Safety culture maturity assessment for mining activities in South America

M. Bascompta[1*], Ll. Sanmiquel[1], C. Vintró[2], J.M. Rossell[3], M. Costa[4]

[1] Department of Mining, Industrial and ICT Engineering, Polytechnic University of Catalonia (UPC)

[2] Department of Business Organization, Polytechnic University of Catalonia (UPC)

[3] Department of Mathematics, Polytechnic University of Catalonia (UPC)

[4] Mineria per al Desenvolupament

Manresa (Barcelona), Spain. Av. Bases de Manresa, 61-73, 08242

*Corresponding author: marc.bascompta@upc.edu; +34 938777242

Abstract

Background and objective: Health and safety is a crucial issue in the mining industry due to the implication of accidents in the sector. This study determines the safety culture characteristics in several mining activities from South America.

Methods: A survey of the safety culture maturity has been done by means of 24 questions regarding the type of activity, number of employees and safety culture characteristics of the activity: information of accidents and incidents, organizational structure to deal with information, involvement of the company in health and safety issues, the way it communicates accidents and incidents and commitment of the company towards health and safety.

Results: The questionnaire was completed by 62 managers from Bolivia, Peru and Colombia. Results show different behaviours depending on the type of company, Artisanal or Large Scale Mines –ASM and LSM respectively–. LSM show a level of maturity according to the size of the company, whereas ASM does not have a clear trend in terms of size even though a relationship between employees and safety culture maturity. In addition, there is a remarkable difference between activities with and without continuous improvement systems implemented as well.

Conclusions: Large scale mining improves their level of safety culture as the size of the company increases, because procedures and control systems are implemented. Cooperatives or small companies also achieve substantial gains when they introduce similar systems.

Keywords:

Safety Culture; Artisanal Scale Mines; Large Scale Mines; South America.

1. Introduction

The mining sector is very important in Latin America. However, legislation, economic and cultural characteristics do not encourage proper levels of safety, while Western activities have already extended effective systems in this direction. Therefore, it is necessary to know the safety culture maturity of these activities to implement better techniques and systems.

This factor has been of great concern in many studies over the years [1]. Fleming [2] details a maturity concept model appropriate to safety culture development for the offshore oil and gas industry by means of interviews with the managers. This model

consists of five levels of safety culture maturity, but it is only relevant to organizations that fulfil all the technical and legal criteria and the majority of the accidents occur due to behavioural or cultural factors. At the same time, other models were developed and modified over the years [3-7], and different authors have used them to determine the safety culture maturity in the oil sector [8-11], safety issues in isolated workplaces [12] and railway industry [13]. Hofstede and Hofstede [14] pointed out the difference between western and South American culture and how these characteristics influence the structure of enterprises and safety culture by means of the society features while Filho et al. [15] performed a study in several oil companies from Brazil by means of a questionnaire and subsequent verification interviews. However, there are few studies regarding the mining sector. Thus, this paper adapts previous studies to mining companies from Latin America, regarding their specific conditions by means of a questionnaire, which is a widely used method to determine safety culture characteristics of an organization [10, 16] as well as health and safety analysis in the mining sector [17].

The study is focused on all aspects of an organization's activities. This information was provided by safety managers from Large Scale Mines –LSM– and Artisanal-Small Scale Mines –ASM– activities from Peru, Bolivia and Colombia. Most of ASM are organized in cooperatives, using basic technics and having poor health and safety conditions [18, 19], which leads to low efficiency rates. Besides, their organizational characteristics do not favour health and safety enhancements either. Hence, it is very important to start introducing management systems to improve all aspects of these organizations [20]. ASM are widely spread in Latin America, having a workforce of 1.6 million according to the International Labour Organization [21], showing even higher figures in some studies [22, 23], such as Colombia, where small mining reaches 72% of all the mines [24]. Some ASM are in the process of implementing a continuous

improvement system, called Fairmined certificate, specifically designed for small scale mining activities extracting gold. They will be mentioned as ASMF henceforward. A comparison is done between mines complying the certificate and ones without it. Figure 1 exposes the countries involved in the survey.

Figure 1. Map with the countries involved in the study in yellow.

