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Application of Machine Learning for Scaffolding Risk Assessment by Navi-Bais Algorithms

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Abstract

Development in Artificial intelligence is providing an unprecedented opportunity to enhance highly advanced computational methods in various fields. The application and prediction require a good availability of qualitative and quantitative data. The construction industry is associated with occupational risks and hazards. The occupational physical hazards involved in scaffolding works are falls and slips, hitting of falling object etc. The existing paper provides and analyze the software of machine learning algorithms in risk evaluation of scaffoldings about workers in construction industry. The consequences associated with such incidents are near miss, major and minor injuries, and fatalities also. scaffolding is a platform where the worker performs different activities like brickwork, painting, plumbing etc. In present studies and examined 150 construction workers to predict the risk assessment in scaffolding based on quantifying the occupational consequences with respect to age, experience and demographic factors, risks associated with the worker involved. Different types of scaffolding works involved in the study are wooden (Bamboo) – single and double scaffolding, steel, suspended (Jula) and trestle scaffolding. The methodology follows starting from collection of data with on-site survey, workers involved in the different construction activities. The risk analysis and assessment were done with application of machine learning using naive bayes algorithms. Based on the experience of a worker the study predicts, the high number of slips and falls is involved with wooden type of scaffolding.

Keywords: scaffolding, risk assessment, construction workers, incident, near miss, major injuries, minor injuries,

Introduction

In recent years, machine learning algorithms have aided in solving domain specific problems in various fields of engineering from detecting defects in reinforced concrete (Butcher et al., 2014) to monitoring natural disasters (Pyayt et al., 2011). The increase in the use of machine learning algorithms may be attributed partly to an unprecedented increase in the development and use of industrial internet of things (IIoT) (Lund et al., 2014). IIoTs allow collection of data for a given application without the need for human intervention during operations. The data collected by the IIoTs can be studied by data-driven techniques to create added value in various fields of engineering (Yinet al., 2015). Construction workplace is a single working industry involved with many parties and dependent to each other [6]. Construction projects are dynamic and complex [8]. The platform used to support the workers, materials under construction and maintenance works is termed scaffolding [1]. The configuration and location of the scaffolding differs and changes with progress of construction [19] Scaffolding mainly involves works at height, supports the work crew to perform various construction activities [3]. For access the higher elevated areas, it is desire to design the scaffolding with proper safety regulations to reduce hazards. According to OSHA hazards in construction are categorized into physical, chemical, biological and ergonomic hazards. The scaffolding related hazards is mainly related to ergonomic as well as physical hazards like slips and fall, cuts

Lacerations etc. According to Eeinrich /Bird safety Pyramid the injuries are classified into Documented and non-Documented injuries. The minor injuries are punctures, cuts, Bruises, abrasions are non-documented mostly. The exposure and danger potential influence the degree of risk for a worker. The slip and falls resulting a major injury, all the minor injuries develop a risk resulting physical hazards causes impact output and effectiveness of the work [19]. Causes of accidents and risks associated with the construction activities is mainly – not able to understand the language, diverse culture, insufficient training, motives towards short term benefits, improper usage of PPE, negligence of the worker – contracting and sub-contracting, improper safety design and inspection of scaffolding. The most critical factors involved in successful completion of construction project are "type of accident and accident reporting and handling", most important subsequent are "Immediate management and safety training" shows higher effect on accident severity [12]. Previous studies explored occupational accidents, and their consequences raised an attention to predict the risk involved in the scaffolding works [7]. Injury and risk rate prediction in construction increases the role of safety management at sites [15]. Risk assessment is the quantitative security status of a construction [5]. According to the Computer from experience E, some task T and performance P, if its performance from the task in T, as measured by P, improves with experience E [10]. The study identifies the number of undocumented injuries associated with scaffolding workers pertaining to cause of hazards involved in building construction projects by the application of machine learning. [11]. For prediction of consequences of risk in scaffolding, optimized machine learning algorithms have been applied [15]. The types of scaffolding and level of risk involved in each type of scaffolding was represented by collected data.

