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QUANTITIVE ANALYSIS OF EXTERNAL FACTORS INFLUENCES SAFETY WHILE CONSTRUCTION OF ROADWAYS IN INDIA

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ABSTRACT

Ensuring safety during roadway construction is essential to protect workers, optimize project execution, and reduce accident rates. However, maintaining safety on construction sites is challenging due to various factors that influence working conditions and operational risks. This research aims to perform a comprehensive quantitative analysis of factors affecting safety in roadway construction. Through extensive literature review and expert consultations, 34 influential safety factors were identified and validated. The study employed the Relative Importance Index (RII) methodology to rank and prioritize these factors based on their significance. The top 10 critical factors were identified, offering valuable insights into key areas requiring focused attention for improved safety outcomes. Furthermore, Analysis of Variance (ANOVA) was applied to evaluate the statistical significance of these factors, providing a deeper understanding of their impact on safety performance. The findings of this research serve as a practical guide for construction professionals, safety managers, and policymakers in formulating effective safety strategies and enhancing resource allocation to minimize hazards on roadway construction sites. By addressing the most significant safety factors, this study contributes to fostering a safer, more efficient construction environment.

Keywords: *Safety During Road Construction, Anova Analysis, Rii Method, Construction Management, Road Construction, External Factors.*

1. INTRODUCTION

The construction of roadways plays a vital role in infrastructure development, facilitating economic growth and connectivity. However, the dynamic and hazardous nature of construction activities poses significant safety challenges. Roadway construction sites often involve complex operations, heavy machinery, and high traffic environments, which elevate the risk of accidents and injuries. Ensuring a safe working environment not only protects workers but also enhances project efficiency and quality. Ensuring the safety and well-being of all stakeholders involved in road construction requires the effective implementation of safety management practices. This assessment aims to evaluate the safety management practices of road construction in the India, focusing on the policies, procedures, and measures established to mitigate risks and safeguard workers. By identifying gaps and areas for improvement, this evaluation seeks to contribute to the enhancement of safer road construction practices in the India.

The importance of safety management in road construction cannot be overstated. Globally, road construction has one of the highest accident rates compared to other industries (Abe and Tamura, 2011). Construction workers face a variety of hazards, including exposure to heavy machinery, risks of falls from heights, vehicle-related accidents, and contact with hazardous materials (Oyedele et al., 2019). Therefore, comprehensive safety management practices are essential for addressing these risks and promoting safer working conditions. Implementing effective safety management measures not only protects workers but also enhances project efficiency and reduces costs related to accidents, injuries, and delays.

This assessment seeks to provide recommendations for improving safety management practices, contributing to safer working environments for road construction workers and more successful infrastructure development projects.

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The evaluation will examine critical areas such as the administration's safety policies and procedures, risk assessment strategies, safety training programs, and the provision of personal protective equipment (PPE). By analysing these aspects, the assessment will offer insights into the level of safety commitment, the effectiveness of existing safety measures, and the extent to which industry best practices are adopted. It will also explore challenges in ensuring compliance with safety regulations and propose strategies for strengthening safety management practices in the India.

Safety management practices are essential in all construction projects, but they are particularly critical in road construction. In recent years, the India has witnessed a surge in road construction projects, raising various safety concerns. One major issue is the involvement of inexperienced or poorly trained workers in many projects, which increases the likelihood of accidents, injuries, and substandard work that may compromise road safety.

Additionally, public safety is a significant concern. Road construction can disrupt traffic flow and create hazards for drivers and pedestrians. Without adequate safety measures, accidents may occur, endangering lives. Another challenge is the lack of proper oversight and enforcement, which makes it difficult to ensure adherence to safety protocols and adequate worker training. Furthermore, there is a general lack of awareness among the public about the risks associated with construction zones, resulting in insufficient precautions when navigating these areas.

