A QUANTITATIVE RISK ASSESSMENT METHODOLOGY FOR OCCUPATIONAL ACCIDENTS IN UNDERGROUND COAL MINES: A CASE OF TURKISH HARD COAL ENTERPRISES

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ABSTRACT

A QUANTITATIVE RISK ASSESSMENT METHODOLOGY FOR OCCUPATIONAL ACCIDENTS IN UNDERGROUND COAL MINES: A CASE OF TURKISH HARD COAL ENTERPRISES

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Underground coal mining is one of the most dangerous occupations throughout the world. The incidence of injuries and the days lost due to accidents in underground coal mines are much greater than industrial average. In general, the reasons behind an underground occupational accident are too complex to analyze. The risk analysis and assessment is the most suitable method to cope with these type of issues. This study proposes a quantitative methodology for the analysis and assessment of risks associated with mine accidents in the mines of Turkish Hard Coal Enterprises (TTK). The accidents in TTK between the years 2000 and 2014 are firstly statistically analyzed with respect to the number, type and location of accidents, education level, experience and age of the casualties and also injuries, days lost resulting from such accidents. Mines are compared with respect to number, type, and location of accidents and days lost using Analysis of Variance (ANOVA). Hazards are classified as individual, operational and locational hazards and quantified using contingency tables and conditional and total probability theorems. Injuries and days lost are considered as severities. Event trees for each hazard class are prepared. Lower and upper boundaries of risks for injury and days lost are determined. Injury and days lost risks are evaluated and mines are compared accordingly. Risk evaluation results show that Armutçuk, Karadon and Üzülmez mines have high risk levels especially for injury risks while Amasra and Kozlu mines are at the safer side. Some measures are recommended to decrease the determined high risk levels.

Keywords: Underground coal mining, occupational accidents, risk analysis, ANOVA, contingency tables

ÖZ

YERALTI KÖMÜR MADENLERİNDEKİ İŞ KAZALARI İÇİN SAYISAL BİR RİSK DEĞERLENDİRME METODOLOJİSİ: TÜRKİYE TAŞKÖMÜRÜ KURUMU UYGULAMASI

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Yeraltı kömür madenciliği en tehlikeli iş kollarından biridir. Yeraltı kömür madenlerindeki yaralanma ve kazalardan kaynaklanan işgücü kaybı da sanayi ortalamasının çok üzerindedir. Yeraltı kömür madenlerindeki iş kazalarının altında yatan nedenlerin analizi oldukça karmaşıktır. Risk analizi bu tür karmaşık konuların üstesinden gelinebilmesi için en uygun yöntemdir. Bu çalışma Türkiye Taşkömürü Kurumu (TTK) ocaklarında meydana gelen iş kazaları ile ilgili olarak risklerin analizi ve değerlendirmesi için sayısal bir metot önermektedir. Çalışmada, TTK madenlerinde 2000 ve 2014 yılları arasında gerçekleşen iş kazalarının sayısı, çeşidi ve yeri ile kazazedelerin eğitim durumu, yaşı ve tecrübesi ve kaza kaynaklı yaralanma ve işgücü kaybına ilişkin veri öncelikle istatistiksel olarak analiz edilmiştir. Varyans Analizi (ANOVA) ile madenler kaza sayısı, çeşidi, yeri ve işgünü kaybı açısından karşılaştırılmıştır. Tehlikeler bireysel, operasyonel ve lokasyonel şeklinde sınıflandırılarak çapraz tablolar ve koşullu ve toplam olasılık teoremleri kullanılarak hesaplanmıştır. Yaralanmalar ve işgücü kayıpları da kaza şiddeti olarak kabul edilmiştir. Her bir tehlike sınıfı için olay ağaçları oluşturulmuştur. Yaralanmalar ve iş gücü kaybı için alt ve üst risk sınırları belirlenmiştir. Yaralanma ve İşgücü kaybı riskleri değerlendirilmiş ve madenler bu yönden karşılaştırılmıştır. Risk değerlendirme sonuçları Armutçuk, Karadon ve Üzülmez madenlerinin özellikle yaralanmalar açısından yüksek risk seviyeleri içerdiğini, Amasra ve Kozlu madenlerinin ise daha güvenli tarafta olduğunu göstermektedir. Tespit edilen yüksek risk seviyelerini düşürmek için bazı önlemler tavsiye edilmiştir.

Anahtar kelimeler: Yeraltı kömür madenciliği, iş kazaları, risk analizi, ANOVA, çapraz tablolar

To my mom Fatma ERDOĞAN

Thank you mom

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LIST OF ABBREVIATIONS

AFR	: Accident Frequency Rate
AHP	: Analytic Hierarchy Process
ANOVA	: Analysis of Variance
ASR	: Accident Severity Rate
CPS	: Current Population Survey
DFSRM	: Difference, Frequency, Severity, Risk, and Monetary
ELİ	: Aegean Lignite Enterprises
FTA	: Fault Tree Analysis
DL	: Days Lost
GDEA	: General Directorate of Energy Affairs
GDP	: Gross Domestic Product
GEE	: Generalized Estimating Equations
GLI	: Western Lignite Enterprises
HFACS	: Human Factors Analysis and Classification System
GSPA-IAHP	: Generalized Set Pair Analysis-Interval Analytic Hierarchy Process
LTI	: Lost Time Injury
LP	: Labor Productivity
LHD	: Load Haul Dump
ILC	: International Labor Conference
ILO	: International Labor Organization
MENR	: Ministry of Energy and Natural Resources
MSHA	: Mine Safety and Health Administration
N	: Number of Accident/Casualty
NOW	: Number of Underground Workers
NSW	: New South Wales
NV(NOW)	: Normalized Value with Number of Underground Workers

NV(ROM)	: Normalized Value with Run of Mine Production
NV(UP)	: Normalized Value with Unit Production
OAL	: Middle Anatolian Lignite Mine
OHS	: Occupational Health and Safety
ORM	: Operational Risk Management
P	: Yearly Run of Mine Production
PHA	: Preliminary Hazard Assessment
PSD	: Presidency of Strategy Development
QLD	: Queensland
RF	: Roof Fall
ROM	: Run of Mine
SAWS	: Chinese State Administration of Work Safety
SGK	: Social Security Institution
TKI	: Turkish Coal Enterprises
TOPSIS	: Technique for Order of Preference by Similarity to Ideal Solution
TTK	: Turkish Hard Coal Enterprise
TUIK	: Turkish Statistics Institution
US BLS	: United States Bureau of Statistics
USGS	: United States Geologic Survey
UP	: Unit Production
Demont. W.	: Demontage Worker
Dev. Face	: Development Face
Dev. W.	: Development Worker
Gt	: Gigatonnes
Mat. Hand.	: Material Handling
Mech. Electr.	: Mechanical and Electrical
Prod. Face	: Production Face
Prod. W.	: Production Worker
Roadw. Gall.	: Roadways and Galleries
Trans.	: Transportation
Trans. W.	: Transportation Worker

CHAPTER 1

INRODUCTION

Coal continues to be primarily used for the generation of electricity and commercial heat. For example, 68% of primary coal is used for the generation of heat and electricity globally in 2013 (Coal Information 2015). The share of coal in electricity generation is around 41% in the world (web 1). Global production of all primary coal types passed 3 Gigatonnes (Gt) in 1972, 4 Gt in 1983, 5 Gt in 2003, 6 Gt in 2006, 7 Gt in 2010 and 8 Gt in 2013 (Coal Information 2015).The global production was mostly driven by hard coal. Projections point out that coal will be one of the most important primary energy source of the world in the future (web 2).

Coal is produced by surface or underground mining. Mining is particularly hazardous because of the nature of the work carried out. Additionally underground coal mining is much more risky (Bennett and Passmore, 1985). Averaging among all occupations in mines, underground coal mining activities are the most hazardous (Groves et al., 2007).

Occupational risk in underground coal mines is much higher than in surface mining. Injuries, fatal or non-fatal, could result from gases, fires, slip and falls, vibrations and so on (Karra, 2005). Accidents and disease have a very high cost to mining industry not only in the direct costs of accidents but also the indirect costs like productivity, losses due to interruptions in the mining operations, equipment breakdowns, compensations etc.

Accidents are very complex and many factors can contribute to their occurrence. Great efforts has been given to analyze the causes of accidents and many investigations have been carried out on the subject. It can be said that individuals are exposed to risk of injury at different levels due to their individual and working area characteristics. For example, experience can help workers in understanding the physical hazards (Paul, 2007). High share of accidents are related to human error, and a large proportion of accidents are related with relatively small percentage of the workforce (Maiti and Bhattacherjee, 1999).

Among the factors affecting the hazards in underground coal mines, stress condition and mine layout are controllable to some extent by an accurate and appropriate mine design. However, controlling the effect of geological conditions that mainly cause roof falls is very difficult since the geological conditions are the nature's uncertainty (Duzgun, 2005). The roof fall hazards are the main problems in underground coal mines, which are generally unpredictable due to the related uncertainties coming from the complexity of geological conditions and variability in the mining parameters (Palei and Das, 2009). Therefore, in order to deal with the uncertainties associated with the roof falls, risk assessment methods are required for decreasing the consequences and related costs of roof fall hazards. Quantitative risk analysis has the advantage of using historical data to determine the occurrences of major hazard-related incidents, and quantify the consequences in a more objective way (Grayson et al., 2009).

This study proposes a quantitative risk assessment methodology for the assessment and management of mine accident risks in underground coal mines. It also demonstrates its application for the mines of Turkish Hard Coal Enterprises (TTK). The risk assessment involves the determination of accident probabilities, possible consequences of accidents and related costs. The risk management is outlined by the use of analytical decision-making approaches. In this study, the data set covers only underground accidents causing injuries resulting in days lost or not. First, the data of accidents between 2000 and 2014 are statistically analyzed for each mine in terms of number, type and location of accidents, main duty, injured parts, education level, age and experience of casualties and also days lost on yearly basis. Then, in order to decrease the deficiencies resulting from the uncertainty of some variables, and to benefit existing comprehensive accident database of TTK, quantitative risk assessment methodology is developed. The fifteen-year occupational accident data are considered in the study. The main significant difference between the applied methodologies in the literature and the developed methodology is that discrete probability concept is used in the developed one since the probabilities are calculated for the existing data, while generally the continuous probability functions are taken into account in the applied methodologies of the risk assessment studies in the literature.

The other main difference is the categorization of hazard into three group in the study as individual, operational and locational hazards which are relatively different from the applied methodologies. Especially the hazard trees is distinctive. Determination of maximum and minimum risks for injury and days lost for each mine is the other different aspect of the study because generally the risk levels are defined (whether qualitatively or quantitatively) considering the hazard and severity levels in the literature. The model allows to compare the mines regarding the hazard types and levels also risks in terms of injury and days lost.

