International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 08 | Aug 2021 www.irjet.net p-ISSN: 2395-0072

Hazard Identification and Risk Assessment in Road Construction Projects in Chhattisgarh

Devvrat Ramteke[1*], T. Rama Rao[2], Manish Kumar Mishra[3]

[1]P.G Scholar, Bhilai Institute of Technology, Raipur, Chhattisgarh, India
[2]Professor, Dept. of Mechanical Engineering, Bhilai Institute of Technology, Raipur, Chhattisgarh, India
[3]Assistant Professor, Dept. of Mechanical Engineering, Bhilai Institute of Technology, Raipur, Chhattisgarh, India

---***---

Abstract - *In the past decade, road construction work in the state of Chhattisgarh has increased at an enormous rate in order to achieve the targets of PMKVY Scheme of Indian government. With the increase in construction work, many hazards and hazardous activities are overlooked and untrained, unskilled workers are undertaken to finish the construction as early as possible. As the construction work zones are amongst the most hazardous work sites in the industry, the workers continuously face the threat of having a fatal accident or injury. Apart from the workers, daily commuters are also impacted by the work zone affecting their safety. These problems represent major challenges to construction planners as they are required to plan vehicle routes around construction zones in such a way that maximizes the safety of construction workers and reduces the impact on daily commuters. The work performed in this research aims at identifying and evaluation the hazard during and after the construction of road in the rural region of Chhattisgarh State in order to determine the hazards having higher risk. By determining the high risk hazards, control measures specific to the hazards can be determined and implemented in the work zone for optimizing the construction work safely. The methodology adopted in the research includes risk assessment and AHP analysis of identified hazards in construction zone. The results obtained from performing the analysis is used to draft hazard specific control measures and recommendation.*

Key Words: **Risk Assessment, Road Construction, Work zone safety, AHP, Risk prioritization**

1.INTRODUCTION

According to 'Road Accidents in India 2019', A report by Union Ministry of Road Transport and Highways that was released in 2019, Chhattisgarh witnessed 13,899 road accidents and 5,003 deaths from it recording one road accident in every 25 minutes, while 6 persons killed in road accidents in every eight hours. Also, accident fatality or severity (deaths per 100 accidents) has also risen by 5.5 percent from 2016 to 2019. [1]

The maximum fatalities were on those roads that were under construction. In all, 498 people lost their lives in accidents owing to road-repair works which was 30 per cent up, compared to 215 deaths reported in 2018. [1] Due to constantly changing work zones, insufficient warning signage and construction zones that disobey the laws put in place to keep both workers and the public safe, many people unfortunately face serious, even fatal, road construction site accidents.

Road construction and maintenance work zones are very common occurrences in most states Chhattisgarh has more than 2,000 construction projects ongoing at the same time. These current projects encompass the largest number of work zones the C.G Department of Transportation has ever had in progress at the same time along the state's main corridor. The sudden growth in the road construction work is the outcome of Pradhan Mantri Gram Sadak Yojana (PMGSY), was launched by the Govt. of India to provide connectivity to unconnected Habitations as part of a poverty reduction strategy. The construction process has numerous uncertainties and risks, which increase with the size and the complexity of a project. Road construction activities involve a lot of hazardous risks. These risks are caused due to the association of several people like the design department team, construction contractors, sub-contractors, workers.

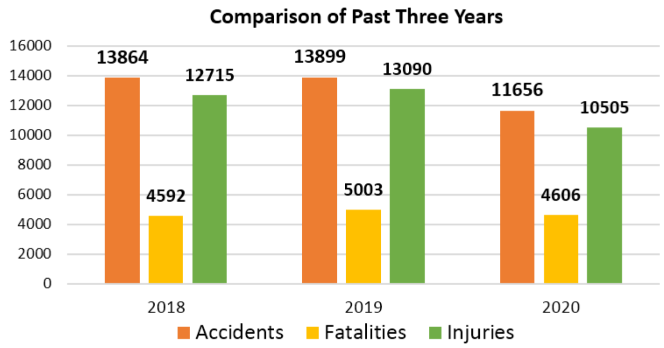

Chart 1: Comparison of accident statistics for the year 2018, 2019 and 2020 [2]

It can be clearly seen from Chart 1, that the percentage increase in the number of accidents increased by 0.25%, the number of fatalities resulting from accidents increased by 8.95% and the number of injuries resulting from accidents rose by 2.94% in the year 2019 as compared to the year 2018. This data clearly points to the fact that negligence has been shown toward the road safety hazards in the past couple of years.

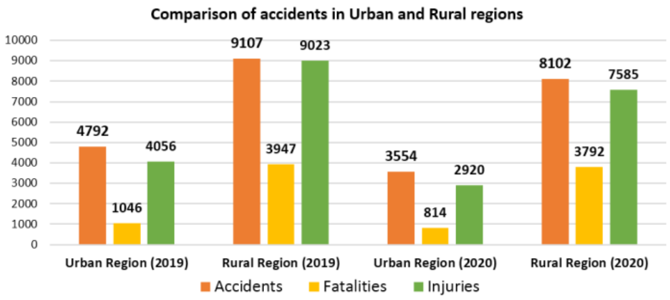

Chart 2: Comparison of accident statistics for urban and rural region in the state of Chhattisgarh (2020) [2]

The statistics shown in Chart 2 clearly shows that the rate of accidents in rural region of Chhattisgarh is almost twice as compared to the rate of accident in the urban region.

Chart 3 clearly shows that the number of accidents in the district roads are almost twice of the number of accidents in the National and State Highways in the year 2019.