Materials and Methodology

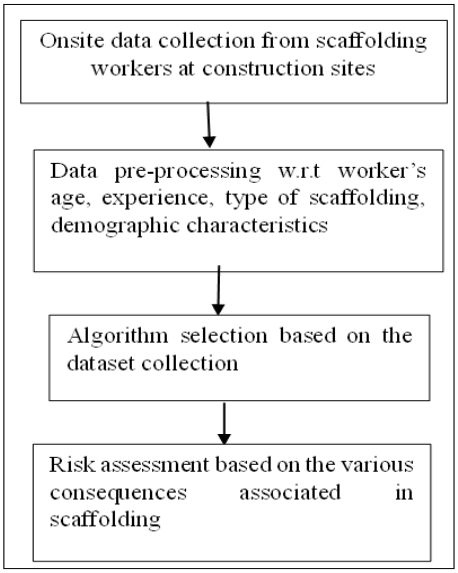

Fig: 1 Flow chart explaining series of the work done in the Risk Assessment [2]

Stages of work involved with scaffolding are:

1) Installation of scaffolding suitable to the work
2) Working near and on the scaffolding platform
3) Dismantling of scaffolding after the completion of work.

Based on the literature review the data for the risk assessment was categorized into Incident, near miss, minor injury and major injury [20].

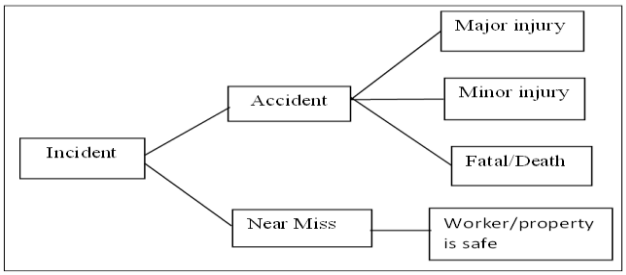

Fig 2: Risk assessment classification [3]

Incident: An unanticipated, undesirable event that disrupts work operations and could result in harm or property damage

Near miss: Incident where no damage of the property or no personal injury occurred

Accident: The undesired event that results because of incident with damage of property or worker injury (Acc to National medical council)

Accident = incident + consequences
Accident is classifieds into major Injury and minor Injury
Minor injuries: substantial treatment or not much recovery time required
Major injuries: A long-term effect resulted, or injury demands a medical leave, might worker getting hospitalized.
The different types of scaffolding and their suitability based on site observations

1) Wooden (Bamboo) Scaffolding
2) Steel scaffolding
3) Trestle scaffolding
4) Suspended Scaffolding (jula)

Wooden scaffolding:
This is the most common type of scaffolding preferred in local construction industry over the years because of low cost and no skilled installation is required. the hazards involved in this, is possibility of base plate settlement is high and the chances of braces and ledgers breakage, possibility of punctures to the fingers because of nails bolts. The degree of risk associated with physical hazards like cuts (minor injury), slips and fall (major injury) is high. Based on the working platform provided the wooden scaffolding are classified into single scaffolding and double scaffolding. These scaffolding are mainly used in Brick works [20-21].

Fig 3: Wooden scaffolding [5]

Steel scaffolding:
An access provided for the worker to access to the maximum heights the series of steel pipes is provided, and platform is laid. The cost of scaffolding is high but provides more safety for the workers. the weight resist by the material is high. This is preferred when the workers involved in the work are larger in number and the base for the scaffolding is irregular unable to provide wooden scaffolding [23]. The risks associated with this scaffolding is electrical shocks, as steel is a good conductor of electricity, slips and falls causes major injury and steel pipes causes slippery causes ergonomic injuries standing for a longtime.

Fig 4: Steel Scaffolding [7]

Trestle Scaffolding:
This scaffolding is mostly observed in painting works and single storey building works. It is supported with proper stable ground points rested on a floor. This scaffolding is also observed frequently working in Verandas and balconies of multi storey buildings and apartments. The slip and fall are the dangerous physical hazard involved in this type of scaffolding. The working platform is supported with movable ladders, recommended for small input works or inside repair works. the hazards involved are cuts, abrasion, Bruises etc. This type of scaffolding is also involved with major and minor injuries.

