International Journal of Occupational Safety and Ergonomics (*JOSE*) 2014, Vol. 20, No. 2, 239–248

Applying Hierarchical Loglinear Models to Nonfatal Underground Coal Mine Accidents for Safety Management

Mustafa Onder
Seyhan Onder
Erhan Adiguzel

Department of Mining Engineering, Eskisehir Osmangazi University, Eskisehir, Turkey

Underground mining is considered to be one of the most dangerous industries and mining remains the most hazardous occupation. Categorical analysis of accident records may present valuable information for preventing accidents. In this study, hierarchical loglinear analysis was applied to occupational injuries that occurred in an underground coal mine. The main factors affecting the accidents were defined as occupation, area, reason, accident time and part of body affected. By considering subfactors of the main factors, multiway contingency tables were prepared and, thus, the probabilities that might affect nonfatal injuries were investigated. At the end of the study, important accident risk factors and job groups with a high probability of being exposed to those risk factors were determined. This article presents important information on decreasing the number accidents in underground coal mines.

occupational injuries   accident analysis   hierarchical loglinear models

1. INTRODUCTION

Mining remains one of the most hazardous occupations worldwide, and underground coal mines are especially notorious for their high accident rates [1]. The mining environment, especially underground operations, is constrained by the absence of natural light, fresh air and open space, and the undesirable presence of high temperature, humidity, dust, fumes, noise and rock stresses. Due to these constraints, the hazards and hazard potential inherent in a mine may trigger accidents unless sound and strong measures are taken to prevent them. The hazardous nature of coal mine operations can be easily deduced from the national statistics of mine accidents and injuries [2].

Despite the record of progress that has been achieved in reducing mining fatalities and injuries, both the number and severity of mining accidents are still unacceptable [3] and incidence rates remain high compared to other industries [4]. Common causes of fatal injuries include rock falls, fires, explosions, mobile equipment accidents and electrocution [5]. To identify the potential problem areas, it is necessary to investigate the causes of accidents and to control them through quantitative analysis of accident data [6]. The objective of accident analysis is to prevent accidents in the future. To prevent accidents, it is necessary to identify common factors and characteristics contributing to fatal and nonfatal accidents. Strategies for accident prevention should be in reasonable agreement with significant variables of occupational accidents. These results can be used to develop more effective programs for preventing accidental occupational death and injuries [7].

In 2007, in Turkey, the rate of injury due to underground coal mining accidents was the

---

The authors thank the management of Turkish Coal Enterprises.

Correspondence should be sent to Mustafa Onder, Department of Mining Engineering, Eskisehir Osmangazi University, Eskisehir, Turkey. E-mail: monder@ogu.edu.tr.

highest, with an injury rate of 10.1% [8]. The present study examined occupational injuries that took place in Western Lignite Corporations (GLI) of Turkish Coal Enterprises (TKI), which is the main state body of lignite coal production in Turkey. GLI is one of the largest underground coal mines of TKI in terms of coal production and the number of employees. Accident records are reliable, detailed, well organized and cover a long period. They include the worker's name and birth date, accident date, accident time, occupation (job title), area (accident location), reason (accident type), part of body affected and days off work [9]. Data on the period of 1996–2009 were obtained from GLI. Accidents were categorized in terms of occupation, area, reason, accident time and part of body affected; statistical analysis was performed with SPSS version 18. Hierarchical loglinear models were used to determine the degree of interaction between the variables. As a result, the study determined the most important elements of risk in occupational accidents.

2. METHODS

2.1. Loglinear Models

The purpose of loglinear modeling is an analysis of association and interaction patterns. Loglinear models are of use primarily when at least two variables are response variables. Modeling cell counts in contingency tables is a common use. Although loglinear models can be used to analyze the relationship between two categorical variables (two-way contingency tables), they are more commonly used to evaluate multiway contingency tables that involve three or more variables. Loglinear models for higher dimensions are more complex than for two-way tables, because of the variety of potential association terms. The variables investigated with loglinear models are all treated as response variables and, therefore, loglinear models demonstrate association between variables [10, 11]. Hierarchical loglinear models express the logarithm of cell probabilities as a sum of effects. The fullest loglinear model includes a constant, the main effects of each variable and all second- and higher-order interactions. This model is known as the saturated model because it has as many parameters as there are cells in the table, and thus fits the data perfectly [10, 12]. The loglinear model used in this study is constructed from a five-way contingency table (Table 1) of occupation, area, reason, accident time and part of body.