Fairmined is a quality label that ensures social development, environmental protection and health and safety improvement. It is backed by a certification and audit system. The importance of implementing a management system is that it has been proven as an appropriate tool to improve safety conditions in different types of companies [25].

2. Methodology

2.1. Safety culture maturity model

Among all models exposed, the five dimensions used by Fleming [2] and Parker et al. [10] have been used as a base of this study, modifying the questionnaire developed by Filho et al. [15]. The mining sector has some particularities, as the oil industry, which suits with the use of maturity models [26-28]. Whereas cultural characteristics in the countries analysed are similar to other studies applied in other South American countries [14, 15]. The five dimensions are:

- Information: It refers to the formal system of the company to report accidents and incidents.
- Organizational learning: Includes the way organization deals with information, accidents, and incidents and how it informs the employees.
- Involvement: How the company boosts participation of the employees in safety issues.
- Communication: What, when and how to communicate information related to safety between the organization and workforce.
- Commitment: Support given by the company in health and safety issues.

The questionnaire has several items within each dimension. Besides, it also analyses whether the company has implemented any management system related to quality or environment issues.

2.2. Questionnaire

The health and safety part of the questionnaire has five possible answers per question, varying the number of questions for each dimension. Each level per question correspond to a stage already defined and used in previous studies [5, 10, 15]:

1. Pathological: Safety issues are caused by the employees. The main drivers are business and avoid the regulator.
2. Reactive: Safety is only taken seriously after accidents.
3. Calculative: Systems are implemented to manage all hazards
4. Proactive: Some problems are still found. The workforce is more involved in safety issues.
5. Sustainable: Safety is part of the corporate philosophy. There is an active participation in all levels.

The questionnaire has 24 questions, including the country, type of organization and number of employees. The sample for the study consisted of 62 mining activities, 37 LSM and 25 ASM. Questions were done according to previous bibliography and field experience working in South America. The first 20 questionnaires were done in situ in several Artisanal and Large Scale Mines to verify the suitability and understanding of the questions. Besides, as there is a certification process in some of them, the test was done before and after the implementation with the idea to know if there is any safety culture evolution related to the Fairmined certificate.

The Likert scale [29] was used to evaluate the level of safety culture maturity level by means of five levels, where it ranges from 1, lowest, to 5, highest. The higher the value in each dimension, the better the cultural maturity will be. Table 1 exposes the main items asked in the questionnaire. Apart from the general questions, each item detailed has five sentences corresponding to the different levels of agreement or disagreement with the item. Abbreviations of the dimensions, part 1-5, are used in the following tables.

Table 1. Items of the questionnaire.

Questionnaire
General questions
1. Country 2. Type of activity 3. Number of employees 4. Existence of any management system implemented
Information (Part 1)
1. Treatment of the accidents and misses by the employees 2. Formal communication method 3. Degree of comfortability reporting an accident or incident 4. Existence of safety parameters done by the organization
Organizational learning (Part 2)
1. Analysis of the accidents and misses by the organization 2. Goal of the organization during the investigation of an accident or incident 3. Actions done to improve safety conditions 4. Report of the investigations
Involvement (Part 3)
1. Involvement of the employees 2. Interest of the employees to participate in safety issues
Communication (Part 4)
1. Method used to communicate between organization and employees 2. Verification system of the communication method/channel used by the organization

Commitment (Part 5)

1. Safety organization and planning
2. Inspections and audits
3. Safety expenditure
4. Safety education and training
5. Health and safety staff
6. Importance of health and safety
7. Safety instructions
8. Encouragement system of health and safety

3. Results and discussion

Mean values of employees and the five dimensions are gathered in Table 2 from the survey of the mining activities. The sample size is n=62, but 4 ASM analysed over time have undertaken the certificate process and therefore the survey was done twice in these cases.

Table 2. Mean values of the five dimensions referred to the safety culture maturity

	N	Part 1	Part 2	Part 3	Part 4	Part 5
LSM	37	4,1	3.9	4.0	4.1	4.2
ASM	25	2.6	2.4	2.7	2.7	2.1
ASMF	4	3.1	3.1	3.2	3.3	2.8

Large Scale Mining activities have an average of 404 employees, while Artisanal Scale Mines and activities with the Fairmined certificate have 58 and 110 miners respectively. Mean values from Table 2 show an important difference between LSM and

ASM in all five dimensions, which is accordance with other previous studies [30, 31]. However, this difference is reduced in the case of ASMF, which present considerably higher scores in safety culture maturity in all dimensions. Figure 2 displays a more visual comparison between LSM and ASM.