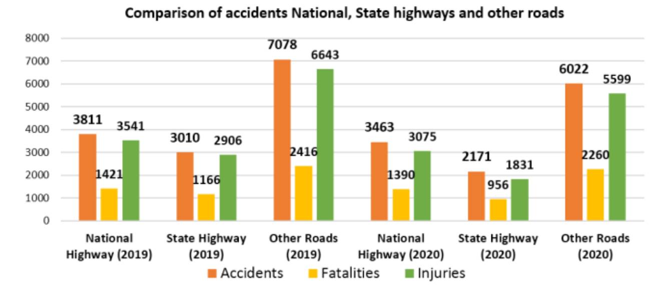

Chart 3: Comparison of accident statistics for different roadways in the state of Chhattisgarh (2020) [2]

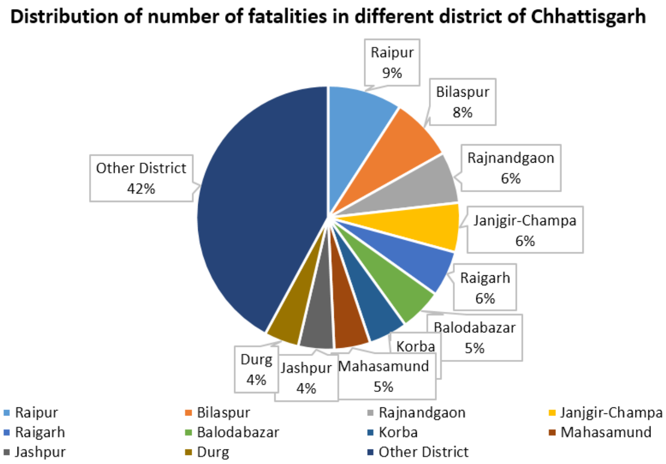

Chart 4: Comparison of accident statistics for different districts in the state of Chhattisgarh (2019) [2]

From Chart 4, it can be clearly deduced that almost 42% accidents in Chhattisgarh are from the districts having lesser population as compared to the top 10 districts in Chhattisgarh.

On the basis of the above data, the prime scope of this research is focused to identify the potential hazards during and after the road construction activity and to rank them according to their inherited risk by using the tools and techniques of risk assessment and AHP. The domain shortlisted for this research is road construction activity in the rural region of Kondagaon district in Chhattisgarh state. The duration of visited construction sites varied from 10 days to 45 days. The persons subjected to study were road construction workers and site supervisors.

To gain knowledge about the previous researches on this field both empirical and theoretical literature survey was performed where the following parameters were reviewed (i) present laws, legislation and safety policies for road construction in India
(ii) Roles and responsibilities of individuals in road projects
(iii) Major causes of accidents and adopted occupational health and safety measures

Nnaji et al. (2020) performed intensive literature review on 147 articles related to work zone safety technologies and point out that the concentration in the practice of equipment to mend safety of workers in high-way construction is growing considerably mainly due to the increased fatalities in and around the workzones. Moreover, the study also categorized the technologies on the basis of their purpose namely "speed reduction systems", "intrusion prevention and warning systems", and "human-machine-interaction detection systems". [3]

The literature survey points out that a lot of studies have discussed and undertaken a number of characteristics of work zone safety; but, most of the studies were shepherded before 2010 and most of them were established on very inadequate statistics. A handful of studies have make an effort to pinpoint the precise physiognomies or evils of work zones that are most unsafe. The literature survey also showed that hardly any study unambiguously considered contacts to work zone activities and traffic passing through the work zones.

2. METHODOLOGY

The methodology adopted in this project involved both qualitative and quantitative techniques for rating the hazards There are three stages involved in this research project:

First, this stage of the project focuses on determining the types of operational risk that had been identified by previous researchers, which have great potential of occurring in the road construction projects and causing significant impact to the project if occur by using HIRAC.

Second, extensive interviews along with questionnaires to be conducted for the collection of qualitative and quantitative data from a number of key personnel and ground workers in order to get their personal opinions and views about the possibility of the operational risks identified from literature review and survey to occur in the road projects in kondagaon.

Third, analysis of collected data using Multi-Criteria Decision Making Techniques.

2.1 HIRAC (Hazard Identification, Risk Assessment and Control)

With the advancement of new technology, techniques and machineries in construction of rural road, new and novel hazards are arising promptly. In order to achieve the target of constructing road within the stipulated time duration, a lot of hazardous activities are neglected and human lives are being put at stake daily. To control the hazards arising during construction of roads most of the contractors follow ISO 45001:2018 Occupational Health & Safety Management System in India, Factories act 1948 and rules as per the construction work. In most of the rules requires Hazard Identification, Risk Assessment and Control (HIRAC) to be performed for managing and controlling the hazards and minimizing the risk associated with the work.

It is legal requirement for all contractors to assess the risk and eliminate or minimize the risk failing to do so attracts enforcement actions. So Hazard Identification, Risk Assessment and Control must be performed where risk assessment is carried out for all potential hazards to achieve zero accident in construction industry

There are five basic steps to perform Hazard Identification, Risk Assessment and Control:

a) Hazard Identification

Hazard identification is the first activity to be performed by a competent team by thoroughly analysing all the tasks and considering previous accident record, first aid cases, enforcement actions and occupational diseases data. The team identifying the hazard must include engineers, safety supervisors, workers and operation specialist.

In this stage, worksite analysis of work activities is carried out, this includes making a list of people to be involved, responsibility to be assigned, detailed work procedures in chronological order, materials required, loading and unloading location, equipment's to be used etc. For this various information's are required such as organizational charts, interviews, records and a 'walk-through' survey of the work site. A walk through survey is considered to be the most effective way of listing out all the activities and possible failures at site. After analysing and listing out everything necessary for completion of the activity, hazard identification is carried out. The goal of hazard identification is to find out potential risks associated with the hazard. The hazards identified during this stage is to be categorized on the basis of their nature, likelihood, severity and risk level. The list of identified hazards needs to be updated and reviewed in regular intervals.

b) Risk Assessment

Risk assessment is the second step in HIRAC in which the level of risk associated with the identified tasks are examined. In this step, a competent risk assessment team having expertise in hazards considers each and every tasks individually and determines the likelihood of the occurrence of hazards and its potential consequences on workers, property, business and environment. Previous accident data is also referred to draft the best possible assessment which is recorded and reviewed regularly. This assessment of risk helps us to determine the seriousness of the risk and its consequences link to the corresponding task.

