampled project. Table 1 shows the details of sample size of respondents for data collection.

**Table 1:** Questionnaire Distribution Breakdown

| Participants | Population and Sample Size |
|---|---|
| Client | 5 |
| Consultant | 8 |
| User Committee | 32 |
| Total Sample Size | 45 |

### 3.3 Data Collection

#### 3.3.1 Primary Data Collection

Questionnaire was developed for primary data collection. A pilot survey was conducted to test the validity of the content and the design of the survey (for example, ease of understanding and consistency), and to improve the questions and the format to be used in the final test. The questionnaire was further distributed to staff of client, consultant and representative of User Committee. Before distribution the questionnaires pilot study was carried out.

#### 3.3.2 Secondary Data Collection

Secondary data included review of journals, articles, thesis and reports to collect major risk factors affecting the water supply projects. It also included consultation with practitioners and experts regarding to get broader knowledge regarding the relevance of risk factors in accordance to Kaski District.

### 3.4 Reliability Analysis

Cronbach's alpha was used to measure the reliability and internal consistency of the response obtained during the questionnaire survey using the following formula Numbered equation:

$$\alpha = \frac{k}{k-1} \times \left(1 - \frac{\sum V_i}{\sum V_t}\right) \tag{2}$$

Where, $K$ = No. of Questions,
$V_i$ = Variance of score on each question,
$V_t$ = Total Variance of overall scores on entire set of question.

Value of alpha less than 0.6 shows unreliability of data obtained, value of alpha between 0.7 to 0.8 means acceptable response, value of alpha between 0.8 and 0.9 means good response and value of alpha above 0.9 shows excellence in reliability of data obtained through questionnaire.

### 3.5 Analysis of Risk Factors

Failure Mode and Effect Analysis (FMEA) technique is used for quantitative analysis which uses Risk Priority Number (RPN) to prioritize the risk factors. In this technique Relative Importance Index (RII) will be initially used to unify the responses as shown in equation 2 :

$$\text{RII} = \frac{\sum W}{A \times N} \tag{3}$$

Where, $\sum W$ = Sum of responses i.e. sum of crisp rating of factor given by respondents,
A = Maximum value of crisp rating which is 5,
N = No. of respondents.

$$\text{Risk occurrence index (ROI)} = \frac{\sum W}{A \times N} \tag{4}$$

$$\text{Risk consequence index (RCI)} = \frac{\sum W}{A \times N} \tag{5}$$

$$\text{Risk detectability index (RCI)} = \frac{\sum W}{A \times N} \tag{6}$$

After the calculation of ROI, RCI, and RDI ,RPN will be calculated using following formula

$$\text{RPN} = \text{ROI} \times \text{RCI} \times \text{RDI} \times 100 \tag{7}$$

After calculating RPN of each risk factor using above formula, to determine the severity of Risk Factors, its ranking was done on the basis of Risk Priority Number (RPN) of risk factors. Thus ranking of Risk Factors was done as per decreasing order of RPN in such a way that the rank of maximum RPN is one with highest severity.

## 4. Result and Anlysis

### 4.1 Risk Identification

Based on the literature review a total of various articles initially 64 risk factors were identified. The checklist was then distributed to practitioners actively involved in construction of water supply projects in Kaski District. Based on the consultation and relevance of the study area the risk was reduced to 40 risk factors which were categorized under 10 categories.