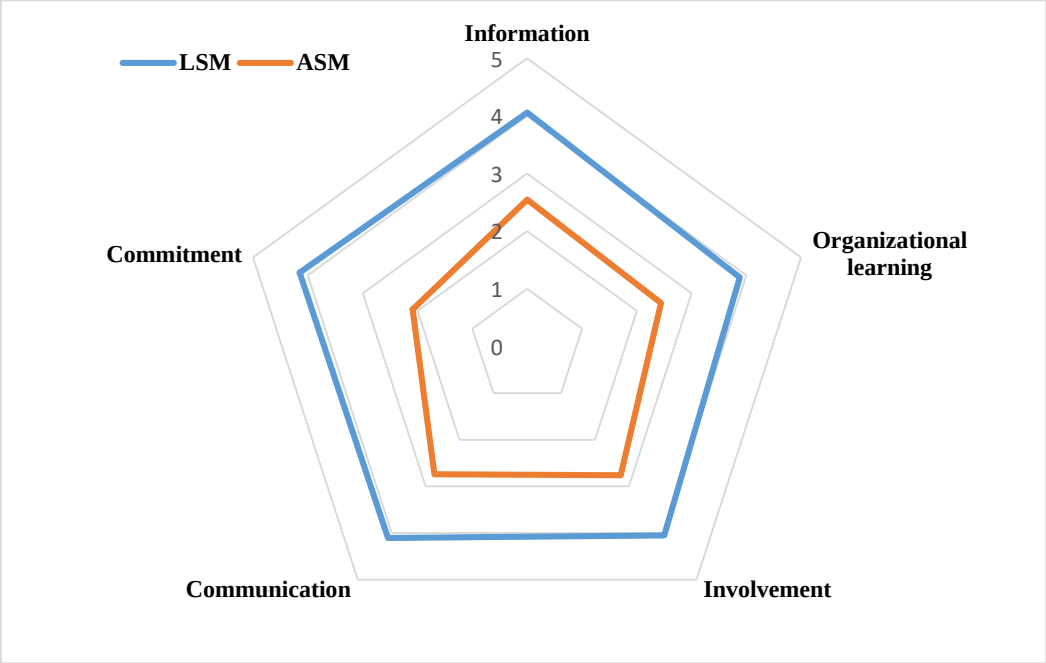

Figure 2. LSM and ASM mean values of the five dimensions.

Artisanal Scale Mines have the involvement dimension more developed than the other four. They encourage the employees to participate in safety matters, but the appropriate tools and knowledge to deal with the issues are not available in these activities. Besides, the socioeconomic conditions in most of the ASM are also a handicap, as well as facilities or environmental conditions. These facts are reaffirmed with lower scores in the other dimensions, especially in commitment, which is a key factor to improve the dimensions [32]. The possible reason, after in situ verification, is the type of corporate organization, which used to change the management board every year. Overall, ASM are placed in a stage between reactive and calculative, the importance of safety is

well known but there is a lack of an appropriate system to deal with all hazards and involve the employees. Actions are only taken after misses or accidents have already happened, having a health and safety system too rigid.

On the other hand, Large Scale Mines have a well-balanced system with all dimensions in a similar level. These activities show a proactive stage, having a safety management system that involves the employees from all organization levels, but without being completely implemented, having difficulties to face unexpected problems and still too rigid [6]. Figure 3 details global safety maturity scores in LSM, ASM and ASMF.