After identifying the hazards, risk associated with the hazard is estimated by considering number of people exposed to each hazard and exposure time. Thus the probability and severity of harm that can be caused by a hazard is estimated. Meanwhile in order to find out the probability and severity of harm, knowledge of the regulations and safety standards under which the facility operates is also important, as some of the regulations provide guidelines about risk assessment procedure.

In the methodology adopted to assess risk quantitative techniques is used. Quantitative risk estimation (QRA) uses numerical values to express both the likelihood and consequences of an accident / incident that is likely to occur. It also involves intensive mathematical calculations and modelling to rank risk; such as low, medium, high. It describes risk as the frequency of injury or death. The risk is calculated considering the potential consequences of an incident / accident, the exposure factor and probability factor. The legends used to describe the likelihood/probability in the project is shown in Table 1.

Table 1: Probability Description

Value	Guide word	Description
1	Rare	Only in some exceptional circumstances
2	Unlikely	Very unlikely but remotely possible
3	Possible	The event may occur at some time
4	Likely	The event will probably occur in most circumstances
5	Almost Certain	The event is almost certain to occur and has occurred in repeatedly in the construction industry

The legends used to describe the consequences/severity of hazards in the project is listed in Table 2

Table 2: Severity Description

Value	Guide word	Result of hazard to personnel / Environmental impact
1	Insignificant	No injuries/ damage
2	Minor	Injury or illness requiring first-Aid treatment/ minor pollution
3	Moderate	Non Reportable Lost Time Injury or Illness resulting in less than two days off work
4	Major	Reportable injury or illness resulting in more than two days off work/ Permanent Total Disability/ Major pollution

5	Catastrophic	Fatality

It is to be noted here that the higher value of likelihood or severity is to be selected always.

c) Risk Analysis

In this step again risk assessment sheet is considered and risk ranking is provided to every activity. Prioritization of risk aids in highlighting the hazards that should be undertaken as a priority for emergency management program. The risk ranking is based on occurrence probability of hazard and its potential consequence arranged to form a risk matrix system.

Risk matrix is a quantitative tool that is used to evaluate and analyses the risk level and to rank the risk according to their severity & probability. According to ISO 45001:2018, preparation of risk matrix is an integral part of the risk assessment process. The rows and columns in the risk matrix are the likelihood and consequences of the hazardous activity undertaken respectively.

Risk (R) = Likelihood (L) × consequences (C)

Or

Risk (R) = Probability (L) × severity (S)

The absolute risk attained after preparation of risk matrix is simply the product of likelihood/probability of occurrence and consequences/severity of hazard. After the determination of likelihood and severity value, risk level is determined by the help of risk matrix as shown in Table 3. The intersection of rows (Likelihood) and columns (Severity) indicates the risk level of the task undertaken.

Table 3: Risk Matrix

Risk matrix		Severity (S)				
		1	2	3	4	5
Probability (P)	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

d) Control Measures

Control measure involves any system, procedure, device or process that is intended to eliminate the hazards or to reduce the severity of consequences of any accident that does occur.

Based on the risk rating attained in the risk matrix, the risk level is determined as shown in Table 4 and on the basis of risk level corresponding control measures are selected to reduce the risk to an acceptance level. This reduction is to be achieved by reducing the likelihood and/ or severity by the implementation of control measures.

Table-4: Recommended action plans against different risk levels

Risk Rating (P XS)	Risk level	Recommended Action Plan/ Implementation
1 to 3	Moderate / Low risk	No additional risk control measures may be needed.
4 to 8	Average / Medium risk	Work can be carried out with risk controls on site
9 to 16	Excessive / High risk	Don't start work, the risk level must be reduced to low/medium level before commencing work.
16 to 25	Very high risk	Unacceptable

The controls measures recommended for the attained risk level from the previous step is based on the concept of "hierarchy of controls" in which the objective to reduce the risk level by implementing measures like elimination, substitution, isolation, Engineering controls and administrative controls and lastly PPEs. Figure 1, illustrates the control hierarchical model adopted in methodology for determining the control measures. [4]

In the occupational health and safety context, risk control is done by using the "risk control hierarchy" methodology. This hierarchy helps to decide on which risk control to implement. The preference of selecting the risk control option is arranged in a hierarchical manner from top to bottom.

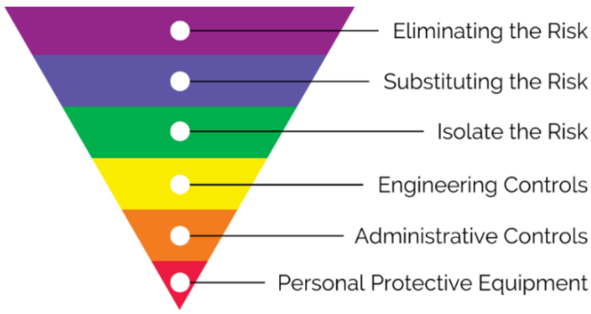

Figure 1: Hierarchy of controls [4]

(i) Elimination – In the elimination part, we will try to eliminate the hazard which can remove the cause of danger completely. However, it is difficult to eliminate all hazards and unsafe conditions, and therefore elimination is not always possible

(ii) Substitution – In the substitution part, we will try to find a substitute, if we can't eliminate the hazard completely, by finding a substitute it will be less risky to achieve the same outcome.

(iii) Isolation – In Isolation control measure, some form of barrier is placed between the employee and the hazard in order to provide protection. The risk is always there but by providing the barrier, workers are shielded by the hazard.

(iv) Engineering Control – In engineering control, we can implement the engineering techniques to reduce the risk of the hazards such as doing any physical changes, adding safe guards etc.

(v) Administrative Control - In administrative control, the administrative works should be followed up properly such as proper training to the employees & workers, risk assessments, issue of permits etc.

(vi) PPE (Personal Protective Equipment) – This is the final stage, here proper PPE to be provided to the employees and workers to save themselves from the hazards.

e) Monitor and Review

All the updated Hazard Identification, Risk Assessment and Control have to be monitored and reviewed by management and competent staff at regular interval.

