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# ASSESSING KEY RISK FACTORS FOR WORKERS DURING NIGHTTIME IN THE INDIAN CONSTRUCTION INDUSTRY

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## *ABSTRACT*

*Construction activities are crucial for global infrastructure development, but are often accompanied by significant risks, particularly at night. The transition from day to night amplifies hazards due to inadequate lighting, disrupted routine work, fatigue, and heightened stress levels. This study uses a field-based approach, incorporating expert interviews, to identify and prioritize 17 critical safety attributes construction workers face during nighttime. The study conducted 15 expert interviews, and the Analytic Hierarchy Process (AHP) was employed to quantify and prioritize these risks in the Indian context. The attributes identified were categorised into five factors, i.e., environmental, human, work-related, equipment, and organizational. By prioritizing through AHP, work-related risks, such as construction height, emergency preparedness, and falling objects, emerge as the most critical. While equipment hazards like poor lighting and faulty electrical grounding also rank high. However, organizational issues, including lack of training and weak supervision, significantly affect safety but are often normalized in the informal sector. Notably, human factors like fatigue, sleep deprivation, and stress rank lowest, despite their known long-term impact on alertness and safety, revealing a significant gap in current safety approaches. The study highlights the need to increase awareness of often-overlooked risks, particularly human and organizational factors. The findings support policymakers and practitioners in prioritizing safety concerns, planning, supervision, and training efforts for nighttime construction. This study contributes to developing more targeted, evidence-informed safety strategies in nighttime construction in the Indian construction sector.*

***Keywords:*** *Construction Worker; Nighttime Construction; Occupational Safety.*

## 1. INTRODUCTION

Occupational accidents are the cause of more than 3,00,000 mortalities and 300 million injuries around the world each year (International Labour Organization, 2014). The construction industry is one of the most hazardous occupational sectors globally. In particular, these risks are magnified during nighttime operations due to reduced visibility,

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disrupted circadian rhythms, and increased fatigue, making night work particularly dangerous for construction workers (Amiri et al., 2015).

One of the earliest studies to examine the differences between daytime and nighttime highway construction was conducted in Colorado in 1986 (Price, 1986), marking a foundational effort to understand the unique challenges associated with night work in the construction sector. Research on shift work's health and safety effects indicates that shift workers experience adverse health symptoms more frequently and severely than day workers (Folkard & Lombardi, 2006). There is a large body of evidence indicating that night workers, in particular, suffer from chronically impaired health and well-being, including sleep problems, headaches, anxiety, poor concentration, nervousness, mild depression, mood disturbances, cardiovascular and musculoskeletal problems (Loudoun & Allan, 2008).

During nighttime construction, the hazard level to construction workers is manifold when working with heavy machinery, operating at elevated heights (Arditi et al., 2005). These risks endanger the lives and health of construction workers, affect economic costs, and cause delays. The transition from day to night creates a complex and challenging work environment, which is very difficult for the workers. The tasks that are straightforward during the day may be hazardous at night.

Despite advancements in safety practices in the construction industry, nighttime construction remains under-researched, especially in low and middle-income countries where most infrastructure development is labour-intensive and informal. India has one of the largest construction industries in the world, employing over 70 million workers (Chellappa et al., 2021; Statista, 2024). However, research on the safety health of Indian construction workers is limited, despite the high prevalence of safety problems among construction workers. In India, the construction sector accounts for one of the highest occupational fatality rates, with estimates ranging between 11,614 and 22,080 fatalities annually between 2008 and 2012 (Patel & Jha, 2016).

In India's rapid urbanization and growing infrastructure demands, nighttime construction has become increasingly common, particularly in metropolitan cities. The Indian construction industry, predominantly informal and labour-intensive, often lacks standardized protocols for nighttime operations (Chellappa et al., 2021). As a result, to complete the tasks, the construction workers have to work more, so the construction safety is lower. The hazards become even more dangerous during nighttime construction, where reduced visibility, extreme weather, and disrupted sleep cycle contribute to an increased threat to occupational health and safety (Arditi et al., 2005).

Challenges such as inadequate lighting, absence of proper signage, insufficient protective gear, and limited health and safety monitoring contribute to increased workers' vulnerability during night shifts (Hinze & Carlisle, 1990). Despite the increasing reliance on nighttime construction, there is a notable absence of empirical research that systematically assesses the risk factors unique to these settings in the Indian context. Addressing this gap is essential for informing evidence-based safety policies and improving working conditions in India's construction sector.