1.1 Occupational Accidents in Turkey

In Turkey, more than one million employers were subjected to occupational accidents between 2001 and 2014. 1.36% of the total resulted in death. According to the statistics of Social Security Institution (SGK) men have been much more prone to accidents with around 94%. The year 2014 was recorded as the worst year in terms of the number of accidents while occupational diseases were the highest in 2008 (Figure 1). 1,710 employer died due to accidents in 2011 which ranks at top followed by 2014 and 2010 with 1,626 and 1,454 death cases, respectively (Table 1).

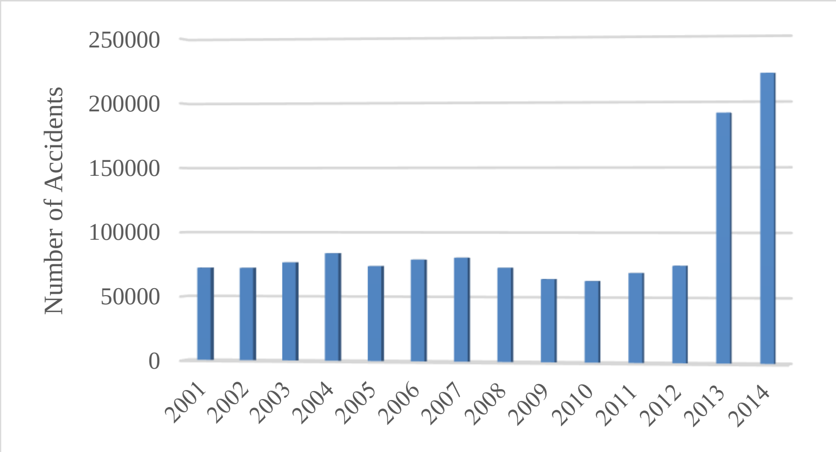


Figure 1 Number of accidents in Turkey between 2001 and 2014 (Source SGK)

According to the SGK statistics, the number of casualties as a result of occupational accidents has been on a decline since 2000. In the first half of the 2000s, nearly 14 workers out of 1000 were subjected to accident, but it was halved in the second half. The same trend continued in the first quarter of 2010s except the year 2013 and 2014 where accidents burst.

Accident rates are the measurements of past performance and an indication of how many accidents occurred, or how severe they were. In this manner, accident frequency rate (AFR) and accident severity rate (ASR) are regarded as key health and safety performance indicators (Equation 1 and Equation 2).

$$AFR = \frac{(Total\ \#\ of\ Accidents)\times(1.000.000)}{(\#\ of\ Workers)\times(Average\ Working\ Period)} \quad [1]$$

$$ASR = \frac{(Loss\ of\ Working\ Days\ due\ to\ Accidents)\times(1.000)}{(\#\ of\ Workers)\times(Average\ Working\ Period)} \quad [2]$$

Regarding all accidents in Turkey, a declining trend has also been observed in AFR and ASR values except 2013 and 2014 (Figure 2). In 2012, AFR and ASR values were recorded as the lowest for the last decade. Cumulatively, between 2001 and 2014, AFR and ASR values were recorded as 3.48 and 0.55, respectively (Figure 2).

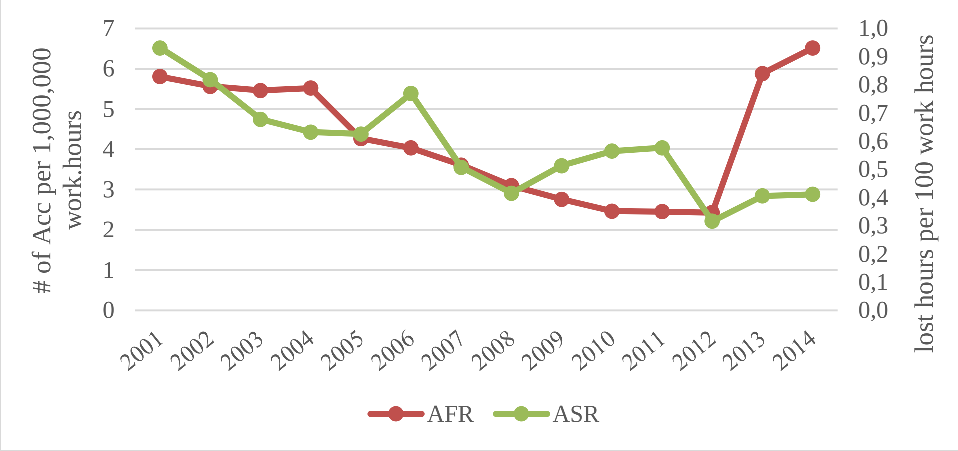


Figure 2 Accident frequency and severity rates of occupational injuries (Source SGK)

All the accidents have to be reported to SGK in Turkey. SGK collects, evaluate and issues all the cases in its web-site. Table 1 presents a summary of basic SGK statistics for accidents. According to SGK statistics, in 2014, of nearly 13.2 million of compulsory insured workers, miners constituted only 1.25% (Table 1). If the cumulative casualties between 2002 and 2014 are considered, the sector has been responsible for about 10% of total incidents (101,033 cases) and 7% of total fatalities. However, the results have been more disastrous when considering occupational diseases. The percentage of occupational diseases resulting from mining activities is about 60%. In other words 60% of 7,184 occupational diseases between 2002 and 2014 belongs to mining sector.

Table 1 Summary of occupation statistics of Turkey (Source SGK)

	Compulsory Insured Total	Compulsory Insured Mining Sector	Number of Employment Injuries	Number of Occupational Disease	Toll of Deaths	Accident Frequency Rate	Accident Severity Rate
2002	5,223,283	81,968	72,344	601	878	5.56	0.82
2003	5,615,238	80,533	76,668	440	811	5.46	0.68
2004	6,181,251	83,624	83,830	384	843	5.52	0.63
2005	6,918,605	94,430	73,923	519	1,096	4.27	0.63
2006	7,818,642	104,942	79,027	574	1,601	4.03	0.77
2007	8,505,390	106,004	80,602	1,208	1,044	3.61	0.51
2008	8,802,989	112,335	72,963	539	866	3.10	0.42
2009	9,030,202	115,934	64,316	429	1,171	2.76	0.51
2010	10,030,810	125,457	62,903	533	1,454	2.46	0.56
2011	11,030,939	135,447	69,227	697	1,710	2.45	0.58
2012	11,357,306	137,630	74,871	395	745	2.43	0.32
2013	12,351,352	140,781	191,389	371	1,360	5.88	0.41
2014	13,240,122	128,962	221,366	494	1,626	6.51	0.41
Cum.	116,106,129	1,448,047	1,223,429	7,184	15,205	3.77	0.54

Although the total number of compulsory insured worker increased in 2014 the corresponding number decreased for mining sector (Table 1). This may be resulted from the two major mining disasters in Soma and Ermenek in 2014. One important point in Table 1 is the huge increase in the total number of injuries and deaths toll in 2013 and 2014.

1.2 Occupational Accidents in the Mines

The Mining Law numbered 3213 has been amended in 2004 and 2010 to regulate the conditions in the survey, exploration and operation activities in mining sector and to increase the mining investments in the country. Together with some regulations for the activities, some incentives for the investments have also been brought with these amendments. The investments in the mining sector have increased. The share of mining sector in Gross Domestic Product (GDP) raised from 1.1% (2003) to 1.5%

(2014) (web 6). Moreover, the mining export revenues have increased from 0.8 billion US Dollars (2003) to 4.1 billion US Dollars (2014) (web 6).

In Turkey, most mine accidents have been observed in the last five years. Before the enactment of the Occupational Health and Safety Law in 2012, provisions of the Labor Law numbered 4857 has been applied regarding OHS issues. Especially in the mining sector, occupational health and safety activities has been carried out according to the "Regulation on Occupational Health and Safety Precautions which will be taken in the Mines and Stone Quarries and Tunnel Construction".

The Occupational Health and Safety Law, published on 30 June 2012, is enacting the duties, authorities, responsibilities, rights and obligations of the employers and employees in order to ensure occupational health and safety and improve the current health and safety conditions at workplaces. With this law, OHS subjects have been converted into a specific law and the scope of workers' statues which have been previously enacted by only the law 4857 expanded. This law enforces risk assessment and defining management system approach in the mines. This law also attaches importance to qualified education, and highlights proactive implementations. Providing broader worker participation and prevention-conservation-development based approaches are some of the main objectives of the law. However, the expected results have not been obtained and the implementation of the law does not demonstrated an enforcement for the number of accidents in the country.

The Regulation on Occupational Health and Safety in the Mines, prepared in accordance with the Article 30 of the Occupational Health and Safety Law and EU Directives, aimed safe operations in mining workplaces. However, 2012, 2013 and 2014 statistics show that the new regulation has not been effective, at least in the short term.

After experiencing mining accidents in the country especially in 2013 and 2014, some additional regulations have been put into force. Regulations have been made to enhance the working conditions of mining workers and their wages. The Mine Health Safety Convention numbered 176 of ILO has been adopted and some changes have been conducted both in occupational health and safety law and regulation on occupational health and safety at mining workplaces in order to decrease the occupational accidents in the country.

1.3 Major Occupational Accidents in Coal Mines in Turkey

Turkey has experienced huge number of mine accidents over the past three years. Coal mining is responsible for more fatalities than the production of any other energy source due to poor working conditions. Mining was the deadliest industry in 2013 according to data from the state statistics agency TUIK.

Coal miners are exposed to occupational accidents more than any other miners. Although the ratio of injuries in coal mine accidents has dropped down to 80% from 90% in 2014 (Figure 3), they remain the major portion of overall occupational accidents in Turkey.

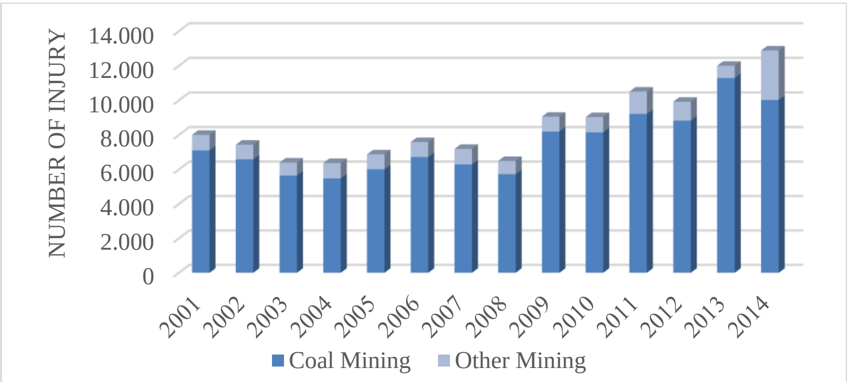


Figure 3 Number of compulsory insured miners exposed to an accident

Over the past three decades, more than 837 workers, including the death toll in Soma disaster, have died in mining accidents (Table 2). Over the past three decades, 14 coal mining accidents occurred in Turkey, with the latest one being the mine fire in Soma, which caused 301 fatalities. The second worst mining disaster was a firedamp explosion occurred in 1992 caused 263 fatalities. The firedamp explosion in the Armutçuk Coal Mine of Turkish Hard Coal Enterprises (TTK), a state owned enterprise, in 1983 resulted in 103 deaths. The other major two explosions were also lived in Amasya and Yozgat mines in the first half of the 1990s.