2.2 Analytic Hierarchy Process (AHP)

Thomas Saaty in the year 1980 developed a tool that is used to make complex decisions and to help the decision maker for setting-up the priorities. Using AHP tool both objective as well as subjective aspects of decision making can be captured by plummeting complex decisions into a succession of pairwise comparisons which is synthesised later to obtain the results. The biasness of the decision maker is reduced in AHP by checking the results for consistency. [5]

The steps involved in the implementation of AHP are

1)Computing the vector of criteria weights.

2) Computing the matrix of option scores.

3) Ranking the options.

It is to be assumed initially that 'm' evaluation criteria are considered, and 'n' options are to be evaluated.

2.2.1 Computing the vector of criteria weights

In order to calculate the weights for the several criteria, a pairwise comparison matrix A is developed in the first step of AHP. The matrix A is a m×m real matrix, where m is the number of evaluation criteria considered. For a matrix A, a_{jk} denotes the entry in the j[th] row and the kth column of A. Each entry a_{jk} of the matrix A represents the importance of the i[th] criterion relative to the kth criterion.

If $a_{jk} > 1$, then the j[th] criterion is more important than the kth criterion, while if $a_{jk} < 1$, then the j[th] criterion is less important than the kth criterion.

If two criteria have the same importance, then the entry $a_{jk} = 1$. The entries a_{jk} and a_{kj} satisfy the following constraint:

$$a_{jk}.a_{kj} = 1$$

Obviously, $a_{jj} = 1$ for all j. The relative importance between two criteria is measured according to a numerical scale from 1 to 9, as shown in Table 1, where it is assumed that the j[th] criterion is equally or more important than the kth criterion. Values 2,4,6 and 8 can be used to represent the intermediate intensity.

Table 5: Interpretation of values for construction of pair wise matrix

Value of a_{jk}	Interpretation
1	Both the hazards are equally hazardous
3	Hazard 'j' is slightly more hazardous than hazard 'k'
5	Hazard 'j' is more hazardous than hazard 'k'
7	Hazard 'j' is strongly more hazardous than hazard 'k'
9	Hazard 'j' is absolutely more hazardous than hazard 'k'
2,4,6,8	Intermediate values

Once the matrix A is built, it is possible to derive from A the normalized pairwise comparison matrix A_{norm} by making equal to 1 the sum of the entries on each column, i.e. each entry a_{jk} of the matrix A_{norm} is computed as

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{l=1}^{m} a_{lk}} \quad (1)$$

Finally, the criteria weight vector w (that is an m-dimensional column vector) is built by averaging the entries on each row of A_{norm}, i.e.

$$w_j = \frac{\sum_{l=1}^{m} \bar{a}_{jl}}{m} \quad (2)$$

2.2.2 Computing the matrix of option scores

The matrix of option scores is a n×m real matrix S. Each entry s_{ij} of S represents the score of the i[th] option with respect to the j[th] criterion. In order to derive such scores, a pairwise comparison matrix $B^{(j)}$ is first built for each of the m criteria, j=1,...,m. The matrix $B^{(j)}$ is a n×n real matrix, where n is the number of options evaluated. Each entry $b_{ih}^{(j)}$ of the matrix represents the evaluation of the i[th] option compared to the h[th] option with respect to the j[th] criterion.

If $b_{ih}^{(j)} > 1$, then the i[th] option is better than the h[th] option, while if $b_{ih}^{(j)} < 1$, then the i[th] option is worse than the h[th] option. If two options are evaluated as equivalent with respect to the j[th] criterion, then the entry $b_{ih}^{(j)}$ is 1. The entries $b_{ih}^{(j)}$ and $b_{hi}^{(j)}$ satisfy the following constraint:

$$b_{ih}^{(j)} = b_{hi}^{(j)} = 1$$

and $b_{ii}^{(j)} = 1$ for all i. An evaluation scale similar to the one introduced in earlier Table may be used to translate the decision maker's pairwise evaluations into numbers.

Second, the AHP applies to each matrix $B^{(j)}$ the same two-step procedure described for the pairwise comparison matrix A, i.e. it divides each entry by the sum of the entries in the same column, and then it averages the entries on each row, thus obtaining the score vectors $s^{(j)}$, j=1,...,m.

The vector $s^{(j)}$ contains the scores of the evaluated options with respect to the jth criterion. Finally, the score matrix S is obtained as

$$S = [s^{(1)} \dots s^{(m)}] \quad (3)$$

2.2.3 Ranking the options

Once the weight vector w and the score matrix S have been computed, the AHP obtains a vector v of global scores by multiplying S and w, i.e.

$$v = S\,w \quad (4)$$

The i^{th} entry vi of v represents the global score assigned by the AHP to the i^{th} option. As the final step, the option ranking is accomplished by ordering the global scores in decreasing order.

3. HAZARD ASSESSMENT

To investigate the work zone safety standards and to identify the hazards along with practical problems in rural regions, road construction activities near Kondagaon district of Chhattisgarh state was selected. Table 6 shows the details of survey sites where investigation was carried out.

Table 6: Details of sites visited

1	Survey Site	Bamhani to Hangwa road construction project, District- Kondagaon, Chhattisgarh
	Duration of Survey	14 Days (19th Nov 20 to 03rd Dec 20)
	No. of labours involved	200 (Approx including different contractual workers)
	Type of work	Semi Rigid Bitumen Pavements construction
2	Survey Site	Umarkot road to Kuljhar Bridge construction project, District- Kondagaon, Chhattisgarh
	Duration of Survey	14 Days (8th Sept 20 to 22rd Sept 20)
	No. of labours involved	250 (Approx including different contractual workers)
	Type of work	Semi Rigid Bitumen Pavements construction
3	Survey Site	Shampur to Kerawahi road construction project, District- Kondagaon, Chhattisgarh
	Duration of Survey	Feb 2021 to May 2021
	No. of labours involved	155
	Type of work	Long span high level bridge and approach road construction

During the survey of the work zone, several hazards were identified on-site which may be harmful and may cause any accident / incident in coming future. Overall 53 major hazardous activities were identified during the site survey of asphalt road construction work zone as listed in APPENDIX 1 (Table A).

Few hazards and hazardous activities have been captured through camera during the site survey, few images have been attached below showing the identified hazards.