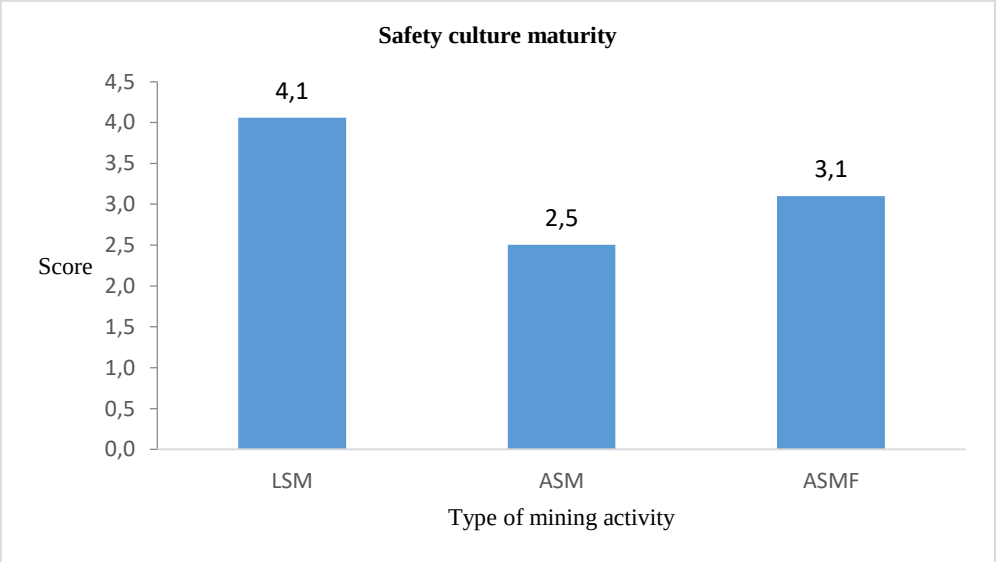

Figure 3. Global cultural maturity scores of the activities surveyed.

Values are quite higher in LSM than in ASM, around 71%, but this difference is considerably reduced in ASMF. The four mines analysed before and during/after the certificate process have a score improvement between 45-103% individually and 31% globally. In addition, 59% of the LSM have stated that they have a continuous improvement system implemented, such as quality or environment management. When LSM with and without continuous improvement systems are analysed, global safety

culture maturity scores are 4.58 and 3.63 respectively, with an average of employees of 473 and 92 respectively. Thus, the relationship between safety culture maturity level and number of employees is analysed by Figures 4 and 5.

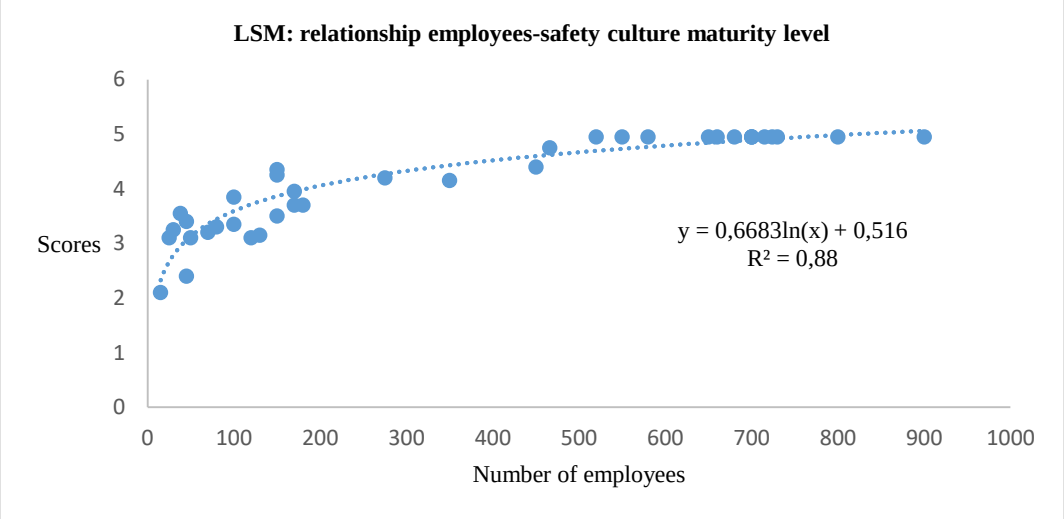

Figure 4. LSM, relationship employees-safety culture maturity level.

