

## An evaluation of Soma underground coal mine disaster with respect to risk acceptance and risk perception

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### ABSTRACT

The underground coal mine disaster that occurred in Soma-Eynez Mine (SEM), Turkey, is one of the largest coal mine disasters of this Millennium. A fire suddenly started in the mine and could not be controlled, resulting in 301 fatalities and approximately 100 injuries. Although the cause of the fire has not yet been determined and there are various hypotheses related to the ignition of the fire, most of the casualties were mainly due to decision-making related problems in various hierarchical levels. Moreover, the decision making related problems in the emergency management have cascading effects and impacts on the casualties, and are related to risk acceptance and perception of the mine management. In this paper, the casualties of Soma Mine Disaster (SMD) are analyzed in terms of risk acceptance and risk perception in order to establish related guidelines for better decision-making practice in case of emergencies in underground mines in Turkey. It is found that quite a high degree of risk was accepted for mine fires by the high-level decision makers, which led mine employees to have a false safety perception. This also resulted in almost full ignorance of self-escape, inappropriate use of personal safety equipment, and unstructured emergency management which yielded large number of mine staff to wait in the mine during the fire instead of a quick implementation of the mine evacuation plan.

**KEYWORDS:** risk perception, risk acceptance, underground coal mining, Soma Mine Disaster

### 1. INTRODUCTION

Coal mining, especially underground operations, is still one of the leading sectors in terms of occupational incidents and illnesses, injuries, and fatalities. The US statistics show that fatality rate per 100 000 full-time equivalent workers in coal mining is almost 1.5 times more than in metal and nonmetal mining and 6 times more than other industrial activities. Additionally, coal mining has the highest rate of non-fatal injuries among all types of mining operations. More specifically Margolis (2010) states based on Bureau of Labor Statistics in the USA in 2007 that underground coal mining has considerably more injuries than surface coal mining operations.

As compared to mine fires, explosions, use of explosives, dust and colliery explosions result in a higher number of fatalities in coal mines in the USA, as they are sudden onset incidents. For example, 10,390 fatalities were recorded as a result of 420 explosion related incidents. On the other hand, 727 fatalities were recorded in 35 mine fires in coal mines in the USA between 1900 and 2006 (CDC, 2009). Between 1983 and 2013, 647 fatalities were recorded in Turkey as a result of 18 major mining incidents (i.e. incidents causing more than three fatalities) and only one of these incidents was a mine fire, caused 19 fatalities and occurred in a metallic mine in Turkey (Düzgün, 2015).

While the number of fatalities due to fires has always been lower than the casualties of explosions among mining accidents since the 20th century both in Turkey and around the world, the Soma Mine Disaster (SMD), which occurred due to a fire in the underground coal mine and caused 301 fatalities, is unique in this respect and requires further investigation. Considering the complex nature of the SMD, where the fire resulted in cascading hazards, various factors were involved in the high number of casualties. Among them, socio-technical factors like unstructured organizational and human performance as well as inadequate safety culture play critical roles (Leveson, 2011).

Risk perception is one of the key parameters in safety culture development as well as effective human and organizational performance. In this paper the role of risk perception and acceptance in cascading hazards after occurrence of the fire in Soma-Eynez Mine (SEM) and the amplified number of fatalities in the SMD's case are analyzed.

### 2. RISK PERCEPTION AND ACCEPTANCE

Although there are various definitions of hazard and risk (e.g. ISO Guide 73:2009, UNESCO), in this paper the definitions used in natural disaster risk are adopted due to the nature of the SMD.

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In quantitative risk assessment (QRA) risk is the multiplication of hazard and its consequences. Hazard is the probability of danger for a given place in a specified period of time. In the SEM case, hazard can be simply defined as the frequency of annual mine fires. The consequences of the mine fires can be listed as production and equipment losses, injuries, and fatalities. Hence the level of risk is controlled by the hazard and its consequences, which should be considered in determining effective risk assessment and management strategies for a safe mine operation. Risk assessment refers to the computation of risk and evaluation of it based on certain acceptability/tolerability criteria (Düzgün and Laccase, 2005). Therefore, understanding the nature of mine fire risks and their systematic management as well as associated uncertainties are key factors for risk acceptance.