Fig 5: Trestle Scaffolding [8]

Suspended scaffolding:
The working platform is associated with a suspended rope with a single point adjustable rope form an overhead support. The adjusted rope is supported either with mechanical point or mechanically supported by other two or three workers from the top. This is the most common type of scaffolding used by window washers,

paintings work and plumbing works. The common hazards are electrical shocks and falls. This scaffolding is mainly involved with major injury (slip and falls), risk with long-term disabilities. The risk involved depends on the age and experience of the worker. Difficulty involved the worker with higher age, will have more experience, age of the worker increases chances of dizziness, faint or blurred vision. working in the afternoon times increases the chance of fall from the scaffolding.

Fig 6: Suspended scaffolding [9]

Table 1: Construction activities

The following are the construction activities involved with scaffoldings

Sl.no	construction activity	physical hazards
1	Excavation work	cavins , soil falling , water accumulation ,heat strokes ,Noise
2	Laying of foundations	cuts, heatstrokes
3	Bar Cutting	cuts, heat, vibration , noise
4	formwork	noise , fall from heights, slips,cuts
5	bar bending works	slips,falls
6	Reinforcement	falls, heat, cuts, pinches,slips
7	concrete pouring	falls,chemical burn, vehicular accidents
8	Removing of shuttering	collapse, pinches, cuts, abrasions , scrapers
9	Brick Work	fall, slips
10	Curing of walls	falls,slips
11	Lintel/framing	noise ,fall from heights ,slips ,cuts
12	flooring	slips ,falls,Noise
13	Electrical work	noise,cuts,abrasion,scrapers
14	Plumbing work	Injury from flying objects , slips,falls

15	plastering work	falls,slips
16	painting work	slips , fall ,heat
17	carpentry	noise, cuts ,pinches,slips

Table 2: Sample of type of scaffolding, workers age and experience

S.no	type of scaffolding	workers age	workers experience	incident	near miss	injury		fatality	workers background
						minor	major		
1	wooden	39	23	yes	yes	yes	no	no	patna , village
2	wooden	45	12	yes	yes	no	yes	no	patna , village
3	wooden	32	14	yes	yes	no	no	no	patna , village
4	wooden	28	11	no	no	no	no	no	patna , village
5	wooden	18	2	yes	yes	no	no	no	orissa
6	wooden, double	32	14	yes	yes	no	yes	no	orissa
7	wooden	28	12	yes	yes	yes	no	no	orissa
8	wooden	35	18	yes	yes	yes	yes	no	gurgam
9	jula	28	14	no	no	no	no	no	bihar, village
10	jula	58	32	no	no	no	no	no	bihar
11	jula	24	6	yes	yes	no	no	no	bihar
12	steel	24	4	no	no	no	no	no	bihar
13	steel	28	12	yes	no	yes	no	no	bihar
14	steel	32	14	yes	yes	no	no	no	bihar
15	steel	38	22	yes	yes	yes	no	no	bihar

Results and Discussions

Table 3: Trestle scaffolding Vs Risk

Type of Scaffolding	Incident	Near miss	Injury		Fatality	Workers Background
			major	minor		
trestle	yes	yes	no	no	no	karanataka
trestle	yes	yes	no	no	no	karnataka
trestle	no	no	no	no	no	orissa
trestle	yes	yes	yes	no	no	Bihar
trestle	no	no	no	no	no	orissa
trestle	yes	yes	no	no	no	orissa
trestle	no	no	no	no	no	orissa
trestle	no	no	no	no	no	bihar,village
trestle	yes	yes	no	no	no	orissa
trestle	yes	yes	yes	yes	no	orissa
trestle	yes	yes	yes	yes	no	bihar, village

