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Rules of Risk Management - Case Study of Open Pit Mine

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Abstract

The issue of human factor risk and rules and regulations in open pit mine is a main focus of this paper in order to develop predictive models of behavior of workers in relation to compliance with the procedures and rules. Presented survey was conducted in open pit coal mine, as high-risk system, involving 476 mineworkers. The survey was in the form of a questionnaire, consisting of 45 questions, aimed to find out the opinions of the mining workforce about risk attitude generally as well as about safety rules and regulations.

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Keywords: Type your keywords here, separated by semicolons ;

1. Introduction

Risk management is a dynamic process which work in a continual state of change with aims to provide a controlled work environment and ensure safe working processes. "Risk management cannot be based on response to past accidents alone anymore, but now must be increasingly proactive. Due to human flexibility and creative intellectual capability, there is a certain potential for such adaptive management (people are a very important source of safety, not just errors). It is difficult to predict the human factor for risk: people make mistakes, may not succeed in performing an operation, or may experience health conditions during work. It is also difficult to evaluate possibilities that result from the uniqueness of human capabilities" (1).

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"When speaking of risk management, the 'human factor' involves gathering and analyzing information about human capabilities, limitations and other characteristics in terms of the work they perform, their mutual interaction and interaction with machines, systems and the environment for the purpose of realizing a safe work process. People activate machines, make and adjust the organization of work processes and apply rules and procedures. While technology and work processes change quickly and relatively easily today, this does not apply to people."(2) In addition, the individual behavior of employees can cause critical situations and thus lead to a catastrophe in high-risk workplaces. According to many researchers, "unsafe behavior of frontline workers is considered as a direct, critical factor contributing to workplace injuries and accidents across diverse high-risk industries", (3)

Taking human and cultural factors into account in order to create effective risk management is one of 11 principles according to ISO 31000:2009, (The International Organization for Standardization). As specific factors contributing to the occurrence of dangerous incidents, they state "inadequate supervision, pressure to meet production targets, inadequate safety management systems, failure to learn lessons from previous incidents, communication issues e.g. between shifts, between personnel and management etc., inadequate reporting systems, complacency, violations/ non-compliance behavior , inadequate training e.g. emergency response, fire and safety, lack of competency, excessive working hours resulting in mental fatigue, inadequate procedures, modification/ updates to equipment without operator knowledge and/or revised risk, assessments, inadequate/ insufficient maintenance, maintenance errors", (4).

2. Research place and methodology

Different types of equipment operating on surface mines (bucket chain excavators, spreaders, belt wagons, stackers) depending on the human factor. "In spite of strictly obeyed prescribed rules and procedures, premature damages and failures of surface mine equipment occur in service, causing significant costs. Such failures are experienced also in opencasts surface coal mines in Serbia, and one of them is considered in detail. In addition to direct costs, the losses due to downtimes caused by failure disturb production of electricity, making them very important", (5). According to (5) "to avoid unexpected failures of bucket wheel excavators (BWE) and save their structural integrity in service, necessary care during operational life, monitoring and diagnostics of all vital elements of the supporting structure, and sometimes repair and redesign are also required". To avoid disasters like the one when "BWE SchRs 1760, unexpectedly and with no warning catastrophically failed in 2004, after 17 years of regular service on an open surface mine in Serbia (Fig. 1)", (5), risk management system should be continually improved.

Fig. 1. Collapse of bucket wheel excavator SRs 1760.

To provide more holistic and better models for risk management, the modern scientific methodology is increasingly looking for the complex relationships between variables. In doing so, the estimates of interrelationships and impacts are the most often iterative and stochastic. The complexity of factors that affect the attitude of employees towards risk is emphasized through a survey. The key concept of factor analysis is that multiple observed variables have similar patterns of responses because they are all associated with a latent and not directly measured variable. To determine the main factors influencing the risk of human factor, a statistical method of factor analysis was applied to a group of 33 variables. The obtained factors were then used as input variables for binary logistic regression in order to determine the predictive model of the miners' behavior with respect to the **rules. IBM SPSS Statistics 25** was used to process the data and the results were presented in MS E**XC**EL.

