iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** V **Month of publication:** May 2023

DOI: https://doi.org/10.22214/ijraset.2023.52978

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

Risk Identification and Assessment in 24x7 Water Supply Scheme for DMA under Smart City project

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Abstract: The objective of this thesis is to propose a decision support tool for contractors to assess the likelihood of risks in water supply system projects before the execution stage. The approach combines fuzzy logic with the relative importance index (RII) method to quantify the probability of these risks. By conducting a comprehensive literature review and expert interviews, a total of 51 distinct risk factors were identified and categorized into seven groups. The RII method was employed to determine the relative importance of each risk factor, and the ranking of both the factors and groups was established based on their level of importance. The case study results facilitated a discussion on the most influential factors and groups that require attention in terms of risk probability. The outcomes were deemed satisfactory and appropriate for the purpose of this thesis.
Keywords: DMA, Smart city, Factors, Relative Importance Index, Risk.

I. INTRODUCTION

In developing countries like India, intermittent water supply systems face various shortcomings, including inadequate and poorly designed infrastructure, operational and maintenance issues, and economic constraints. Many areas experience insufficient quantity and sub-standard quality of water at the consumer end, leading to unsatisfactory service levels in the water sector even after the country's independence. With an estimated 50% of the population projected to live in urban areas by 2050, ensuring a safe and continuous water supply poses a significant challenge for water engineers. Despite the benchmarks set by the Government of India (GoI), all cities currently provide intermittent water supply to their population. However, some cities, under the GoI's initiative, are taking steps to convert their existing intermittent water supply systems into continuous systems to enhance service quality.

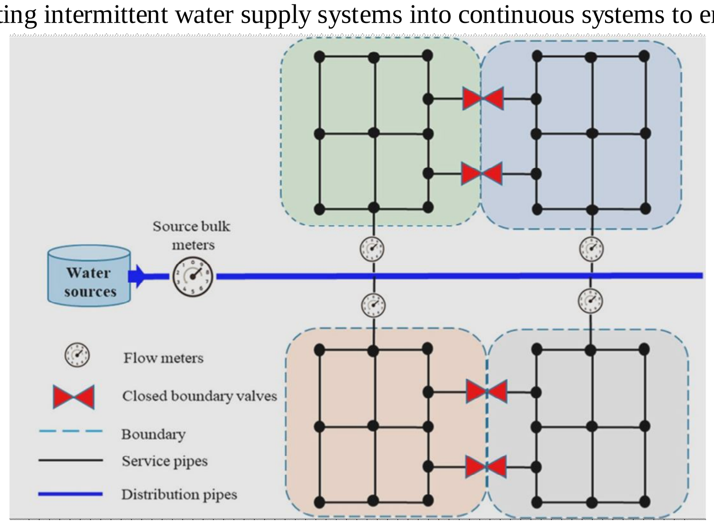

Fig. 1 A schematic diagram of district metered area (DMA)

A. Need of the study

While undertaking water supply projects in India, there are various risks and challenges that arise during the project's completion. These risks are influenced by numerous factors during the execution phase of any 24x7 water supply project under the DMA (Demand Management Area). It has been observed that project execution often encounters problems and risks. Therefore, it is crucial to identify and analyze these risks during the execution stage of the project life cycle. This proactive approach will help mitigate risks for both the public and private sectors, ensuring timely project delivery to the public. Conducting an in-depth study on this topic will facilitate effective management of the Construction, Operation & Maintenance, and Transfer phases while also aiding in risk identification.

B. Objectives

1) To identify the risk factors associated with 24x7 water supply scheme projects study fleet management in road construction projects.
2) To assess the relative importance of these risks and establish a ranking of factors and groups based on their level of importance.
3) To examine and highlight the most influential factors and groups where risks may arise and groups that require attention.

II. REVIEW OF LITERATURE

Some theoretical and analytical investigations performed in this field are presented in the following literature survey.