Although several studies have explored construction site safety and occupational risks, most focus on daytime conditions or aggregate safety data without distinguishing between shift timings. Research addressing the specific challenges of nighttime construction, such as reduced visibility, worker fatigue, psychological stress, and lack of supervision, remains limited, especially in low and middle-income countries like India. Furthermore, existing literature seldom applies multi-criteria decision-making methods like the Analytic Hierarchy Process (AHP) to prioritize these risks based on expert judgment. This lack of focused, empirical research on night-specific risks in the Indian construction context represents a critical gap that this study aims to address.

## 2. LITERATURE REVIEW

Nighttime work presents unique challenges and risks due to visibility issues, worker fatigue, and environmental factors. This review synthesizes findings from multiple studies to highlight the factors affecting nighttime operations. Nighttime work increases hazards for workers due to poor visibility and human factors such as sleep deprivation.

### 2.1 FATIGUE AND SLEEP DEPRIVATION IN NIGHTTIME OPERATIONS

Fatigue is a leading risk factor in nighttime construction, often resulting from disrupted circadian rhythms and insufficient rest. Sleep deprivation has been shown to impair attention and cognitive function, increasing the likelihood of accidents (Powell & Copping, 2010). In a study conducted in Vancouver, construction workers monitored with actigraphs exhibited sleep patterns far below the recommended 8 hours, correlating with a 9% increase in accident risk.

### 2.2 IMPACT OF SHIFT WORK AND SUBSTANCE USE

Night shifts are also a source of stress, a situation that can induce "escapist" consumption of addictive substances such as tobacco, coffee, alcohol, etc. To this must be added the problem of having to work during periods of rest that are usual for the rest of the population, such as holidays, weekends, and nights (Elrahman & Perry, 1994). All these circumstances, acting together, reduce the efficiency of the workers at the time of concentration. Night shifts are stressful, and to counteract it, workers use tobacco or alcohol to feel better and stay attentive during nighttime construction. This may be effective during the time of work, but when it becomes an addiction, then the absence of it may lead to ineffectiveness, and workers become inattentive. Working at a time when most people take rest, like nights, weekends, or holidays, makes it more challenging. This disrupts personal and social connections, which are needed to help in recovering from addiction.

### 2.3 LIGHTING, VISIBILITY, AND ENVIRONMENTAL HAZARDS

Similarly, lighting is an essential element of any nighttime project since it affects quality, productivity, and safety. Adequate lighting makes constructing at night as easy as constructing during the day, as it positively affects visibility. In a study by Hinze and Carlisle (1990), state highway agencies and contractors stated that adequate lighting is an important safety aspect in nighttime construction projects. Based on the study's suggestions, Hyari and El-Rayes (2006) developed illumination guidelines for nighttime highway construction and maintenance.

In addition to lighting, weather has contributed significantly to construction safety factors, especially during night shifts. Many studies show that adverse weather can influence the frequency of accidents and the seriousness of their consequences. The data also reveal that wet conditions, particularly night shifts, pose significant safety risks (Kim & Xiong, 2025). This pattern underlines the riskiness of construction work on and offsite, especially considering that weather conditions are exacerbated by "lighting conditions"- day versus night. Low light and visibility increase the chances of falls at night, especially at height. In addition to physical injuries, falls from heights can also cause mental trauma (Zaini et al., 2020; Hyari & El-Rayes, 2006).

In addition, slippery surfaces, reduced visibility, and structural instability due to severe weather contribute to heightened accident risks. During nighttime, the temperature drops, and due to this, the moisture in the air condenses. This condensation makes the surfaces, such as walls and ground, slippery. Due to this, accidents occur, and workers slip on these surfaces and fall. If they carry a heavy object, they cause harm to themselves (Amiri et al., 2015).

### 2.4 EQUIPMENT, MACHINERY AND HUMAN FACTORS

Scaffolding failures, lack of personal fall protection systems, and inadequate safety barriers are primary factors leading to fall-related accidents. Unsafe working conditions at elevated platforms, combined with insufficient training on height safety protocols, significantly increase the risk of severe injuries or fatalities (Amiri et al., 2015).