Addressing the lack of safety measures in road construction projects in India is crucial. Without proper safety protocols, accidents and injuries can have long-lasting consequences. To tackle these issues, stricter safety regulations and enforcement mechanisms must be introduced. This requires a commitment from both public and private stakeholders in the region. Providing proper training and education for road construction workers is vital for improving safety outcomes. This training should cover safety protocols and the correct use of tools and equipment. Furthermore, raising public awareness about road construction hazards and the necessary precautions for safe travel through these areas is essential. Public awareness campaigns targeting drivers and pedestrians can help mitigate risks. Implementing these measures can lead to better safety outcomes in Indian road construction projects, protecting workers and the public while contributing to the long-term success and sustainability of these vital infrastructure initiatives.

Governments, construction firms, and regulatory bodies must work together to implement comprehensive safety policies, conduct regular safety audits, and invest in worker education programs. The discussion explores the significance of safety in road construction, the primary risks involved, and the most effective strategies for ensuring a secure working environment. By prioritizing safety, construction projects can be completed efficiently while reducing accidents and saving lives.

In India, the rapid expansion of road infrastructure has led to a significant increase in construction activities across the nation. This surge is driven by initiatives such as the Prime Minister's Rural Road Development Schemes and the National Highway Development Project (NHDP), aiming to enhance connectivity and support economic growth. However, the accelerated pace of construction has brought forth substantial safety challenges. Ensuring the safety of workers, motorists, and pedestrians amidst these developments is paramount. The dynamic environment of road construction sites, characterized by heavy machinery, high traffic volumes, and evolving work zones, necessitates stringent safety protocols. Implementing comprehensive safety measures, including effective traffic management plans, proper signage, and the use of personal protective equipment, is crucial to mitigate risks and prevent accidents. Moreover, regular safety audits and adherence to established guidelines can significantly contribute to safer construction practices. Addressing these safety concerns is essential to protect lives and ensure the successful completion of road infrastructure projects in India.

2. LITERATURE REVIEW

2.1 Occupational Hazards in Road Construction

Johnson and Wilson (2020) provide an in-depth review of occupational hazards in road construction. Their study highlights critical risks such as exposure to hazardous materials, heavy machinery-related dangers, and traffic-related threats. The authors categorize common accidents and analyze their causes, emphasizing the importance of engineering controls and structured safety training to mitigate these risks. The study concludes that a combination of advanced safety measures, including personal protective equipment (PPE) and structured protocols, can significantly reduce workplace injuries in the road construction sector.

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2.2 Safety Performance in Road Construction Projects
Doe and Smith (2018) focus on the essential factors influencing safety performance in road construction projects. Their research underscores the role of safety culture, management dedication, and worker training in minimizing accidents. The study argues that proactive safety measures and continuous improvement programs contribute to accident reduction and enhance overall project efficiency. By integrating strategic safety initiatives with employee engagement, construction projects can achieve higher safety standards and reduce workplace hazards effectively.

2.3 Best Practices in Safety Management in Road Construction
White and Green (2018) emphasize the significance of risk assessment, safety training, and incident reporting as crucial components of safety management in road construction. Their review advocates for the implementation of comprehensive safety management plans that integrate worker feedback and employ data analytics to pre-emptively identify potential risks. The authors suggest that utilizing data-driven approaches can lead to substantial improvements in occupational safety by addressing vulnerabilities before they result in workplace accidents.

2.4 Effectiveness of Safety Training Programs for Construction of Roads
Lewis and Robinson (2020) assess the impact of various safety training programs on accident reduction and safety awareness among construction workers. The review highlights the importance of customized training programs tailored to address specific job site hazards. The authors conclude that safety training should be interactive and scenario-based to enhance retention and applicability. By aligning training programs with real-world construction challenges, organizations can better equip workers with the necessary knowledge and skills to navigate occupational hazards.

2.5 Factors Influencing Project Success in Road Construction
Brown and Davis (2020) explore the interplay of time, cost, and quality in construction project success. Their study identifies factors such as material shortages, inefficient planning, and project rework as primary contributors to schedule delays. Additionally, they discuss how cost overruns can result from fluctuating material prices, managerial inefficiencies, and errors during construction. The authors emphasize that adherence to quality standards, proper inspection procedures, and effective project management are fundamental to ensuring project success in the construction industry.