Management, operating, labor, material contractual technical political and legal economical and financial social and natural risks were different categories of risk identified. Inappropriate use of project planning and scheduling methodology, strained relationships between parties involved in design/construct process, not enough and skilled technical manpower, lack of access in project management, poor qualification, skills and experience of user committee, absence of accurate feasibility studies, delay in decision making under critical and emergency condition are risk factors identified under management category. Poor construction safety management, shortage of construction materials, unfavorable/ unforeseen site conditions, delays in land acquisition, lack of timely notification of adjustment indicators, gaps between implementation and specification are risk factors identified under operating category. Absenteeism of labor in construction site, lack of skillful labor, incompetence of skilled labor due to lack of motivation and services are risk factors identified under labor risk category. Lengthy tendering process, no timely procurement of construction material, delay in material supply, price escalation of construction materials, incapable and unreliable suppliers are risk factors identified under material risk category. Procurement delays, excessive contract variation, awarding contract to extremely low bids are risk factors identified under contractual risk category. Insufficient data collection and survey before design, error in design drawings, inaccurate estimation, and delay in approving the design are risk factors identified under technical risk category. Interference by political parties, change in governmental rules and policies, complicated administrative approval process are risk factors identified under political and legal risk category. Inflation and change in exchange rates, fluctuation in interest rate, inability to ensure source of fund according to project estimated amount, delay in payment process are risk factors identified under economical and financial risk category. Inappropriate / frequently changing requirement, stake holders conflict, lack of consensus of community members in project participation are risk factors identified under social risk category. Unexpected natural disaster in project area and unexpected severe weather in project area are risk factors identified under natural risk category.

### 4.2 Reliability Analysis

Cronbach's alpha ($\alpha$) was used to check the reliability of response collected from questionnaire using SPSS Version24. The value of $\alpha$ was determined for response regarding severity of impact (RC), probability of occurrence (RO) and detection probability (RD) for categories of risk factors and individual risk factors using equation 1. Table 2 shows the value of $\alpha$ for response for response collected for categories of risk factors. For risk categories value of k i.e. number of question was taken 10 and number of respondent was taken 37. Since value of $\alpha$ is more than 0.6, response collected are considered reliable for further analysis

**Table 2:** Reliability statistics for risk categories

| S.N. | Parameters | Cronbach's alpha |
|---|---|---|
| 1 | Risk consequence | 0.672 |
| 2 | Risk occurrence | 0.752 |
| 3 | Risk detectability | 0.662 |

Table 3 shows the value of $\alpha$ for response for response collected for risk factors under different categories. A total of 40 questions were asked which was taken as value of k. Value of $\alpha$ for Risk Consequence is between 0.8 and 0.9, response collected is good for further analysis. Similarly, value of $\alpha$ for Risk Occurrence and Risk Detectability is more than 0.9, internal consistency of data is excellent and reliable for further analysis.

**Table 3:** Reliability statistics for risk factors

| S.N. | Parameters | Cronbach's alpha |
|---|---|---|
| 1 | Risk consequence | 0.866 |
| 2 | Risk occurrence | 0.942 |
| 3 | Risk detectability | 0.931 |

### 4.3 Ranking of Risk Factors

The categories of risk factors are ranked based on their risk priority number in figure 1 which shows that economical and financial risks are the major risk factors affecting water supply projects in Kaski district.


**Figure 1:** Figure showing ranking of categories of risk factor based on Risk Priority Number

Further individual risk factors under different categories were also further analyzed based on the response obtained from the questionnaire. Risk Priority Number (RPN) was calculated for each risk factors based on which factors were ranked. Based on the ranking risk factors can be prioritized during different phases of the project. Figure 3 shows the top 10 risk factors based on the Risk Priority Number (RPN.)

