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Evaluation of occupational injuries with lost days among opencast coal mine workers through logistic regression models

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ABSTRACT

Despite precautions, mining remains the most hazardous occupation, and coal mining is one of the most dangerous industries for non-fatal occupational accidents. Accidents are complicated events with many factors that affect their formation, and statistical evaluation of accident records can produce valuable information that may prevent such accidents. In this study, a logistic regression analysis method was applied to non-fatal occupational injuries from 1996 to 2009 in an opencast coal mine for Western Lignite Corporation (WLC) of Turkish Coal Enterprises (TKI). The accident records were categorized as occupation, area, reason, age, part of body and lost days, and the SPSS package program was used for statistical analyses. Logistic regression analyses were used to predict the probability of accidents that resulted in greater or less than 3 lost workdays. It is found that the job group with the highest probability of exposure to accidents with greater than 3 lost workdays for non-fatal injuries was the maintenance personnel and workers. The employees were primarily exposed to accidents caused by a mining machine, and the lower and upper extremities have the highest probability of exposure to such risks. Finally, an equation for calculating the probability of exposure to accidents with greater or less than 3 lost workdays was derived. Then, the equation was used to determine the important accident risk factors.

1. Introduction

Compared with other industries, the mining industry and related energy resource industries are associated with high rates of occupational injuries and fatalities, and mining is one of the most hazardous work environments in many countries around the world (Sari et al., 2009; Groves et al., 2007; Bajpayee et al., 2004; Donoghue, 2004). Mining is a hazardous profession and considered at war with the unpredictable forces of nature. As a result, the mining industry continues to be associated with a high level of accidents, injuries, and illness (Maiti et al., 2004). Despite the record of progress in reducing mining fatalities and injuries, both the number and severity of mining accidents remain unacceptable (Kecojevic et al., 2007), and the incidence rates are high compared with other industries (Komljenovic et al., 2008). To identify the potential problem areas, it is necessary to investigate the causes of accidents and control exposure of such risks through quantitative analysis of accident data (Maiti et al., 2001).

Human factors approaches to system safety have been used to provide greater insights into the causes of accidents and can be applied to the mining context (Lenné et al., 2012). These models of human error in organizational systems take a systems approach (Reason, 2000). Such models have supported the development of several methods of accident investigation and analysis that use error and latent condition classification schemes to provide an analysis of the types of failure involved in accidents. One of the more widely used approaches is the Human Factors Analysis and Classification System (HFACS) (Shappell and Wiegmann, 2000). HFACS describes four levels of failure: (1) Unsafe Acts, (2) Preconditions for Unsafe Acts, (3) Unsafe Supervision, and (4) Organizational Influences (Shappell and Wiegmann, 2004). Reason proposed the “Swiss Cheese” model of human error where four levels of failure are described. Each level influences the next level as seen in Fig. 1 (Shappell and Wiegmann, 2000).

Lost workdays in mining industries are valuable indicators for a number of aspects in job safety programs (Coleman and Kerkering, 2007). According to the European Statistics on Accidents at Work (ESAW), the definition of a non-fatal accident at work is “The definition of what constitutes a notifiable work accident ranges from any work accident, whether it results in an interruption of work or not, to a minimum absence of more than three days”. Accidents with greater than 3 days’ absence from work are reported more than accidents with less than 3 days’ absence from work. Only accidents with greater than 3 days’ absence are considered in the ESAW methodology (EUROSTAT, 2001).

In this study, based on the ESAW accident definition, a logistic regression method was used for categorical data analysis to predict