Risk perception plays a vital role in the establishment of risk acceptance criteria for mine safety management, because an individual's behavior highly interacts with the degree on his/her perception of danger, professional and personal objectives, and his/her contacts within the organization (Badri et al., 2013). Moreover, risk perception is highly related with behavioral factors of mine executives and employees in the framework of organizational safety behavior (Zhao et al., 2016). Consequently, understanding the behavioural factors is significant for reduction of risks, as behavior based safety is one of the major contributors to accident prevention and risk reduction (Paul and Maiti, 2007).

Various hazard assessment methodologies based on several parameters, such as machinery, housekeeping, geotechnical data, age, experience, frequency, physical and environmental conditions, etc. are proposed in the literature (e.g. Düzgün and Einstein, 2004; Sarı et al., 2004; Coleman and Kerkerin, 2007; Margolis, 2010), as well as risk assessment methods (e.g. Düzgün and Einstein, 2004; Khanzode et al., 2014). Recent works on the determination of optimal evacuation routes in case of mine fire for underground coal mines (e.g. Klote, 2002; Adjiski et al., 2015) have potential for development of effective risk mitigation strategies for mine fires. However, despite the well-developed methodologies for hazard and risk assessment, the risk acceptance and perception is rarely taken into account in underground coal mining, which also plays critical role in risk mitigation.

Rohrmann (2008) defines risk perception as the individuals' judgments and evaluations of hazards. The occupational risks and mitigation methods differ for the sectors and sectorial stakeholders, including the individuals, operational, and regulative institutions/decision-making bodies.

Therefore, it should be expected that understandings of each stakeholder are variable and subjective (Rohrmann, 2008). Hence, different socio-psychological factors such as fear, culture, education, norms, value systems, society, experiences, and type of hazard and knowledge affect the risk perception of individuals and organizations (Zhao et al., 2016; Rohrmann, 2008). Furthermore, these factors are highly related with the risk acceptance and risk behavior of diverse stakeholders (Rohrmann, 2008).

Osei et al. (1997) and Renn (1998) lists factors influencing risk perception and acceptance:

- being voluntary vs. involuntary
- controllability vs. uncontrollability
- familiarity vs. unfamiliarity
- short vs. long-term consequences
- presence of existing alternatives
- type and nature of consequences
- derived benefits
- presentation in the media
- information availability
- personal involvement
- memory of consequences
- degree of trust in regulatory bodies

Voluntary risks (e.g. cigarette smoking) tend to be higher than involuntary risks (building a new chemical plant). Once the risk is under personal control (e.g. driving a car), it is more acceptable than the risk controlled by other parties (e.g. traveling as a passenger). In case of mine fires, for coal mines having frequent fires due to spontaneous combustion propensity of the coal, management may be more willing to accept it. Hence mine management experiencing frequent fires may have different risk acceptance than those experiencing rare fire situations.

Moreover, having frequent mine fires and mitigating them successfully may lead to accepting higher fire risks due to personal involvement and controllability. The risk acceptance also depends on for example level of available information. Informed mine workers can have better preparedness for mine fires when they have fresh memories of the consequences. In this paper, these factors are taken into account in order to analyze perceived and accepted risk for the SMD case.

### **3. BRIEF DESCRIPTION OF SOMA-EYNEZ MINE (SEM) AND THE INCIDENT**

Soma coalfield, located in the Aegean Region in the western Turkey, is one of the first reserves with Seyitömer coalfield, explored in Turkey after the establishment of MTA in 1935 (Ediger et al., 2014). The coalfield is one of the most economically

valuable lignite resources with around 600 million tonnes reserve in 11 different locations (Bilgin et al., 2015). Soma coalfield has higher calorific values with Tunçbilek coalfield compared to other lignite reserves in Turkey; the calorific values vary from 2080 to 3340 kcal/kg (Ediger et al., 2014; Bilgin et al., 2015).