2.2. Risk Estimation Studies in GLI

A good knowledge of statistical features of certain accidents is the basic requirement in implementing a safety management system. In other words, identifying major hazards is necessary. A statistical study on accident cases would be a powerful tool to meet this requirement [13]. The way in which risks are perceived is strongly correlated with the way in which they are calculated. Risks based on historical data are particularly easy to understand and are often considered reliable. It is, therefore, easy to illustrate a risk calculated from historical data to understand some characteristics of risk estimation [14]. The historical approach can only be used to estimate risks when the hazard has been present for some time. For this purpose, occupational injury and accident data related to GLI in 1996–2009 were collected.

Accident analyses are used to identify common factors contributing to occupational accidents and to give recommendations for accident prevention [7]. Studies on the occurrence of injures in underground coal mines have identified a number of variables affecting mine accidents. Based on the published literature [6, 9, 15, 16, 17, 18] and accident records, the variables chosen in this study were divided into five main groups: occupation, area, reason, accident time and part of body affected.

The GLI-Tuncbilek coal reserve, located in midwest Turkey, is mined by two underground panels, namely the Tuncbilek Mine and the Omerler Mine. Coal production started in the Tuncbilek Mine in 1940 with a retreat longwall mining method and sublevel caving. The coal seam with an inclination gently varying from 0° to 8° is 4–12 m thick. In a conventional system, the face area is supported with wooden posts and hydraulic shields perpendicular to the face. Two meters of the lower part of the coal seam are

TABLE 1. Cross-Classification Table of Variables

Occupation	Area	Reason	Time	Body
occupation1	area1	reason1	time1	body1
				body2
				body3
				body4
			time2	body1
				body2
				body3
				body4
			time3	body1
				body2
				body3
				body4
		reason2	–	–
				–
				–
	area2	–	–	–
–	–	–	–	–
–	–	–		–
occupation5	area1	reason1	time1	body1
	–	–	–	–

loosened by blasting, then excavated with hand-held drills, while the remaining roof coal is excavated behind by caving in to the face conveyor. In 1985, production began in the Omerler Mine; conventional longwall mining was used. In 1997, the management of the mine changed and the current method of a fully mechanized retreating longwall with sublevel caving began to be used. In this method, the bottom of coal is mined 3 m high with a shearer/loader mounted on an armored face conveyor with self-advancing hydraulic-powered roof supports while the remaining roof coal is subsequently caved in. The panels are 450–600 m as limited by major faults. The length of a longwall face is generally 90 m and includes 58 units of lemniscate-type shield supports [19]. Figure 1 shows the number of persons employed in the mine and injuries.

Injuries caused by underground coal mining accidents were recorded officially and a total of 1135 occupational injuries and 3 occupational fatalities were reported in 1996–2009. All accidents, including occupational ones, are reported to the authorities to determine the cause and

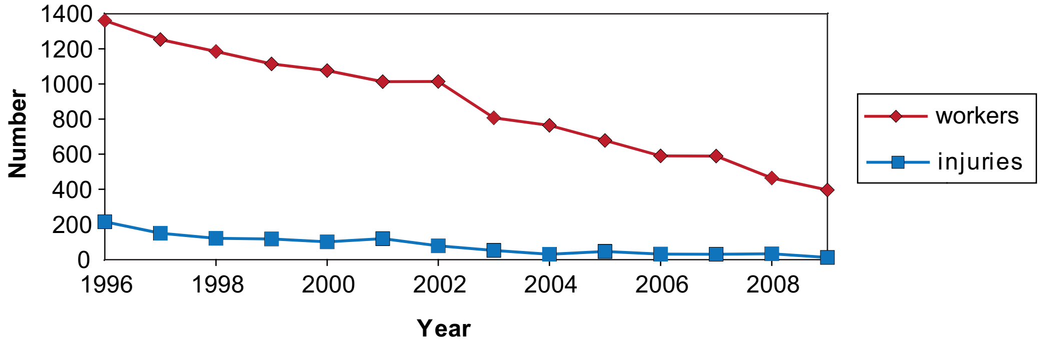

Figure 1. Total numbers of workers and injuries in 1996–2009.