Table 2 Major coal mine accidents in Turkey

Place	Date	Mine Type	Accident Type	# of Deaths	Public/Private
Zonguldak-Armutcuk	07.03.1983	Coal	Gas Explosion	103	Public
Zonguldak-Kozlu	10.04.1983	Coal	Collapse	10	Public
Zonguldak-Kozlu	31.01.1987	Coal	Collapse	8	Public
Bartin-Amasra	31.01.1990	Coal	Gas Explosion	5	Public
Amasya-Yeni Celtek	07.02.1990	Coal	Gas Explosion	68	Public Subsidiary
Zonguldak-Kozlu	03.03.1992	Coal	Gas Explosion	263	Public
Yozgat-Sorgun	26.03.1995	Coal	Gas Explosion	37	Private
Erzurum-Askale	08.08.2003	Coal	Gas Explosion	8	Private Sector
Karaman-Ermenek	22.11.2003	Coal	Gas Explosion	10	Private Sector
Çorum-Bayat	09.08.2004	Coal	Methane	3	Private Sector
Kütahya-Gediz	21.04.2005	Coal	Gas Explosion	18	Public Subsidiary
Balıkesir-Dursunbey	02.06.2006	Coal	Gas Explosion	17	Private Sector
Bursa-M.Kemalpasa	10.12.2009	Coal	Gas Explosion	19	Private Sector
Balıkesir-Dursunbey	23.02.2010	Coal	Gas Explosion	13	Private Sector
Zonguldak-Karadon	17.05.2010	Coal	Gas Explosion	30	Private Sector
K. Maraş-Elbistan	10.02.2011	Coal	Slope Failure	11	Private Sector
Zonguldak-Kozlu	08.01.2013	Coal	Methane Release	8	Private Sector
Manisa-Soma	13.05.2014	Coal	Fire	301	Private Sector
Ermenek	28.10.2014	Coal	Flooding	18	Private Sector

More than 100 coal mines have been closed in the last three years as a result of failure to comply with safety standards. However, new measures should be taken to decrease fatalities and accidents in the short, medium and long term.

1.4 Statement of the Problem

In underground coal mines, the working conditions are relatively hard compared with other industries. The accidents causing injuries and sometimes fatality occur in a variety of forms. The cause of the accident may be a rock fall or due to an interaction with a machinery or may be related with struck by an object. Whatever the cause, the result would pose a high direct or indirect cost for the mine depending on the severity of the accident.

As indicated previously, due to the nature of the formations, coal mining, either surface or underground, has many dangers that make it unique in the industrial health and safety area. Soft, faulted and folded sedimentary strata is always a risk for the safe and economic removal of the coal. Therefore, it has been regarded as a relatively dangerous industry through the world. Employees in coal mining are more likely to be killed or to incur a non-fatal injury or illness, and their injuries are more likely to be severe than workers in private industry as a whole (US BLS, 2007).

Accidents are painful and costly to the workers and their families. They can be also a burden on the mining companies because, in addition to the costs of personal injuries, they may incur far greater costs from damage to property or equipment, and production losses (Sari et al., 2004). The total cost of fatalities and lost time injuries due to occupational accidents on average resulted in more than 100 million USD in 1987 in USA (Bhattacherjee et al., 1994). In a similar study carried out for Turkish Coal Enterprises (Istanbulluoglu, 1999), the total cost of lost working days due to accidents in a year is calculated as 4.3 million USD without considering indirect losses. Therefore, one of the main concerns of mining companies is to cut the costs of accident while improving mine safety.

Accidents in a coal mine do not result from the reasons due to geological conditions every time. As in the case of other industries, mining activities involve materials, equipment, human resources and an environment where the potential risk of catastrophic losses is very high. Generally, losses resulted from mining accidents are examined without taking into consideration the uncertainty in the occurrence of hazards and the analysis of those losses are mostly deterministic in nature. For this reason, the stochastic assessment of accident risks and the determination of proper risk control methods for mining applications has become a requirement for decreasing the costs resulted from the occurrence of hazards (Sari et al., 2004).

A quantitative risk assessment approach has been performed on the available days-lost data and risk levels were first identified for conventional and mechanized panels of two underground coal mines in earlier studies (Sari et al., 2004).

An accident in a coal mine may be resulted from a coal dust or methane explosion, mine flood is another important reason of accidents, roof falls have a great ratio among the reasons of coal mine accidents. Additionally, accidents due to transportation, material handling, machinery or electricity interactions, struck by objects, slip and falls are also the other accident reasons. Many researches have been carried out to investigate the reasons of the accidents, the nature of the accidents in coal mines. Different methodologies have been performed to analyze the structure of the accidents in a mine.

The studies on the equipment related fatal accidents carried out by Groves et al. (2007) and Kecojevic et al. (2007) are two examples for the investigations of relation between the underground accidents and machinery used during workings. The risk analysis of roof fall accidents in underground coal mines (Duzgun, 2005; Maiti, 2009) are representative examples to the studies on nature of accidents. There are also a lot of risk analysis and assessment studies about the coal and gas explosions. The researches carried out by Thomas (2009) and Tian-jun et al (2011) are only two of them. The behavioral factors are also important in underground mine accidents. Paul (2007) and Jiang-shi et al (2011) have investigated the effects of the behaviors of workers on the occupational accidents in underground mine accidents.

Coal is one of the most widely used indigenous energy source in Turkey. It is the second energy source after natural gas (29%). Although modern underground mining methods have been introduced, mine accidents in Turkey still cause loss of lives and money in certain mines (Sari et al., 2004). This study proposes a quantitative methodology for the assessment of risk due to mine accidents. The application of the methodology is demonstrated using the case study conducted for the mines of TTK. In the proposed methodology, risk assessment requires the determination of probabilities, possible consequences and cost of these consequences.

TTK is the only public authority responsible from the hard coal production in the country. Since TTK has been in deficiency for years and since the share of labor cost in production cost (around 60%) is extremely high in the Enterprise, occupational accidents and their consequences are utmost importance for the institution especially due to the direct and indirect costs of the accidents. There are five different underground mines in the district having different characteristics both in geological and operational aspects. The economic condition of the TTK has been getting worse year by year. One of the main reason of this fact is the big difference between the production cost of coal and sale price of it. The revenues of TTK could not cover the overall cost of the enterprise. There are so many reasons under this fact and most of these reasons do not exist within the subject of this thesis. However one and the most important reason is the high share of labor cost in the unit production cost of coal in TTK. From this point of view, analysis of occupational accidents resulting injuries and days lost is very important to be able to determine the risks due to these accidents.

1.5 Objectives of the Study

The objectives of this study are:

- To develop a quantitative risk assessment methodology
- To determine the risk levels of occupational accidents in terms of defined categories in all underground mines of TTK
- To support TTK in decreasing its production cost by decreasing the days lost cost resulted from occupational injuries

In this study, to realize the objectives of the study, a new approach is developed to determine the maximum and minimum risk levels for defined categories. It is also aimed to differentiate the mines from each other in terms of occupational injuries and resulted costs.

1.6 Outline of the Study

This study is divided into eight main chapters. After a brief introduction, in Chapter 2, a detailed literature survey is presented, in this survey mainly the methodologies used in safety assessment for mining activities in Turkey and in the world are dealt. In Chapter 3, the available risk assessment methods are described briefly. In Chapter 4, the developed methodology applied in this study explained briefly. In Chapter 5, Turkish Hard Coal Enterprises is explained in detail. All occupational accidents in TTK between 2000 and 2014 are statistically analyzed in many aspects in Chapter 6. Hazards, are defined and categorized and calculated for each mine in TTK in Chapter 7. In this Chapter, severities and related risks are calculated and maximum and minimum risks for each category are determined. Results and discussions on the findings also exist in this Chapter. Some conclusions are stated and some recommendations for further studies are given in the last Chapter.

CHAPTER 2

OVERVIEW OF RISK ASSESSMENT METHODS IN MINING

According to International Labor Organization (ILO) Statistics, 120 million occupational accidents occur annually at workplaces worldwide. Of these, 210,000 are fatal accidents. Every day, more than 500 men or women do not come home because they were killed by accidents at work. These are dramatic numbers which draw fairly little public attention. Although, accidents take a considerable economic toll from nations, companies and individuals, accidents do not get much publicity (Sari, 2011). Mining accidents and disasters are preventable. It is a tragedy that history is often repeated and the lessons from previous accidents and hazards seem to be forgotten or ignored. While technological improvements and tight safety regulations have reduced coal mining related deaths, accidents are still too common. There are a lot of hazards inherent to mining but coal mining tends to be the most hazardous because of nature of the coal reserve and its geological setting, presence of methane, toxic asphyxiating gases that can be explosive etc.

The mining hazards and related consequences forced the ILO to hold a specific convention pertaining to miner's health and safety and hence the Safety and Health in Mines Convention was adopted at the 82nd International Labor Conference (ILC) of the ILO. However, up to now only 30 countries have ratified the Convention. Turkey, after a long and challenging struggle, has ratified the Convention in December 9, 2014. In the literature, there are different studies on finding relation between hazards and geological conditions, behaviors of workers and mine layout e.g. (Sari et al., 2004; Duzgun and Einstein, 2004; Duzgun, 2005, Maiti and Khanzod, 2009; De-shun and Kai-li, 2011).

Maiti and Bhattacherjee (2001) examined differences between the groups in accident susceptibility among underground coal mine workers accounting for their personal and workplace characteristics. Previous studies clearly demonstrated the differences in accident/injury susceptibility among different groups/classes of workers. However, they studied insufficiently considering two important aspects. First, the majority of these studies included only the injured miners into their analysis ignoring the effect of uninjured miners' population. Second, some studies although they considered the uninjured miners' distribution, they addressed only their bivariate relationships. They investigated the risk of occupational injuries among underground coal mine workers through the multinomial logit analysis to address the issues of accident proneness taking into consideration the injured and uninjured workers population. The logistic regression model was applied in the study to evaluate the differences in accident susceptibility to various groups of underground workers controlling for both their personnel and workplace characteristics. Data were collected from five underground coal mines for a period of four years for the case study. The dependent variable considered is degree of injury and independent variables are the personnel and workplace characteristics of the miners. The degree of injury was categorized as fatal, serious, reportable and no injury. Since there were only a few fatalities occurred in the case study mines during the study period, the fatal and serious injuries were merged into a single category as severe injury. The case study results revealed that different age and experience groups of workers bear no significant differences in their accident susceptibility; however, the workplace location and occupation groups show significant differences in their risk of injuries (Maiti and Bhattacherjee, 2001). It is inferred based on the logistic regression model results that among the three occupation groups, the face workers are more susceptible towards accidents/injuries compared to the haulage and other workers.