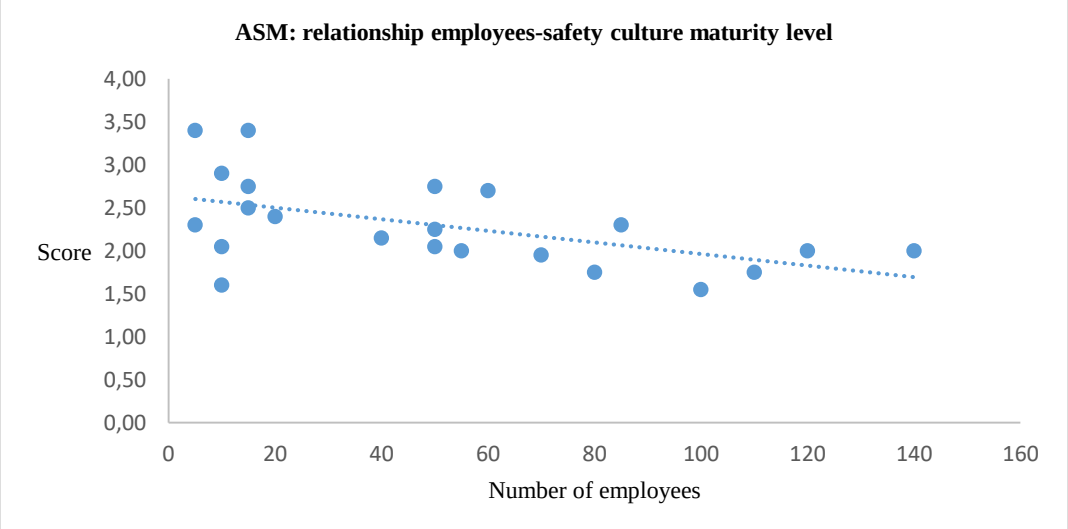

Figure 5. ASM, relationship employees-safety culture maturity level.

LSM follow a lognormal distribution with a coefficient of determination value 0.88, the score increases together with the number of employees per mine until a certain

level where it stabilizes. Besides, the Spearman correlation coefficient also reveals correlation between number of employees and safety culture maturity scores. Whereas, the Spearman's rho is also higher, 0.35, than the critical value according to the number of observations.

On the other hand, values from ASM show a great variability, especially in activities with less than 20 employees. However, larger mines display a slight decrease in the score as the number of employees increases. On-site visits are in accordance with this behaviour, small ASM have different health and safety conditions depending on the initial awareness of the miners, while the conditions tend to worsen as the mine enlarges.

The analysis of the different questions in each dimension of ASM and LSM is done in Tables 3 and 4, while their total average values with the corresponding standard deviations are gathered in Table 5.

Table 3. Average values of parts 1-3 in ASM and LSM.

Questions	ASM	LSM	Difference (%)
Information (Part 1)			
Treatment of the accidents and misses by the employees	3,08	4,22	37
Formal communication method	2,46	4,00	63
Degree of comfortability reporting an accident or incident	2,96	4,08	38
Existence of safety parameters done by the organization	1,69	3,95	133
Organizational learning (Part 2)			

Analysis of the accidents and misses by the organization	2,19	3,95	80
Goal of the organization during the investigation of an accident or incident	2,58	3,54	37
Actions done to improve safety conditions	2,81	4,11	46
Report of the investigations	2,19	3,92	79
Involvement (Part 3)			
Involvement of the employees	2,69	4,08	52
Interest of the employees to participate in safety issues	2,73	4,03	47

While LSM show all answers with similar scores, ASM display mixed results, especially in the implementation of procedures such as “safety parameters” in the dimension of information or “accidents and misses analysis” and “reporting the investigations” in the dimension of organizational learning.

Table 4. Average values of parts 4 and 5 in ASM and LSM.

Questions	ASM	LSM	Difference (%)
Communication (Part 4)			
Method used to communicate between the organization and the employees	2,77	4,14	49
Verification system of the communication method/channel used by the organization	2,62	4,08	56
Commitment (Part 5)			
Safety organization and planning	2,46	4,19	70

Inspections and audits	1,46	4,11	181
Safety expenditure	2,69	4,24	58
Safety education and training	1,58	4,19	166
Health and safety staff	1,92	4,05	111
Importance of health and safety	2,35	4,19	79
Safety instructions	3,12	4,35	40
Encouragement system of health and safety	1,88	3,89	107

The same characteristics are found in the dimension of commitment, where the items “inspections and audits” and “safety education and training” have considerably lower scores than the rest in ASM, whereas LSM have more steady scores.