manner of fatalities and injuries. Fatal cases were not included in the analysis since occupational injuries were investigated. To standardize accident statistics, to identify safety problems and to be able to measure safety performance of one organization, accident frequency rate (AFR) and accident severity rate (ASR) are often used. AFR and ASR can be calculated as follows:

$$\text{AFR} = \frac{\text{total number of accidents} \times 10^6}{\text{total number of person-hours worked}}, \quad (1)$$

$$\text{ASR} = \frac{\text{total number of days lost} \times 1000}{\text{total number of person-hours worked}}. \quad (2)$$

AFR is an expression relating the number of specific accidents to the number of person-hours worked. The objective of ASR is to give some indication of the loss in terms of incapacity resulting from occupational accidents. AFR is calculated by dividing the number of accidents (multiplied by 10^6) that took place during the period covered by statistics by the number of person-hours worked by all persons exposed to the accident risk during the same period. ASR should be calculated by dividing the number of working days lost (multiplied by 1000) by the number of hours of working time of all persons included [19]. Figures 2–3 present the AFR and ASR graphics of GLI, respectively.

Figure 2 shows a significant reduction in accident frequency rates. Although the reductions in AFRs are obvious, ASRs did not decrease significantly. Despite significant reductions in the number of accidents, the loss of work days due to accidents did not decrease, which is noteworthy.

In this study, occupational injuries were evaluated with respect to occupation, area, reason, accident time and part of body affected. The occupation variable had five categories: worker-coal winner, supporter, development worker,

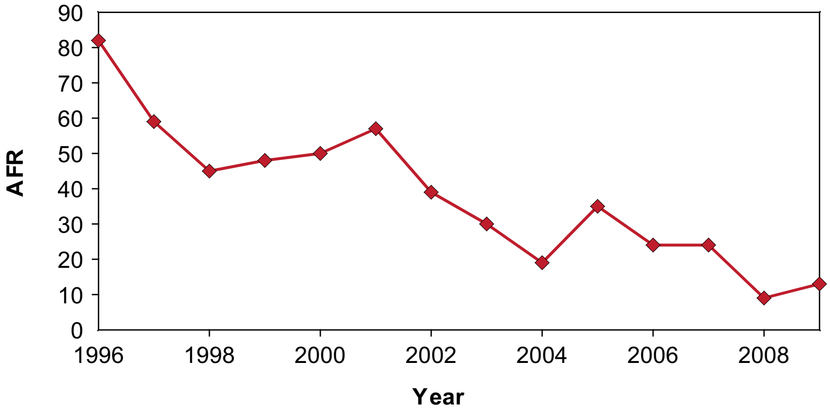

Figure 2. Accident frequency rates (AFR).

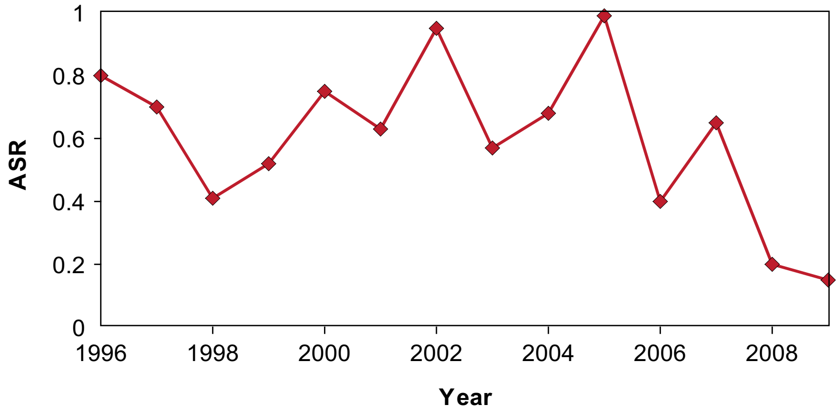

Figure 3. Accident severity rates (ASR).