Many construction accidents occur due to a lack of proper training, with workers often failing to recognize or respond appropriately to hazards in their work environment. New and inexperienced workers are at a higher risk of injury, making structured safety education and on-site training essential components of accident prevention strategies (Amiri et al., 2015; Brolin et al., 2021).

Many accidents occur due to inadequate hazard identification and risk assessment before the commencement of construction activities. Effective risk assessment strategies, such as predictive analytics and data-driven decision-making, can significantly reduce workplace hazards. Though safety awareness in the construction industry is increasing, a significant research gap remains, as most trainings focus on general or daytime risks, with minimal attention to nighttime hazards (Yang et al., 2024). There is a lack of structured studies using statistical methods to prioritize these risks for decision-making. The current study addresses this gap by identifying and evaluating the factors that impact workers' safety in nighttime construction through applying the Analytic Hierarchy Process (AHP), particularly from an Indian perspective.

## 3. RESEARCH METHOD

The research adopts a structured approach consisting of the following steps: identification of the factors, data collection, data analysis, computations, and results. Each step is defined in the following subsections as shown in Figure 1.

### 3.1 IDENTIFICATION OF RISK FACTORS

A thorough analysis was conducted from literature reviews of research articles, news articles, and government reports. This study identifies key risk factors that affect construction worker safety, specifically during nighttime operations. These factors and attributes are shown in Table 1.

### 3.2 AHP – BASED RISK PRIORITIZATION

The safety climate refers to the overall attitude of workers towards safety precautions and practices during construction. Thus, the information should be handled qualitatively.

Therefore, in this study, an AHP questionnaire was administered to a group of safety experts who have performed safety management tasks for an extended period to maintain the consistency of the results. To do so, a questionnaire was first formed based on the AHP technique. In AHP analysis, the evaluation criteria and alternatives are organized in a hierarchical structure, and then, the priority is determined by deriving relative importance. A flowchart of the AHP process is shown in Figure 2.

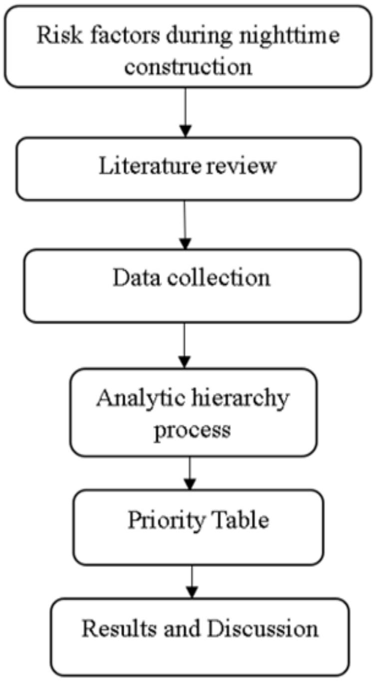


*Figure 1: Research methodology flowchart*

*Table 1: Categorization of risk factors and attributes identified from literature*

| Factors | Attributes |
|---|---|
| Environmental | A1. Glare from Roadways<br>A2. Extreme temperature<br>A3. Slippery surface due to moisture during the night |
| Human | B1. Hypertension<br>B2. Fatigue<br>B3. Sleep Deprivation<br>B4. Addictive intake<br>B5. Psychological Impact |
| Work-related | C1. Height of construction sites<br>C2. Lack of emergency readiness<br>C3. Falling and Falling Objects |
| Equipment and Machinery Hazards | D1. Reflective PPE Kits (if not used properly)<br>D2. Inadequate lighting at the construction site.<br>D3. Heavy machinery operation (crane, hoists) is riskier in low visibility<br>D4. Grounded electrical wiring |
| Organizational and Supervision | E1. Inadequate training for nighttime hazards<br>E2. Improper supervision during construction |