The characteristics of ASM agree with the conditions found in situ. Despite these activities have consciousness about the importance of health and safety, they have problems to implement regulations, work methods and planning long term actions.

Table 5. Total average values and standard deviation.

	Part 1	**StDev**	**Part 2**	**StDev**	**Part 3**	**StDev**	**Part 4**	**StDev**	**Part 5**	**StDev**
ASM	2,55	0,83	2,44	0,70	2,76	0,74	2,69	0,87	2,18	0,53
LSM	4,06	1,06	3,88	1,04	4,05	0,99	4,11	0,94	4,15	0,93
Diff. %	59		59		47		53		90	

Average values per dimension show safety culture maturity levels between 53-90% higher in LSM than in ASM. However, the standard deviation is higher in Large Scale Mines than in Artisanal Scale Mines, which means larger differences between LSM conditions.

4. Conclusions

The model used to determine the safety culture maturity level has proved to be an adequate tool for the mining sector. The survey done has more answers than other previous studies [15, 19]. The questionnaire demonstrates a remarkable difference between LSM and ASM, around 71%, in terms of safety culture maturity. This difference is considerably reduced in the case of ASMF. However, there is a long path, in all cases, to improve their systems. According to stages described by Hudson [6], ASM are in a stage between reactive and calculative, while LSM are in a proactive stage.

The existence of any type of continuous improvement system show significant increases in safety culture maturity levels, almost 40% in LSM and 31% in ASM. This fact suggests the importance of implementing this kind of procedures in any company and their consequences to the sake of the health and safety conditions. Although the enhancements are higher in companies with a well-developed organizational structure, there is a remarkable improvement in informal organizations, at least in terms of safety and health.

The behaviour of the organizations in terms of safety and health also show a completely different pattern between Large and Artisanal Scale Mines. While LSM follow a lognormal distribution, the higher the number of employees the higher the score of safety culture maturity, ASM display lower scores as the number of employees increases. This phenomenon suggests that LSM implement more efficient management systems as they increase their size, whereas ASM continue without any system despite the increasing difficulty increments as their company size grows. In addition, Artisanal Scale mines with less than 20 employees show a great variability, probably because of the different awareness of the co-operative associates. Weaknesses found in some items

from the same dimension of the questionnaire may negatively affect the health and safety management system as well as its enhancement. Thus, the first actions should be working on these problems in order to subsequently improve the system.

More data would be necessary to verify the results, minimise the possible sampling error and know if there is any important difference among Latin American countries and the difference in ASM with continuous improvement systems. However, there are a lot of difficulties to obtain results because of social and cultural conditions of such mining activities.

Acknowledgment

The authors would like to thank the organization Alliance for Responsible Mining (ARM), the NGO Mineria pel Desenvolupament and the Centre de Cooperació pel Desenvolupament (CCD) from the Polytechnic University of Catalonia.

References

[1] Choudhry, R.M., Fang, D., Mohamed, S., 2007. The nature of safety culture: A survey of the state-of-the-art. Safety Science 45 (10), 993–1012.

[2] Fleming, M., 2001. Safety Culture Maturity Model. Report 2000/049. Health and Safety Executive. Colegate, Norwich.

[3] Westrum, R., 1993. Cultures with requisite imagination. In: Wise, J.A., Hopkin, V.D., Stager, P. (Eds.), Verification and Validation of Complex Systems: Human Factors Issues. Springer-Verlag, New York.

[4] Reason, J., 1997. Managing the Risks of Organisational Accidents. Ashgate, Aldershot.

[5] Hudson, P., 2001. Aviation safety culture. Safeskies 1, 23.

[6] Hudson, P., 2003. Applying the lessons of high risk industries to health care. Quality & Safety in Health Care 12, 7–12.

[7] Lawrie, M., Parker, D., Hudson, P., 2006. Investigating employee perceptions of a framework of safety culture maturity. Safety Science 44 (3), 259–276.

[8] Cox, S.J., Cheyne, A.J.T., 2000. Assessing safety culture in offshore environments. Safety Science 34 (1), 111–129.

[9] Mearns, K., Whitaker, S.M., Flin, R., 2001. Benchmarking safety climate in hazardous environments: A longitudinal, interorganizational approach. Risk Analysis 21 (4), 771–786.

