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Original Article

An Innovative Methodology for Identification of Fall Hazards and Assessment of Risk at High-Rise Construction Site

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Abstract - *The work productivity of laborers in an organization is impacted by a few variables, one of which is related to the occupational health and safety system, and there is a huge impact of safety and health program on the work productivity of laborers either all the while or somewhat. An unfortunate safety standard fundamentally starts from the conviction that safety and productivity are totally unrelated targets, one consuming the other. Yet, by and by, they are associated. Statistics from the Occupational Safety and Health Act 1994 have shown that the number of fatalities in the construction industry is five times greater than in other sectors. Thus, there is a critical need to alleviate this issue. Research has been conducted to investigate the root causes of fall hazards on construction sites. Therefore, this research is intended to identify and highlight the types of fall hazards that are most commonly found at construction sites today and the main causes that contribute to falls, as well as, by using a hierarchy of control methods, the most effective solutions to overcome the fall hazards. In this research, how the loss of time and productivity occurred due to fall hazards on high-rise construction sites has been analyzed based on the data obtained from various departments of the organization. The fall hazards have been overcome by substituting innovation (fabricated scaffold and stool) and the functional relationship between safety and productivity element analyzed. Hence, we achieved the loss of time and productivity at an acceptable level, which shows that the increase in safety culture reduces accidents and increases the organization's productivity.*

Keywords - *Fall hazards, Fall accidents, Risk identification, Risk assessment, Construction site.*

1. Introduction

1.1. Background of the Study

The construction sector is an essential and integral part of infrastructure development, which gives – a tremendous boost to our country's economy. The development business has enlisted gigantic development worldwide lately. Albeit the advancement of innovation is fast in a large portion of the areas, development work is still work concentrated. The most dangerous initiatives are in the development field. People frequently perish away as a result of accidents involving words or illnesses pertaining to the business. More than 2.78 million people die each year as a result of business-related causes, and 374 million more suffer non-fatal injuries and illnesses as a result [31]. The human cost of this frequent misfortune is significant. It is estimated that inadequate word-related security and well-being practices cost the world 3.94% of its Gross Domestic Product annually [31]. Accidental injuries are a major cause of death and a substantial general medical problem globally [27]. The next leading cause of unintentional injury in the world, after wounds from street traffic, is falling. Estimates put the number of fatal falls at 646000 and the number of non-fatal falls at 37.3 million [28].

A threat is a known source of harm or a negative influence on people's welfare. Risk is the likelihood that a person will suffer harm or adverse effects on their wellness when exposed to danger. Consequently, even if there is danger, chance may be controlled. Abdul et al.'s [1] classification of two key risks typical of construction locations identifies these risks. Actual injury risks are frequently caused by equipment such as structures, power access equipment, stepping stools, plant and machinery for uncovering and cycles like manual handling and rooftop work [1]. These dangers can directly harm construction workers and, in severe cases, could even result in death. This study focuses on identifying the causes of accidents at tall structure construction sites and differentiating the preventative actions for accidents there. In addition, this research aids in understanding the causes of accidents. It identifies areas where prevention efforts should be made, raising awareness among workers and senior management about preventing accidents on construction sites.

1.2. Objectives of the Research

- To identify all possible hazards related to falls in High-rise Building Construction to conduct occupational health risk assessment.
- To study the underlying causes of accident cases and near-miss incidents that occurred at the project site.
- To make the statistical analysis of accidents and costs associated with it.
- To calculate the risk rating based on the risk matrix and to compare the risk rating before & after the control measure taken.
- To reduce injuries related to working at a height.
- Raise awareness of Occupational Health Safety Workers' obligations and our workplace services profile in the construction industry.
- A coordinated approach by the team in the method of addressing identified hazards, measuring improvement by comparison of workplace condition assessment data.

1.3. Scope of the Research

The scope of the research study is focused on identifying the causes of accidents at high-rise building construction sites and identifying the preventive measures for accidents at high-rise building construction sites. Besides that, this research helps explain the causes of accidents and identify areas where prevention action should be implemented so that workers and top management will increase awareness of preventing site accidents.