1) Minh Thanh Nguyen, et. al. (2021) did an extensive examination revealed 26 critical risks that have a substantial impact on schedule delays in Water Supply Projects. These risks were systematically evaluated and ranked according to their degree of influence, providing actionable recommendations to mitigate or eliminate their effects. The findings of this study provided valuable insights for investors and contractors, aiding them in achieving timely project completion and maximizing the advantages associated with Water Supply Projects.
2) Anca Elena Gurzau, et. al. (2011) introduced techniques for identifying and evaluating risks in central water supply systems, using a case study of the central water supply system in Luna locality, Cluj county from 2009 to 2010. The assessment of the system was conducted using historical data on water quality monitoring and analysis of water samples, specifically focusing on parameters mandated by Law 458/2002 (audit monitoring). The laboratory facilities at the Environmental Health Centre were utilized for this purpose.
3) F. Cubillo & P. Perez (2014) introduced a risk assessment methodology that involved calculating three types of indicators. These indicators were based on the probability of threat incidents occurring and the subsequent evaluation of their consequences. The consequences were measured by the impact on service disruption, the extent of the disruption (typically quantified by the number of affected properties), and the duration of the disruption. The duration of the disruption is linked to the concept of system resilience or response capacity.
4) S. J. T. Pollard, et. al. (2004) examined various risk management frameworks, as well as tools and techniques for risk analysis, commonly employed in the water sector. They had explored the utilization of said frameworks and tools across various levels of decision-making, including strategic, programmatic, and operational contexts. Additionally, the analysis expanded the scope beyond public health considerations to encompass financial risk management, reliability and risk-based maintenance, and the application of business risk maturity models within the water sector.
5) B. Tchorzewska-Cieslak (2011) presented a complex model of risk management of failures in drinking water technical system manly in water pipe network which can be used in practice in system operator's decision-making process. An adaptation of the fuzzy set theory to analyse risk of failure of water mains was not a standard approach for water works.
6) Bixiong Ye, et. al. (2015) assigned a set of 13 and 12 utility operational limits. The primary risk factors impacting water safety were identified across various aspects, including water sources, water processes, water disinfection systems, and water utility management. To address these risks, several control measures were implemented, such as enhancing the protection of water sources, closely monitoring water treatment processes, establishing emergency protocols, improving the use of chemicals, and enhancing the management of operating systems. The findings suggest that implementing Water Safety Plans (WSP) was a viable approach for effectively managing water supplies in rural areas.
7) Albert P. C. Chan, et. al. (2015) indicated that completion risk, inflation, and price change risk has a greater influence on water Public-Private Partnership (PPP) projects in China. On the other hand, government corruption, deficiencies in the law and supervision system, and fluctuations in market demand has a relatively lower impact on the water supply sector. The findings offered valuable insights for project stakeholders to enhance the effectiveness of privatization in public utility services. Furthermore, they provided private investors with a deeper understanding of the significant Chinese water market when participating through the PPP model.
8) Andreas Lindhe, et. al. (2009) did a thorough probabilistic risk analysis on a significant drinking water system in Sweden, utilizing fault tree analysis at an integrated level. The study aimed to achieve two primary objectives: (1) to develop a methodology for conducting integrated and probabilistic risk analysis of entire drinking water systems, and (2) to evaluate the effectiveness of Customer Minutes Lost (CML) as a metric for measuring risk.
9) Davood Fereidooni (2015) said the major seismic sources were small and large faults identified in the study area mostly directed in NW-SE. The MCE and PGA were measured based on both DSHA and PSHA approaches.