Duzgun and Einstein (2004) analyzed 1141 roof fall data from 12 underground mines in Appalachian region and proposed a risk and decision analysis methodology for the assessment and management of risk associated with mine roof falls. In the study, danger, hazard and risk were used to mention the state of the nature and quantification of uncertainties or estimation of probabilities and consequences. Since the sufficient data were obtained the objective method was utilized for the probability assessment. Duzgun and Einstein (2004) grouped the consequences as fatality, disability, injury, equipment damage, interruption and delay in operation, clean up, emergency operations, loss of wages and documentation of the accident. The cost of consequences is modeled by relative cost criterion. A decision analysis framework is developed in order to manage the evaluated risk for a single mine.

Bajpayee et al. (2004) examined 412 blasting injury records for coal and metal mines during the 21-year period from 1978 to 1998 in order to describe several fatal injury case studies, analyze causative factors and emphasize preventive measures. Although the Mine Safety and Health Administration (MSHA) publications were the primary source of information the authors also utilized United States Geologic Survey (USGS) and other sources. According to the observations of the authors, during the 10-year period from 1989 to 1998 a reduction in fatal and nonfatal blasting injuries in surface coal mines was observed compared to the previous 10-year period. However, in the surface metal/nonmetal mining sector such reduction was not observed. They also found that during the study period, the mean yearly explosive-related injuries (fatal and nonfatal) for surface coal mines was 8.86, and for surface metal/nonmetal mines 10.76. Fly rock and lack of blast area security accounted for 68.2% of these injuries. The study reveals that careless or improper blasting were the main causes of fatal injuries. They concluded that the injury prevention approach is invariably multifaceted. This includes interventions conducted through training and education, engineering controls, and administrative and regulatory guidance.

Sari et al. (2004) studied two separate underground coal panels (conventional and mechanized) in order to determine the effect of mining methods on productivity and safety. In the study, the data was collected from two underground coal mines (GLI Tunçbilek- Omerler and ELI Soma-Eynez) and the evaluation has been carried out at three stages. First part include conventional mining accident record, second part include conventional injury records while mechanized panels were in operation and third part covers the injury data belonging to mechanized panels. Fatality and nonday lost injuries was excluded in the study. Multiple linear regression and time series analysis were used in the the study. They found that safety and productivity are improved together with mechanization. They also concluded that improvement in the productivity for mechanized panels has more pronounce effect than that in the safety. The comparison of the injury profiles of the system revealed that the most risky place shifted from the face areas in the conventional panels to the development areas in the mechanized panels. Hence, the production workers were less injured in the mechanized system than the conventional system. The workers in the middle age group had a higher accident rate in both systems. The results of the present study have been compared with the previous studies.

Duzgun (2005) applied a methodology in order to cope with uncertainties in roof fall hazards in underground mines of Zonguldak coal basin. In this study, roof fall risks associated with underground coal mines in the Zonguldak coal basin, Turkey, are assessed based on analysis of annual roof fall occurrences. Risk assessment is performed by decomposing the roof fall risk into two components: hazard and consequences of the hazard. Then the two components of the roof fall risk are identified and quantified. A cost model for the quantification of roof fall consequences is developed. Finally, a decision analysis methodology is proposed for the effective management of roof fall risks. The data, covers the annual number of accidents, annual number of injuries and fatalities, accident type and annual number of workers for each of the five mines for the years of 1986–2003. The results show that the underground coal mines in the Zonguldak coal basin have considerably high risk levels and hence require comprehensive risk management schemes.

Karra (2005) analyzed the fatal and non-fatal mine injury data of MSHA during 1983-2002 in order to assess non-fatal and fatal injury rates among operator and contractor employees in underground and surface mines and their trend over the years to be able to describe the relative effects of worker and work location variables using the Poisson or negative binomial statistical models. Based on the literature, both the Poisson and the negative binomial regression models were selected for studying their applicability to model the injury rate data. The study showed that the 20 year injury rate data for workers in the mines can be represented by the negative binomial model. On the other hand, the mean fatality rate for workers can be adequately represented by the Poisson model. Hence, based on the models, it is found that the mean injury rate declined at a 1.69% annual rate, and the mean injury rate for work on the surface is 52.53% lower compared to the rate for work in the underground whereas the mean fatality rate declined at a 3.17% annual rate, and the rate for work on the surface is 64.3% lower compared to the rate for work in the underground.

Kecojevic et al. (2007) analyzed 483 fatality records from MSHA's database between 1995 and 2005 in order to better characterize equipment-related mining fatalities and injuries. The equipment are: belt conveyors, haulage trucks, front-end loaders, continuous miners, dozers, forklifts, shuttle cars, hoisting equipment, load-haul-dump (LHD), roof-bolters, shovel, scraper, locomotive, dragline, crusher, etc.). The accidents categorized considering the type of equipment used during accident. Then, the relation between the experience of the workers and frequency of accidents were examined for each category. They found that equipment-related accidents continue to represent an area requiring attention and increased prevention efforts since they still account for over 50% of fatalities. The study showed that 40% of the equipment-related fatalities have arisen from haul trucks, belt conveyors, front end loaders and continuous miner subcategories. Less experienced workers appear to be the most vulnerable to equipment-related accidents They concluded that a comprehensive program of equipment safety needs to be considered by both surface and underground mining operations and significant resources need to be budgeted by the decision makers.

Similar study has been carried out by Groves et al. (2007). They investigated a total of 190,940 accidents from MSHA and Current Population Survey (CPS) data, both surface and underground, in order to investigate the equipment-related mining injuries. They also searched the relationship between number of fatal accidents and the mining experience of the workers involved. They used the demographic survey conducted by Butani in 2008 to evaluate the significance of data for injury. The study showed that accidents resulting from non-powered hand tools are frequently causes nonfatal injuries, which also accounted for the largest number of lost days. Off-road and underground ore haulage were the categories most often involved in fatal injury. They also found that younger workers having less than five years of experience are more vulnerable to non-fatal injuries while the older workers older than 55 years old have higher risk for fatalities. They concluded that continued reductions in accidents and injuries will require additional efforts to develop new and creative approaches.

Ya-jing et al. (2007) carried out an evaluation of a coal mine using a hierarchical grey analysis. The study proposes an index system of safety assessment based on corresponding factors in coal mining and an evaluation model that combines the advantages of the Analytic Hierarchy Process (AHP) and a grey clustering method. In the study firstly, the weight of each index were confirmed quantitatively by means of AHP according to an established index system; secondly, they determined the assessment matrix elements using grey numbers. They stated that one of the main advantages of the approach is that it does not rely on the experience of experts and it can improve the precision of evaluation. The results of the study show that there are several factors affecting the safety of a coal mine. A number of important factors impact significantly on the results of the assessment. They also concluded that the method is applicable and realistic. Although they found that the method is applicable and realistic, they underlined that more studies were required to have a uniform and objective criteria for the assessment of a safety index.

Paul and Maiti (2007) achieved a case study in order to evaluate the role of behavioral factors on the occurrence of mine accidents and injuries using the data from two neighboring underground public coal mines. High–low plots and t-test were applied in order to investigate the differences between behavioral characteristics of casualties and other workers. Structural equation modeling was utilized to estimate how these differences may cause accidents in mines. The case study results show that workers more job dissatisfied, negatively affected, and highly risk taking are more accident prone compared to the non-accident group of workers. The multivariate analysis also reveals that there is no relation between the experience of casualties and work injury. In other words, a less experienced worker is equally likely to be injured as an experienced worker (Paul and Maiti, 2007). They concluded that the results of the study would contribute to the design of safety trainings on safety regarding behavioral properties of workers.

The main purpose of Coleman et al. (2007) was to examine the distributions and summary statistics of all injuries reported to the MSHA from 1983 through 2004. They modelled the days lost data using a beta distribution function and made a comparison between underground coal mining and underground metal/nonmetal mining. They found that probability of an injury having 10 or more lost workdays is higher in coal mine cases as compared to metal/nonmetal mine ones. They concluded that the days lost values in mining injuries are valuable indicators of a number of aspects of job safety programs. Total days lost can help to distinguish the mining operations as lower and higher risk operations with respect to their risk levels (Coleman et al 2007).

In the study carried out by Wang et al. (2008), the subject was mine flooding. The parameters affecting mine flooding have been analyzed and a software of quantification theory is applied to study the risk prediction problem about mine flooding. Wang et al. have investigated hydrogeology structural conditions, mine water detection, and plans to prevent mine water disasters in the mining area. In the study eight risk assessment items have been determined. The risk is categorized into four levels as extremely dangerous, very dangerous, dangerous and moderately dangerous. A prediction model for the risk of mine flooding is formed. The study solves the quantification problems about safety assessment of qualitative data and developed a new way of safety assessment (Wang et al., 2008). This method has significant application value. It was concluded that the model can be used as a final risk assessment model for mine flooding.

In the study carried out by Poplin et al. (2008) the changes in days lost injury rates among coal mines in the US and Australia for the years 1996 and 2003 have been compared, taking into account the risk-based regulatory system implementation in Australian coal mining industry. 39,820 days lost injuries have been documented in

US bituminous coal mines, 2,587 in Queensland (QLD) and 6,806 in New South Wales (NSW). Generalized estimating equations (GEE) were used to assess days lost trends among mines in the US, QLD, and NSW. In this analysis, the negative binomial response distribution was used with a log link and autoregressive-1 correlation structure. In addition to the days lost accidents the data belonging to size of the mine, tons of coal produced, and type of mine were also gathered before the analysis. Since the distribution of mine sizes in the US and Australia are different, a stratified analysis by mine size was employed and the mines are divided into three categories as Mines with 10–99 miners; 100–249 miners; and 250+ miners. All mines with less than 10 miners employed were excluded in the analysis.

The results of the study reveals that the number of days lost injuries in the US, QLD, and NSW decreased between 1996 and 2003 by 37.7%, 68.4% and 65.7%, respectively. The study showed the risk of days lost injuries associated with various factors. One of the important results of the study was that underground mines pose a statistically significant increased risk of injury when compared to surface mines. According to the study underground mines were 2.4 times more likely to report a lost time injury than were surface mines. Another finding of the research is that the risk increases with mine size. Smaller mines (10–99 employees) had a significantly increased risk of injury associated with each 1000-tons produced while there was no association with production for mines with 100 employees or greater. The study has shown a remarkable reduction in days lost injuries in Australian coal mining relative to the US, related to the institution of a risk-based regulatory approach in Australia.