2. Literature Review

One of OSHA's Focus Four contributing to worker fatalities on construction sites is falls [24]. Fall is defined as a downward progression all the way to the ground. One of the real risks that might result in a specialist's body losing balance while working on a construction site is the risk of falling. Falls are typically brought on by risky demonstrations, unsafe working conditions, communication problems, and executive responsibility. The lack of communication between employees and the person in charge and the workers' attitude towards wealth are the main factors contributing to the workers' increased risk of falling [25].

Due to the need for high-rise development projects, Malaysia's construction sector has driven the nation's growth [12]. The construction sector had made 3-5 percent of the GDP during the previous 20 years and was crucial to the nation's growth [14]. However, the Malaysian construction sector is notorious for its poor time execution, and as a result, the majority of projects there are accounted for as being behind schedule [14, 15]. The customer and partners are thus dealing with grave problems related to financial waste, quality failures, and burdens from development project delays [13]. Construction project delays have an impact on both the local and macro levels of the nation's economy. At the small scale, project abandonment and cost overruns are related, whereas, at the broad scale, agreements are made with the slow rate of national public development [16].

Building projects are among the major undertakings that, in the opinion of V. Sakthiniveditha et al. (2003), play a crucial role in the course of events in the country. According to estimates, the elevated structure (or multi-story structures) are the most important component of the development because of the more conspicuous turn of events. Tall building towers are a result of the larger component of the construction. As a result, the risk associated with this area of the construction industry is also higher. One of the most well-known problems that have various negative effects on development initiatives is taking risks in those projects. When the cause is understood, building risks must be kept to a minimum. Investigating gamble appraisal when creating high buildings was the goal of this project. A questionnaire and a literature review served as the foundation for this investigation. An itemised assessment of polls will be used to compile the data for this investigation. The survey is divided into two parts: the first part is general questions, and the second part is a list of major risks and any associated side bets. This endeavour focuses on identifying, assessing, and improving the risks associated with high structures and building development [5].

According to Ahsan Nawaze et al. (2019), the building industry is particularly dangerous and falls short in terms of executive risk exposure. However, increased conflict and development activities gradually give it genuine significance. In the sense of the region, it is what the exploration demonstrates. A minimal amount of gambling control was used. The findings also show that there is a stronger degree of association between particular gambling outcomes and task productivity. The results demonstrate the value of risk in the executive's processes, their application, inclusion, and influence on the presentation of the development projects perspective of the worker for hire, so enabling the primary task members to utilise risk the board [7].

Pitroda et al. (2021) provided information on risk factor identification and expectations of Indian construction professionals, including workers for hire, business owners, project managers, and designers, on the significance of various development risks and how the risks should be distributed among contracting parties. Risk the board is an approach that includes risk inquiry, evaluation, and guidance on responding qualitatively and quantitatively with the best administration and control practices. The phrase has developed an identifiable quality in a variety of industries. The technique is also employed by unrelated businesses to enhance their endeavours' production in an effort to save costs and boost earnings. The overall significance record (RII) gadget is used to evaluate the poll test for clients, employees for hire, experts, and engineers. We put a lot of effort into comprehending the Gamble board architecture for development activities and offering in-depth information on the usage of risk management in tall structure projects [4].

Leenu Paul et al. (2018) An instrument for identifying and adequately addressing particular risks in an activity is the risk management executive. The idea of this study is based on a poll assessment that was put together by hired local skyscraper developers. Pilot research and interviews are done to determine the risk variables that impact the construction business's effectiveness. Pilot research and master counsel have identified a total of 24 gambling-affecting elements in three categories. Utilising both qualitative and quantitative approaches, risk analysis may be better managed and assessed [8].

In accordance with section 24 [17] of the Occupational Safety and Health Act of 1994, workers are required to wear or utilise any protective equipment or clothing provided by the employer at all times. The best defence against development-related accidents is good housekeeping [19]. As a result, maintaining a clean environment is crucial to a construction site's ability to prevent accidents and increase overall safety [20]. One of the common sorts of evaluation to avoid any accidents is investigation. The proactive or preventative approach to accident prevention includes inspections [29]. Training is a crucial and important component of a strategy for anticipating accidents [21]. Everyone in the organisation has to ensure that the training programme is an essential component of the advice provided to all men engaged in development work and that they get special care for security concerns [29]. As a result, it is critical to use the proper avoidance strategy to avert event disasters successfully.