10) Swarup Varu & Dipsha Shah (2018) applied research & design and built a detail project report for 24x7 water supply system at Sabarmati and old Wadaj ward of Ahmedabad city. It included feasibility study; software based hydraulic design, operation and maintenance strategy and economic feasibility for the project by studies of research paper, case study, census data, need and demand of the future.
11) Abhay Tawalare & Yazhini Balu (2016) assessed the performance of continuous water supply projects in relation to different risks. The study employed a case study research approach to investigate this matter. Through a review of existing literature, various risks associated with water supply projects were identified. Two contrasting cases were chosen for the analysis: one implemented through Public Private Partnership (PPP), and the other funded directly by the government budget.
12) K. Vairavamoorthy, et. al. (2007) presented a new software tool IRA-WDS. This GIS-based software predicts the risks associated with contaminated water entering water distribution systems from surrounding foul water bodies such as sewers, drains and ditches. Intermittent water distribution systems are common in developing countries and these systems are prone to contamination when empty.
13) Abbas Roozbahani (2013) prepared an integrated fuzzy hierarchical risk assessment model for water supply systems (IFHRA-WSS) which was proposed to assess hazards in a complex UWSS using a systematic approach incorporating both water quantity and quality issues. This model uses a hierarchical framework for breaking down the UWSS infrastructures to their interrelated elements to reduce the overall complexity of the system.
14) Janusz R. Rak (2019) proposed a method of assessing threats to people and property from waterworks systems functioning in self-government units (SGUs). Four categories of factors affecting the risk of threat to tap water consumers were assumed: the frequency or the probability of exposure - P, financial losses - C, damages to peoples' health - HL, the degree of the security - S. Based on this, a four-parametric risk matrix was developed. It was assumed that risk is a function of the parameters mentioned above: R = f (P, C, HL, S). For every parameter, the five-parametric weight scale was assumed.
15) Janusz Karwot (2016) reported current state of investigation as well as implementations in practice of some results of research projects, which have been focused on water use in urban area and carried on in the City of Rybnik, Upper Silesia Region, Poland, since 2004. The problem of water distribution and use as well as problems of managing technical infrastructure of water management is described in this paper from the point of view both of scientists and practitioners involved in the projects.

III. METHODOLOGY

In this, participants with experience in the construction of water supply projects were surveyed using a questionnaire method to evaluate the risks and their impact on the construction process. The questionnaire was developed based on an examination of the existing literature, which explored the risks and factors associated with water supply system construction projects, specifically focusing on the Nashik Smart City. The questionnaires were analysed by using Relative Importance Index Method (RII). RII is to determine the relative importance of various risk factors. The five - point scale ranged from 1 (less influencing or very less severe) to 5 (more influencing or extremely high severe) is adopted and transformed to relative importance indices (RII) for each factor as follows: $RII = \sum (W_1 + W_2 + W_3 + \ldots\ldots + W_n) / (M * n)$
Where, W = Weight given to each factor in questionnaire, M = Maximum rating in Questionnaire Scale (5 in this case)
n = Total number of responses received (total 64 responses received).

Fig. 2 Risk Categorization

IV. RESULTS ANALYSIS AND DISCUSSIONS

The Risk groups are further divided into various risk factors as shown in table below.

Table 1 Risk due to natural and social factors

Sr. No.	Sub-factors
1	Volatility in raw material prices
2	Volatility in the labour market
3	Fluctuations in capital market
4	Changes in weather, climate, and natural disasters
5	Policy changes
6	Caused by topography and geology
7	Caused by security
8	Construction site is unfavourable & overlapping with other work items
9	Cause of pandemic

Table 2 Risks due to contracts

Sr. No.	Sub-factors
1	Implicit transaction to sign the contract (Collusion)
2	Due to uncertain and unclear contract terms
3	Due to changes or additions to the terms of the contract
4	Terms of responsibility of the two parties are not clear
5	Contract price adjustment clause
6	Cause of contract dispute

Table 3 Risk due to Project Management

Sr. No.	Sub-factors
1	Construction project supervisor is not good
2	Poor construction safety management
3	Poor coordination of the investor and general contractor
4	Quality control of materials
5	Poor management information system
6	Not enough human resources to manage the project
7	Staff's management capacity is not good
8	Due to repairs after the commissioning test
9	Poor access to operation management technology

Table 4 Risk due to Economy

Sr. No.	Sub-factors
1	Caused by the financial resources of the investor
2	Investor is slow to pay the contractor
3	Financial capacity of the contractor
4	Construction ground clearance compensation is overly complicated
5	Due to risks of inflation
6	Due to fluctuations in interest rates of bank
7	Changes in tax policies

Table 5 Risks due to Design Consulting Work

Sr. No.	Sub-factors
1	Capacity of construction supervision consultancy

Table 6 Risks due to Contractor's Construction capacity

Sr. No.	Sub-factors
1	Construction crews' capacity

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

2	Capacity of the design consultant
3	Use of typical design drawings & lack of actual correction
4	Incorrect use of Technical Standards
5	Using the job code in the incorrect estimation
6	Calculation of the quantity of materials of the consultant is incorrect
7	Due to the field experiment