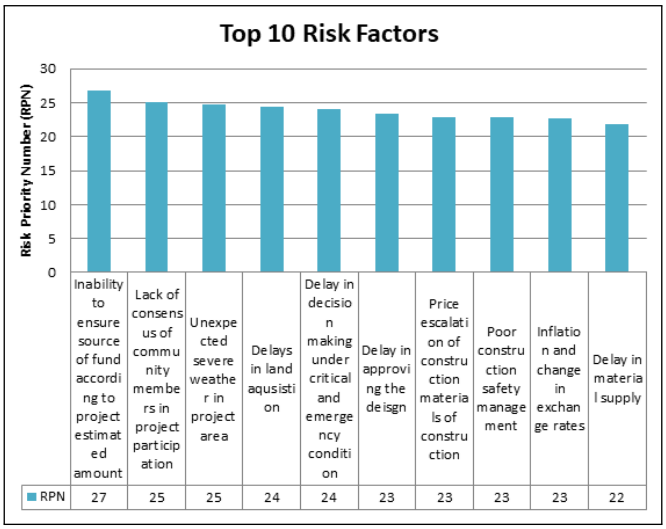


**Figure 2:** Top 10 risk factors affecting water supply projects in Kaski District

## 5. Conclusion and Recommendation

The study was conducted to identify and analyze the risk factors using FMEA approach. Different risk factors were identified and further categorized. These categories and individual risk factors were ranked on the basis of their scores for severity of impact, occurrence and detectability. The analysis of risk categories showed that economical and financial category of risk was the major risk factors with highest severity. Detailed analysis of individual risk factor showed that inability to ensure the source of fund according to project estimated amount has been a major risk factor in successful completion of water supply project. So assuring project fund during the planning stages of projects is necessary so that fund unavailability is not a major issue halting the project progress. Lack of consensus of community member in project participation, unexpected severe weather in project area, delays in land acquisition, delay in decision making under critical and emergency condition, delay in approving the design, price escalation of construction materials of construction, poor construction safety management etc are the risk factors with descending order of risk priority number. Thus, this study can be useful in planning and implementation stage of project to prioritize significant risk factors and minimize. Further study can be carried out to analyze the risk quantitatively and develop suitable risk response strategy.

## References


[1] G. Su and R. Khallaf. Research on the influence of risk on construction project performance: A systematic review. sustainability. *Sustainability (Switzerland)*, 14 (11), 2022.

[2] N. Bazin. Project and risk management – 4. initiation of risks management plan. *VIA University College, Denmark*, 2017.

[3] H. Gain, A. K. Mishra, , and P. S. Aithal. Risk management practice adopted in road construction project. *International Journal of Management, Technology, and Social Sciences*, 112055, 2022.

[4] N. Alassadi and Norhayatizakuan. The impact of risk management practices on the performance of construction projects. *Estudios de Economia Aplicada*, 39(4), 2021.

[5] Mishra Anjay and Mallik Kamalendra. Factors and impact of risk management practice on success of construction projects of housing developers, kathmandu. *International Journal of Sciences: Basic and Applied Research (IJSBAR)*, 4531, 2017.

[6] Mishra Anjay. Strategic risk management practice in urban road construction project of nepal. *Journal of Advanced Research in Civil and Environmental Engineering)*, 07, 2020.

[7] M Parsad Koirala. Contribution of risk factors for infrastructure development of nepal. *American Journal of Civil Engineering*, 05, 2017.

[8] I. Mañelele and M. Muya. Risk identification on community-based construction projects in zambia. *Journal of Engineering, Design and Technology*, 06, 2008.

[9] M. T. Nguyen, S. H. Mai, and Q. H. Vu. Risk assessments in construction of water supply projects in hanoi, vietnam. *Journal of Engineering, Design and Technology*, 11, 2021.

[10] Y. Kheradmand, A. Honarbakhsh, S. M. Movahedifar, and A. R. Afshari. Risk prioritization in water and wastewater projects using a decision model based on the analytic hierarchy process. journal of rehabilitation in civil engineering. *Journal of Engineering, Design and Technology*, 9(2), 2021.

[11] Kamal Sharma and MK Trivedi. Risk analysis in highway construction projects using failure mode & effect analysis. *International Journal for Research in Applied Science & Engineering Technology (IJRASET) pp 311*, 318, 2019.

[12] Hemant Gain and A.K. Mishra. Risk analysis in road construction using failure mode and effect analysis. *Nat. Volatiles & Essent. Oils*, 8(4), 2021.

[13] S. Shakya and A.K. Mishra. Risk assessment in construction of gautam buddha international airport. *Journal of Advanced Research in Construction and Urban Architecture*, 4(1), 2019.