Figure 2: Perilous vertical cut

Figure 3: Unsafe barricading

Figure 4: Working on a high level bridge without any PPE and harness to protect from falling

Figure 5: Construction worker working on an unstable platform

Figure 6: Construction workers exposed to wet concrete without any PPE and Foot protection (safety footwear, gumboots etc)

Figure 7: Construction worker entering rebar cage without any PPE and harness.

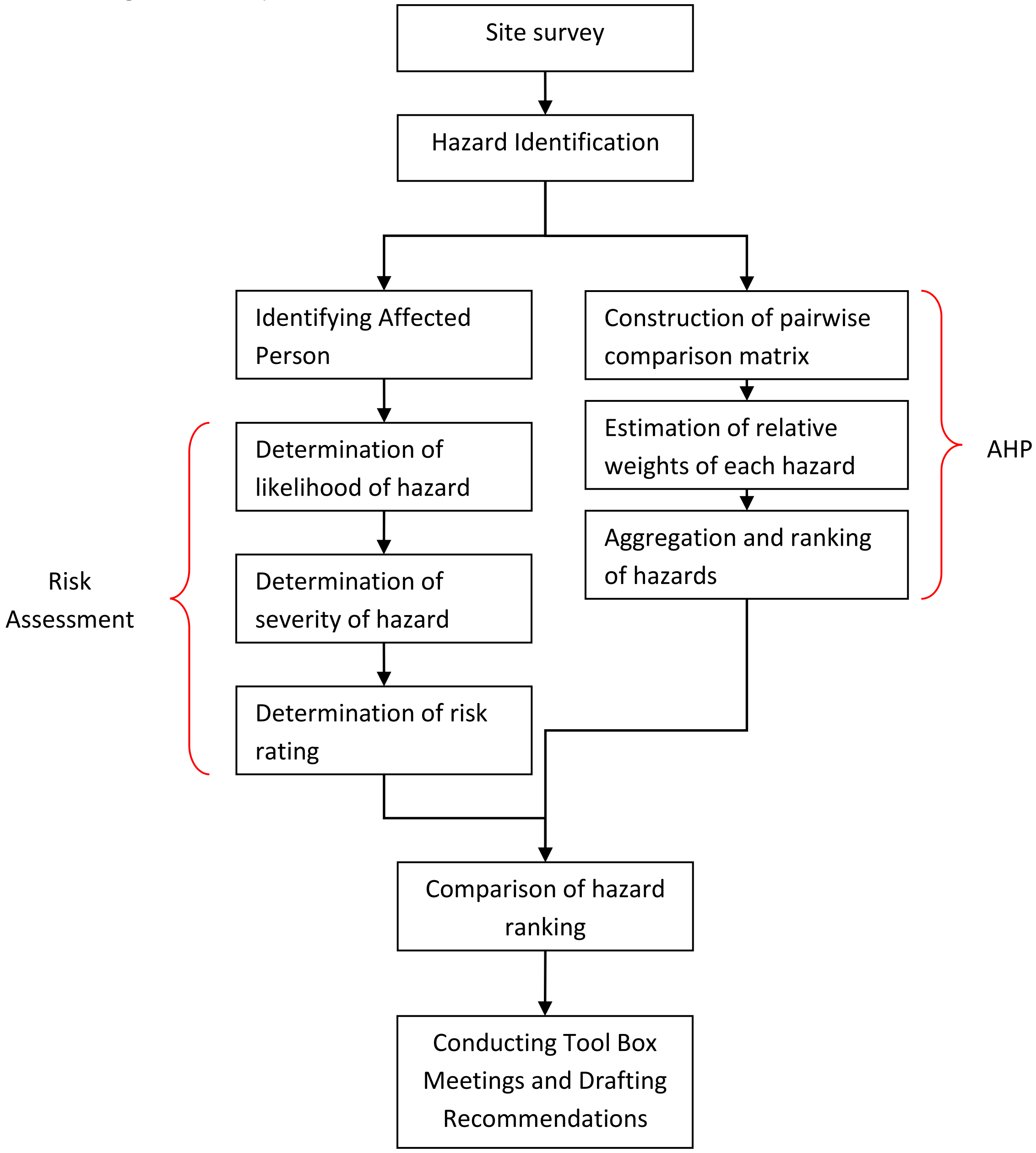

Figure 8: Layout of the adopted methodology to assess the risk

4. RESULT & DISCUSSION

4.1 Risk Assessment on the basis of Probability and severity of hazard

From the site survey conducted near the rural region of kondagaon district in Chhattisgarh, 53 hazards were identified in the work zone of road construction as listed in Appendix 1. The identified hazards are then subjected to risk assessment by the workers for the evaluation of risk they possess. To determine the likelihood of hazard and the severity of hazard the scale and guide words as shown in Table 1 and Table 2 were adopted respectively. The risk possessed by each hazard is then determined by multiplying the likelihood value with the severity value obtained as shown in Table B (APPENDIX 2). Table 9 shows the risk evaluated for each identified hazard in terms of its probability of occurrence and the severity of the hazard. Using the risk matrix of order 5×5, we can categorize the evaluated risk and rank the hazard on the basis of risk. On the basis of risk matrix, 8 hazards were identified as "very high risk" hazard, 24 hazards were identified as "High risk" hazard and 21 hazards were identified as "low risk" hazards whereas no "low risk" hazards were found.

The hazards involving higher risks score includes:

- Falling from tree
- Loss of control of machinery
- Falling debris on top of workers
- Collision/Run-over by heavy machinery
- Contact with overhead power lines

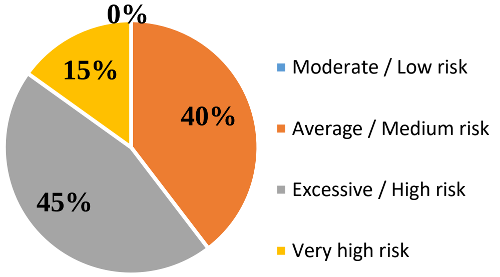

Figure 9: Risk categorization

It was observed from the outcomes of questionnaires that the responses of workers were driven by their own working experience and training they had. Since most of the construction workers are untrained and lack the knowledge to recognize the potential and severity of hazards their responses were based on what their supervisor told them to say so. In order to get more diversified assessment of risk, the author had ranked the identified risks using AHP in the next section.

