Prediction accident triangle in maintenance of underground mine facilities using Poisson distribution analysis

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Abstract. In Indonesia, mining is categorized as a hazardous industry. In recent years, a dramatic increase in the mining equipment and technological complexities have resulted in higher maintenance expectations that accompanied by changes in the working conditions, especially on safety. Ensuring safety during the process of conducting maintenance works in underground mine is important as an integral part of accident prevention programs. Accident triangle has provided a support to safety practitioner to draw a road map in preventing accidents. Poisson distribution is appropriate for the analysis of accidents at a specific site in a given time period. Based on the analysis of accident statistics in the underground mine maintenance of PT. Freeport Indonesia from 2011 through 2016, it is found that 12 minor accidents for 1 major accident and 66 equipment damages for 1 major accident as a new value of accident triangle. The result can be used for the future need for improving the accident prevention programs.

1. Introduction
In Indonesia, mining activities are categorized as hazardous, especially for underground mining [1]. In recent years, a dramatic increase in the mining equipments and technological complexities have resulted in higher maintenance expectations that accompanied by changes in the working conditions, and one of these conditions is safety [2]. It has become an important issue because each year a vast number of people die and get seriously injured due to various types of accidents [3]. Ensuring safety during the process of conducting maintenance works in underground mining is important as an integral part of accident prevention programs.

When the results of incidents are analyzed over a period of time and possibly, aggregated by region or industry, the distribution of their severities may look similar to the classical model of an accident pyramid or safety triangle, introduced by H.W.Heinrich in 1931 [4]. Figure 1 presents this model, and also reflects suggestions by Bird and Germain [5]. It supports to safety practitioner to draw a road map in preventing accidents [6].
The purpose of this paper is to determine the new accident triangle based on accident data statistics in the underground mine maintenance of PT. Freeport Indonesia. Using a Poisson distribution as a statistical method, this analysis will show how information derived from these accident summaries can be used to predict potential future events.

2. Literature Review
The criteria of the mining accidents in Indonesia must involve five elements according to the ministry of mining and energy decree of the Kepmen 555.K/26/M.PE/1995, in article no. 39. The mining accident is an unplanned, unexpected, undesired, uncontrolled, and unintentional event which occurs suddenly and caused injury to the workers in connection with a work relationship of the mining operations. The five elements of the mining accident are the actual accident occurred, resulting injured to the mine worker or people who get a permit from the technical mine manager, consequences of the mining business activities, the accident occurred during working hours to injure of mine worker or people who get permit, and the accident occurred within the area of the mining activity or operation or in the project area [8].

In 1931, Herbert William Heinrich, one of the founding fathers of industrial safety and accident prevention, published the results of a study he performed while working for Traveler’s Insurance [9]. His original work revealed that, for every “major injury” resulting from a single accident, there were 29 “minor injuries” resulting from accidents and 300 no-injury accidents. The figure produced by this analysis was depicting these ratios, came to be known as Heinrich’s Triangle.

According to the ministry of mining and energy decree of the Kepmen 555.K/26/M.PE/1995, article no. 40, mining accidents shall be recorded and classified into the following categories:

- Minor, if any injury resulting from a mining accident which causes the mine worker to no longer be able to carry out his/her normal duties for more than one day and less than three weeks, including Sundays and holidays.
- Major, minor accident that any injury which causes the mine worker to become an invalid and who can no longer carry out his/her original duties and irrespective of any duration of absence, any mining accident causing one or more of the following injuries, such as fractures of skull, spine, pelvis, lower arm, upper arm, leg or foot; Internal hemorrhage or unconsciousness caused by oxygen deficiency; Severe wounds or lacerations likely to cause permanent disability; and Any dislocation of any joint which had never previously occurred.
- Fatal, if any accident causing the death of a mine worker within 24 hours calculated from the time the accident occurred.

PT. Freeport Indonesia on Internal FRESH Standards no. 4.11, incident classification will be as follow:
• Fatality, if any injury/ill health or incident directly resulting in death by working at the mine area irrespective of time
• Lost Time (LT) means, injury/ill health in which the employee is not able to return to work on the next regularly scheduled work shift or any subsequently scheduled work shift as a result of the injury/ill health
• Restricted Duty (RD) means, injury or ill health in which the employee returns to work, but is unable to perform all the duties normally connected with the job or where the employee is assigned to another job due to the injury or ill health on a temporary basis.
• Medical Treatment (MT), if any reportable injuries or ill health not classified as an LT or RD but requires medical treatment. Treatment by a medical doctor does not constitute an MT case if the doctor merely performs first-aid treatment, conducts diagnostic procedures (i.e. lab work, x-rays, tetanus injections, etc.) or hospitalizes the employee for observation. Examples of medical treatment include: fracture, removal of embedded foreign objects, debridement of wounds or burns, application of sutures, and administering prescribed medication for eye injuries.
• First Aid (FA), if any one time treatment or follow-up of minor scratches, cuts, burns, splinters, etc. which do not ordinarily require professional medical care or treatment.
• Property damage, if any damage to company property as a result of accident; incidents which are within the control or realm of operational control, supervisory control and established preventive maintenance or other management practices, classified as light vehicle damage, heavy equipment damage, and stationary equipment damage [10].