2	Investment in purchasing asynchronous and poor-quality equipment
3	Weak technical capacity of the general contractor
4	Poor technical skills and human resources
5	Not enough technical workforce
6	Poor finished product

Table 7 Risks due to Administrative and Legal procedures

Sr. No.	Sub-factors
1	Construction unit lacks understanding of law
2	Relationship of the investor, the contractor with the competent agency to the project
3	Local construction management regulations
4	Complicated administrative procedures
5	Adjustment of the project's scale of the investor
6	Causes of labour safety
7	Changes in laws, regulations, standards, etc.

Following are the readings which were collected from 64 responses with the help of Google Form Questionnaire-

Table 8 RII of risk attributes

Code	Categories	Degree of its contribution where risk occurs					Sum	RII
		1	2	3	4	5		
(A) Risks related to Natural and Social factors								
RNSF1	Volatility in raw material prices	5	7	13	29	10	64	0.70
RNSF2	Volatility in the labour market	3	7	18	28	8	64	0.70
RNSF3	Fluctuations in capital market	2	10	19	27	6	64	0.68
RNSF4	Changes in weather, climate, and natural disasters	7	9	20	15	13	64	0.66
RNSF5	Policy changes	5	18	19	15	7	64	0.60
RNSF6	Caused by topography and geology	8	10	19	20	7	64	0.63

Code	Categories	Degree of its contribution where risk occurs					Sum	RII
		1	2	3	4	5		
RNSF7	Caused by security	11	10	21	16	6	64	0.59
RNSF8	Construction site is unfavourable & overlapping with other work items	6	6	27	16	9	64	0.65
RNSF9	Cause of pandemic	3	15	14	23	9	64	0.66
(B) Risks due to Contracts								
RC1	Implicit transaction to sign the contract (Collusion)	5	19	18	20	2	64	0.58
RC2	Due to uncertain and unclear contract terms	5	12	16	25	6	64	0.65
RC3	Due to changes or additions to the terms of the contract	3	19	12	21	9	64	0.64
RC4	Terms of responsibility of the two parties are not clear	7	14	12	24	7	64	0.63
RC5	Contract price adjustment clause	6	16	15	20	7	64	0.62
RC6	Cause of contract dispute	4	11	17	24	8	64	0.67
(C) Risks due to Economy								
RE1	Caused by the financial resources of the investor	7	7	16	26	8	64	0.67
RE2	Investor is slow to pay the contractor	4	11	13	25	11	64	0.69
RE3	Financial capacity of the contractor	5	7	14	23	15	64	0.71
RE4	Construction ground clearance compensation is overly complicated	5	13	10	24	12	64	0.68
RE5	Due to risks of inflation	3	5	12	25	19	64	0.76
RE6	Due to fluctuations in interest rates of bank	5	10	12	25	12	64	0.69
RE7	Changes in tax policies	3	9	17	23	12	64	0.70
(D) Risks due to Project Management								
RPM1	Construction project supervisor is not good	7	12	10	24	11	64	0.66
RPM2	Poor construction safety management	6	11	10	22	15	64	0.69
RPM3	Poor coordination of the investor and general contractor	5	11	13	23	12	64	0.68
RPM4	Quality control of materials	9	10	11	22	12	64	0.66
RPM5	Poor management information system	5	16	8	19	16	64	0.68
RPM6	Not enough human resources to manage the project	3	14	17	20	10	64	0.66
RPM7	Staff's management capacity is not good	7	11	12	26	8	64	0.65
RPM8	Due to repairs after the commissioning test	7	9	15	21	12	64	0.67