4.2 AHP Analysis

All the 53 identified hazard are evaluated using AHP, where n=53 alternatives are evaluated. Each identified hazard (criterion) is expressed by an attribute. The larger the value of the given attribute, results into better performance of the alternative with respect to the corresponding hazard (criterion)

Initially, the decision maker (subject expert) first forms the subsequent pairwise comparison matrix for the 53 identified hazards (criteria) in which both the rows and columns represent the identified hazards using the values for construction of pair wise matrix as shown in APPENDIX 3. After completing the matrix, weight of each hazard is calculated using eq. (1) and eq. (2). Then the calculated weight value is multiplied with the obtained matrix to get the ranking as discussed in the methodology section.

APPENDIX 3 shows the pairwise comparison matrix obtained by comparing each hazard with all the other hazard on a scale of 1 to 9 as shown in Table 5.

Using the pairwise comparison matrix the score matrix in formed to determine the weight of each hazard. The final raking of the hazards obtained after the multiplication of weight values with the score matrix is shown in the Table 7.

Table 7: Ranking of Hazard using AHP

Hazard No.	Score	Rank
H53	0.115426	1
H46	0.045866	2
H32	0.044471	3
H21	0.041675	4
H39	0.040014	5
H18	0.039035	6
H30	0.038892	7
H29	0.033016	8
H38	0.032718	9
H35	0.031181	10
H15	0.030528	11
H9	0.030029	12
H41	0.029894	13
H19	0.028397	14
H16	0.028063	15
H31	0.027805	16
H40	0.027774	17
H33	0.027212	18
H17	0.025966	19
H8	0.022174	20
H13	0.021631	21
H37	0.020332	22
H28	0.019858	23
H12	0.013827	24
H5	0.013335	25
H43	0.013233	26
H4	0.010294	27
H6	0.009853	28
H42	0.008592	29
H7	0.008554	30
H23	0.007371	31
H1	0.007104	32
H52	0.007049	33
H11	0.006486	34
H2	0.006382	35
H45	0.006232	36
H10	0.005806	37
H44	0.005504	38
H34	0.005268	39
H47	0.005191	40
H20	0.00519	41
H3	0.004998	42
H22	0.004743	43

H36	0.004643	44
H48	0.004627	45
H51	0.004525	46
H14	0.004506	47
H50	0.004428	48
H24	0.004166	49
H49	0.004163	50
H27	0.004026	51
H26	0.004012	52
H25	0.003932	53

The hazard ranking obtained from Table 7 is categorized on the basis of their respective score. If the score is more than 0.03 then the corresponding hazard is considered to have very high risk whereas if the score is between 0.006 to 0.03 then it is considered to be of medium risk and if the score is below 0.006 then the hazard is having low risk.
From the ranking of hazards obtained in Table 7, it can be clearly identified that the hazards corresponding to very high risk scores are:

- Fire and explosion hazards
- Electrocution by power lines
- Loss of control over machinery
- Collisions
- Run Over by Machines and Heavy Vehicles while reversing/ turning

4.3 Control Measures

The control measures that should be adopted in order to mitigate the risk or minimize the risk level have been listed below in general as recommendations to the construction authority:

- No cigarettes, tobacco or alcohol are to be permitted on work zone.
- Appropriate provisions for health care and waste disposal amenities to evade potential transmission of transmissible diseases.
- No work to be performed without the work order from authorized person.
- Induction and safety talk to be delivered at the commencement of work accordingly.
- Proper First Aid training to be given to identified workmen, who will train the others at work zone.
- Workers must be provided with fluorescent jackets and safety helmet with reflective tapes all the time near work zone and proper monitoring should be done.
- Ample barriers should be provided to guard the workers.
- Safety shower should be installed in the vicinity (20 m radius) of the loading/unloading areas when working with bitumen.
- Water ingress with bitumen must be avoided, to avoid violent foaming.
- One 6kg dry powder extinguisher should always be positioned in work zone where hot bitumen is used. Water hose or extinguisher must not be used on a bitumen fire.
- When working with bitumen Resistant gloves should be worn to protect hands, Safety glasses with side shields should be worn, ear plunges, long sleeved shirts and long pants should be worn all the time.
- Activities during which the atmosphere is dusty due to presence of cement, silica or dirt from excavation, must be performed by wearing goggles and respiratory protection equipment all the time since the inhalation of very fine silica dust can lead to silicosis.
- Materials should be removed regularly to prevent Tripping accidents because of asphalt build-up on the bottoms of boots.
- If any equipment or machinery fails the pre-inspection, the equipment or machinery has to be reverted back to make necessary repairs. All construction vehicles should have reverse horns.
- The driver of heavy machinery (Dozers, Loader / Shovel, Excavator/ Backhoe, Scrapers, Grader, Hauler) must always be aware of the blind spots while reversing the machinery. Rear view mirror should be used in order to maximize the viewing area along with a spotter for communication while reversing/ turning.
- The driver of heavy machinery (Dozers, Loader / Shovel, Excavator/ Backhoe, Scrapers, Grader, Hauler) must identify the hazardous uneven and sloping surfaces in order to prevent tip-overs.
- The driver of heavy machinery (Dozers, Loader / Shovel, Excavator/ Backhoe, Scrapers, Grader, Hauler) must operate with material along with any other vehicle by their side.
- The driver of heavy machinery (Dozers, Loader / Shovel, Excavator/ Backhoe, Scrapers, Grader, Hauler) must locate the boulders, overhead power lines, fences during loading and hauling operation.
- All scaffolds, ladders and other safety device should be maintained in a safe and sound condition.