3. Proposed Methodology

3.1. Introduction

At the time of the research, all basic fall protection systems were provided on the construction site. Hard barricading, horizontal and vertical safety net provision on the building periphery area, vertical and horizontal closing by weld mesh for the lift shaft, all floor cut-outs covered by weld mesh and provision of an automatic climbing system for the operational floor were seen. All proactive precautionary safety measures were taken on the construction site, but continuous breaking on running work occurred due to height work held inside the periphery area. The survey was conducted on administrative management and production worker of building construction to determine the health and safety awareness in hazardous areas. The real names are not used for confidentiality purposes. Moreover, the methodology used for the relation between productivity and safety is done by using data that occurred on research and using this data graph plotted accordingly. The graph is plotted between a month versus a loss of productivity and a month versus a loss of time due to an accident or incident. The two graph shows the loss of productivity and loss of time due to accident or incidents and how it is overcome after innovation implementation on the construction site.

3.2. Methodology

In this research, the methodology used for reducing fall hazards is Hazard Identification and Risk Assessment (HIRA) and the control hierarchy. During the site survey, the number of reportable and non-reportable accident/incidents, height work and fall from height was recorded. To minimize these reportable and non-reportable accidents/incidents, prepare HIRA and implement it on the construction site. Using a hierarchy of control, eliminate the main hazard, substitute the innovative thing, and apply engineering and administrative control. The graph is plotted between loss of productivity and loss of time due to reportable and non-reportable accidents/incidents. Also, the plotted graph shows how the hazard has been overcome and productivity gained with following safety on the construction site after substituting the hierarchy of control.

3.3. Data Obtained from Industry

The construction site chosen for research is a commercial building project. This commercial construction project started on 1st November 2019, and the completion date has been decided on 31st October 2021. However, due to the Covid-19 pandemic, the construction site has been going late. Also, there was a huge problem stand to arrange the workforce for construction sites during this pandemic. When the workforce was arranged, the construction activities were going in full swing. At this stage, most workers bypass safety to achieve the target of per-day productivity. In research, it was found that most reportable and non-reportable accidents/incidents occurred during this period.

In research, the reportable and non-reportable data has been collected by first aid records, medical treatment records and accident/incident records by the organization.

For total reportable incidents, please see Appendix 1 below. It shows the details of total man-hours loss due to reportable incidents and affected the total safe person-hours of the financial year.

3.4. Data Analysis

Analysis of this collected data by month wise happening the all reportable and non-reportable accidents/incidents, it was found that most accidents/incidents occurred due to the height work and material fall from height. Due to unsafe acts and unsafe conditions of working at height, analyze that there was a huge loss of time and loss of productivity occurred in every month.

Table 1. Total non-reportable incidents

Month	Non-Reportable Incidents Due to…	Number of Non-Reportable Incidents
Mar-21	Scaffolding	7
	Elevated platform	1
	Ladder	5
	Floor opening	2
	Roof	2
	Other	5
Apr-21	Scaffolding	11
	Elevated platform	1
	Ladder	4
	Floor opening	1
	Roof	0
	Other	3
May-21	Scaffolding	10
	Elevated platform	5
	Ladder	3
	Floor opening	0
	Roof	0
	Other	7
Jun-21	Scaffolding	7
	Elevated platform	1
	Ladder	5
	Floor opening	3
	Roof	0
	Other	7
Jul-21	Scaffolding	9
	Elevated platform	7
	Ladder	11
	Floor opening	5
	Roof	0
	Other	5
Aug-21	Scaffolding	11
	Elevated platform	4
	Ladder	6
	Floor opening	3
	Roof	1
	Other	5
Sep-21	Scaffolding	7
	Elevated platform	6
	Ladder	9
	Floor opening	10
	Roof	0
	Other	7
Oct-21	Scaffolding	11
	Elevated platform	3
	Ladder	5
	Floor opening	1
	Roof	2
	Other	3
Nov-21	Scaffolding	10
	Elevated platform	0
	Ladder	1
	Floor opening	1
	Roof	0
	Other	3
Total		**236**

The following calculation has been done taking data from Table 1 of loss of productivity due to loss of time because of non-reportable accidents/incidents.

The construction site has 1200 nos. workers strength and the productivity of a single day was 600000/- Rs.

So,

$$LP = \frac{P \times T}{SWH} \quad (1)$$

Where, LP = loss of productivity
T = Total loss of time in a month (in hrs.)
P = productivity of a day
SWH = Standard working hours = 8 hrs.