LT and RD categorized as major accident, in line with MT and FA categorized as minor incident.

3. Methodology

3.1. Accident Data Statistic
The data that shown on table 1 is captured from Safety Department in Mine Maintenance Division of PT. Freeport Indonesia. It provides information about accident that happened in Underground Mine Maintenance Division from 2011 through 2016. Accident is categorized as property damage, major accident, and minor accident.

| Category       | Property Damage | Major Accident | Minor Accident |
|----------------|-----------------|----------------|----------------|
|                | HE Damage       | LT             | RD             |
| 2011           | 3               | 1              | 0              |
| 2012           | 7               | 0              | 0              |
| 2013           | 5               | 0              | 0              |
| 2014           | 8               | 0              | 0              |
| 2015           | 8               | 0              | 0              |
| 2016           | 8               | 0              | 0              |
| Total          | 39              | 1              | 1              |

| Category       | LV Damage       | ST Damage      | FA              |
|----------------|-----------------|----------------|----------------|
| 2011           | 11              | 1              | 0              |
| 2012           | 16              | 3              | 2              |
| 2013           | 12              | 0              | 3              |
| 2014           | 16              | 3              | 4              |
| 2015           | 14              | 0              | 4              |
| 2016           | 10              | 2              | 4              |
| Total          | 79              | 13             | 17             |

The data trends were analyzed and used to determine the probability of accident (property damage, major accident, minor accident) that will be occurred. If we assume that accident prevention program will not change or affect the working safety of Underground Mine Maintenance Division, the data accident from past can be used to predict future trends.

3.2. Data Analysis
The number of rare events occurring within a fixed period of time has Poisson distribution [11]. It is appropriate for the analysis of accidents at a specific site in a given time period [12]. Probability using a Poisson distribution can be calculated using the following formula:
Probability = \frac{e^{-\mu} \cdot \mu^k}{k!} \quad (1)

Where:
- \mu = \text{Mean of the Poisson distribution} = \lambda \cdot t;
- t = \text{Selected time interval};
- k = \text{Total number of successes (or failures) or, in this case, one or more major accidents.}

Microsoft Excel was used for all of the statistical data analyses presented in this paper.

4. Result and Discussion
Trends during 2011-2016 were analyzed to determine the annualized and overall ratios of minor accident to major accident and property damage cases to major accident. Parameter Poisson that used for minor accident is \mu = 4, for major accident \mu = 1, and for property damage \mu = 22. The result for probability accident occurrence in underground mine maintenance is shown in Figure 2, while the cumulative probability accident occurrence in Figure 3. In these graph, the green line show probability of having n successful event for major accident, while the red line is for property damage, and the blue line is for minor accident. From graph in Figure 2, we can conclude that probability of having 1 major accident is 0.36 (36%), probability of having 4 minor accidents is 0.19 (19%), and probability of having 22 property damages is 0.08 (8%).

![Figure 2. Probability of Accident Occurrences in Underground Mine Maintenance](image-url)

![Figure 3. Cumulative Probability of Accident Occurrences in Underground Mine Maintenance](image-url)
From the ratio result of cumulative data shown in table 1, 12 minor accidents for 1 major accident and 66 equipment damages for 1 major accident were derived as a new value of accident triangle for Underground Mine Maintenance Division PT. Freeport Indonesia appear as seen in figure 4.

One of the fundamental underlying principles of Heinrich’s original triangle is that major accident as the top of pyramid cannot occur without a foundation of less severe incidents. In other words, increasing numbers of minor accident and equipment damage eventually support the existence of more serious and fatal incidents. Number of unsafe condition and/or unsafe act as the direct cause of an accident will be the base layer of the accident triangle.

Realizing that accidents in the mining industry are inevitable does not stop the company for believing that they are also preventable. Based on the triangle, PT. Freeport Indonesia implemented program called as Master Observation Program to reduce the number of unsafe condition and/or unsafe act which was found in the area of work. From this program, we capture the data of unsafe act and/or unsafe condition as shown at table 2.

**Table 2. Data Master Observation Program.**

| Category           | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|--------------------|------|------|------|------|------|------|
| PPE                | 973  | 690  | 1056 | 1298 | 1396 | 1353 |
| Housekeeping       | 4316 | 2856 | 4350 | 4671 | 4561 | 4785 |
| Procedure          | 4307 | 2624 | 4194 | 3918 | 3710 | 3846 |
| Position of people | 581  | 385  | 552  | 564  | 568  | 608  |
| Tools and Equipment| 3419 | 1866 | 3658 | 4220 | 3900 | 4126 |
| **Total**          | **13596** | **8421** | **13810** | **14671** | **14135** | **14718** |
The unsafe condition and/or unsafe act found in area of work should be stopped and followed up. Through the commitment of all line in the organization, especially leaders and supervisors, for the elimination of it, PT. Freeport Indonesia will be able to improve the safety performance.

5. Conclusion
One of the fundamental underlying principles of accident triangle is that major accident cannot occur without a foundation of less severe incidents. In other words, increasing numbers of minor incidents and property damage eventually support the existence of major incidents. The new value of accident triangle from the data is 1 major accident; 12 minor accident; and 66 property damage.

6. References
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