Fig 7: Graph for Trestle scaffolding Vs Risk

Table 4: Jula scaffolding Vs Risk

Type of Scaffolding	Incident	Near miss	Injury		Fatality
			major	minor	
jula	No	no	no	no	no
jula	No	no	no	no	no
jula	Yes	yes	no	no	no
jula	Yes	yes	no	no	no
jula	No	no	no	no	no
jula	Yes	yes	no	yes	no
jula	No	no	no	no	no
jula	Yes	yes	yes	no	no
jula	No	no	no	no	no
jula	No	no	no	no	no
jula	No	no	no	no	no
jula	Yes	yes	no	yes	no
jula	Yes	yes	yes	no	no
jula	Yes	yes	yes	no	no
jula	No	no	no	no	no
jula	No	no	no	no	no
jula	No	no	no	no	no
jula	Yes	yes	yes	no	no
jula	Yes	yes	no	no	no

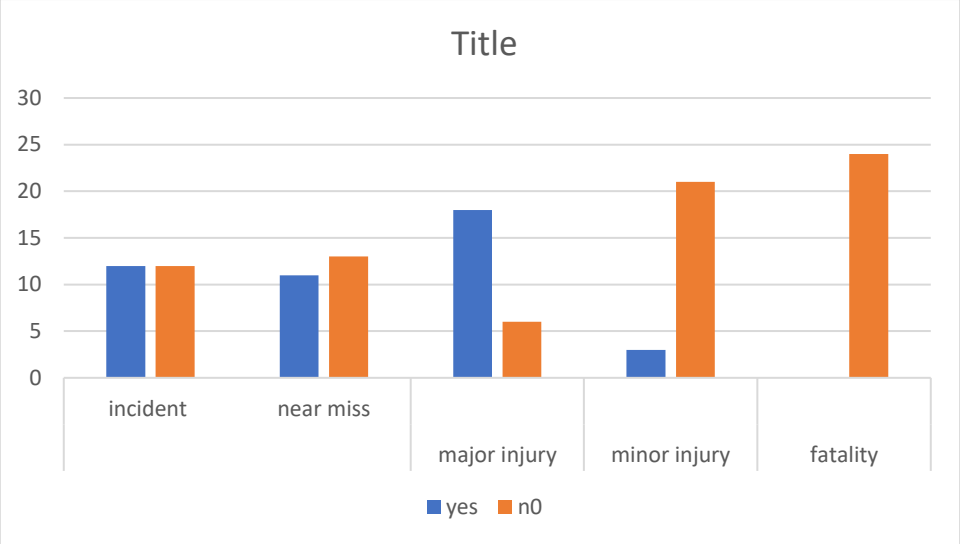

Fig 8: Graph for Jula scaffolding Vs Risk

Table 5: Steel scaffolding Vs Risk

sl.no	type of scaffolding	workers age	workers experience	incident	near miss	injury		fatality
						major	minor	
1	steel	38	6	yes	yes	No	No	No
2	steel	45	8	No	No	No	No	No
3	steel	39	12	yes	no	No	no	no
4	steel	27	11	yes	yes	yes	no	no
5	steel	38	9	yes	no	yes	no	No
6	steel	25	7	no	no	no	no	No
7	steel	32	3	yes	yes	no	no	No
8	steel	48	14	no	no	no	no	No
9	steel	23	2	no	no	no	no	No
10	steel	38	13	yes	no	yes	no	No
11	steel	34	8	yes	yes	no	no	No
12	steel	33	6	yes	no	yes	no	No
13	steel	25	6	no	no	no	no	No
14	steel	34	7	no	no	no	no	No
15	steel	39	16	yes	yes	no	no	No