mechanic-electrician, repairman and conveyor man. The common responsibilities of these job groups can be given as coal excavations for worker-coal winner; arrangement and maintenance of support units for supporter; gate roads and stone drifts for development worker; repairs and maintenace of machinery, motor and electric equipment for mechanic-electrician; other maintenance and repair duties for repairman; loading and removing coal from mines for conveyor man. The area variable had three groups: face areas, developments and others. Reasons of accidents leading to injuries were categorized into four main groups: falls of ground (roof, rock and coal); manual and mechanical handling; struck by a falling object; and machinery. The time variable had three categories: 8:00–16:00, 16:00–24:00 and 24:00–8:00. The part of body injured was categorized into four groups: lower extremities (leg and foot), upper extremities (hand and arm), torso and head. Table 2 shows percentage distributions of injured persons.

Table 2 shows worker-coal winners were more likely to be injured than the other workers. The largest proportion of occupational injuries occurred in face areas. Table 2 indicates falls of ground were the most common accident reason is and the largest proportion of injuries took place in the 8:00–16:00 period. In the analysis of the parts of body most often injured, lower and upper extremities accounted for 61.1% of all injuries.

TABLE 2. Percentage Distributions of Injured Persons

Category	Effect Name	%
Occupation	worker-coal winner	59.0
	supporter	10.0
	development worker	9.3
	mechanic-electrician	8.5
	repairman	7.2
	conveyor man	6.0
Area	face areas	60.5
	others	28.6
	developments	10.9
Reason	falls of ground	36.7
	manual and mechanical handling	28.8
	struck by a falling object	23.6
	machinery	10.9
Accident time	8:00–16:00	46.8
	16:00–24:00	33.5
	24:00–8:00	19.7
Part of body	lower extremities	31.3
	upper extremities	29.8
	torso	24.7
	head	14.2

The data collected from the GLI underground coal mine were evaluated with hierarchical loglinear method for detailed investigation of effective factors on occupational injuries. The results follow in section 3.

3. RESULTS AND DISCUSSION

Loglinear analysis is a multivariate extension of χ^2 used to detect the varying associations and interactions between variables; it provides a systematic approach to the analysis of complex multidimensional tables. This study used hierarchical loglinear analyses and the analyses were carried out with SPSS version 15. A loglinear analysis was applied to the frequency data using occupation (6), area (3), reason (4), accident time (3) and part of body affected (4). Table 3 illustrates those relationships; the associations and interactions are discussed thereafter.

Table 3 shows the main effects and higher-order interaction terms of the hierarchical loglinear model. The significance of the interaction terms was tested with the likelihood-ratio (χ^2) test [6]. It was found that the third-, fourth- and fifth-order interaction terms were not significant and the main effects and area × occupation, reason × part of body, reason × occupation and area × reason interaction parameters were statistically significant ($p < .05$). In addition, because for area × reason × occupation, $p = .052$ and for area × occupation × accident time, $p = .079$, i.e., third-order interactions are very close to .05, they can be regarded as important.

SPSS prints out the required parameters in the “Parameter Estimates” table of the output. One of these parameters is lambda and it is the usual designation for the effect coefficient. Lambdas appear as “coefficients” in the estimates column of this table. These parameters can be labeled as β coefficients and Exp(β) is the odds ratio (*OR*).

TABLE 3. Tests of Main Effects and Higher-Order Interactions

Degree of Interactions	Interactions	*df*	χ^2	*p*
Main effects	occupation	5	629.243	<.001
	area	2	266.013	<.001
	reason	3	106.007	<.001
	accident time	2	77.813	<.001
	part of body	3	53.259	<.001
2	area × occupation	10	157.041	<.001
	reason × part of body	9	126.312	<.001
	reason × occupation	15	96.510	<.001
	area × reason	6	45.488	<.001
	occupation × part of body	15	19.559	.190
	occupation × accident time	10	10.126	.430
	area × part of body	6	9.294	.158
	reason × accident time	6	7.996	.238
	part of body × accident time	6	5.555	.475
	area × accident time	4	0.543	.969
3	reason × occupation × part of body	45	50.155	.276
	area × reason × occupation	30	43.598	.052
	reason × occupation × accident time	30	39.999	.105
	area × occupation × part of body	30	37.968	.151
	occupation × part of body × accident time	30	33.165	.315
	area × occupation × accident time	20	29.485	.079
	area × reason × part of body	18	25.056	.123
	area × part of body × accident time	12	15.457	.217
	area × reason × accident time	12	13.691	.321
	reason × part of body × accident time	18	13.236	.777
4	reason × occupation × part of body × accident time	90	38.683	1
	area × occupation × part of body × accident time	60	38.357	.987
	area × reason × occupation × part of body	90	30.298	1
	area × reason × occupation × accident time	60	24.834	1
	area × reason × part of body × accident time	36	17.682	.996
5	area × reason × occupation × part of body × accident time	180	5.313	1