Md-Nor et al. (2008) developed a risk assessment process for the haul-track and loader-dozer related fatalities in US mines based on historical data obtained from the U.S. MSHA investigation reports between 1995 and 2006. Risks have been identified and quantified using the preliminary hazard assessment (PHA) method while a risk matrix has been established to estimate risk levels. Komljenovic et al. (2008) examined injuries in the US mines for the interval 1995-2004 based on a structured and systematic risk management approach, where risk analysis represents an integral process for determining levels of accident risks for the categories: fatalities, nonfatality-days-lost injuries, and no-days-lost injuries. They underlined the need for continued efforts to reduce mining injuries. Paul (2009) applied the retrospective case-control study design to identify the various factors responsible for work related injuries in mines and to estimate the risk of work injury to mine workers from two neighboring underground coal mines within a large public sector organization in the eastern part of India using a step-by-step multivariate logistic regression modelling. 18 variables were examined in the study and a questionnaire type survey was applied to quantify the variables which were not directly quantifiable. Age, negative affectivity, job dissatisfaction, and physical hazards were determined as the four main variable affecting the risk of injury. He found that negatively affected workers are 2.54 times more prone to injuries than the less negatively affected workers and this factor is a more important risk factor for the case-study mines. He also proposed providing a friendly atmosphere during work to increase the confidence of the injury prone miners. Much care is necessary for the aged and experienced workers with respect to their job responsibility and training requirements (Paul, 2009).

Sari et al. (2009) analyzed 1390 days lost accident cases recorded at GLI-Tuncbilek underground lignite mine from 1994 to 2002 and proposed a stochastic uncertainty model including randomness in the occurrence of those accidents. Non-days lost injuries like only equipment damage, occupational diseases, permanent disability and fatal cases were excluded in the study. The basic accident data were categorized as name, age, and occupation of injured; the date, time, location and type of accident; the parts of body injured and the number of days work. In the study, firstly, the frequency and the severity of the accidents have been modeled statistically by fitting appropriate distributions. Poisson distribution was used for the frequencies and lognormal distribution was fitted to days-lost data. Then, two distributions were basically combined by Monte Carlo simulation to form relative risk levels in yearly base. In the study, two components of accident risk, level of hazard multiplied by probability of occurrence, were modelled using a distributional approach including uncertainty dictated by the available accident data. A simple forecasting modelling was also carried out in order to quantitatively predict the expected risk levels by using decomposition technique in time series analysis. They concluded that although, there would be substantial reduction in the expected number of accidents in the near future, the higher level of risks still should be a concern for the mine management.

Maiti et al. (2009) developed cause-wise hazard rate functions and cause-wise cumulative risk functions to make a retrospective study on severity analysis of Indian coal mines accidents for 100 years considering fatal and serious accidents and the resulting casualties. An event valuation algorithm was developed in order to assess the impact of recommendations based on safety conferences and committees over the years. The study showed that there is also a high probability of occurrence of 550 serious injuries every year and the costs of such accidents are huge. They demonstrated that no significant reduction in fatal accidents and fatalities was experienced as a result of the conference-based recommendations. In addition to the previous study, a relative risk model for roof and side fall fatal accidents was developed by Maiti and Khanzode (2009) using loglinear analysis of two way contingency tables. The model is applied to large scale roof and side fall fatal accidents occurring in 6-years for 292 underground coal mines in India. Poisson distribution was applied for prediction of the accident and fatality counts. Then, an estimate of the number of possible fatalities that can take place over a period of time at a particular location in a mine due to roof and side fall fatal accidents, the potential fatalities, was estimated, and the relative risk of fatality was calculated. Finally relative risk distribution was estimated using Monte Carlo Simulation. The study showed that safety measures adopted for reducing roof and side fall accidents in Indian underground coal mines are largely based on potential fatalities. It was also found that there is a strong reliance on preventing maximum consequences by focusing only on avoiding fatality. Maiti et al. (2009) concluded that safety measures effectivity across different locations in underground coal mines varies and focus is mainly concentrated in highly populated workplaces such as face.

In the study carried out by Grayson et al. (2009) a pilot sample quantitative risk analysis has been performed for underground coal mine fires and explosions using MSHA data. The pilot study database was created using data from the year

2006. 488 underground coal mines in the US with 441 of them producing coal were handled in the study. 31 mines in the pilot study were randomly selected and stratified based on mine size and mines were grouped as; very small mines, small mines, medium-size mines, large mines and very large mines considering the number of workers working in the mine. In the study used risk matrix is an expansion of the generic risk matrix used in Md-Nor et al. in 2008. Later on, in the study the weighted average risks for the top five major hazard related citations were calculated for each group of mine. The risks for each group of mine have been tabulated in the study and the results analyzed separately. Then the mines were categorized in terms of risk category considering the results. In the study the risks for mine groups have been determined regarding the inspector hours and number of citations. The results of the study reveals that very large and small mines are high risky mines.

Zheng et al. (2009) analyzed 106 coal dust explosion accidents occurred between 1949 and 2007 in China to analyze the overall situation and supply quantitative information on coal dust explosions. In this study, space, time, volatile ratio of coal dust, ignition sources, and accident categories were analyzed but they especially focused on statistical features such as space and time in the study. Space was analyzed at provincial and municipal level separately. Explosions with and without methane were taken into account. In time analysis, the frequency of coal dust explosions have been examined at yearly, monthly and hourly to be able to reach the effect of time on the explosions. Volatile ratio of the coal samples were determined and the explosions were put into five category considering the volatility of coal samples. The study showed that coal dust explosions are highest in certain provinces in certain periods of the year and the authors proposed giving much more attention to these provinces. Since flame of blasting and electric spark were found as first two key ignition sources responsible for huge portion of the explosions, the authors put forward much more efforts to seek new safe explosives. They concluded that safety management system (including management of technical affairs) and safety culture need to be put into practice in order to prevent coal dust explosions in coal mines. Zheng et al., (2009) stated that there was a clear fact that the average production technique and safety consciousness of employees in coal mines in China is not high enough to meet the requirements of work safety. Thomas and Dubaniewicz (2009) carried out a study on mine explosions to identify the ignition locations and ignition sources responsible for the most severe explosion events resulting in fatality. In the study, the fatal accident reports of MSHA related to the explosions occurred between 1976 and 2006 were tabulated and the results were analyzed statistically. Ignition locations and electrical equipment were categorized. With few exceptions, explosion protected equipment is not required in intake air courses of gaseous underground coal mines in the US (Thomas and Dubaniewicz, 2009). The results of the analysis reveals that all intake air entry explosions occurred when the ventilation system failed or was determined to be inadequate. The analysis point out that most of the fatalities occur in the explosions ignited in intake air courses and face due to different ignition sources. Another important conclusion reached in the study was that the non-permissible equipment has the greatest share for the fatality portion considering the ignition source for the explosions. In the study, use of explosion protected vehicles in intake air courses of gassy underground coal mines is recommended by Thomas and Dubaniewicz (2009) to reduce the hazard.

Palei and Das (2009) developed a logistic regression model based on some major parameters to evaluate severities of 128 roof fall accidents in five underground coal mines in India applying board and pillar mining method. They grouped the roof fall accidents to three categories as major, serious and minor accident considering the degree of injuries in the accidents. The fatal and serious accidents are merged into a single category namely major accident and the roof fall accidents involving one or more reportable injuries were encoded as minor accidents. In the study, the dependent variable was the degree of roof fall accident, while width of gallery, mining height, depth of cover, seam thickness, roof support status were classified as independent variables. The results of the study revealed that wider gallery is more prone to major and serious accidents than narrower one and major accidents are more likely in thin seams compared to thick coal seams. They also found the unsupported, or partially supported roofs are more prone to major accidents than the supported roofs. They proposed that a great attention should be paid on the support design based on the depth of strata and the gallery width should be restricted to reduce the risks of roof fall.

Yun-bing et al. (2009) established an expert reliability uncertain AHP model to be able to overcome the difficulties of the statistic weighting in the traditional method. They stated that the model can solve the problem of expert decision reliability more objectively and scientifically, and thus improves the accuracy and reliability of assessment results. Lilic et al., (2010) applied combined Artificial Intelligence (AI) methods, a hybrid system which is combination of neural networks and expert system technology, in the analysis and estimation of the state of mining environment safety in the opencast mine Kolubara Field D, the largest coal opencast mine in Serbia. The new system called as PROTECTOR has been formed. The base of the system bears the expert knowledge in the mine safety area (Lilic et al., 2010). The parameters like gas, dust, climate, noise, vibration, illumination, geotechnical hazard mainly which determine the general mine safety state and category of hazard in mining environment were estimated by the system. The authors concluded that a reduction in mine injuries as well as an improvement in the overall state of the mine safety has been achieved after implementation of the system.

Patterson and Shappell (2010) used a modified version of the Human Factors Analysis and Classification System (HFACS), an investigation framework that utilizes a system approach, to analyze incident and accident cases from across the state of QLD to identify human factor trends and system deficiencies within mining. The results of the study revealed that skill-based errors were the most frequent unsafe event and does not differ according to the mine type. But decision errors varies from mine to mine (Patterson and Shappell, 2010). They concluded that the created framework could be used to systematically identify underlying human factor causes in mining incidents and accidents. In the study performed by Onder and Adiguzel (2010), data covering the occupational fatalities occurred in the period of 1980–2004 in TTK was studied. Hierarchical loglinear analysis method was applied in the study. The accident records were evaluated and the factors affecting the accidents were identified as mine, age, occupation, and accident type. Considering the other factors, multi way contingency tables were prepared and the probabilities might affect fatality accidents were analyzed. The study showed that production workers are the mostly affected workers considering fatal accidents and roof collapses and methane explosions are two main accident types they were exposed.

With increasing utilization of coal resources in People's Republic China (PRC) the research studies especially about the risk analysis in coal mines has also increased. In 2011 there have been so many studies on the risk analysis and risk assessment for coal mines in the country. Some of them are as follows:

Lirong et al. (2011) investigated 26 huge coal mining accidents causing more than 100 fatalities in China between the years of 1949 and 2009 by statistical methods to review the general situation and supply information on major accidents of coal mines in China. Statistical properties of factors related with accidents such as time, death toll, accident reasons, characteristics and nature of enterprise were analyzed in the study. Some special recommendation were put forth by Lirong et al. (2011) on safety management of China coal mining, including the perfection of safety supervision organization, the establishment of cooperating agency among government, coal mines and workers, the perfection of safety rules and regulations, the improvement of safety investment, the enhancement of safety training, the development of safety technique, and the development of emergency rescue technique and equipment.

The factors of coal mine accidents were differentiated and analyzed by Liang et al. (2011) and they established a coal mine accident causation model on a combination of hazard theory and energy accidental releasing theory in order to analyze the roof-fall accidents of Baishui Coal Mine. Using the hazard theory, the accident causation in coal mine production system has been divided into three as inherent hazards, technology equipment defects and safety management misconducts. The authors concluded that the level of technology and equipment determines the basic safety standards of the coal mine, and safety management is a powerful tool for improving the technology and equipment level. Na and Yi (2011) investigated 433 gas explosion accidents causing 10056 fatalities during 1950-2006 in order to find the unsafe behaviors causing the highest coal mine death toll accident of gas explosions. They proposed two unsafe behavior correction methods, scenario design and virtual reality games in order to correct the unsafe behaviors in Chinese coal mines. Kun et al. (2011) proposed a renovated fuzzy overall model based on expert judgement in order to evaluate safety culture of coal mine enterprises and applied to the three coal enterprises. They concluded that the fuzzy overall evaluation model can be used for evaluating the safety degree of coal mine enterprises. Zhu-wu et al. (2011) built up a risk assessment model for occupational hazards in coal mine based on the Hazard Theory developed by Prof. Tian Shui-chen and then evaluated three distinct coal faces using fuzzy comprehensive evaluation method to demonstrate the rationality and practicability of the model. The results of the study reveals that the occupational hazard prevention and control should be focused on the supervision and control of the third dangerous sources. Zhu-wu et al. (2011) concluded that the study is helpful to the improvement of theory and work quality of the occupational hazard prevention and control. De-Shun and Kai-li (2011) established a risk assessment model and introduced generalized set pair analysis (GSPA) and proposed a subjective weight based on GSPA-IAHP (generalized set pair analysis-interval analytic hierarchy process) in order to make full use of the interval information of the certainty and uncertainty. At the end, they concluded that the subjective weight based on GSPA-IAHP is more scientific and reasonable.