From eq.1, the productivity loss in the month of March-21 is

$$LP\ (mar\text{-}21) = \frac{600000 \times 7.08}{8} = Rs.\ 531000/\text{-} \quad (2)$$

$$LP\ (apr\text{-}21) = \frac{600000 \times 6.50}{8} = Rs.\ 487500/\text{-} \quad (3)$$

$$LP\ (may\text{-}21) = \frac{600000 \times 7.63}{8} = Rs.\ 572250/\text{-} \quad (4)$$

By using eq. 1, the loss of productivity of the balance month is found out, and the given data are shown Table 2.

4. Results and Discussion

Analyzed data shows that a huge loss of time and productivity occurred day by day, and the impact of this loss indirectly falls down the company graph. So, to overcome the loss, we prepared the hazard identification and risk assessment. Using HIRA, document the fabricated scaffold and stool (innovative substitution) implemented on the construction site. After this innovative substitution on the construction site, we got our result which was planned at the start of the research. By using innovative substitution, the hazards related to height work and fall of material/person come to an acceptable level. The given data shows that the loss of time and productivity comes to an acceptable level.

With reference to data from Tables 2 and 3, the following graph plotted between loss of productivity and loss of time with respect to the month. It has shown the loss of productivity and time before and after innovative substitution implemented on construction sites.

Table 2. Loss of time & productivity due to non-reportable incidents before innovative substitution

Month	Non-reportable incidents due to…	Total non-reportable incidents	Loss of time (in min.)	Total loss of time in a month (in min.)	Total loss of time in a month (in hrs.)	Loss of Productivity in a month (Rs.)	Total loss of productivity
Mar-21	Scaffolding	7	145	425	**7.08**	**531000.00**	**51,40,500 Rs. before innovation**
	Elevated platform	1	20				
	Ladder	5	95				
	Floor opening	2	40				
	Roof	2	30				
	Other	5	95				
Apr-21	Scaffolding	11	225	390	**6.50**	**487500.00**	
	Elevated platform	1	20				
	Ladder	4	75				
	Floor opening	1	20				
	Roof	0	0				
	Other	3	50				
May-21	Scaffolding	10	205	458	**7.63**	**572250.00**	
	Elevated platform	5	95				
	Ladder	3	53				
	Floor opening	0	0				
	Roof	0	0				
	Other	7	105				
Jun-21	Scaffolding	7	145	373	**6.22**	**466500.00**	
	Elevated platform	1	20				
	Ladder	5	65				
	Floor opening	3	48				
	Roof	0	0				
	Other	7	95				
Jul-21	Scaffolding	9	165	595	**9.92**	**744000.00**	
	Elevated platform	7	115				
	Ladder	11	170				
	Floor opening	5	85				
	Roof	0	0				
	Other	5	60				
Aug-21	Scaffolding	11	220	548	**9.13**	**684750.00**	
	Elevated platform	4	65				
	Ladder	6	90				

	Floor opening	3	48				
	Roof	1	20				
	Other	5	105				
Sep-21	Scaffolding	7	145	643	**10.72**	**804000.00**	
	Elevated platform	6	99				
	Ladder	9	144				
	Floor opening	10	150				
	Roof	0	0				
	Other	7	105				
Oct-21	Scaffolding	11	118	371	**6.18**	**463500.00**	
	Elevated platform	3	48				
	Ladder	5	90				
	Floor opening	1	15				
	Roof	2	45				
	Other	3	55				
Nov-21	Scaffolding	10	210	310	**5.16**	**387000.00**	
	Elevated platform	0	0				
	Ladder	1	20				
	Floor opening	1	20				
	Roof	0	0				
	Other	3	60				

Table 3. Loss of time & productivity due to non-reportable incidents after innovative substitution

Month	**Non-reportable incidents due to…**	**Total non-reportable incidents**	**Loss of time (in min.)**	**Total loss of time in a month (in min.)**	**Total loss of time in a month (in hrs.)**	**Loss of Productivity in a month (Rs.)**	**Total loss of productivity**
Dec-21	Scaffolding	0	0	15	**0.25**	**18750.00**	**56250 Rs. after innovation**
	Elevated platform	0	0				
	Ladder	0	0				
	Floor opening	0	0				
	Roof	0	0				
	Other	1	15				
Jan-22	Scaffolding	0	0	15	**0.25**	**18750.00**	
	Elevated platform	0	0				
	Ladder	0	0				
	Floor opening	0	0				