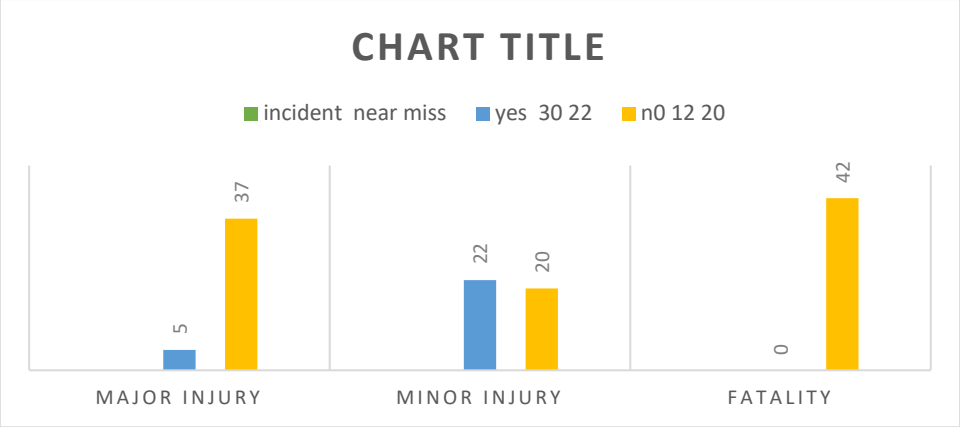

Fig 9: Graph for Steel scaffolding Vs Risk

Table 6: Wooden scaffolding Vs Risk

S.No	Type of Scaffolding	Incident	Near miss	Injury		Fatality
				major	minor	
1	wooden	yes	no	yes	no	no
2	wooden	no	no	no	no	no
3	wooden	yes	yes	no	no	no
4	wooden	no	no	no	no	no
5	wooden	no	no	no	no	no
6	wooden	yes	no	yes	no	no
7	wooden	no	no	no	no	no
8	wooden	yes	no	yes	no	no
9	wooden	Yes	no	no	no	no
10	wooden	Yes	no	no	no	no
11	wooden	Yes	yes	no	yes	no
12	wooden	no	no	no	no	no
13	wooden	Yes	yes	no	no	no
14	wooden	No	no	no	no	no
15	wooden	Yes	no	yes	no	no