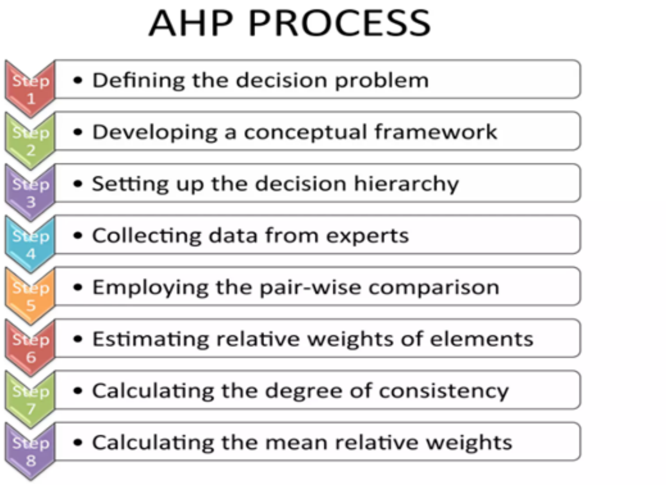


*Figure 2: Flowchart of AHP process*

After developing a questionnaire, industrial experts were interviewed to acquire the data to conduct AHP. The experts have given weight to the combination of two risks. This structured approach ensures that the identified risks are prioritized systematically and aligned with expert judgment.

### 3.3 STUDY EXPERTS

This study surveyed safety experts working at construction sites in India. The survey period was for 2 months from March to April in 2025. Out of the 20 questionnaires collected, only 15 with a consistency of 0.1 or less were selected.

As shown in Table 2, most of the surveyed experts (53.33%) had between 5 and 10 years of experience in construction safety, indicating a well-informed sample with mid-level professional insights. Among all the interviewees, all 15 were male and had graduate degrees in allied construction engineering.

Although the sample size of 15 experts is relatively limited, it aligns with established practices in AHP studies, where smaller expert panels (typically between 10–20 participants) are considered sufficient when participants have high domain expertise and consistency ratios are within acceptable thresholds (Saaty, 2008; Tsyganok et al., 2012; Nguyen et al., 2022). In this study, all selected responses had a consistency ratio ≤ 0.1, indicating reliable judgment. Moreover, the selected experts had a minimum of graduate-level education and significant field experience in construction safety, further supporting the adequacy and credibility of the sample.

*Table 2: Demographic profile of safety experts participating in AHP survey*

| Experience (in years) | Number of experts | Percentage |
|---|---|---|
| less than 5 years | 4 | 26.6 |
| 5-10 years | 8 | 53.3 |
| 10-15 years | 2 | 13.3 |
| 15+ years | 1 | 6.6 |

## 3.4 ANALYSIS

In AHP analysis, the evaluation criteria and alternatives are organized in a hierarchical structure, and the priority is determined by deriving relative importance (Lim et al., 2021). For conducting AHP, the evaluation factors and attributes should be stratified to analyse the relative importance of the risk severity evaluation. The decision-making issues of this study were developed with the help of the experts in the form of a stratified pattern as shown in Figure 3. Therefore, the goal of AHP analysis in this study is to derive the importance of the safety climate evaluation factors. This comprises five dimensions (factors) and 17 items (attributes). Refer to Table 1 for details on the evaluation items for each level in Figure 3. The items of each dimension are analyzed after determining the relative importance of the dimensions of the first level. Subsequently, the relative priorities of the evaluation factors are derived.