	Roof	0	0				
	Other	1	15				
Feb-22	Scaffolding	0	0	15	**0.25**	**18750.00**	
	Elevated platform	0	0				
	Ladder	0	0				
	Floor opening	0	0				
	Roof	0	0				
	Other	1	15				

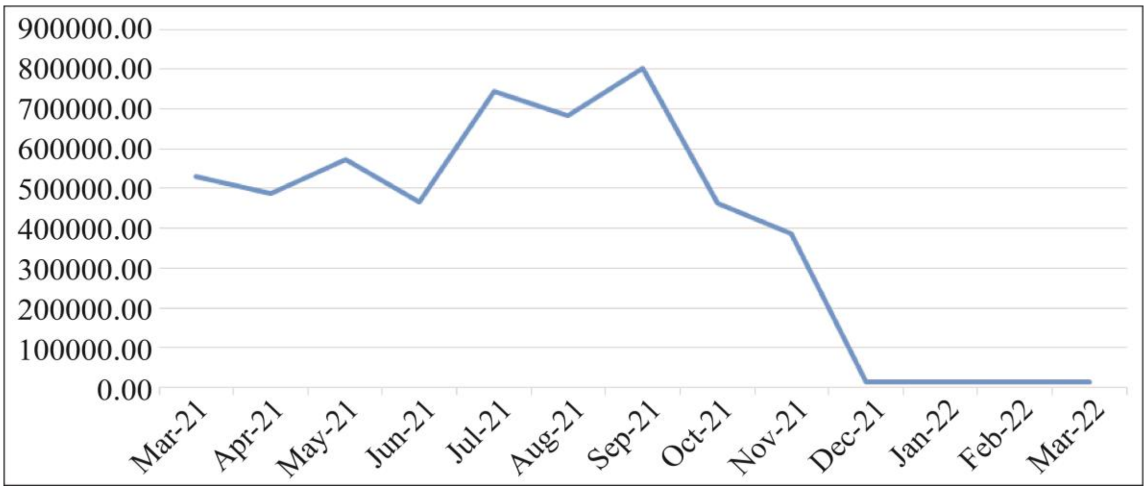

Fig. 1 Loss of productivity with respect to month

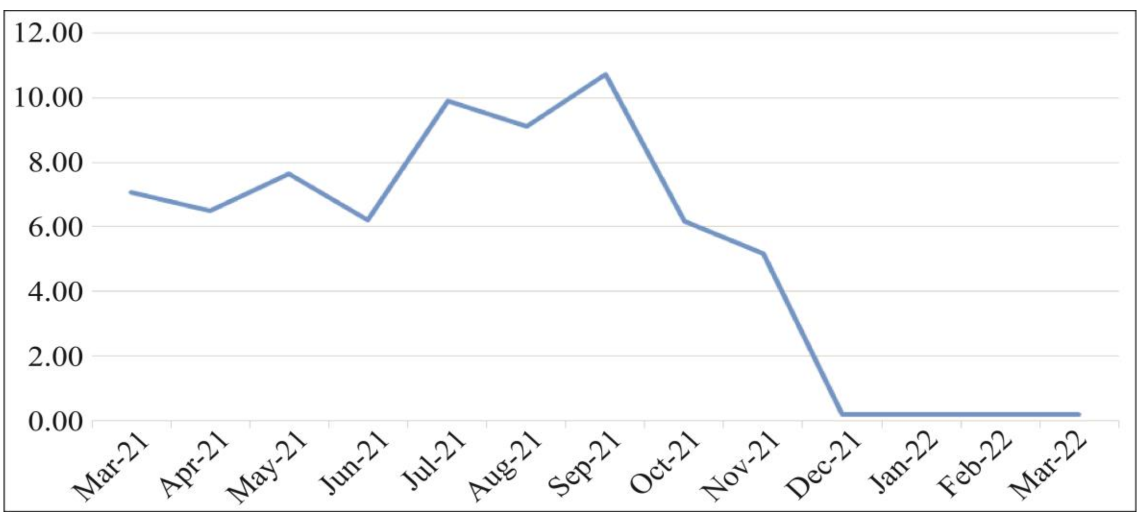

Fig. 2 Loss of time with respect to month

5. Future Scope

Production and safety play an important job in promoting the smooth running of an organization. To run an organization, both need to run inappropriate equilibrium. From the results, it is seen that with the section of time, production increases and simultaneously, occurrences diminish.