3. Case study – Open pit mine "Kostolac"

The research sample consisted of 476 a random selection of open pit mines, extracting coal. Information about examinees and their personal attitudes provided data which are considered most relevant for the problem being researched, and are related to the following five variables: gender, age, employment status, education, hierarchy level in the mine and work in shifts. The observed variables are listed in (2).

In order to determine the main factors which affect the risk behaviour, exploratory factor analysis is applied along with the Extraction Method: Principal Component Analysis.

Checking if the data set is appropriate for the factor analysis: since KMO= 0.841> 0.6 and the level of significance, Sig= 0.000< 0.05, the justifiability condition is fulfilled.

Based on the criterions of eigenvalues, Catel criterion (scree plot) and rule of retain any eigenvalue that accounts for at least 5% of the variance, it was decided to retain four factors for further research. These will approximately explain 48, 86% of the variance. These factors are named as:

Satisfaction with life, related to items: I'm ready to work together, I'm always focused on work, I'm an extrovert, I consider myself effective, I feel good in my skin, I'm social, I am happy, I am happy with my overall life, I have a high degree of self-esteem, I plan to work at the mine for the next 5 years, Being careful will reduce the chance of an accident, Rules and regulations are important for my safety, When I notice something that may lead to a problem or an accident, my reaction depends on my assessment of the danger, I have enough knowledge for my job, Improved training and introduction to job will help in understanding and implementing rules and regulations.

Supportive leadership style, related to items: My manager controls security, The manager tells me if I'm doing well, My manager supports me, I feel the support of my colleagues at work, Colleagues are generally predictable, competent and well-meaning, I communicate well with my colleagues and there is no problem to understand each other, We all strive to work safely,I work in a group / team of colleagues, Managers explain why rules or regulations are necessary,The description of my job is clear to me.

Experiance, related to items: Years of service, Age, I know that people violate rules and regulations, Executives are aware of violations of rules and regulations, Sometimes it is necessary to break the rules to get the job done.

Risky job, related to items: The nature of my workplace is at increased risk for me, The nature of my workplace is at increased risk for others.

Analysis has shown that 109 (22.9%) claimed that they break rules and regulations, whereas 367 (77.1%) claimed that they do not break rules and regulations, Table 1. Figure 2 shows answers of the mine workers about reasons for risk taking, Figure 3 shows problems with the rules and regulations, while Figure 4 shows Attitude to the rules.