OR is a type of effect size measure; *OR* = 1 indicates no effect. Although *OR* > 1 indicates the variable in question increases the odds, *OR* < 1 indicates the variable decreases the odds [10]. If *OR* > 1 and the lower bound of the confidence interval (CI) does not go below 1, it can be said that a proposed risk factor acts as a significant risk to accidents [10].

In this study, seeing that occupational injuries were evaluated, to achieve more detailed accident analyses, the statistically significant parameters in Table 3 were evaluated. The values obtained from SPSS were used to calculate *OR*s and their 95% CI. The main effects were evaluated; Table 4 shows the results.

According to Table 4, by taking into account both *OR* and CI, it can be said that worker-coal winner is the occupation with the highest risk of occupation injuries. It is followed by supporter, development worker, mechanic-electrician, repairman and conveyor man. It was determined that face areas had the highest risk of exposing to an accident. Manual and mechanical handling are the reason with the highest risk of exposing to an accident. The other reasons are falls of ground, struck by a falling object and machinery. Accident

TABLE 4. Results of Main Effects for the Loglinear Model

Main Effects	Effect name	β	*OR*	95% CI
Occupation	worker-coal winner	.275	1.317	[1.171, 1.481]
	supporter	–.003	0.997	[0.881, 1.128]
	development worker	–.004	0.996	[0.881, 1.126]
	mechanic-electrician	–.024	0.976	[0.863, 1.105]
	repairman	–.034	0.967	[0.854, 1.094]
	conveyor men	–.061	0.941	[0.830, 1.066]
Area	face areas	.131	1.140	[1.046, 1.242]
	others	.072	1.075	[0.986, 1.171]
	developments	–.053	0.948	[0.869, 1.036]
Reason	manual and mechanical handling	.071	1.074	[0.972, 1.186]
	falls of ground	.066	1.068	[0.967, 1.180]
	struck by a falling object	.039	1.040	[0.941, 1.149]
	machinery	–.027	0.973	[0.880, 1.077]
Accident time	8:00–16:00	.116	1.123	[1.031, 1.223]
	16:00–24:00	.041	1.042	[0.955, 1.136]
	24:00–8:00	–.008	0.992	[0.909, 1.083]
Part of body	upper extremities	.084	1.088	[0.985, 1.201]
	lower extremities	.056	1.058	[0.957, 1.168]
	torso	.026	1.026	[0.928, 1.135]
	head	–.016	0.984	[0.890, 1.089]

Notes. OR = odds ratio, CI = confidence interval.

time with the highest risk of exposing to an accident was 8:00–16:00. It was determined that upper extremities were the most affected part of body. Lower extremities and torso carried a similar risk. Table 5 shows the most important results of the second-order interaction terms of the loglinear model.

When the second-order interactions in Table 5 are evaluated, the area × occupation interaction shows that worker-coal winners have high exposure to work accidents in face areas. Moreover, development workers working in developments are at high risk. When the reason × part of body interaction is evaluated, it is found that torso and

TABLE 5. Results of Second-Order Interaction Terms for the Loglinear Model

Interactions	Effect Name	β	*OR*	95% CI
Area × occupation	face areas × worker–coal winner	.450	1.568	[1.298, 1.895]
	developments × development worker	.164	1.178	[0.956, 1.453]
	face areas × development worker	–.167	0.846	[0.683, 1.048]
Reason × part of body	manual and mechanical handling × torso	.178	1.195	[0.985, 1.450]
	falls of ground × lower extremities	.110	1.116	[0.919, 1.356]
	manual and mechanical handling × head	–.131	0.877	[0.716, 1.075]
Reason × occupation	falls of ground × worker-coal winner	.227	1.255	[1.002, 1.571]
	machinery × mechanic-electrician	.174	1.190	[0.935, 1.515]
	machinery × worker-coal winner	–.206	0.814	[0.640, 1.035]
Area × reason	others × manual and mechanical handling	.133	1.142	[0.967, 1.349]
	face areas × falls of ground	.111	1.117	[0.945, 1.321]
	face areas × struck by a falling object	.094	1.099	[0.929, 1.299]