The main components of safety, like safety training, Risk assessment, Hazard analysis, and consistent checking, are essential in accomplishing decreased mishap rates with high efficiency. So the main job in accomplishing these is to keep up with all the safety components in the working environment. By upholding more safety components, training, analysis, and corrective actions, management ought to give need to both efficiency and security then an organization can be known as an effective organization. So it is recommended in future that these boundaries ought to have been given inclination by an organization for improvement and smooth running.

In future including these boundaries more boundaries must be incorporated to make more incident and accident-free organizations. Anyway, it is suggested that organizations ought to keep up with the fundamental safety boundaries to make the industry accident free for this inclination given to production as well as to somewhere safe.

6. Conclusion

Production and safety play an important job in promoting the smooth running of an organization. To run an organization, both need to run inappropriate equilibrium. From the results, it is seen that with the section of time, production increases and simultaneously, occurrences diminish.

The main components of safety, like safety training, Risk assessment, Hazard analysis, and consistent checking, assume an essential part in accomplishing the decreased mishap rates with high efficiency. So the main job in accomplishing these is to keep up with all the safety components in the working environment. By upholding more safety components, training, analysis, and corrective actions, management ought to give need to both efficiency and security then an organization can be known as an effective organization.

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Appendix 1

Table 4. Total reportable incidents

Monthly Performance Report - S&H																
Sr. No.	**Elements**	**Month**													**Cumulative for Current Year**	**Cumulative for Project**
1	**Statistics**	**Mar' 20**	**Apr' 20**	**May' 20**	**June' 20**	**July' 20**	**Aug' 20**	**Sept' 20**	**Oct' 20**	**Nov' 20**	**Dec '20**	**Jan' 21**	**Feb' 21**	**Mar' 21**		
1.1	Avg. No. of Staff per day (Client)	15	0	4	5	28	28	2	2	3	3	5	5	5	8	11
1.2	Avg. No. of Staff per day (Contractors)	23	0	24	35	34	39	63	90	96	107	126	144	151	76	49
1.3	Avg. No. of Worker per day (Client+ Contractor)	153	0	32	26	62	159	369	533	561	672	875	1,094	1002	449	301
1.4	Man-days Worked	37891	0	992	1960	2991	6793	13040	19375	19800	24242	31,186	34,804	35898	135383	173274
1.5	Man-hours Worked	359696	0	9968	18940	33695	67857	117360	174375	178200	213178	311,860	348,040	358980	1832453	2192149
1.6	Reportable Accidents/ LTI	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2
1.7	Fatal / Total Permanent Disability	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.8	Medical Treatment Case	0	0	1	0	0	1	1	0	2	0	0	1	2	8	8
1.9	Dangerous Occurrences	1	0	0	1	0	0	0	0	0	1	1	0	1	4	5

1.10	Fire Incident	0	0	0	0	0	0	0	0	0	1	0	0	1	2	2
1.11	Occupational Health Illness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.12	First aid	10	0	0	1	0	4	5	5	6	5	6	8	77	117	127
1.13	Near Miss	1	0	0	0	0	0	0	1	3	1	1	1	0	7	8
1.14	Man-days Lost due to LTI (including fatal) Incident	**0**	0	0	0	0	0	0	0	0	0	0	**2**	0	2	2
1.15	Safe Man-hours LTI Free	**359696**	0	9968	18940	33695	67857	117360	174375	178200	213178	311,860	**22620**	358980	1507033	1866729
1.16	Frequency Rate(FR)	0	0	0	0	0	0	0	0	0	0	0	5.74647	0	1.09	0.91
1.17	Severity Rate(SR)	0	0	0	0	0	0	0	0	0	0	0	5.74647	0	1.09	0.91
1.18	Frequency Severity Index	0	0	0	0	0	0	0	0	0	0	0	0.18172	0	0.03	0.03
1.19	Incident Rate (IR)	0	0	0	0	0	0	0	0	0	0	0	1.60901	0	3.76	5.53