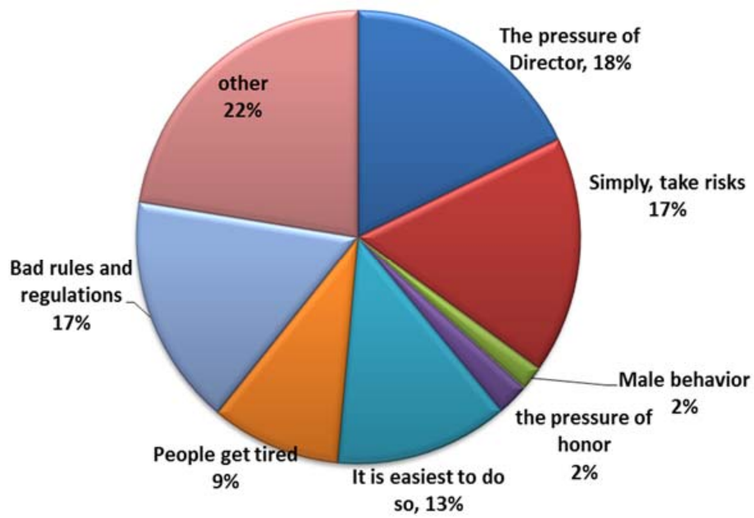

Figure 2. Reasons for risk taking

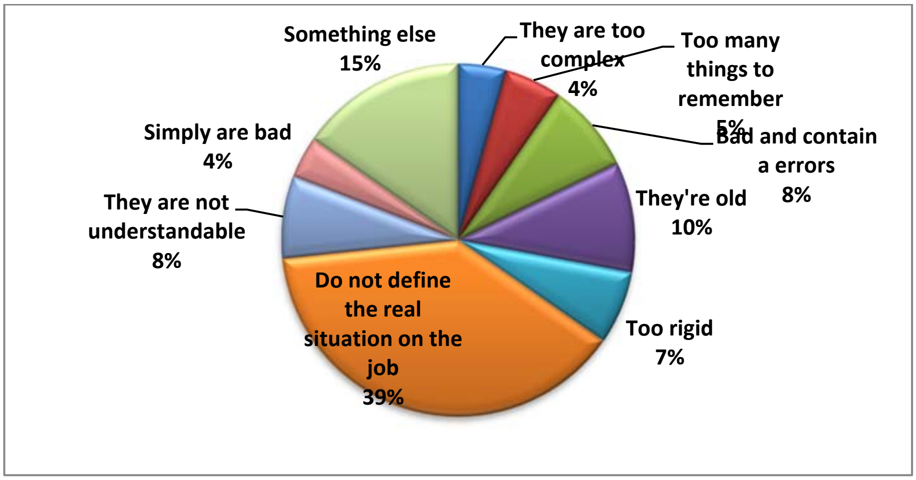

Figure 3. Problems with the rules and regulations

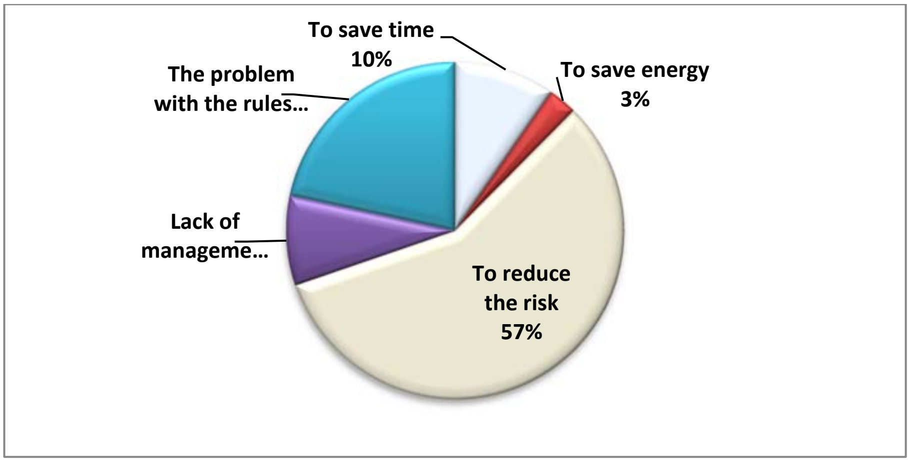

Figure 4. Attitude to the rules

Table 1. Number of examinees according to rule breaking.

	Frequency	Percent	Valid %	Cumulative %
I deviate	109	22,9	22,9	22,9
I don't deviate	367	77,1	77,1	100
total	476	100	100	

4. Prediction model

Situations where **the criterion variable**, i.e. the variable we want to explain or **predict, based on one or more predictor variables,** is **dichotomous or binary,** are relatively common in studies. By default, SPSS logistic regression does a list wise deletion of missing data. This means that if there is missing value for any variable in the model, the entire case will be excluded from the analysis. We have 476 cases, but there are 467 of them included in analysis.

The Omnibus Tests of Model Coefficients is used to check that the new model (with explanatory variables included) is an improvement over the baseline model (without predictors) Omnibus Tests: -2LL = 80.104 = Model χ^2 , $df = 4$, $p < .001$**.** In this case there is a significant difference between the Log-likelihoods of the baseline model and the new model (sig<0,001).

Goodness-of-fit (GOF) tests help deciding whether the model is correctly specified. They produce a p-value, if it's low (say, below .05), one rejects the model. If it's high, then your model passes the test.

Table 2 Case summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	467	98,1
	Missing Cases	9	1,9
	Total	476	100,0
Unselected Cases		0	0,0
Total		476	100,0

Table 3. Goodness-of-fit test

Step	Chi-square	df	Sig.
1	10,240	8	0,249

Sig=0,249>0, 05. The nonsignificant chi-square is indicative of good fit of data with linear model.