Five hundred and sixty two machinery and haulage equipment related accidents between 2000 and 2007 were studied by Ruff et al. (2011) using MSHA database. The aim of the study was to understand the contributing factors in the accidents, to determine whether it is necessary to focus for certain types of equipment or mines and to propose new ideas. They classified accidents accordingly with MSHA’s classifications of powered haulage, machinery and hoisting. They found that, as indicated in the other studies, severe injuries involving, stationary and mobile machineries have accounted for more than 40% of all severe accidents at mining operations in the United States. Most severe accidents were associated with the operation or maintenance of the machines. According to the results of the study conveyors, rock bolting machines, milling machines and haulage equipment are the major instruments causing occupational accidents. They concluded that additional emphasis on safety interventions and training should be directed towards these machineries, especially for tasks associated with machine maintenance. In order to decrease accidents further, researchers recommended additional efforts in the development of new control technologies, training materials and dissemination of information on best practices. Ruff et al. (2011) also proposed much more close partnerships between the mining industry, machine manufacturers, labor organizations, government regulators and research organizations in order to make significant reductions in mining accidents and injuries.

Guoyu and Chuanlong (2012) investigated the effect of the psychological state in the coal mine accidents and used fuzzy mathematical theory to evaluate the factors affecting the miner's healthy psychological state. They concluded that safety psychology education has a great significance in the coal mine safety production. Wenbi et al. (2012) studied 146 roof fall accidents between 1980 and 2000 using the triangular fuzzy algorithm combined with traditional fault tree. They found that large area of empty-support is the greatest hazard sources in roof fall accident. Yunxiao and Ming (2012) formed a hazard list for coal-mine in China through studying the relationship between hazard and accident and analyzing the three components of hazard elements, initiating mechanism and target and thread.

Ghasemi et al. (2012) developed a methodology to assess and control the roof fall risk in room and pillar mines during retreat mining using semi-quantitative techniques. After identifying all the effective parameters under three main categories, they explained their roles using Joy's pre-proposed probability tables and weighted them form the judgements of mining engineers and ground control experts. They also applied their methodology to the main panel of Tabas Central Mine of Iran. They concluded that the proposed methodology is easy and does not require extensive training.

In comparison to their Turkish colleagues, Onder (2013) used a logistic regression analysis method in order to predict the probability of accidents that resulted in greater or less than three days lost in an opencast coal mine for Western Lignite Corporation of Turkish Coal Enterprises between 1996 and 2009. He analyzed the significance values (p) to examine the effects of independent variables on days lost. A simple binary logistic regression analysis was used for each independent variable to establish its statistical significance and possibility for inclusion in the model. To generate an equation for calculating the probability of exposure to accidents with greater or less than three days lost, a binary logistic regression model was also created. His study revealed that the job groups with the highest probability of exposure to accidents with greater than three days lost were maintenance personnel and workers excluding fatalities. According to the results of the study the workshops were the highest risky area and lower and upper extremities were the most affected part of the body. The other finding was that the age group with the highest probability of exposure to accidents resulting days lost greater than three was the 25–34 age group. He concluded that from evaluating the significant parameters from the analyses together, the maintenance personnel working in the workshops have the highest probability of exposure to accidents with greater than three days lost. Looking at the findings, the author proposed use of protective equipment for lower and upper extremities and providing the maintenance person with special training related to their profession. This education should include ergonomic hand carrying, careful use of hand tools, working at high, and importance of using personal protective equipment (Onder, 2013).

Yu and Chen (2013) analyzed the seasonal relationship between the fatal mine accidents and production output pressure using an error correction model (ECM). They found that there is a strong causal relationship between those parameters in the short and long term, and they made some recommendations to deal with the seasonal variation in coal mine accident fatalities. Yu and Chen (2013) recommended that coal mines should increase their investment in safe work practices. Smoothing the peak load production across the year and setting production output ceiling for each mine by the government were also recommended by Yu and Chen (2013).

Eratak (2014) analyzed the accident data regarding days lost, age, injured part, season, and shift of the accidents for Turkish Coal Enterprises (TKI) and TTK mines. In the study, a risk analysis and risk assessment study was performed. Risk matrices were developed and the most hazardous working places were determined and TTK and TKİ were compared also. In the study, regression, neural network and fuzzy logic techniques have been applied. These techniques applied to all data and decision analysis was made to choose the most suitable technique by comparing the results. In the study carried out by Eratak (2014) it was also aimed to develop a model for severity component using the applied techniques. Accident estimation models were developed based on the data such as number of accidents, deaths, injured, total working hours, total workers and total raw coal production of those mines. Eratak (2014) concluded that hard coal mines are much more hazardous than lignite mines and hard coal mines have different risk reasons compared to lignite mines. The results of the study revealed that fatalities are mainly related to gas or dust explosions, blasting and strata problems in hard coal mines while machinery o equipment is the major risk in lignite mines. Hajakbari and Bidgoli (2014) proposed a new scoring system to classify workplaces and determine their risk levels using data mining techniques. The proposed model is based on calculating five main variables: Difference, Frequency, Severity, Risk, and Monetary (DFSRM). After examining and processing the 2010 and 2011 data coming from the technical reports of the Iran Ministry of Labor and Social Affairs, they identified 21 workplaces as critical to be inspected in 2012.

Onder et al. (2014) examined the accident data for underground mines of TKİ, in order to determine the degree of relationship between the categorized variables and assess the risks of occupational accidents. For the study, a total of 1,135 occupational injuries and 3 occupational fatalities which were reported in 1996–2009 were scrutinized. They used the hierarchical loglinear model which 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. The loglinear model used in this study is constructed from a five-way contingency table of occupation, area, reason, accident time and part of body. Occupational injuries were evaluated with respect to occupation, area, reason, accident time and part of body affected. Their study showed that the coal winners were more likely to be injured than the other workers and the largest proportion of occupational injuries occurred in the faces mostly due to roof falls, whereas mechanic-electrician had high risk due to machinery. Faces had the highest risk of exposing to an accident due to roof falls and struck by object. Upper extremities were the most affected part of body while lower extremities and torso had a similar risk but head had a lower risk. The results of the study showed that torso and head injuries were mostly caused by manual and mechanical handling; moreover, occupational injuries related to roof falls affected lower extremities. At the end, they recommended use of improved supporting systems and if possible mechanized systems instead of manual handling operations. They also proposed, as in the previous study, use of protective equipment and training of workers related to work accidents and accordingly with their professions.

Mahdevari et al. (2014) after scrutinizing hazards and potential incidents from the three underground coal mines located at the Kerman coal deposits of Iran identified 86 events and categorized them into eight and proposed a risk management methodology based on fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to provide decision-making support regarding choice of solutions and control measures of human health and safety. At the end, they identified 12 events having high hazards and applied the hierarchy procedure of risk control to address those risks. They concluded that the proposed methodology can be a reliable technique for management of the minatory hazards and coping with uncertainties affecting the health and safety of miners in the absence of quantitative data. Choi (2014) conducted a formal analytical study on sustainability of the mining operations with respect to the mining quantity decision. The number of accidents occurring in a mining operation was modeled as a Poisson distribution with a quantity dependent distribution parameter and the objective function was formulated via the mean-variance approach. Analytic constraints and corporate social responsibility were incorporated into the model. After analyzing the conditions under which the mining company should consider implementing the pollutant reduction technology and the accident reduction technology they found that the mining company's degree of risk aversion affects the choice of pollutant reduction technology, but not the accident reduction technology.

Sanmiquel et al. (2015) searched main causes of nearly 70 thousands occupational incidents recorded in the Spanish mining sector between 2003-2012 using data mining techniques such as Bayesian classifiers, decision trees or contingency tables. They collected 58 variables but selected only 15 variables of which type of accident and days lost were considered as response while the remaining thirteen variables (age, experience, size, contract, previous causes, place, physical activity, preventive organization, risk, day week, hour day, work hours and contractual status) as predictors. They found that most of the accidents are originating from the variables of previous causes, place, size, physical activity, preventive organizations, experience and age. They also concluded that the two variables, type of accident and days lost can be used to measure the severity of the accidents.

Geng et al. (2015) scrutinized the official mining safety statistics obtained from the Chinese State Administration of Work Safety (SAWS) Official Online Accident Database between 2000 and 2014 and studied the relation of the rate of fatal accidents with structural and legislative changes. They also inquired the reliability of data in the study. They found that significant under-reporting and/or data manipulation of fatality numbers together with mis-classification of accidents such as natural disasters make the data before 2007 unreliable. They also argued that the official fatality statistics may underestimate the actual fatality numbers by a factor ranging from 3 to 5. At the end, they established a risk matrix of coal mines and proposed a prioritized list of coal mining hazards for targeted safety interventions and improvements accordingly.

In risk assessment studies, depending on the availability of related data different methods are utilized. In case of absence of adequate data in calculating corresponding hazards some qualitative techniques are applied. Bayesian approach may be an alternative in estimating probabilities in the calculations. Expert opinions are also very important in that cases. There are different techniques to minimize the uncertainties in risk assessment studies. Fuzzy logic, analytical hierarchical process are some examples to these techniques.

On the other hand, if there is sufficient data to calculate the required parameters in a risk assessment study, quantitative methodologies can be used. In that case statistical analysis could be utilized to derive some evaluations regarding risk analysis. Additionally, distribution functions could be used in calculating frequencies and probabilities of related items. Relative cost criterion is a method used to estimate the cost of related hazards.

After defining risks and estimating their values the next step is supporting decision makers by presenting different alternatives to minimize risks. Decision trees is an approach to support decision makers in that.

Table 3 shows some methodologies handled in risk analysis and risk assessment studies. In all studies carried out in the past, different data sets have been scrutinized and different methods have been applied (Table 3). General statistical analysis, loglinear analysis, distribution functions, fuzzy logic, neural network, regression analysis, normalization, contingency tables, time series, multivariate analysis, analytical hierarchical process, chi square test, T test, relative cost criterion, decision tree, hazard theory, risk matrices are some specific examples used at past.

