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Full Length Research Paper

A logistic regression analysis of the occurrence of mine accidents in the Burgersfort area in South Africa

S. J. Riba, M. Lesaoana, C. Sigauke* and M. R. Makwela

School of Mathematical and Computer Sciences, University of Limpopo (Turfloop Campus), P. Bag X1106, Sovenga, 0727, South Africa.

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In this paper a logistic regression model is developed and used to predict the probability of accidents occurring in mines and to estimate the occurrence of accidents due to machines and falling rocks. We designed a questionnaire and conducted interviews among workers in the mines of Burgersfort area in the Limpopo Province in South Africa. A total of 372 people responded of which 29% were accident victims. From the primary data that was collected, the independent variables were accident victims due to machines and accident victims due to falling rocks. These independent variables were significant to enter the model to predict the occurrence of accidents in the mines. Empirical results show that most accidents in the mines occur due to conduct with machines and falling rocks. The results also show that falling rocks in the mines is the most cause of accidents. Awareness campaign programs should be carried out so as to educate miners on the major causes of accidents in the mines and how to prevent them.

Key words: Logistic regression, mine accidents, safety, falling rocks.

INTRODUCTION

Mining has long been regarded as a relatively dangerous industry in every country in the world. For example, in the United States coal mining is considered to be one of the most hazardous occupations (Poplin et al., 2008). It has been shown by Bhattacherjee and Ramani (1992) that the total cost of accidents on average resulted in a loss of 1 million USD per accident in a case mine in the eastern USA. In a similar study carried out for Turkish coal enterprises (Istanbulluoglu, 1999), the total cost of lost working days due to accidents in a year is calculated as 4.3 million USD without considering indirect losses. A deterministic risk assessment approach has been performed on the available days-lost data and risk levels were first identified for conventional and mechanized panels of two underground coal mines in earlier studies (Sari et al., 2004). In that study, an uncertainty analysis methodology was proposed as its steps were clearly identified. Risk due to accidents in the GLI-Tuncbilek coal mine was basically evaluated by a stochastic analysis of past traumatic accident/injury experience data. Bennet (1982) found no relationship between age and injury severity and stated that more experienced miners were slightly less probable of receiving injuries than less experienced miners. However, Bennet and Passmore (1985) showed that older miners were more fatally injured than younger miners and injury severity was not related to miner's total mining experience. Butani (1988) stated that injuries in the coal industry varied more by experience at the present company than by age. The workers were experiencing injuries at the same rate when grouped by worker's age, but not when grouped by worker's experience at the present company. Employees with 1 year or less experience were at a considerably higher-than-average risk, while employees with more than 15 years' experience were at a lower-than-average risk.

Phiri (1989) found conflicting results indicating that the younger miners showed no difference in the probability of occurrence of an injury than middle aged miners, whereas, older miners showed 2% less probability of an

*Corresponding author. E-mail: Caston.Sigauke@ul.ac.za.

injury than the younger miners. Hull (1996) indicated that older mine workers were more severely injured than younger miners since older mine workers were being less resilient than younger mine workers to some of the energy impacts encountered in underground coal mines. Therefore, a given amount of energy may result in more severe injuries and it may also take an older mine worker longer to recover from a given type of injury than a younger mine worker. Maiti and Bhattacherjee (1999) showed that age and experience of the miners did not have any significant effect on the risk of occurrence of injuries. Other studies indicate that employees without experience have a higher risk of injuries than older employees with experience. Leigh (1990) found out that employees under the age of 40 years had a higher risk of injuries than older employees. The effect of age and experience on accident occurrence in the mines have been studied by many researchers (Bennet and Passmore, 1985; Butani, 1988; Phiri, 1989; Hull et al., 1996; Maiti and Bhattacherjee et al., 1999). Hull et al. (1996) found out that injuries experienced by mechanical unit men were significantly more severe than injuries experienced by other tradespersons, but only by 17%. Maiti and Bhattacherjee (1999) showed that the face workers were at risk more than the haulage and other workers in the occurrence of an injury. Bennet (1982) examined the relationship between accidents location and severity of injury. The author concluded that within the mine, the location shaft/slope would have less serious injuries, whereas, the location intersection would experience the same probability of severe injuries as the face area. Bennet and Passmore (1985) showed that a severe injury was slightly more likely at the face area than other locations. Hull (1996) found that injurious incidents occurring in other underground locations such as workshops and drift areas were significantly more severe than injuries occurring at the coalface.