Table 4. Goodness-of-fit-contingency table

		Deviation from rules = Not deviate		Deviate		Total
		Observed	Expected	Observed	Expected	
Step 1	1	44	45,660	3	1,340	47
	2	44	44,344	3	2,656	47
	3	42	42,538	5	4,462	47
	4	41	40,936	6	6,064	47
	5	40	39,145	7	7,855	47
	6	37	37,456	10	9,544	47
	7	36	35,347	11	11,653	47
	8	40	32,248	7	14,752	47
	9	24	27,739	23	19,261	47
	10	14	16,587	30	27,413	44

Table 5 shows the stacking of the empirically obtained (Observed) categorical affiliation of observation units on a criterion variable and their predicted (Predicted) categorical affiliation based on a logistic model containing all the predictors introduced in block 1. This table is the equivalent to that in Block 0 but is now based on the model that includes our explanatory variables. As you can see our model is now correctly classifying the outcome for 81, 4% of the cases.

Table 5. Classification table

Observed			Predicted		
			Deviation from rules		Percentage Correct
			Not deviate	Deviate	
Step 1	Deviation from rules	Not deviate	352	10	97,2
		Deviate	77	28	26,7
	Overall Percentage				81,4

Table 6 contains the logistic coefficients estimates for the model with the predictors introduced in block 1 (column B). In this case, there is a coefficient b0 in the Constant row, S.E. Presents the asymptotic standard errors for the individual logistic coefficients are shown. The Wald column contains Wald 's H^2 statistics, the df degree of freedom column, and the Sig column (to test the hypothesis that the logistic coefficient for the predictor variable vj is zero). Column exp (b) contains exponential logistic coefficients that are very important for interpreting logistic regression outcomes. These are the values for the logistic regression equation for predicting the dependent variable from the independent variable. Therefore, the logistic model estimated from a given sample looks like this:

$$\ln(ODDS) = \ln\left(\frac{\hat{Y}}{1-\hat{Y}}\right) = \ln\left(\frac{P(deviate)}{1-p(deviate)}\right) =$$
$$= -1{,}547 - 0{,}612 * Satisfaction\ with\ life - 0{,}292 * Leadership\ style + 0{,}506 * Experience + 0{,}797 * Risky\ job$$

If we expose the logistic coefficient for „Satisfaction with life“, we get the value -0,612 in the „B column“ and the column Exp (b) of the Variables in the Equation table:

exp (b1) = exp(-0,612) = 0.542 is odds ratio (2 no deviate responses for every 1 „deviate from rules“, p=0,33),

Thus, the chances of answering the question with „deviated from rules“(according to non-deviated) are dicreased about twice when the "value" on the „Satisfaction with life“predictor variable is "increased" by 1 and the other three predictors in the model are kept constant.

Table 6. The model variables

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Satifaction with life	-0,612	0,118	27,054	1	0,000	0,542	0,430	0,683
	Leadership	-0,292	0,118	6,071	1	0,014	0,747	0,592	0,942
	Experience	0,506	0,135	14,116	1	0,000	1,658	1,274	2,159
	Risky job	0,797	0,134	35,280	1	0,000	2,219	1,706	2,886
	Constant	-1,547	0,140	121,767	1	0,000	0,213		

Likewise, if we expose the logistic coefficient for Risky JOB, we get the value in the row Risky JOB and the column Exp (b) of the Variables in the Equation table: exp (b4) = exp(0,797) = 2.219. This actually means that the chances for the answer „deviated from rules“is 2.219 times higher for those who has risky job.

5. Discussion and Conclusions

Survey was conducted to identify the major human risk factors that then served as predictors for predicting workers' behavior with respect to adherence to rules and procedures. Obtained results indicate that leadership plays an important role in worker behavior. Supportive leadership style results in more responsible employee behavior and a lower probability of deviation of rules and procedures. Results also indicates that the safe behavior of workers is strongly influenced by the difficult to control factor of "life satisfaction". It has also been found that riskier work and longer work experience increase the likelihood of breaking the rules. Reasons for risk taking are “the pressure of director”, “simply, people take risk”, “bad rules and regulation“, “ it is easiest way to do it, and other reasons which needs to be explored more deeply. Workers' views on rules and procedures were explored. Obtained results show that 39% of workers consider that rules are not adequate and do not define the real situation on the job; 8% think the rules are not understood, 8% think „rules are bad and contains errors“, while 7% of workers thins that rules are too rigid.

Regulatory requirements for workplace safety represent factors that force companies to devote considerable attention to considering the human factor in risk management and improvement of safety at work.

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