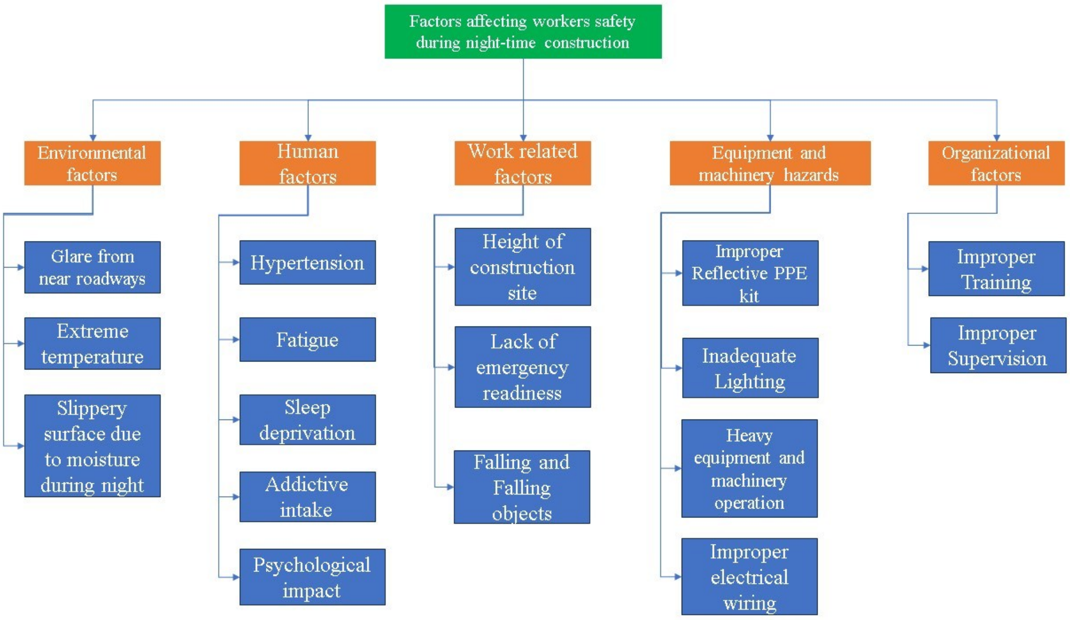


*Figure 3: Hierarchical structure of AHP factors*

After developing the hierarchical structure, the weights to each of the 17 items were computed with the help of the 9-point Likert scale developed by Saaty (2008). This scale is widely used in the Analytic Hierarchy Process (AHP) for pairwise comparisons. The experts related the importance of each item through a consistent framework ranging from 1 (equal importance) to 9 (extreme importance). The comparison matrix of this study takes the form of an inverse centred around the diagonal. When the values of the two factors in the matrix are 1, they have equal relative importance. In addition, the size of the comparison matrix may depend on the number of factors in the hierarchy. The AHP scale used in this study is shown in Table 3.

*Table 3: Saaty's 9-point AHP scale for pairwise comparison*

| Scale | Definition | Explanation |
|---|---|---|
| 1 | Equally important | Both factors have the same criteria. |
| 3 | Moderately important | One criterion is slightly more important than the other. |
| 5 | Strongly important | One criterion is more important than the other. |
| 7 | Very strongly important | One criterion is far more important than the other. |
| 9 | Extremely important | One criterion is hugely more important than the other. |
| 2,4,6,8 | The median of the two scales | The median of the two scales. |

## 4. RESULTS AND DISCUSSION

The results of the AHP analysis revealed the ranking of the five primary risk dimensions based on their overall impact on worker safety during nighttime construction. As shown in Table 4, work-related factors received the highest priority (weight = 0.353), followed by equipment and machinery hazards (0.286), organizational factors (0.242), environmental factors (0.070), and human factors (0.049).

*Table 4: Relative importance and priority of risk dimensions identified through AHP analysis*

| Code | Dimension | Weight | Priorities |
|---|---|---|---|
| C | Work-related | 0.353 | 1 |
| D | Equipment and machinery hazards | 0.286 | 2 |
| E | Organisational | 0.242 | 3 |
| A | Environmental | 0.070 | 4 |
| B | Human | 0.049 | 5 |

The criticality of the factor is justified by the fact that there is a much higher chance of slips. It falls during nighttime construction when there is inadequate lighting, particularly in areas with uneven surfaces or elevation changes (Chan et al., 2008). The significance of hazards related to equipment, like poor lighting and improper electrical grounding, shows the technical issues that are often overlooked during nighttime construction, especially since nighttime work and bad weather can negatively impact how well the equipment works (Arditi et al., 2005).

Furthermore, the local and global relative importance and priority measurements on items in risk factors during nighttime construction are shown in Table 5. Local weight measures a sub-criterion's relative importance within its main criterion in multi-criteria decision-making techniques such as AHP. It is obtained by comparing sub-criteria under the same category pairwise. Conversely, global weight indicates a sub-criterion's overall significance concerning the ultimate objective. It is determined by multiplying the sub-criterion's local weight by the weight of the main criterion. This aids in determining each sub-criterion's overall influence on the choice and ranking them all on a standard scale.