Accidents occurring at the mine surface and on haul/transport roads were not different, in terms of severity, from those occurring at the face. Maiti and Bhattacherjee (1999) showed that the risk indices for the out by-face location was higher than the face location for three injury degrees. This finding was contradictory in relation to the occupation categories and a closer examination of data revealed that the possible reasons could be the following:

(a) Slip and fall injuries of the face workers at the out by-face location during transportation,
(b) Allocation of job to the face workers at the out by-face location and;
(c) Tendency of the workers to underestimate the potential dangers in performing tasks away from the face area.

Most of the studies found face area as a risky place in the mines. This kind of an area is whereby accidents such as rock falling, falling of high walls, falling of small rocks, falling of face, falling of rib, falling of side, falling of roof or back, takes place. Duzgun and Einstein (2004) proposed a risk and decision analysis methodology for the assessment and management of risk associated with mine roof falls in underground coal mines. Engineers all over the world have already paid much attention to the falling of roofs/rocks and malfunctioning of mining equipment and obtained some knowledge about it, such as surface control techniques, inadequate installation procedures and equipments characteristics (Cashdollar et al., 1996). In this paper a logistic regression model is developed and used to predict the probability of accidents occurring in mines and to estimate the occurrence of accidents due to machines and falling rocks in the Burgersfort area of Limpopo Province in South Africa. The rest of the paper is organized as follows: the logistsic regression model used is this study is discussed in the next study. Here, we also estimate the parameters of our model. This is then followed by a detailed discussion of our results. The conclusion is covered in the last study.

THE LOGISTIC REGRESSION MODEL

Here, the logistic regression model is developed. The developed model is used to predict the probability of accidents occurring in mines and to estimate the occurrence of accidents due to machines and falling of rocks.

METHODOLOGY

A questionnaire was designed and interviews were conducted among workers in the mines of Burgersfort area in the Limpopo Province in South Africa. A total of 372 people responded of which 29% were accident victims. From the primary data that was collected, the independent variables were accident victims due to machines and accident victims due to falling rocks. These independent variables were significant to enter the model to predict the occurrence of accidents in the mines. The logistic regression model used to predict the probability of accidents occurring in mines due to machines and falling rocks is developed in the next study.

The logistic regression model

The logistic regression model used in this paper is defined as follows: Let y be a dichotomous dependent variable defined as:

$$y = \begin{cases} 1, & \text{if accident victim} \\ 0, & \text{if not accident victim} \end{cases} \quad (1)$$

then;

$P(Y=1\,|\,x)$ = the probability of accident victims in the mine

Table 1. Parameter estimates of model given by Equation 4.

Par	Constant	Age	Accident_machine	Accident_rockfall
Coef	-1.782 (0.000)	-0.015 (0.897)	0.204 (0.026)	3.025 (0.000)
Exp(B)	0.168	0.985	1.226	20.59

Table 2. Parameter estimates of Model 2.

Par	Constant	Age(1)	Age(2)	Age(3)
Coef	-2.199 (0.130)	0.349 (0.815)	0.402 (0.784)	0.416 (0.777)
Exp(B)	0.111	1.417	1.495	1.516
Par	Age(4)	Age(5)	Accident_Machine	Accident_Rockfall
Coef	0.218 (0.883)	0.863 (0.596)	0.203 (0.028)	3.048 (0.000)
Exp(B)	1.244	2.37	1.225	21.072

Where,

$$P(Y=1|x)=\frac{1}{1+e^{-Y}}, \quad (2)$$

x is a vector of predictor variables, and;

$$Y = \beta_0+\beta_1 x_1+\beta_2 x_2+\beta_3 x_3+\beta_4 x_4+\beta_5 x_5+\beta_6 x_6+\beta_7 x_7+\varepsilon_t \quad (3)$$

Where $x_1 =$ age.

Equation 1 represents mine workers aged less than or equal to 20 years, $x_2 =$ age.

Equation 2 represents mine workers aged between 21 and 30,

$x_3 =$ age.

Equation 3 represents mine workers aged between 31 and 40,

$x_4 =$ age.

Equation 4 represents mine workers aged between 41 and 50,

$x_5 =$ age.

Equation 5 represents mine workers aged 51 or more,

$x_6 =$ accident_machines represents accidents victims due to machines in the mines of Burgersfort, $x_7 =$ accident_rockfall represents accidents victims due to falling of rocks in the mines of Burgersfort, β_0 represents the constant of the equation, β_i represents the coefficients for the accidents victims, $i=1.2,\ldots 7$ and ε_t is the stochastic disturbance term with mean zero and variance σ^2.