Soma-Eynez Mine (SEM) is one of the underground mining operations in the Soma coalfield and the mining activities have three operational periods. The first one is the period of Turkish Coal Enterprises (TKİ), the state-owned mining company, which covers between 1990 and 2006. In this period the mining operations were conducted in seven underground mines, including the Eynez operation. The state-own period in the SEM ended in 2006 after the privatization of the mine for a period of 10 years with a planned production of 15 million tonnes (Union of Turkish Bar Associations, 2014). The private company, Park Teknik A.Ş., operated the SEM between 2006 and 2009 (the second period). After production of 0.852 million tonnes of lignite in three years, the company applied for the termination of the contract due to the technical problems and operational difficulties in the SEM. As a result, the third period in the SEM started in 2009 after signing the transfer agreement among the parties with TKİ as the license owner, Park Teknik A.Ş. as the company willing to end its operations in the SEM, and Soma Coal Enterprises A.Ş. as the private company willing to take over the SEM to produce the 14.1 million tonnes of lignite for seven years (Union of Turkish Bar Associations, 2014).

In this third period, the production is performed by conventional, semi-mechanized, and fully-mechanized systems. Conventional and semi-mechanized systems have mostly short face lengths of 40-70 m, and coal is extracted with pneumatic hand drills and explosives and moved with the face conveyors. The main difference between the conventional and semi-mechanized systems is the type of support, where hydraulic and timber supports are used in semi-mechanized and convectional systems, respectively. Coal is extracted by a drum shearer and loaded into armed face conveyor with longer face lengths in the mechanized system (Sari et al., 2004).

The coalfield has three seams, namely, upper-KP1, lower-KM2, and middle-KM3 (Hokerek and Ozcelik, 2015) with thickness ranges of 7-8 m, 15-35 m, and 6-10 m, respectively. Because of the thickness of the coal seams, longwall top coal caving (LTCC) is adopted. The simplified mine layout is given in Figure 1.

In 2014 the production in the SEM, were based on five panels with 10 production faces. The mining

method, adopted in each face in the SEM, is given in Table 1.



Figure 1: Mine layout for the SEM.

Table 1: List of the mining method in each face in SEM.

Panel	Face	Type
A	A1	Semi-mechanized
A	A2	Fully-Mechanized
H	H1	Semi-mechanized
H	H2	Semi-mechanized
S	S2 upper	Semi-mechanized
S	S2 lower	Conventional
S	S3 upper	Semi-mechanized
S	S3 lower	Conventional
R	R7 (East)	Fully-mechanized
K	140	Conventional

Due to the spontaneous combustion propensity of the coal, ventilation rate was kept around 2300 m<sup>3</sup>/min. Moreover, coal seams in Panel A contained a considerable amount of methane (Erdoğan, 2015). The SEM worked in three shifts with approximately 800 workers per shift.

On May the 13<sup>th</sup>, 2014, a fire started between 14:40-14:45 in the roof of the main road (Figure 1) and ignited the wooden pieces used for fixing steel sets. Due to the existence of methane, the upper part of the belt conveyor also ignited. The possible location of the mine fire (Figure 1) is the point where the conveyor number 4 conveys materials to the belt number 3. The airflow was quite slow to the point of almost being stagnant and there were no methane detectors in this area. Therefore, it is not possible to find out whether there was an accumulation of methane here that would trigger or contribute to the fire before it broke out.

The outbursting smoke and the smoke from the open flaming fire that broke out in the gallery combined and spread in a short time moving with high pressure through all the main roads to the A and H panels and in the main road to the S panel in the main ventilation direction of the mine. By the time the fire started (14:40-14:45) there was an electricity blackout in U3 area (Figure 1), belts stopped, and

intense smoke appeared on the main road of the belt conveyor number 4 and evacuation team was requested to the accident scene. At around 15:00 smoke appeared in the A panel and at approximately 15:10 smoke first appeared in the main road of the H panel going to the S panel. At 15:20 smoke arrived at the first floor of the faces in the S panel. At this point fainting and deaths began. At around 17:00 the mine management decided to change the direction of ventilation, which was changed at around 17:30. Due to this change, 142 workers, who accumulated at the A panel area, where smoke was not effective, started fainting and some died. At around 20:20-20:30 the mine rescue teams reached the A panel area. The search and rescue operation took almost three days and the mine management was unable to announce the number of fatalities until the research and rescue operations were finalized.