Notes. OR = odds ratio, CI = confidence interval.

head injuries are mostly caused by manual and mechanical handling; also, occupational injuries related to falls of ground affect lower extremities. The reason × occupation interaction shows that worker-coal winner has high exposure to occupational injuries due to falls of ground and machinery, and mechanic-electrician has high risk due to machinery. The area × reason interaction shows that face areas have high exposure to accidents due to falls of ground and struck by a falling object. When *OR* and CI are evaluated together, it can be said that falls of grounds in face areas carry exceptionally high risk for worker-coal worker. After second-order interactions, third-order interactions are evaluated. Table 6 shows the values of important third-order interactions.

Firstly, the area × reason × occupation third-order interaction was evaluated and it was found that the face areas × falls of ground × worker-coal winner interaction was the most important risk group. This interaction shows that the possibility of injuries related to falls of ground for worker-coal winner in face areas is high. Additionally, it can be said that struck by a falling object and machinery have high risk for workers working in face areas. From the area × occupation × accident time interaction, it was found that the face areas × worker-coal winner × 8:00–16:00 interaction was the most important risk group. This interaction indicates that the possibility of being exposed to work accidents for worker-coal winner in face areas from 8:00 to 16:00 is high. By evaluating the other remaining interactions in the same way, the reasons related to accidents for occupation, area, reason, accident time or part of body affected can be defined.

4. CONCLUSIONS

Risk assessment is useful in making decisions about hazards, so it is important to gain some perspective about the meaning of the magnitude of risk. When nonfatal accidents in GLI were evaluated with hierarchical loglinear analysis, it was found that worker-coal winner was the most risky job group. It was followed by supporter, development worker, mechanic-electrician, repairman and conveyor man. The worker-coal winner job group had high exposure to nonfatal work accidents in face areas due to falls of ground, whereas mechanic-electrician had high risk due to machinery. Face areas had high exposure to accidents due to falls of ground and struck by a falling object. Manual and mechanical handling were the reason with the highest risk being exposed to accidents. The study showed upper extremities were the most affected part of the body in nonfatal accidents. Lower extremities and torso had a similar risk; head had a lower accident risk. Torso and head injuries were mostly caused by manual and mechanical handling; moreover, occupational injuries related to falls of ground affected lower extremities. The possibility of being exposed to work accidents for worker-coal winner in face areas was highest between 8:00 and 16:00. These results show it is necessary to decrease nonfatal work accidents by decreasing manual handling operations, improving supporting systems, and using mechanized production systems. Moreover, in training related to work accidents, job groups must be considered and they must be educated about possible risks. Workers should receive appropriate personal protective equipment.

TABLE 6. The Results Of Third-Order Interaction Terms for the Loglinear Model

Interactions	Effect name	β	*OR*	95% CI
Area × reason × occupation	face areas × falls of ground × worker-coal winner	.357	1.429	[1.006, 2.029]
	face areas × struck by a falling object × worker-coal winner	.310	1.363	[0.957, 1.943]
	face areas × machinery × worker-coal winner	–.214	0.807	[0.547, 1.192]
Area × occupation × accident time	face areas × worker-coal winner × 8:00–16:00	.192	1.212	[0.893, 1.644]
	others × mechanic-electrician × 8:00–16:00	.158	1.171	[0.830, 1.652]
	face areas × worker-coal winner × 24:00–8:00	.137	1.147	[0.833, 1.579]

Notes. OR = odds ratio, CI = confidence interval.

Within the scope of this study, nonfatal accidents were investigated taking into consideration five different parameters: occupation, area, reason, accident time and part of body affected. However, factors to be considered may differ depending on the researcher's interests. Hierarchical loglinear models are flexible and suitable data can be grouped in categories. Therefore, if factors change, the established loglinear model will change and, thus, provide valuable information to researchers.