*Table 5: Local and global priority rankings of risk attributes in nighttime construction*

| Dimension | Risks | Local weight | Local priorities | Global weight | Global priorities |
|---|---|---|---|---|---|
| Environmental (0.070) | A1. Impact of glare from near roadways on construction worker safety. | 0.099 | 3 | 0.007 | 14 |
| | A2. Influence of extreme temperatures on worker performance and risk levels. | 0.537 | 1 | 0.037 | 7 |
| | A3. Influence of slippery surface due to nighttime moisture. | 0.364 | 2 | 0.025 | 9 |
| Human (0.049) | B1. Effect of hypertension on construction worker safety. | 0.102 | 4 | 0.005 | 15 |
| | B2. Influence of fatigue on accident risks. | 0.008 | 5 | 0.0002 | 17 |
| | B3. Impact of sleep deprivation on worker efficiency and safety. | 0.324 | 1 | 0.016 | 10 |
| | B4. Risks associated with addictive intake during night shifts. | 0.293 | 2 | 0.014 | 11 |
| | B5. Psychological effects of night shift work on construction safety. | 0.199 | 3 | 0.009 | 13 |
| Work-related (0.353) | C1. Safety concerns are due to the height of construction sites. | 0.195 | 2 | 0.069 | 5 |
| | C2. Readiness and effectiveness of emergency response at night. | 0.717 | 1 | 0.253 | 1 |
| | C3. Risks associated with falling and falling objects in nighttime construction. | 0.088 | 3 | 0.003 | 16 |
| Equipment and Machinery hazards (0.286) | D1. Proper usage and potential risks of reflective PPE kits. | 0.042 | 4 | 0.012 | 12 |
| | D2. Impact of inadequate lighting on construction site safety. | 0.235 | 2 | 0.067 | 6 |
| | D3. Safety risks are associated with operating heavy machinery (cranes, hoists) in low visibility. | 0.104 | 3 | 0.029 | 8 |
| | D4. Hazards are due to the improper grounding of electrical wiring at construction sites. | 0.619 | 1 | 0.177 | 2 |
| Organisational (0.242) | E1. Adequacy of training programs for nighttime construction hazards. | 0.500 | 1 | 0.121 | 3 |
| | E2. Effectiveness of supervision during night shifts to ensure safety compliance. | 0.500 | 1 | 0.121 | 3 |

Table 5 provides a more granular breakdown, showing the local and global weights of the individual attributes. Among the highest-ranked sub-criteria are the readiness and effectiveness of emergency response at night, hazards due to improper electrical grounding, and training adequacy for nighttime safety. These attributes indicate a clear need for improving operational readiness and supervision for nighttime operations.

Interestingly, organizational risks, specifically inadequate training and poor supervision, ranked third, suggesting that while these factors are acknowledged as influential, they may not be as immediately threatening as physical or environmental risks. However, this could also reflect a deeper issue within India's predominantly informal construction sector, where regulatory enforcement and structured safety programs are limited. The lower weight may indicate that such systemic challenges are normalized and therefore underestimated by practitioners.

Human factors, including hypertension, sleep deprivation, and psychological stress, were ranked lowest. This may be because their impacts are often long-term and not as directly observable as other risks. Nonetheless, chronic fatigue and mental stress have been shown to reduce alertness and decision-making ability, contributing to accidents over time (Powell & Copping, 2010). Their low ranking highlights a critical oversight in workplace safety strategies, which often focuses more on immediate risks than long-term worker health.

The high priority assigned to equipment and lighting issues, such as poor visibility and risks from machinery operation, reinforces the urgent need for infrastructure investment in lighting systems and updated equipment standards for nighttime work. For example, the significance of electrical grounding issues points to a systemic lack of technical inspections and quality control during off-peak operations.

# 5. CONCLUSIONS

This study presents a thorough literature review to find the risks to construction workers during nighttime construction. Twenty safety experts were interviewed to analyse the priority of each risk by conducting an AHP analysis. The study concluded that the most significant factors are work-related, equipment, safety hazards, and organisational aspects. Emergency response readiness and effectiveness at night are the most critical subfactors, highlighting the importance of a rapid response mechanism and robust emergency planning. The study advocates enhanced planning in construction sites, specialized training for workers during nighttime operations, and improved site management to ensure safety during nighttime operations. These measures will lead to safer work environments and more efficient, resilient construction practices.

The study also has some limitations, such as expert interviews were conducted on a limited sample size, which may not fully represent the insights of the global construction industry. Additionally, the Analytic Hierarchy Process (AHP) relies on subjective judgments, which may introduce bias. Real-time data observations from active night construction sites could further enhance the results.

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