4.4 Tool Box Talk

It is the responsibility of safety officer/ supervisor to conduct Tool Box Meeting daily prior to work for the following reasons:

- To prevent any fatality or serious injury to the workers and pedestrians near the work zone.
- To create awareness of all the work zone hazards to which the workers are exposed and also to remind them daily about the same.
- To fortify community awareness on work zone hazards

During the project, several hazards were identified whose risk rating were very high and which possess very high risk of serious injury and fatality during the work at the work zone. It was also observed that Tool Box Meetings were not regularly conducted and the workers lack the basis knowledge about the hazards present at the work site. In order to address the issue, Tool Box Talks were conducted by the author to create awareness amongst the workers and to maintain safe as well as healthy working environment.

Figure 10: Taking details of Tool box meetings from safety officer and delivering Tool Box Talk to the workers

5. CONCLUSIONS

In the past decade, the road construction work has increased drastically in order to meet the demand and to connect different regions together. But, the rapid progression of construction work also invoked many accidents and injuries to the workers. The methodologies adopted in this work initially identified the potential hazards and hazardous activities during the construction work and risk of each identified hazard was assessed by the traditional risk assessment methodology and AHP method. Using both the method risk was evaluated and eventually the results obtained were almost in hands with each other.

But the time and effort required in both the methodology were quite different. AHP method took a lot of time and it is very cumbersome to evaluate the risk apart from the limitation that only the domain expert having prior knowledge in AHP can only participate. Whereas, Risk assessment took less effort and time to assess the risk by just evaluation the likelihood and severity of each identified hazard. Therefore, it would be correct to conclude that AHP method should only be used to evaluate for matrixes having order less than 10 to avoid the hefty evaluation work.

REFERENCES

[1] MORTH, "ROAD ACCIDENTS IN INDIA -2019," 2019. Accessed: May 17, 2021. [Online]. Available: www.morth.nic.in.

[2] C. P. Headquater, "Road Accidents in Chhattisgarh 2019," 2020. [Online]. Available: https://cgpolice.gov.in/sites/default/files/book-2019.pdf.

[3] C. Nnaji, J. Gambatese, H. W. Lee, and F. Zhang, "Improving construction work zone safety using technology: A systematic review of applicable technologies," J. traffic Transp. Eng. (English Ed., vol. 7, no. 1, pp. 61–75, 2020.

[4] "Hierarchy of Control | Workplace Health and Safety | Conserve®." https://conserve.com.au/how-the-hierarchy-of-control-can-help-with-workplace-health-and-safety/ (accessed Jun. 28, 2021).

[5] T. L. Saaty, "How to make a decision: the analytic hierarchy process," Eur. J. Oper. Res., vol. 48, no. 1, pp. 9–26, 1990.

APPENDIX 1

Table A: Identified hazardous activities during road construction

S.No	Task	Activity/ Machines in use	Description of hazard	Affected person
1	Surveying	Survey work in field	Falling or Sliding due to steeps and slopes	Survey team
2			Presence of snakes, wild dogs and wild animals near trees and bushes	Survey team
3			Dehydration, heat stroke, heat cramps and heat stress	Survey team
4	Clearing and Grubbing	Tree cutting/ cropping trees, bushes, roots, grass, weeds	Debris/ wood chips falling into eyes (Impact)	Workers
5			Falling debris from tree top on workers (Impact)	Workers/ Pedestrians
6			Crushing/ abrasion from catching fingers between wooden logs.	Workers
7			Engulfment of loose clothes and wires	Workers
8			Falling from trees	Workers
9			Electric shock from nearby pole	Workers
10			Slip and trips	Workers/ Pedestrians
11			Presence of snakes near trees and bushes	Workers
12		Excavation	Struck by Bucket or Debris	Workers/ Pedestrians
13			Machine Rollovers	Workers/ Pedestrians
14			Exposure to silica dust	Workers
15			Run Over by Machine while reversing/ turning	Workers/ Pedestrians
16			Collision	Workers/ Pedestrians/ Vehicle
17			Trenching Accidents	Workers
18			Contact with overhear power lines	Workers
19			Cave-Ins	Workers
20			Overloading of dumpers	Workers/ Road users
21			Loss of control of machinery	Workers/ Road users
22			Insecure loading of materials.	Workers/ Road users
23	Traffic Diversion/ Control	Road Signage	Improper and insufficient retro reflective regulatory and warning signage in Advance Warning Zone, Approach Transition Zone, Activity Zone, Terminal transition Zone and Work Zone end.	Road users
24		Channelizing Devices	Absence or misplacement of Channelizing devices (Traffic Cones, Drums, Barricades)	Road users
25		Temporary Pavement Markings	Absence of temporary pavement Markings & road studs	Road users
26		Pedestrian Routes	Absence of a separate pedestrian routes	Road users

Table A (Contd.)

24		Channelizing Devices	Absence or misplacement of Channelizing devices (Traffic Cones, Drums, Barricades)	Road users
25		Temporary Pavement Markings	Absence of temporary pavement Markings & road studs	Road users
26		Pedestrian Routes	Absence of a separate pedestrian routes	Road users
27		Message Signs	Absence of temporary traffic control signals, message signs and flag man	Road users
28	Levelling	Levelling the road by using Dozers , Motor Grader, Scrapers, Water Bowsers, Crawler Excavator and Road roller Machines	Machine Rollovers	Workers/ Pedestrians
29			Run Over by Machine while reversing/ turning	Workers/ Pedestrians
30			Collision	Workers/ Pedestrians
31			Trenching Accidents	Workers/ Pedestrians
32			Contact with overhear power lines	Workers
33			Cave-Ins	Workers
34			Overloading of dumpers	Workers
35			Loss of control of machinery	Workers/ Road users
36			Insecure loading of materials.	Workers/
37	Compacting	Compactor machine, Water Bowsers	Machine Rollovers	Workers/ Pedestrians
38			Run Over by Machine while reversing/ turning	Workers/ Pedestrians
39			Collision	Workers/ Pedestrians
40			Cave-Ins	Workers
41			Trenching Accidents	Workers/ Pedestrians
42	Asphalt Pavement	Pavement Machine	Entanglement of hairs, clothes, gloves or any loose material with moving parts.	Workers
43			Crushing, Cutting and shearing of workers in blind spot during operation.	Workers
44			Exposure to high temperatures	Workers
45			Exposure to high pressurized fluid	Workers
46			Electrocution by power lines.	Workers
47			Falling and slipping	Workers
48			Prolonged exposure to toxic gases, vapours, fumes, dust, noise and vibration	Workers
49	Coating	Prime coat and Tack coat using pneumatic tyred self-propelled pressure distributor	Tripping due to sticky surface	Workers & pedestrians
50			Exposure to asphalt fumes	Workers & road users
51			Direct contact with asphalt via. Skin &Eye	Workers
52			Exposure to higher temperature and source of ignition (Sparks, electricity, open flames)	Workers
53			Fire and explosion hazards	Workers