[10] Parker, D., Lawrie, M., Hudson, P., 2006. A framework for understanding the development of organisational safety culture. Safety Science 44, 551–562.

[11] Hudson, P., 2007. Implementing a safety culture in a major multi-national. Safety Science 45 (6), 697–722.

[12] Mearns, K., Whitaker, S. M., Flin, R., 2003. Safety climate, safety management practice and safety performance in offshore environments. Safety Science 41 (8), 641–680.

[13] Blewett, V., Rainbird, S., Dorrian, J., Paterson, J., Cattani, M., 2012. Keeping rail on track: Preliminary findings on safety culture in Australian rail. Work: A Journal of Prevention, Assessment and Rehabilitation 41(1), 4230–4236.

[14] Hofstede, G., Hofstede, G.J., 2005. Cultures and Organizations: Software of the Mind, second ed. McGraw Hill, New York.

[15] Filho, A.P.G., Andrade, J.C.S., Marinho, M. M.O., 2010. A safety culture maturity model for petrochemical companies in Brazil. Safety Science 48 (5), 615–624.

[16] Cooper, M.D., 2000. Towards a model of Safety Culture. Safety Science 36, 111–136.

[17] Sanmiquel, L., Rossell, J.M., Vintró, C., Freijo, M., 2014. Influence of occupational safety management on the incidence rate of occupational accidents in the Spanish industrial and ornamental stone mining. Work: A Journal of Prevention, Assessment and Rehabilitation 49 (2), 307–314.

[18] Helwege, A., 2015. Challenges with resolving mining conflicts in Latin America. Extractive Industries and Society 2 (1), 73–84.

[19] Smith, N.M., Ali, S., Bofinger, C., Collins, N., 2016. Human Health and Safety in Artisanal and Small-Scale Mining: An Integrated Approach to Risk Mitigation. Journal of Cleaner Production 129, 43–52.

[20] Seccatore, J., Marin, T., De Tomi, G., Veiga, M., 2014. A practical approach for the management of resources and reserves in Small-Scale Mining. Journal of Cleaner Production 84(1), 307–314.

[21] International Labour Organization, 1999. Social and labour issues in Small-scale mining, Geneva.

[22] Fisher, E., Mwaipopo, R., Mutagwaba, W., Nyange, D., Yaron, G., 2009. The ladder that sends us to wealth: Artisanal mining and poverty reduction in Tanzania, Resources Policy 34 (1-2), 32-38.

[23] Siegel, S., Veiga, M., 2009. Artisanal and small-scale mining as an extralegal economy: De soto and the redefinition of “formalization”. Resources Policy 34 (1-2), 51-56.

[24] Güiza, L., 2013. Small Scale Mining in Colombia: Not Such a Small Activity. Dyna 181, 109–117.

[25] Bottani, E., Monica, L., Vignali, G., 2009. Safety management systems: Performance differences between adopters and non-adopters. Safety Science 47 (2), 155–162.

[26] Joy, J., 2011. Minerals Industry Safety and Health Centre, University of Queensland.

[27] University of Queensland, 2008. Minerals Industry Risk Management Maturity Chart. University of Queensland Minerals Industry Health and Safety Centre, Brisbane, Australia.

[28] Foster, P., Hoult, S., 2013. The safety journey: Using a safety maturity model for safety planning and assurance in the UK coal mining industry. Minerals 3 (1), 59–72.

[29] Geoff, N., 2010. Likert scales, levels of measurement and the laws of statistics. Advances in Health Science Education 15 (5), 625-632.

[30] Gillen, M., Kools, S., McCall, C., Sum, J., Moulden, K., 2004. Construction managers' perceptions of construction safety practices in small and large firms: a qualitative investigation. Work: A Journal of Prevention, Assessment and Rehabilitation 23 (3), 233–43.

[31] Jannadia, M.O., Assaf, S., 1998. Safety assessment in the built environment of Saudi Arabia. Safety Science 29 (1), 15–24.

[32] Schwatka, N. V., Rosecrance, J. C., 2016. Safety climate and safety behaviours in the construction industry: The importance of co-workers commitment to safety. Work: A Journal of Prevention, Assessment and Rehabilitation 54 (2), 401–413.