Table 3 Some major methodologies used in risk analysis and risk assessment and risk management studies

Type of Data Analyzed	Applied Methodologies	Reference
Coal Mine Accidents	Renovated Fuzzy Overall Model, Neural Network Hazard Theory and Fuzzy Comprehensive Evaluation Method GSPA-IAHP, Data Mining DFSRM, AHP and Grey Clustering Method HFACS, Statistical Analysis, Logistic Regression Cause-wise Hazard Rateand Cumulative Risk Functions Hierarchical Loglinear model (saturated model) Semi Quantitative Technique, Bayesian Classifier Contingency Tables, Decision Tables, Hierarchy Procedure Fuzzy TOPSIS, Mean-variance Approach Statistical analysis and Null Hypothesis Technique	Maiti and Bhattacherjee(2001) Sari et al. (2004) Ya-jing et al.(2007) Maiti et al. (2009), Paul (2009) Lilic et al.(2009) Patterson and Shappell (2010) Lirong et al. (2011), Zhu-wu et al. (2011) De-Shun et al.(2010), Lirong et al.(2010) Hajakbari and Bigdoli (2014) Guoyu and Chuanlong (2012) Yunxiao and Ming (2011) Onder and Adiguzel (2010) Onder et al. (2014), Sanmiquel et al. (2015) Mahdevari et al.(2014),Choi (2014)
Roof Falls and Roof and Side Fall Fatal Accidents	Loglinear Analysis of Contingency Tables, Monte Carlo Simulation Relative Cost Criterion, Decision Tree Logistic Regression Model, Energy Accidental Releasing Theory Triangular Fuzzy Algorithm, Fault Tree, Semi Quantitative Technique	Duzgun and Einstein(2004) Duzgun(2005) Maiti and Khanzode (2008) Palei and Das (2009), Liang et al.(2011) Wenbi et al. (2011), Ghasemi et al.(2012)
Days Lost Injuries	Mean Variance Approach, Risk Matrices, Decision Tree Regression, Neural Networks and Fuzzy Logic Technique Generalized Estimating Equations (GEE), Time Series Analyses	Coleman et al.(2007) Komljenovic et al.(2007) Poplin et al. (2008), Sari et al. (2009) Eratak (2014)

Table 3 (continued)

Type of Data Analyzed	Applied Methodologies	Reference
Blasting Injuries Equipment Related Accidents Behavioral Factors in Accidents Explosions	Statistical Analysis, Frequency Distributions	Bajpayee et al.(2004), Kecojevic et all.(2007), Groves et al.(2007),Paul and Maiti(2007) Thomas and Dubaniewicz (2009) Zheng et al.(2009) Na and Yi (2011), Ruff et al. (2011)
Fatal Mine Accidents	Regression models, Hierarchical Grey Analysis PHA, Risk Matrix, Error Correction Model	Karra (2005), Liu et all.(2004) Yu and Chen (2013) Md-Nor et al.(2008), Geng et al.(2014)
Mine Fire and Explosions	An Expansion of the Generic Risk Matrix	Grayson et. all. (2009)
Mine Floods	Multivariate analysis	Wang et all.(2008)

CHAPTER 3

RISK ASSESMENT METHODS

Risk Assessment covers three main stages which are identification of risk, analysis of risk and evaluation of risk (web 4). In the first stage, the working environment and operating context should be understood well. Danger which does not contain any estimation should be defined first in risk assessment (Duzgun 2005). It is very important that during this stage all risks are determined and recorded.

The second stage is the analysis of risk which contains the determination of level and nature of risks. The assessment of the probability of the event which is called hazard (Duzgun 2005) should be handled in this stage. Determining the consequences of risk is another step in risk analysis. Finally, relating the probabilities with the consequences of the hazard comprises risk (Duzgun 2005). The degree of risk could be predicted by using statistical analysis and calculations.

The third stage of risk assessment is evaluation of risks. In this stage decisions have to be made considering the identified risk levels and analysts should consider the risk management criteria while making decisions. At this stage it should be decided which risks are going to be tackled which are not.

Risk assessment could be carried out by qualitatively or quantitatively depending on the availability of related data. In the case of availability of enough data the quantitative techniques are applied and all the results are obtained quantitatively. On the other hand, if there is not enough data to be able to carry out quantitative methods, the qualitative techniques are applied taking into account expert opinions. In this chapter, frequently used risk assessment methods are briefly described.

3.1 Qualitative Methods

Qualitative risk analysis is used more frequently since it is simple and quick to perform. In qualitative methods, the potential loss and hazard is qualitatively estimated and linguistic scales are used such as low, medium and high (web 3). In this type of methods a matrix is formed and it characterizes risk in the form of the frequency of the loss versus potential magnitudes of the loss in qualitative scales. Policy and risk management decisions are defined based on the matrix. However, qualitative risk analysis is excessively subjective. Therefore, this type of risk analysis can be chosen for simple systems like a single product safety, simple physical security, and straightforward processes (Modarres, 2016). The following subsections briefly describes the qualitative risk assessment methods.

3.1.1. Risk Matrix Method

It also known as operational risk management (ORM). One of the dimensions is probability (hazard) dimension and it is broken into qualitative categories such as improbable, remote, occasional, probable and frequent, which are generally defined in a narrative manner. In the same way, the other dimension, which is loss or consequences, is broken into a number of qualitative categories such as negligible, marginal, critical and catastrophic (Figure 4). Examining the evidence and assessing the risk is possible if the probability and consequence categories are given evidence based definitions (Corps, 2016).

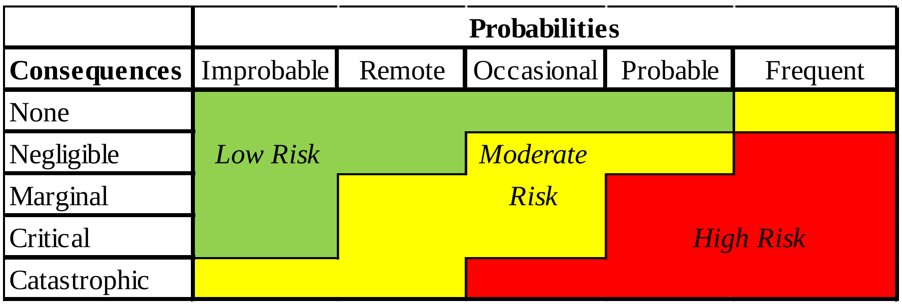


Figure 4 Sample risk matrix

In this technique, a set of mutually exclusive and collectively exhaustive evidence based probability and consequence categories are defined. After that, collecting evidence to support the rating for the probability and consequence of each potential risk becomes the basis for risk matrix. A list of potential risk items or elements, each of which has a probability and consequence rating that is defined on the basis of the evidence, is the output of the technique. Every item on the list of assessed risks are placed in one of the cells in the risk matrix. The cells are categorized into subjective ordinal clusters like red, yellow or green. Red typically indicates cells with an unacceptable risk, yellow identifies moderate risks and green indicate no immediate concern (Corps, 2016).

The strength of this method is that it summarizes both the consequence of a potential risk and its probability of occurrence based on the available evidence systematically. However, its weakness is that it is one of the most easily abused risk assessment tools. Rating or scoring of consequence are usually assigned arbitrarily and without considering available evidences (Corps, 2016).

3.1.2. Delphi Method

It can be described as a practice in group communication among geographically dispersed experts. The experts can evaluate a complex problem or task systematically with this method which is fairly straightforward. A series of questionnaires are delivered to a experts by mail, message, *etc*. They are designed to reveal and develop personal responses to the problems. Also, the experts can reflect their opinions as the team work progresses in accordance with the assigned task (Mario-Sanchez, 2005).

The main advantage of Delphi method is that questionnaires can be directed to several experts of varied background, hence different opinions and evaluations can be filed into a single document. However, the main disadvantage is the high demand of resources. The evaluators must be coordinated, informed, controlled and communicated with all this demands such as money, time and material (Mario-Sanchez, 2005).

3.1.3. Evidence Mapping Method

Evidence maps are useful when the data are incomplete, inconsistent or contradictory. It is helpful with summarizing information and defining that it is certain or uncertain. The basic components of an evidence mapping are;

- a well-defined potential hazard,
- the evidence basis such as number and quality of relevant scientific, engineering or economic studies,
- a panel or discussion of experts to review the evidence,
- the pros and cons arguments,
- the conclusions with remaining identified uncertainties about the issue.

The risk assessment process for the evidence map should consider the related studies with input from an expert panel. These studies should be reached with literature search. Then an expert can extract arguments for hazard or risk and contra-arguments against for hazard or risk. Then, some tentative conclusions about the hazard or risk are drawn while noting remaining uncertainties about the issue. The output of the evidence mapping assessment is a map of the arguments for hazard and contra-arguments against for hazard along with the remaining uncertainties (Figure 5). This method can give information about the current state of the scientific evidence and provides an unbiased summary of what is and is not known about the issue that can emphasize the strength of evidence mapping. This method is well suited to cases where there are contradictory opinions a case or issue. However, the weakness of it is that it cannot be applied unless a reasonable evidence base exists (Corps, 2016).

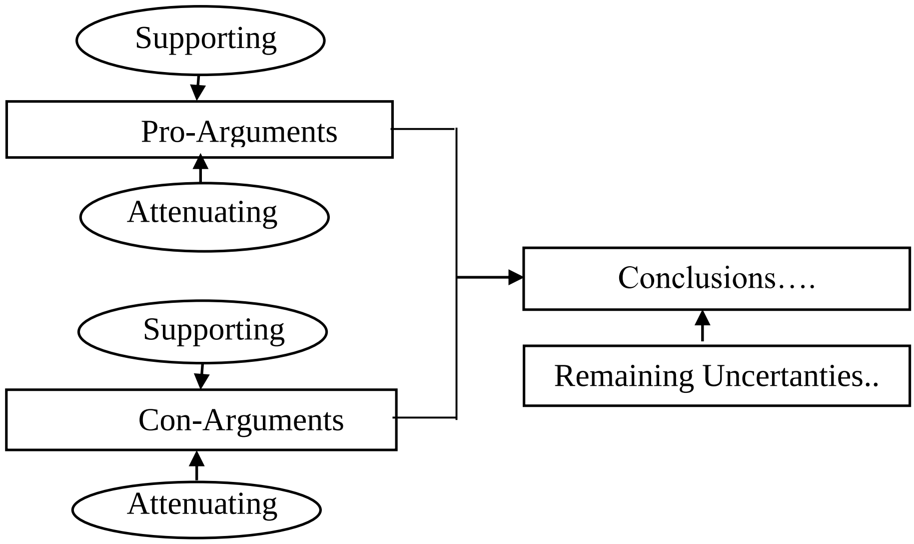


Figure 5 Example evidence map template (Wiedmann et al, 2008).