APPENDIX 2

Table B: Risk Assessment of identified hazards

S.No	Activity/ Machines in use	Description of hazard	Probability of Occurrence					Severity of hazard					Probability Value	Severity Value	Risk
			Rare	Unlikely	Possible	Likely	Almost Certain	Insignificant	Minor	Moderate	Major	Catastrophic			
			1	2	3	4	5	1	2	3	4	5			
1	Survey work in field	Falling or Sliding due to steeps and slopes				✓			✓				4	2	8
2		Presence of snakes, wild dogs and wild animals near trees and bushes		✓								✓	2	5	10
3		Dehydration, heat stroke, heat cramps and heat stress				✓			✓				4	2	8
4	Tree cutting/ cropping trees, bushes, roots, grass, weeds	Debris/ wood chips falling into eyes (Impact)			✓					✓			3	3	9
5		Falling debris from tree top on workers (Impact)			✓							✓	3	5	15
6		Crushing/ abrasion from catching fingers between wooden logs.		✓						✓			2	3	6
7		Engulfment of loose clothes and wires			✓						✓		3	4	12
8		Falling from trees				✓						✓	4	5	20
9		Electric shock from nearby pole		✓								✓	2	5	10
10		Slip and trips				✓			✓				4	2	8
11		Presence of snakes near trees and bushes	✓								✓		1	4	4
12	Excavation	Struck by Bucket or Debris		✓							✓		2	4	8
13		Machine Rollovers		✓								✓	2	5	10
14		Exposure to silica dust			✓					✓			3	3	9
15		Run Over by Machine while reversing/ turning		✓	▪	▪						✓	2	5	10
16		Collision			✓	▪						✓	3	5	15
17		Trenching Accidents		✓	▪	▪						✓	2	5	10
18		Contact with overhear power lines			✓▪	▪						✓	3	5	15
19		Cave-Ins		✓	▪	▪						✓	2	5	10
20		Overloading of dumpers			▪	✓				✓		▪	4	3	12
21		Loss of control of machinery			▪	✓					✓	▪	4	4	16
22		Insecure loading of materials.			▪	✓			✓			▪	4	2	8

Table B (Contd.)

S.No	Activity/ Machines in use	Description of hazard	Probability of Occurrence					Severity of hazard					Probability Value	Severity Value	Risk
			Rare	Unlikely	Possible	Likely	Almost Certain	Insignificant	Minor	Moderate	Major	Catastrophic			
			1	2	3	4	5	1	2	3	4	5			
23	Road Signage	Improper and insufficient retro reflective regulatory and warning signage in Advance Warning Zone, Approach Transition Zone, Activity Zone, Terminal transition Zone and Work Zone end.					✓	✓					5	1	5
24	Channe -lizing Devices	Absence or misplacement of Channelizing devices (Traffic Cones, Drums, Barricades)				✓		✓					4	1	4
25	Temporary Pavement Markings	Absence of temporary pavement Markings & road studs				✓		✓					4	1	4
26	Pedest-rian Routes	Absence of a separate pedestrian routes				✓		✓					4	1	4
27	Messag e Signs	Absence of temporary traffic control signals, message signs and flag man				✓		✓					4	1	4
28	Levelling the road by Dozers , Motor Grader, Scrapers, Water Bowsers,	Machine Rollovers		✓							✓		2	4	8
29		Run Over by Machine while reversing/ turning		✓								✓	2	5	10
30		Collision			✓							✓	3	5	15
31		Trenching Accidents		✓								✓	2	5	10
32	Crawler Excavator and Road roller Machines	Contact with overhead power lines		✓								✓	2	5	10
33		Cave-Ins		✓								✓	2	5	10
34		Overloading of dumpers				✓				✓			4	3	12
35		Loss of control of machinery				✓					✓		4	4	16
36		Insecure loading of materials.				✓			✓				4	2	8
37		Machine Rollovers		✓							✓		2	4	8
38	Compactor machine, Water Bowsers	Run Over by Machine while reversing/ turning		✓								✓	2	5	10
39		Collision			✓							✓	3	5	15
40		Cave-Ins		✓								✓	2	5	10
41		Trenching Accidents		✓								✓	2	5	10

Table B (Contd.)

S.No	Activity/ Machines in use	Description of hazard	Probability of Occurrence					Severity of hazard					Probability Value	Severity Value	Risk
			Rare	Unlikely	Possible	Likely	Almost Certain	Insignificant	Minor	Moderate	Major	Catastrophic			
			1	2	3	4	5	1	2	3	4	5			
42	Pavement Machine	Entanglement of hairs, clothes, gloves or any loose material with moving parts.			✓						✓		3	4	12
43		Crushing, Cutting and shearing of workers in blind spot during operation.		✓						✓			2	3	6
44		Exposure to high temperatures				✓		✓					4	1	4
45		Exposure to high pressurized fluid			✓				✓				3	2	6
46		Electrocution by power lines.			✓							✓	3	5	15
47		Falling and slipping				✓			✓				4	2	8
48		Prolonged exposure to toxic gases, vapours, fumes, dust, noise and vibration			✓						✓		3	4	12
49	Prime coat and Tack coat using pneumatic tyred self-propelled pressure distributor	Tripping due to sticky surface		✓						✓			2	3	6
50		Exposure to asphalt fumes				✓				✓			4	3	12
51		Direct contact with asphalt via. Skin & Eye				✓				✓			4	3	12
52		Exposure to higher temperature and source of ignition (Sparks, electricity, open flames)		✓						✓			2	3	6
53		Fire and explosion hazards			✓							✓	3	5	15