2.6 Human Factors in Road Construction Safety
Clark and Adams (2021) investigate human factors influencing construction site safety, focusing on worker behavior, fatigue, and ergonomics. Their study identifies ergonomic interventions, optimized work design, and targeted training as essential strategies for improving safety. The authors argue that considering human factors in safety protocols leads to a substantial decrease in workplace injuries. Furthermore, by addressing issues such as mental and physical fatigue, construction sites can create safer and more efficient working environments.

2.7 Importance of Safety Audits in Road Construction
Anderson and White (2020) highlight the role of safety audits in hazard identification and regulatory compliance. Their study finds that regular safety audits contribute to continuous safety improvements and help establish a safety-conscious culture among workers. By systematically evaluating workplace hazards and implementing corrective measures, safety audits ensure that road construction projects adhere to the highest safety standards.

2.8 Risk Management in Road Construction
King and Young (2021) discuss risk management practices in road construction, with a focus on hazard identification, risk assessment, and mitigation strategies. Their research presents case studies demonstrating the effectiveness of risk management initiatives in improving site safety. The authors emphasize that a well-structured risk management plan should incorporate considerations such as site conditions, traffic flow, and worker behaviour. The study concludes that fostering a proactive risk management culture is key to reducing accidents and enhancing overall project safety.

Overall, the reviewed literature collectively underscores the importance of a multifaceted approach to road construction safety. Common themes include the necessity of management commitment, continuous worker training, comprehensive risk assessment, and adherence to safety regulations. A strong safety culture, bolstered by structured training programs, human factor considerations, and rigorous safety audits, is fundamental in minimizing accidents and fostering a secure working environment in road construction projects.

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3. METHODOLOGY

3.1 Identification and Validation of Factors

A total of 49 factors were initially identified for this study. These factors were derived from an extensive literature review and expert consultations. To ensure the relevance and reliability of these factors, a validation process was conducted involving senior managers, senior engineers, and academicians. Through this rigorous review and feedback process, 34 factors were finalized for further analysis.

3.2 Data Collection Process

Data for this study is being collected from a diverse group of professionals engaged in road construction projects. This includes engineers, project managers, relevant stakeholders, and other key industry participants. A Google Form serves as the primary tool for gathering responses, ensuring an efficient and systematic approach to data collection.

The questionnaire within the Google Form includes a structured list of validated factors. Respondents are required to evaluate each factor using a Likert scale ranging from "Strongly Agree" to "Strongly Disagree." This scaling method allows for a quantitative assessment of the importance of each factor in the context of road construction projects.

3.3 Data Analysis Methodology

The collected data is analyzed using the Relative Importance Index (RII) method. This approach enables the ranking of factors based on their significance as perceived by respondents. The RII is calculated using the following formula:

$$RII = \Sigma W / (A*N)$$

Where:
W represents the weighting assigned to each factor by respondents (ranging from 1 to 5),
A is the highest possible weight (5 in this case), and
N is the total number of respondents.
A higher RII value indicates a greater influence of the respective factor on the scheduling of multiple projects in road construction.

3.4 Significance Testing Using ANOVA

To further validate the significance of the identified factors, an Analysis of Variance (ANOVA) is performed. ANOVA helps in determining whether there are statistically significant differences among the identified factors, ensuring a comprehensive understanding of their impact. By employing ANOVA, the study can effectively distinguish the most critical factors influencing road construction projects, enhancing the robustness of the findings.

This systematic methodology ensures that the study identifies and prioritizes the key factors affecting road construction while providing statistically validated insights for improving project scheduling and management.