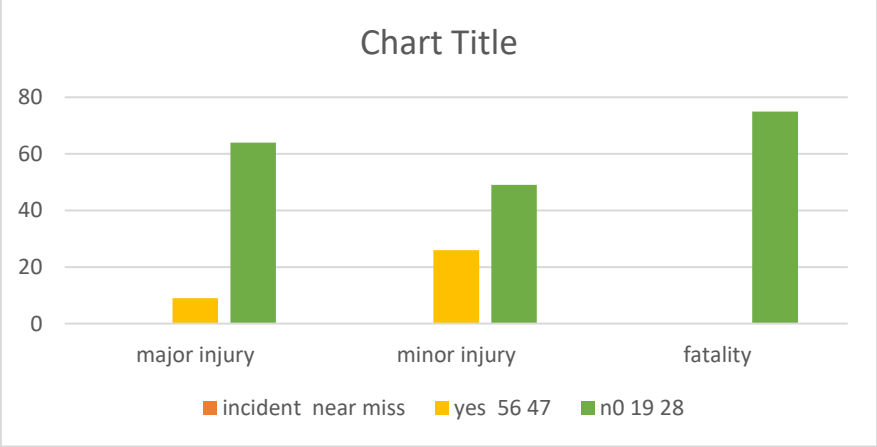

Fig 10: Graph for wooden scaffolding Vs Risk

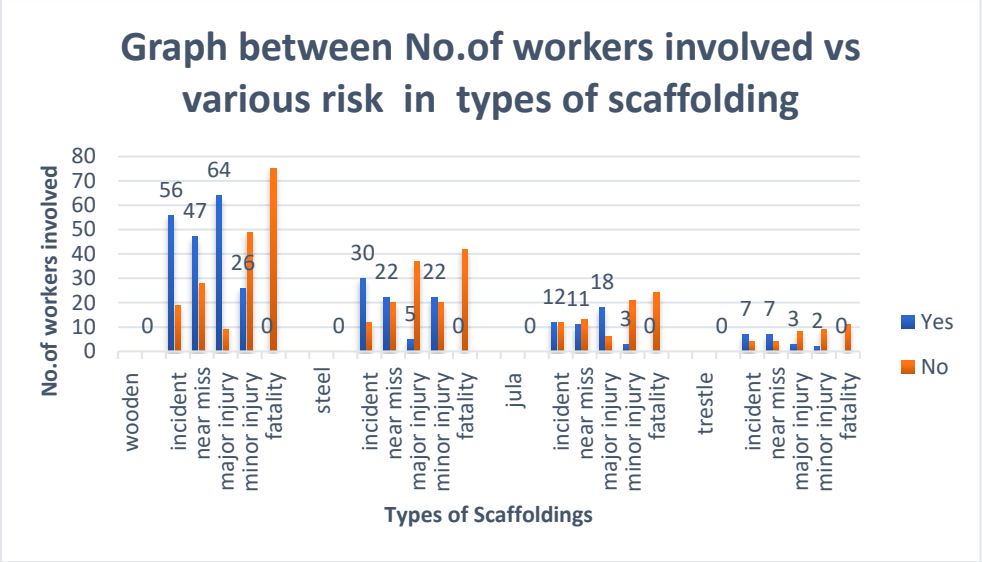

Fig 11: Comparison graph for types of scaffolding to major, minor injury and fatality

Summary:
This paper affords an evaluation into the motives of scaffolding incidents ensuing in people casualties primarily based on statistical records of such incidents compiled via different sources. The study constitutes part of a multi-phase research effort consisting of a series of interrelated tasks to develop at technical basis for the improvement of the safety aspects of scaffolding practices.

To bring critical research needs for scaffolding systems into focus, a number of a venues may be explored, such as an analysis of incident data, evaluation of applicable codes and standards, or field investigations of current practices. Out of all mentioned scaffoldings, the wooden scaffoldings are more risk associated scaffolding.

Machine Learning Naïve-bays algorithms for different types of scaffoldings

A sample of 150 Scaffolding workers was involved in the data collection of different age, experience and demography during their work hours as well as lunch-time hours, the effects and difficulties involved with scaffolding activity was noted. By the application of Machine learning the risk assessment was done. Machine learning is a subfield of Artificial intelligence defines the capability of machine imitate the intelligent human behavior.

- A Colabs online software is used to run the program, the naive-bays classifier to distinguish/classify the scaffolding risk based on worker's age, experience, types of scaffolding, types of injuries as inputs for risk involved in scaffolding work.
- The data was collected from the workers involved in scaffolding construction workers and placed in order of Serial number. types of scaffolding, worker's age, experience, incident, near miss, injury -minor and major, worker's nativity (demographic data) and effect to the worker.
- The data was segregated by rating the above-mentioned consequences from 1 to 5 named as 1-no risk, 2-3 minor risk, 4-5 high / major risk, given the extension as .CSV for the convenience of running the program
- Risk is scaled on Y-axis and the independent variables i.e., types of scaffoldings on X-axis.
- Different algorithms were searched and sorted for solving the problem of the dataset collected
- Concluded the risk assessment involved with naive Bayes random forest classification, multiple linear regression, Svm, Decision tree classification
- The training dataset and testing the data was given by using different datasets for knowing the degree of accuracy.
- Classified the data based on worker's age and risk, worker's experience and risk, injury and risk

- Concluded which type of scaffolding is safe for the worker involved in scaffolding works and workers involved in major risk category.