#### 4. ANALYSIS OF THE SMD BASED ON RISK PERCEPTION AND ACCEPTANCE

In order to understand the accepted risk levels and risk perception by the SEM management, the decisions made during the onset of the fire as well as the emergency management activities should be considered. Moreover, the mine layout and mine operational conditions indicate risk perception of the mine management and organizations that approve and audit the mine operations.

##### 4.1. Risk Perception and Acceptance Related to Decision Making and Emergency Management

Based on the testaments of the survivors in the case files, it can be clearly stated that the mine management did not make a decision of evacuation for the whole mine; rather, the decision of evacuation was made only for some parts of the mine. Almost all of the survivors of the SMD, were those who received an order to evacuate the mine based on the news of the fire and who left the mine immediately. Those who did not leave the mine and stayed behind lost their lives.

The principle of self-escape in coal mining, especially in mine fires, proves its validity. Although there were no records of the exact location of fatalities who were found by the rescue staff, based on the distribution of locations where the rescue teams accumulated the bodies for taking them to surface, the distribution of the fatalities in the mine layout can be predicted (Table 2).

Table 2: The distribution of bodies according to where they were collected before they were taken to the surface.

Panel	Number of Victims
S Panel and around	209
R Panel and around	10
140 Face	4
A and H Panels and Fire Zone	78
<b>Total</b>	<b>301</b>

Since the S Panel is located remotely in the mine layout (Figure 1) and clearly separated from other panels, it is obvious that most of the bodies kept here belonged to those who worked in this panel and its surroundings. Accordingly, 209 people lost their lives in this panel and its surroundings (Table 2). On the other hand, 78 people lost their lives around A and H panels. The low numbers of casualties in the R panel and around the 140 Face was because fewer people worked in these panels and those who worked there could evacuate the mine immediately after the fire broke out.

It can also be decisively said that the decision for evacuation of the S Panel, where the biggest number of deaths occurred (209), were not made. As it can be seen in the statements of the surviving victims in the case file, the safety engineers responsible for the S Panel did not allow workers in this panels to leave the panel. The main reason for not evacuating the S panel is related to the factors of familiarity and controllability. As the mine experiences frequent fires due to spontaneous combustion propensity of the coal, the mine management considered this case to be similar to previous cases and assumed they would be able to control it in a short period of time.

However, mine management ignored the location of the fire in the SMD, where it started in one of the main roads handling ventilation air intake with probable methane in the environment. The majority of the fires experienced in the past took place in the production faces, which were easier to mitigate. As these fires are always controlled, the fire of the SMD was also considered to be the one that could be controlled easily.

For this reason the engineers responsible for the safety of the S panel were not given inadequate information about the severity of the accident by the control center and the top management. Moreover, the ventilation of the S panel was serial ventilation, which does not allow the workers to take an alternative safe escape route. Under such a mine environment with the assumption of the controllability of the fire, the decision for keeping workers in this area rather than evacuating the mine was considered to be the best option.

This decision is in fact related to the risk acceptance parameter of the presence of existing alternatives (unavailability of alternative escape

route), and derived benefits (assumption of safer faces than the main road full of smoke). It was most probably thought that the fire would soon be taken under control, so the workers should wait. It was assumed that the workers might be exposed to smoke while evacuating the mine before the fire was controlled, and their masks would not function sufficiently during evacuation.

For this reason, the engineers fought against the smoke by blowing clean air to the faces in the S panel using the compressed air pipes so that the workers in the S panel faces would not get affected by the smoke. However, they all died during this action.

The information availability and personal involvement aspects of risk acceptance emerge when the actions of executive mine management are examined. All the top management bodies that had heard about the fire entered the mine and were trying to reach the scene of the fire, in order to increase the level of information availability. This prohibited the effective application of an organized emergency management and evacuation plan.