4. DATA COLLECTION

A structured questionnaire was developed based on the 34 validated factors to gain industry insights through a quantitative survey. A purposive sampling technique was employed to select a representative group of Indian construction professionals. The questionnaire was segmented into three key respondent categories: Project Managers, Contractors, and Engineers. This classification ensures that feedback is obtained from various crucial stakeholders in safety of road construction. A five-point Likert scale was used, enabling participants to assess the influence of each factor on material management. The survey was distributed to 170 industry professionals, resulting in 117 valid responses, aligning with the required sample size calculations. This approach facilitates a well-rounded and diverse understanding of the challenges and best practices in material management within the construction industry. Out of 117 responses 38 project managers, 45 engineers and 34 contractors filled the questionnaire form and submit their responses.

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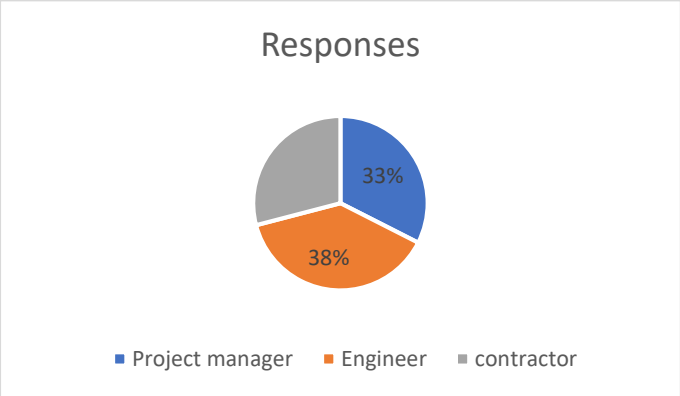

4.1 figure: Responses collected for various categories

5. DATA ANALYSIS

5.1 Ranking of Factors

A higher RII value indicates a greater influence of the respective factor on the scheduling of multiple projects in road construction. The RII analysis is utilized to rank these factors based on their impact levels. This ranking enables the identification of the most significant factors, allowing construction professionals to make well-informed and strategic decisions. By integrating statistical analysis with prioritization, a comprehensive assessment of material management challenges can be achieved. The given tables give the RII analysis and ranking of those factors which were identified and validated.

Factors	RII	Rank
Information and Education	0.9114754	1
Site Management and Supervision	0.8896175	2
Inadequate supervision and regulation work	0.8765027	3
Material Quality and Availability	0.8759563	4
Traffic control regulation practised at the site	0.8743169	5
Lack of adequate skilled labour	0.8704918	6
Enforcement of safety rules	0.8688525	7
Unskilled equipment operators	0.8672131	8
Equipment Availability and Maintenance	0.8655738	9
Material procurement	0.863388	10
Coordination and lack of knowledge	0.8601093	11
Use of safety tools demonstration	0.8601093	11
Restricted access at site	0.8557377	12
Unforeseen Events (e.g., Natural Disasters)	0.852459	13
Poor qualification of the contractors technical staff	0.8519126	14
Poor Site Management and supervision	0.8497268	15
Incompetent supervisors	0.8480874	16
Lack of tool and equipment	0.847541	17
Bad weather condition External related	0.847541	17
Improper Use of Equipment	0.847541	17
The complexity of project design	0.8448087	18
Poor communication and coordination between projects parties	0.8437158	19
Safety issue in project	0.8415301	20
Unskilled machine operators	0.8398907	21
Poor site condition	0.836612	22
Poor communication and coordination between the parties and others	0.8349727	23
Incompetent Project Team		
Equipment of lesser efficiency	0.8344262	24

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The low productivity level of labours	0.8344262	24
Unavailability of adequate unskilled labour	0.8322404	25
Awarding the project to lowest bid price	0.8273224	26
Continuous Monitoring	0.8229508	27
Personal conflict of labour	0.8180328	28
Interdependencies and conflict	0.8169399	29
Awarding the project to lowest bid price	0.795082	30

Table: Ranking of factors by using RII

To evaluate the impact of the identified factors, a one-way ANOVA analysis is conducted. This analysis helps determine whether there are significant variations in ratings among the factors. Utilizing this statistical approach ensures that conclusions are based on objective data rather than personal opinions. The given table evaluates the variance of each factor to do the Analysis of variances.