Based on, the naive-bays algorithms the following graphs were extracted

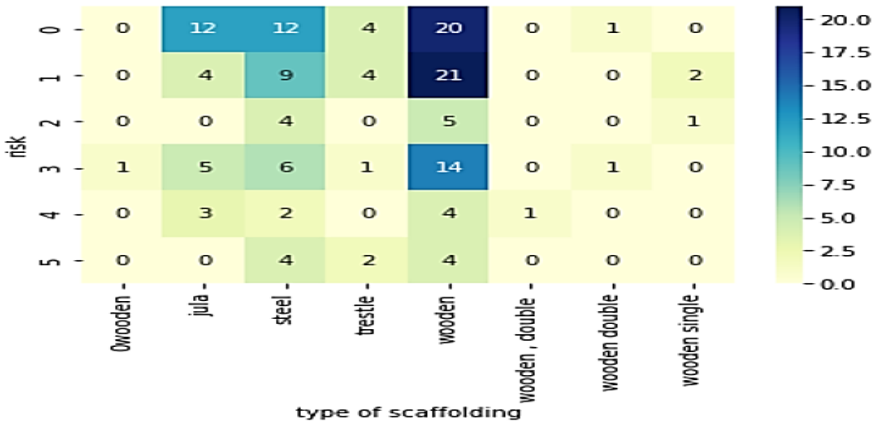

Fig 12: Graph drawn between type of scaffolding and risk

From the graph in fig 12, the wooden scaffolding involves with more major injury as compared with other type of scaffoldings.

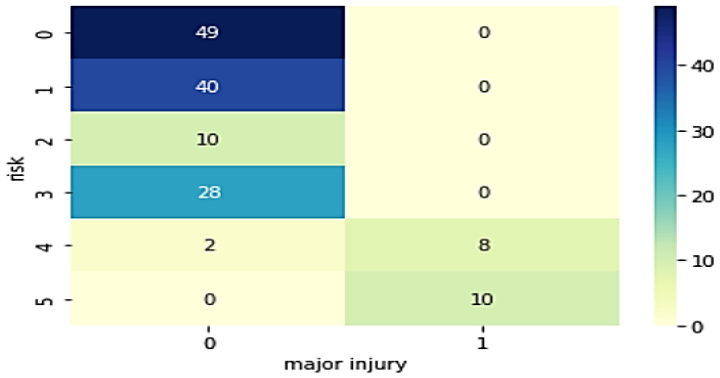

Fig 13: Graph drawn between major injury and risk

Fig 13 shows graph on risk to major injury, based on only major injury risk assessment the worker with major injury is having the high and no worker attains the low and medium risk.

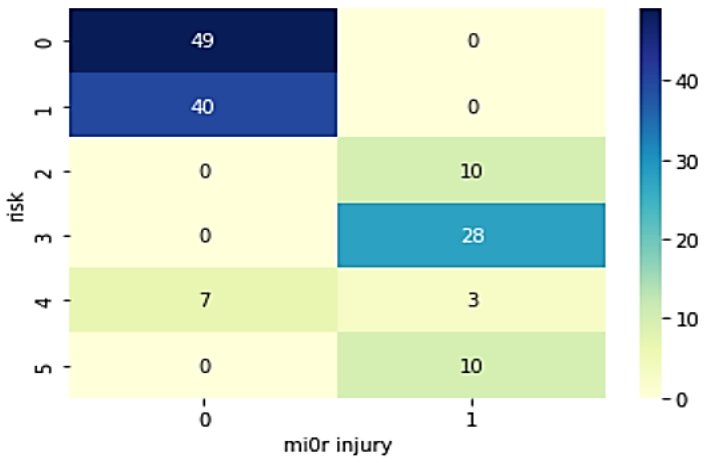

Fig 14: Graph drawn between minor injury and risk

Fig 14, shows minor injury to risk, based on only minor injury the risk assessment maximum number of workers are involved in medium risk

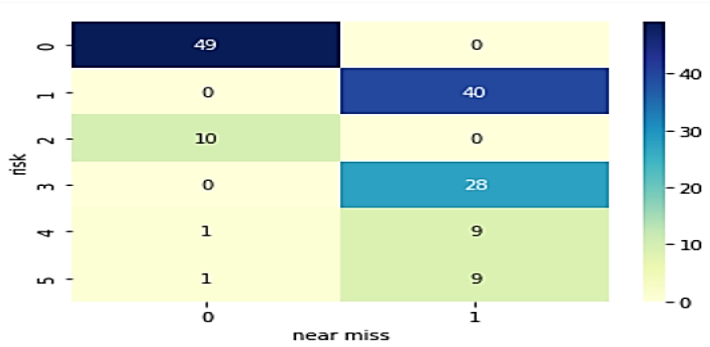

Fig 15: Graph drawn between near miss and risk

Based on fig 15, shows near miss to risk, maximum number of workers involved in low-risk category, explains the accidents supposed to be high but the consequences are relatively low and next maximum is with medium risk.