Data analysis

It looks at the results of the binary logit model. Table 1 shows the parameter estimates of the model given by Equation 4. The estimated model is:

Y = -1.782 - 0.15age + 0.204accident_machine + 3.048accident_rockfall (4)

The coefficient of accident_rockfall has a large positive effect on the probability of an accident. This indicates that more accidents are as a result of rockfall and fewer accidents are caused by machines. The coefficients for accident victims due to machines and falling of rocks are statistically significant at $\alpha = 0.05$. Exp(B) for accident victims due to machines is 1.226, the odds of accident victims due to machines are 1.226 times that of accident victims not due to machines assuming all the other variables are held constant. Similarly, Exp(B) for accident victims due to falling rocks is 20.590, the odds of accident victims due to falling rocks are 21.072 times that of accident victims not due to falling rocks assuming all the other variables are held constant. The odds of accident victims increase by about one unit as age increases by one year when all the variables are held constant. Table 2 shows the parameter estimates of model 2. The estimated model is:

Y = -2.199 + 0.342age(1) + 0.402age(2) + 0.416age(3) + 0.218age(4) + 0.863age(5) + 0.203accident_machine + 3.048accident_rockfall (5)

The coefficients for accident victims due to machines and falling rocks are statistically significant at $\alpha = 0.05$. Exp(B) for accident victims due to machines is 1.225, the odds of accidents victims from the accident victims due to machines are 1.225 times that of accident victims not due to machines assuming all the other variables are held constant. Similarly, Exp(B) for accident victims due to falling of rocks is 21.072, the odds of accidents victims from the accident victims due to falling of rocks are 21.072 times that of accident victims not due to falling of rocks assuming all the other variables are held constant. The odds of accident victims increase

Table 3. Final logit model.

Par	Constant	Accident_machine	Accident_rockfall
Coef	-1.821 (0.000)	0.204 (0.025)	3.022 (0.000)
Exp(B)	0.162	1.226	20.538

by about one unit as all age groups increases by one year when all the variables are held fixed. Table 3 shows the parameter estimates of the final binary logit model. The final logit model is:

$$Y = -1.821 + 0.204accident\_machines + 3.022accident\_rockfall \quad (6)$$

The odds that accident victims due to machines are 1.226 times the odds for accident victims due to other factors that causes accidents in the mines. The odds that accident victims due to falling of rocks are 20.538 times the odds for accident victims due to other factors that causes accidents in the mines. This indicates that falling of rocks and conduct with machines are the most cause of accidents in the mine.

RESULTS AND DISCUSSION

Accidents which occur in the mines due to machines and falling rocks have serious effects on the occurrence of accidents in the mines. The majority of the respondents who work in the mines were aged between 21 and 30 years. Most of the respondents suggested that many accidents in the mines occur due to falling rocks. This is consistent with our findings as the coefficient of the variable accident_rockfall was 3.025 indicating a large positive effect on the probabilty of an accident. Our findings are consistent with findings of other researchers (Bennet and Passmore, 1985; Bhattacherjee, 1992; Maiti and Bhattacherjee, 1999; Sari et al., 2004; Kecojevic et al., 2007; Paul and Maiti, 2007; Shu-gang et al., 2008; Paul, 2009; Maiti et al., 2009; Zheng et al., 2009; Khanzode et al., 2010; Margolis, 2010) in the sense that the occurrence of accidents due to machines and falling rocks in the mines constitute a large number. The responses proved that the majority of the respondents being injured due to falling rocks in the mines were more than those who were injured due to machines. In view of these findings we recommend that more research be done on the subject of occurrence of accidents due to machines and falling rocks in the mines of Burgersfort area. There is need for awareness programs offered in the mines on the dangers of accidents in the mines. The government through the relavant ministry should take measures in the mines concerning the issue of safety.

CONCLUSION

In this paper a binary logit model was developed and used to predict the probability of accidents occurring in mines and to estimate the occurrence of accidents due to machines and falling rocks. Empirical results show that most of the accidents in the mines of Burgersfort area are due to falling rocks. Findings from this study have shown that safety measures are not adhered to. Accidents which occur in the mines are problems which have serious effects on current and future lives of the mine workers. More research based on accidents occurring due to machines and falling rocks in mines is needed in order to create effective programmes to resolve these problems.

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