Groups	Count	Sum	Average	Variance
F1	117	512	4.376068	0.44356
F2	117	530	4.529915	0.578839
F3	117	509	4.350427	0.608901
F4	117	479	4.094017	1.379016
F5	117	462	3.948718	1.014589
F6	117	479	4.094017	1.103154
F7	117	489	4.179487	0.958886
F8	117	500	4.273504	0.941792
F9	117	476	4.068376	1.047009
F10	117	470	4.017094	1.034188
F11	117	484	4.136752	0.63631
F12	117	500	4.273504	0.976275
F13	117	472	4.034188	0.964338
F14	117	505	4.316239	0.718096
F15	117	488	4.17094	1.108459
F16	117	487	4.162393	1.119953
F17	117	487	4.162393	0.861332
F18	117	501	4.282051	0.65252
F19	117	494	4.222222	0.846743
F20	117	512	4.376068	0.633215
F21	117	516	4.410256	0.606101
F22	117	493	4.213675	0.738432
F23	117	493	4.213675	0.755673
F24	117	482	4.119658	1.140731
F25	117	482	4.119658	1.209696
F26	117	494	4.222222	0.898467
F27	117	476	4.068376	1.047009
F28	117	483	4.128205	1.095491
F29	117	486	4.153846	1.027851
F30	117	494	4.222222	0.829502
F31	117	471	4.025641	0.973475

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F32	117	491	4.196581	0.762747
F33	117	490	4.188034	0.843649
F34	117	512	4.376068	0.581491

Table: Summary of one way ANOVA for variance of each factor

6. RESULTS

The one-way ANOVA (Analysis of Variance) is conducted to determine whether there are statistically significant differences in the mean ratings of the identified factors. The analysis compares the variation between groups (the different factors) to the variation within groups (the individual responses). The results are interpreted as follows:

P-Value (0.00013): The probability that the observed differences occurred by chance. Since the p-value is less than 0.05, it indicates a statistically significant difference among the factors.

F-Critical Value (1.44): This is the threshold value for significance at a given confidence level (typically 95%). Since the F-statistic (2.17) exceeds the critical value (1.44), we reject the null hypothesis, confirming that at least one factor has a significantly different impact level compared to the others.

Variation	SS	df	MS	F	P-value	F crit
Between Groups	63.35269	33	1.919778	2.165823	0.000131	1.439345
Within Groups	3495.949	3944	0.886397			
Total	3559.301	3977				

Table: One way ANOVA for p-value

The ANOVA results indicate that there are significant differences in the ratings of the factors. This suggests that some factors have a stronger impact than others, justifying the need for further ranking using the Relative Importance Index (RII) to prioritize them effectively.

7. CONCLUSION

Ensuring safety in roadway construction is crucial for protecting workers, improving project efficiency, and minimizing accidents. This study identified and ranked 34 key safety factors using the Relative Importance Index (RII) method and validated their significance through Analysis of Variance (ANOVA). The findings highlight the most critical factors that influence safety performance, providing a structured approach for prioritizing safety measures in construction projects.

The results indicate that factors such as proper site management, enforcement of safety regulations, and adequate training for workers play a significant role in enhancing safety outcomes. The identification of these high-impact factors serves as a practical guide for construction professionals, policymakers, and safety managers in developing targeted safety strategies. By addressing these critical factors, stakeholders can implement more effective safety measures, reducing risks and fostering a safer construction environment.

Furthermore, this research underscores the importance of continuous monitoring, regulatory enforcement, and worker education in sustaining safety improvements. Integrating these elements into construction management practices can lead to long-term advancements in workplace safety and operational efficiency. Future research can expand on these findings by exploring innovative safety technologies, automation in construction processes, and region-specific safety challenges. Overall, this study contributes valuable insights to the ongoing efforts to enhance safety standards in roadway construction.

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