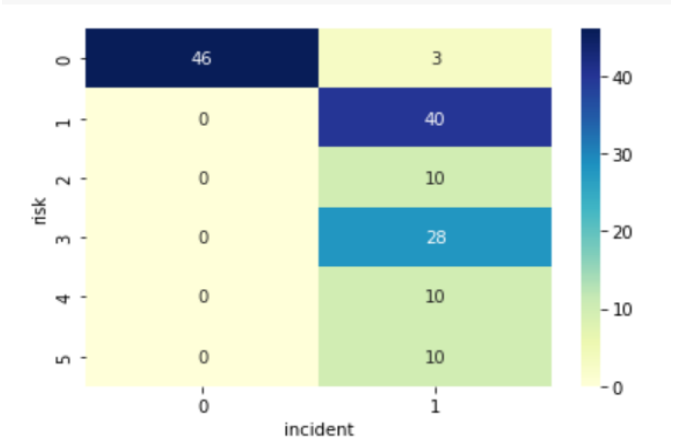

Fig 16: Graph drawn between incident and risk

Fig 16, shows assessment on the incident happened with low risk is high next to medium risk.

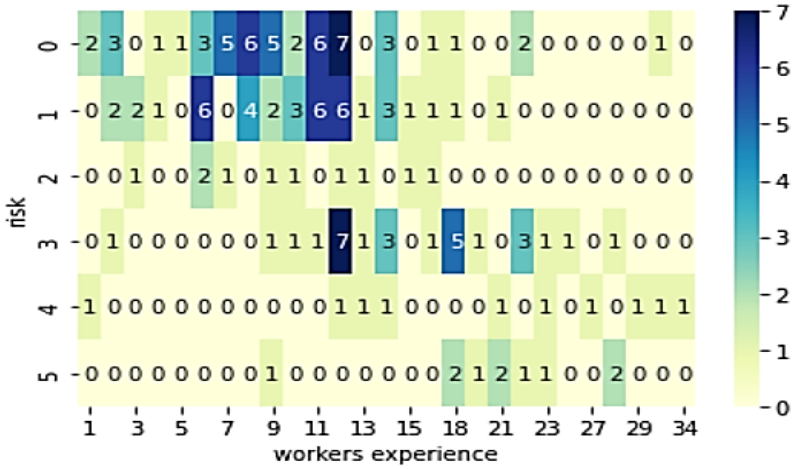

Fig 17: Graph drawn between workers experience and risk

The above assessment in fig 17, explains that the workers with initial experiences attain minor injury and workers with maximum experience aren't involved in any of the consequences.

Conclusions

Currently, a variety of machine learning methods are being used to aid phases of risk assessment, such as risk identification, risk analysis, and risk evaluation. Both statistical and real-time data are being utilized to develop machine learning models capable of providing inputs to traditional risk assessment techniques. This paradigm shift is occurring across different industrial sectors, such as automotive, aviation, construction, railways etc.

From the study slips and falls, it was concluded that construction workers are involved with risks in scaffolding works, because of the immediate act of the worker, the occurrence of the incidents with low risks are more in number. The minor injury rate falls under medium risk can be decreased with proper utilization of PPE (Personal Protective Equipment). The major injury resulted more number with high risk indicates that the worker should be properly trained and educated by attending the workshops or toolbox meeting, explaining the hazards and long-term effects involved in scaffolding. Based on the assessment that as the experience increases the consequences are decreasing, indicates the worker will understand the problems involved in the workplace. Out of all mentioned scaffoldings, the wooden scaffoldings are initiated risk associated with more number of slips and falls, from the manual survey and navi-based algorithms, it was concluded the wooden scaffolding settlements with respect to ground, not suitable for all climates, PPE like harness is not completely supported by the wooden scaffolding. Working platforms are not stable and hard might lead to the breakage, resulted ergonomic hazards since workers works more time on scaffolding, physical hazards, like cuts, punctures are more in number than other scaffoldings.

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