REFERENCES

1. Saleh JH, Cummings AM. Safety in the mining industry and the unfinished legacy of mining accidents: safety levers and defense-in-depth for addressing mining hazards. Saf Sci. 2011;49(6):764–77.
2. Paul PS. Predictors of work injury in underground mines–an application of a logistic regression model. Mining Science and Technology (China). 2009;19(3):282–89.
3. Kecojevic V, Komljenovic D, Groves W, Radomsky M. An analysis of equipment-related fatal accidents in U.S. mining operations: 1995–2005. Saf Sci. 2007; 45(8):864–74.
4. Komljenovic D, Groves WA, Kecojevic VJ. Injuries in U.S. mining operations—a preliminary risk analysis. Saf Sci. 2008; 46(5):792–801.
5. Donoghue AM. Occupational health hazards in mining: an overview. Occup Med (Lond). 2004;54(5):283–9. Retrieved May 21, 2014, from: http://occmed.oxfordjournals.org/content/54/5/283.full.pdf.
6. Maiti J, Bhattacherjee A, Bangdiwala SI. Loglinear model for analysis of cross-tabulated coal mine injury data. Inj Control Saf Promot. 2001;8(4):229–36.
7. Jeong BY. Comparisons of variables between fatal and nonfatal accidents in manufacturing industry. Int J Ind Ergon. 1999;23(5–6): 565–72.
8. Türkiye İstatistik Kurumu [Turkish Statistical Institute]. 2006–2007 iş kazalari ve işe bağll sağlik problemleri araştirma sonuçlari [Results of the research on accidents at work and work-related health problems, 2006–2007]. 2007. Retrieved May 21, 2014, from: http://www.tuik.gov.tr/PreHaberBultenleri.do?id=3916.
9. Sari M, Duzgun HSB, Karpuz C, Selcuk AS. Accident analysis of two Turkish underground coal mines. Saf Sci. 2004;42(8):675–90.
10. Agresti A. An introduction to categorical data analysis. 2nd ed. Hoboken, NJ, USA: Wiley; 2007.
11. Jeansonne A. Loglinear models. 2008. Retrieved May 21, 2014, from: http://online.sfsu.edu/~efc/classes/biol710/loglinear/Log%20Linear%20Models.pdf.
12. Berry KF. The effect of missing data in the analysis of a bariatric surgery program [Bachelor of Arts thesis]. South Hadley, MA, USA: Mount Holyoke College; 2007. Retrieved May 21, 2014, from: https://ida.mtholyoke.edu/xmlui/bitstream/handle/10166/616/247.pdf?sequence=1.
13. Zheng YP, Feng CG, Jing GX, Qian XM, Li XJ, Liu ZY, et al. A statistical analysis of coal mine accidents caused by coal dust explosions in China. Journal of Loss Prevention in the Process Industries. 2009; 22(4):528–32.
14. Wilson R, Crouch EAC. Risk assessment and comparisons: an introduction. Science. 1987;236(4799):267–70.
15. Maiti J, Bhattacherjee A. Evaluation of risk of occupational injuries among underground coal mine workers through multinominal logit analysis. J Safety Res. 1999;30(2): 93–101.
16. Jansen JC, Brent AC. Reducing accidents in the mining industry—an integrated approach. Journal of the South African Institute of Mining and Metallurgy. 2005; 105:719–25. Retrieved May 21, 2014, from: http://www.miningsafety.co.za/documents/reducing%20Mining%20Accidents.pdf.
17. Maiti J, Bhattacherjee A. Predicting accident susceptibility: a logistic regression analysis of underground coal mine workers. Journal of the South African Institute of Mining and Metallurgy. 2001;203–08. Retrieved May 21, 2014, from: http://www.saimm.co.za/Journal/v101n04p203.pdf.

18. Ghosh AK, Bhattacherjee A, Chau N. Relationships of working conditions and individual characteristics to occupational injuries: a case-control study in coal miners. J Occup Health. 2004;46(6):470–78.

19. Sari M, Selcuk AS, Karpuz C, Duzgun HSB. Stochastic modeling of accident risks associated with an underground coal mine in Turkey. Saf Sci. 2009;47(1):78–87.