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Code	Categories	Degree of its contribution where risk occurs					Sum	RII
		1	2	3	4	5		
RPM9	Poor access to operation management technology	7	11	14	23	9	64	0.65
(E) Risks due to Design consulting work								
RDCW1	Capacity of construction supervision consultancy	8	9	12	21	14	64	0.68
RDCW2	Capacity of the design consultant	5	12	13	22	12	64	0.68
RDCW3	Use of typical design drawings & lack of actual correction	3	8	12	22	19	64	0.74
RDCW4	Incorrect use of Technical Standards	5	9	10	27	13	64	0.71
RDCW5	Using the job code in the incorrect estimation	3	9	12	25	15	64	0.73
RDCW6	Calculation of the quantity of materials of the consultant is incorrect	4	11	9	21	19	64	0.73
RDCW7	Due to the field experiment	5	10	10	27	12	64	0.70
(F) Risks due to Contractor’s Construction capacity								
RCCC1	Construction crews’ capacity	12	10	13	19	10	64	0.62
RCCC2	Investment in purchasing asynchronous and poor-quality equipment	7	14	13	20	10	64	0.64
RCCC3	Weak technical capacity of the general contractor	7	10	16	19	12	64	0.66
RCCC4	Poor technical skills and human resources	5	10	13	23	13	64	0.69
RCCC5	Not enough technical workforce	4	9	15	22	14	64	0.70
RCCC6	Poor finished product	6	10	13	18	17	64	0.69
(G) Risks due to Administrative and Legal procedures								
RALP1	Construction unit lacks understanding of law	11	10	10	27	6	64	0.62
RALP2	Relationship of the investor, the contractor with the competent agency to the project	6	7	19	25	7	64	0.66
RALP3	Local construction management regulations	2	11	19	24	8	64	0.68
RALP4	Complicated administrative procedures	2	8	17	26	11	64	0.71
RALP5	Adjustment of the project’s scale of the investor	2	11	15	28	8	64	0.69
RALP6	Causes of labour safety	6	17	11	19	11	64	0.64
RALP7	Changes in laws, regulations, standards, etc.	7	10	16	22	9	64	0.65

1) *Risks associated with design consulting work:* The group related to design consulting work was identified as the most critical in terms of potential risks. This was primarily attributed to factors such as the utilization of standard design drawings without proper revisions, incorrect calculations of material quantities by the consultant, and the use of incorrect job codes in estimations.

2) *Risks related to the economy:* The group associated with the economy was ranked as the second most important group where risks can occur. This was primarily due to factors such as the risks posed by inflation, the financial capacity of the contractor, and changes in tax policies.
3) *Risks related to project management:* The group associated with project management was identified as the third most important group where risks can occur. This was attributed to factors such as poor management of construction safety, inadequate coordination between the investor and general contractor, and deficiencies in the management information system.
4) *Risks associated with the contractor's construction capacity:* The group related to the contractor's construction capacity was ranked fourth in terms of importance. Factors such as insufficient technical workforce, subpar quality of finished products, and inadequate technical skills and human resources contributed to the significance of this group.
5) *Risks due to administrative and legal procedures:* The group associated with administrative and legal procedures was identified as the fifth most important group where risks can occur. This was primarily due to factors such as complex administrative procedures, adjustments in the project's scale by the investor, and adherence to local construction management regulations.
6) *Risks related to natural and social factors:* The group associated with natural and social factors was ranked sixth in importance. Factors such as volatility in raw material prices, fluctuations in the labor market, and changes in the capital market were identified as significant contributors to this group.
7) *Risks due to contracts:* The group related to contracts was determined to be the least important group where risks can occur. This was primarily due to factors such as contract disputes, uncertainties and ambiguities in contract terms, and changes or additions to the contractual terms.

V. CONCLUSION

The first objective was to identify the risk factors in 24x7 water supply scheme projects. Through an extensive literature review and expert interviews with a prominent construction company, a total of fifty-one (51) risk factors were identified.

The second objective was to quantify the relative importance of the identified risk factors and demonstrate their ranking. This objective was accomplished by conducting interviews with a panel of experts. All factors and groups were ranked based on their computed relative importance indices, with the most and least crucial factors and groups identified accordingly.

The third objective was achieved from

Table **8** RII of risk attributes. Each important risk factor was marked according to their RII value, whether it is high or low. Risks associated with design consulting work were the most influencing group and needs to be looked after to avoid future risks.

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