In other words, instead of focusing on evacuating the mine safely and implementing emergency management, they tried to respond to the fire, which is directly related to personal involvement of the risk acceptance. In fact, some of the workers of the following shift, who did not know about the fire, entered the mine and lost their lives due to inefficient emergency management.

#### *4.2. Risk Perception of the Mine Management and Organizations for Approval of the Mining System*

The S and H panels are ventilated by means of serial ventilation. The workers, who were working at the H panel, learned about the fire since they were very close to the fire were informed about the decision to evacuate the mine. This decision was probably conveyed to the H panel by the safety engineer, who was in that area and took the first precautions to ensure the safety of workers after the outbreak of the fire. Some of those workers working in the H panel could not leave because of the smoke, but they waited safely first in the A panel area and then in this area, which were nearby and ventilated through parallel ventilation.

Construction of a second ventilation gallery for the S panel was planned in 2012, but this was not realized. Without doubt, if this gallery had existed at the time of the incident, workers could have been saved. As A panel was ventilated by parallel ventilation system, it allowed safety engineers to make a short circuit with the use of ventilation doors in the A panel area to protect workers in this zone from the smoke. Since the H panel was close to A panel, the workers of the H panel were able to reach

this safe zone. It was not questioned by supervising institutions why this gallery, which had been planned in the mine since 2012 but had not been constructed.

Although risk assessment and emergency drills were conducted in the SEM, a fire that might occur in the main roadway was not among the anticipated risks. An effective drill in which all of the mine was evacuated was never performed. Therefore, the liability of all the institutions that checked and approved the risk assessment cannot be overlooked.

In the SEM, the production increase (from 1.5 million ton/year to 3 million ton/year) was realized before the ventilation system was improved. Hence, all the institutions who approved such a production increase, before the ventilation conditions were improved in the mine, accepted a high level of risk, which is mainly associated with the short/long-term consequences. The long-term consequences of such a decision were ignored and trust for the regulatory bodies led all the organizations to take a high level of risk.

The production increase also brought about increases in the labor force in the mine since the production was mainly dependent on semi-mechanized and conventional systems. Among the 10 production faces, only two operated in a fully mechanized system. Risk is the combination of probable losses when a hazard occurs. In other words, even if the danger is slight, the risk is still high if the losses that will occur are significant. Therefore, the high number of workers in the S panel had already increased the risk level of the SEM.

## **5. RESULTS AND DISCUSSION**

The production with high risks in the SEM was in fact supported by the legislation prior to the accident. The legislation was renewed shortly before the SMD and details about the actions to be taken for safety were removed. The new legislation had some general statements that stipulated that the mine enterprise should take any precautions necessary. With this legislation, internal and external bodies making audits in the mine were also unable to report problems related to mine systems threatening safety. Though there are such legislations available around the world, standards or protocols have been developed for their implementation. Hence audits are performed based on whether these protocols are followed or not.

In Turkey, specific sections in the old legislation were taken out without developing such protocols for both coal mining and other types of mining, and the legislation containing the general statements valid before the accident resulted in risks being taken more easily. Unfortunately, the amendments made in the legislation following the disaster are not sufficient to

improve the safety conditions in current coal mines. Besides, any type of legislation enacted to improve safety cannot achieve the expected outcome without developing the standards or protocols, which has never been taken into account during legislation changes.

## 6. CONCLUSION

The reason why there was an extraordinary number of fatalities in the SMD was not the fact that a fire started in the mine, rather the decisions taken in the mine after the fire broke out. These decisions were made under the perceived risks, which were accepted despite their high level and caused a cascading impact of the fire due to the adopted mining system and management in the SEM. This also resulted in almost full ignorance of self-escape, inappropriate use of personal safety equipment, and unstructured emergency management that led a large number of mine workers to wait in the mine during the fire instead of implementing the mine evacuation plan. Therefore, regulations based on research on risk acceptance and perception of the mine management and organizational bodies is required for effective risk management in underground coal mines.

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