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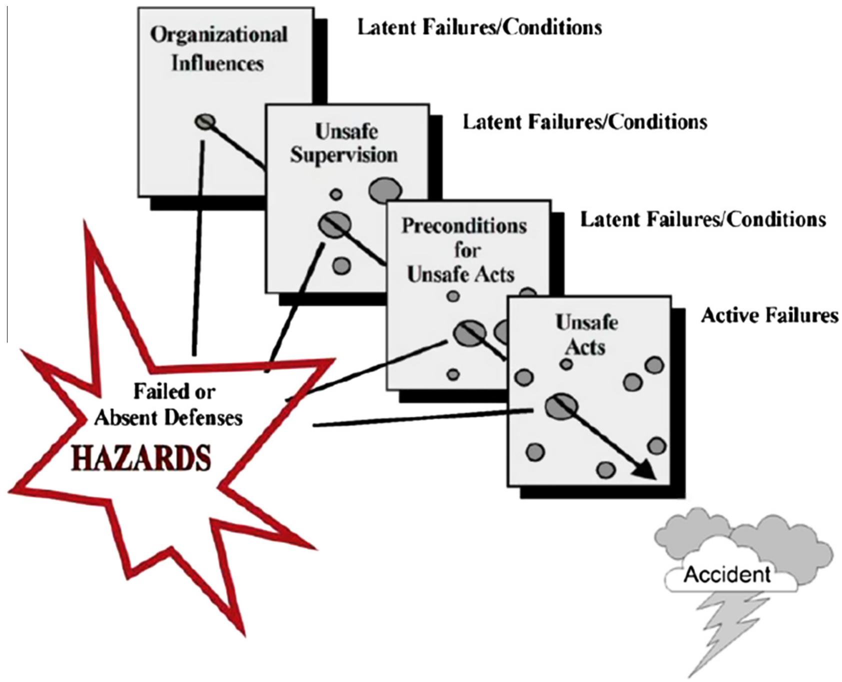

Fig. 1. The "Swiss Cheese" model of human error causation (adapted from Reason, 2000).

the probability of accidents with greater or less than 3 lost workdays. Occupational injuries for the Western Lignite Corporation (WLC) of Turkish Coal Enterprises (TKI), which is the primary state body of lignite coal production in Turkey, were examined. The accident records kept by WLC are reliable, detailed, well organized, and cover a long period. The records include the name of the employee, birth date, accident date, accident time, occupation (the job title of the worker), area (accident location), reason (accident type), body parts affected, and days off from work (Sari et al., 2004). The data used herein comprised occupational accidents from 1996 to 2009 in the opencast coal mine for the WLC. The accidents were categorized for occupation, area, reason, age, part of body as well as lost workdays, and the SPSS package program was used for logistic regression analyses.

2. Logistic regression analysis

Regression methods have become an integral component of any data analysis that describes the relationship between a response variable and one or more explanatory variables. Often, the outcome variable is discrete and comprises two or more possible values (Hosmer and Lemeshow, 2000). Logistic regression is a statistical method used to predict the probability of an event and is the most important model for categorical response data. Categorical data is a statistical data type consisting of categorical variables, used for observed data whose value is one of a fixed number of nominal categories, or for data that has been converted into that form, for example as grouped data. The explosion in the development of methods for analyzing categorical data that began in the 1960s has continued apace in recent years. Today, because of this development and the ubiquity of categorical data in applications, most statistics and biostatistics departments offer courses on categorical data analysis (Agresti, 2002).

Linear regression assumes that the expected value of Y for a given value of x may be expressed as an equation that is linear in x, such as $E(Y/x) = \beta_0 + \beta_1 x$. The specific form of the logistic regression model is as follows:

$$\pi(x) = e^{\beta_0+\beta_1 x}/(1 + e^{\beta_0+\beta_1 x}).$$

The logit of the multiple logistic regression model is determined using the following equation:

$$g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p.$$

The logistic regression model is then the following (Hosmer and Lemeshow, 2000):

$$\pi(x) = e^{g(x)}/(1 + e^{g(x)}).$$

Multiple logistic regression was used to estimate the odds ratios for the accidents with greater or less than 3 lost workdays. Given the primary risk factors that affected such accidents, the variables used were occupation (x_1), area (x_2), reason (x_3), age (x_4), and part of the body (x_5). Because the data used in this study comprised categorical and continuous variables, logistic regression was used to predict the probabilities for accidents with greater or less than 3 lost workdays. Thus, herein lost workdays were used as the dependent variable and categorized as greater and less than 3 days.

$$\pi(x) = e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\beta_3 x_3+\beta_4 x_4+\beta_5 x_5}/(1 + e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\beta_3 x_3+\beta_4 x_4+\beta_5 x_5}).$$

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5$: Coefficients of regression, and
x_1, x_2, x_3, x_4, x_5: Independent variables.

3. Risk estimation studies for the WLC

In the open pit mines of the WLC in the eastern part of Turkey, mining activities include overburden stripping and coal winning. For overburden removal, an excavator, truck, and dragline are employed, whereas, for coal winning, a hydraulic excavator and truck are used. Drilling is performed using drilling machines and an ammonium nitrate and fuel oil (ANFO) mixture is used for explosives (Sensogut and Cinar, 2007).

The number of persons employed in the WLC and injuries from 1996 to 2009 are shown in Fig. 2.

Fig. 2 shows a significant reduction in the number of accidents since 2004. In addition, the number of workers also decreased from