3.1.4. Risk Narrative Method

It includes a narrative description to identify hazard or probability, consequence and risk definition. The risk narrative method should answer the four basic questions of the risk assessment with available evidence. This method is suitable in cases where risk level and uncertainties are low. The decision makers do not need to know details of risk assessment. However, they need an overview of the risk level and the implications. The narrative method is robust and flexible that can be used for any of the risk assessment problems. An effective risk narrative should point risk story, risk reduction story and describe effectiveness of risk management options. It should also find out possibility of residual, transferred or transformed risks (Corps, 2016).

Risk narratives are valuable as a first step risk assessment in many cases because they can supply sufficient information for decision making. The strengths of risk narrative are a definition of the risk given the available evidence, an account of the available evidence and a risk hypothesis that identifies the remaining uncertainty. On the contrary, the weaknesses of it is incomplete risk hypotheses when uncertainty is great (Corps, 2016).

3.1.5. Ordering Techniques

The ordering techniques can be used to define hazards, risk potential, pathways, mitigation measures, *etc*. They involve screening, rating and ranking. They require increasing levels of detail and information.

Screening can be applied to define hazards of potential concern or no concern. In screening technique, the elements are separated into one or more categories. It is not the tool used to find the best item among or within the groupings because it is a tool used to create groups. Items to be separated, carefully defined categories, evidence criteria for separating items into categories and a method are the main inputs for screening (Corps, 2016).

A list of items or elements that is sorted into the mutually exclusive and collectively exhaustive categories of interest is the output of a screening process. The main advantages are simplicity, reliance on evidence and ease of documentation. On the other hand, the disadvantage of this method is that items in the piles cannot be differentiated from one another. Only the grouping of items is differentiated (Corps, 2016).

Rating is a systematic tool of separating items or elements into multiple categories or groups of varying degrees of interest. Items with similar ratings are collected into similar categories where the categories usually have an ordinal logic to them. Individual items may be rated high, medium, low or no risk. The main inputs for a rating system which are items to be rated, defined rating categories, evidence based criteria for ratings, evidence and a well-defined method for rating the items are basically the same as screening technique (Corps, 2016).

The rating technique compile the list of items to be rated and then identify the rating categories. The rating is more than simply identifying items are rated high, medium or low. It objectively defines the criteria for rating an item high, medium or low. This process requires analysis to identify the evidence based criteria. This criteria is used in the rating. If the rating is not defined based on objective evidence, the rating system is a limited tool in risk assessment. The output of rating technique is a rating for each item in the list. The strength of the technique is flexibility, reproducibility and as well as a finer degree of intuition than simple screening. The main weakness is that the process is sometimes abused and the ratings are defined subjectively (Corps, 2016).

A ranking technique process is similar to a rating technique but it assigns a scale of one item relative to other items. Therefore, there is an ordinal logic. In ranking system inputs are the same with screening or ratings. However, this process can also add the element of weighting the importance of various criteria (Corps, 2016).

3.1.6. Brainstorming Method

It is a useful method for identifying hazards, risks, decision criteria, risk management options. The main point of it is that generating ideas from a group of experts (participants). A large number of ideas in a limited time can be generated by this method. A well-defined problem, a group of people with knowledge of the case or problem, a brainstorming technique, a moderator or facilitator and means to record and disseminate the results are the inputs for a successful brainstorming (Corps, 2016).

One of the main advantages of brainstorming is containing the ability to refresh ideas and using every ones input to develop specific opinions, on the other hand disadvantages of it is including the hindrance that it can impose on an individual's creativity (web 5).

3.1.7. Interview Method

The basic idea of this technique is that individual experts are asked a set of questions. Interviews can be defined as an important and useful technique for risk and uncertainty identification. It can be classified as structured interviews and semi-structured interviews.

Structured interviews are held by using prescript questions. Semi-structured interview is not rigid as structured one. Therefore, it allows the conversation to explore topics that arise during interview. The experts can be encouraged to analyze problems with different perspectives by a well-constructed interviews. This type of technique is more useful when it is undesirable to get people together for brainstorming (Corps, 2016).

3.1.8. Expert Opinion Method

It is a useful technique for risk identification. It is a systematic process of formalizing and usually quantifying, often in probabilistic terms, expert judgments about uncertain quantities. It is discussed here among the qualitative methods because it has also been used to elicit qualitative judgments about matters of uncertain facts. The process generally involves integrating data with scientific judgment and determining a range of possible outcomes and probabilities. Thus, it can also be a quantitative technique. Documenting the underlying thought processes of experts is the essence of the process (Corps, 2016).

Defining the problem by identification, selection and development of technical issues, sharing the body of evidence with experts, formal elicitation to encode the experts' judgments are some of the essential inputs to expert opinion method.

Once a decision problem is defined and the technical issues have been determined, the experts have been identified, and the relevant evidence has been shared, it is common to have a facilitated discussion with the experts to refine the issues. Here the experts define the scope of the problem, clarify terminology and all contextual matters that will influence their ability to render judgment. At this point, the experts are trained for the elicitation process. The elicitation process is facilitated according to a chosen protocol. A protocol provides for the elicitation of opinions, analysis, aggregation, revision of those opinions, and the development of a consensus when one is needed. The best processes may include a peer review. The outputs of the process include the expressed consensus, judgment or degree of belief expressed qualitatively or, at times, quantitatively (typically probabilistically) (Corps, 2016).

Getting the valuable views of experienced experts from different perspectives and obtaining some estimates for the missing data and information are the main advantages of the method. On the other hand, finding informed experts may be difficult and the evaluation of each expert may not be at the same calibration (Corps, 2016).

3.2 Quantitative Methods

In quantitative methods, the uncertainty related with estimation of occurrence of the undesirable events' probability and magnitude of hazards (consequences) are defined by the probability concepts. Quantitative risk assessment should be chosen as a tool when adequate field data, test data and other evidences exist to estimate the probability and magnitude of hazards. In recent years, usage of this type of risk analysis has been rising due to availability of different type of quantitative techniques and also the rise in ability to make quantitative estimation with limited data.

3.2.1. Direct Quantitative Risk Calculation Method

The way of perceiving the risks is related with the way they are calculated (Sari et al., 2009). If historical data is available, it is easy to illustrate a risk calculated from the existing data to identify some characteristics of risk estimation (Sari et al., 2009). In the studies performed by Duzgun (2004) and Sari et al. (2009), since there exist sufficient historical data, the risk is calculated quantitatively. In the calculation of risk, hazard and consequences, which are the two main components of risk, are calculated first. In this calculation, the frequencies are used for the calculation of hazard and the consequences in the form of days lost or estimated cost are used for the calculation of severities. Duzgun (2004) applied a Relative Cost Criterion for the calculation of severities of roof fall accidents in underground coal mines. However, in the study carried out by Sari et al. (2009), days lost values due to the underground coal mine accidents were used in the calculation of the severity component. The determined frequency and severity functions are fitted to suitable distribution functions to estimate the probabilities. After the determination of risks, the risks are evaluated. Duzgun (2004) applied decision tree method to evaluate the suggested support improvement alternatives considering the expected values of these alternatives.

3.2.2. Event Tree Method

It can be used either qualitative or quantitative technique to model a system or sequence of events. In this technique, events are represented by nodes. Chance events are represented by circles, decisions by squares and endpoints by triangles (Corps, 2016). A sample of event tree is given in Figure 6.

In event tree analysis, the events or nodes are assumed to be defined by chance. It is the distinguishing characteristic of this type of analysis. No decisions are identified to be made along any of the pathways. If decision points are included in an event tree, it can be called as the technique a decision tree. Probabilities of the various possible outputs are estimated by event trees which is also called as probability trees. Therefore, it is suitable to answer “what happens if...?” question. The event tree analysis is a preferable technique to model failure modes where there are multiple modes of failure. To compile a quantitative event tree, sufficient data is needed to

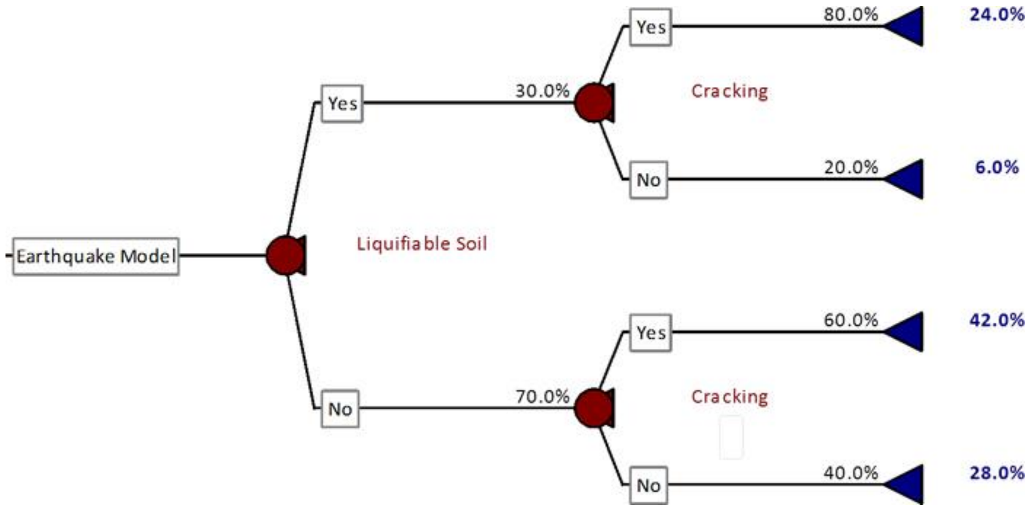


Figure 6 Simple event tree of earthquake effect on a concrete monolith (Corps, 2016)

quantify failure of the system under consideration. Probabilities for each branch emerging from a node are estimated in quantitative event tree and they are usually listed above the branch. If there are some additional consequences which are included in the analysis, they are listed in the branch. Each probability is a conditional likelihood estimated on the nodes and branches that preceded it (Corps, 2016). Direk (2015) and Mevsim (2016) applied this method in their studies. Direk (2015) used Fault Tree Analysis (FTA) to determine major causes of roof and rib falls in underground coal mines. Mevsim (2016) implemented the FTA in order to determine the main reasons for firedamp explosions in underground coal mines.

3.2.3. Multi-Criteria Decision Analysis (MCDA)

The multi-criteria decision analysis (MCDA) is designed for decision problems that involve multiple criteria. Several decision weighting methods are involved in MCDA technique. It can be used in establishing a ranking between alternatives. In qualitative methods, enhanced evidence based or criteria based ranking process can be applied.

MCDA technique can be combined with other methods like rating, ranking, and expert opinion. Besides it may also be used with scenario building techniques. The main strength of the MCDA technique is that it can answer multiple criteria decision questions. It can also point out sensitivity of solution to different weights and range of uncertainty level. However, the weights are assigned subjectively. It is difficult to decide and get agreement on the most proper set of weights in many decision problems. Also, different applied techniques can assign different rankings of alternatives. In addition, different algorithms can yield different rankings of alternatives (Corps, 2016).

3.2.4. Monte Carlo Simulation

It consists of generating random numbers in compliance with assumed probabilities linked with a source of uncertainty. The technique simulates a case by selecting random values for each variables and selected random values are used for single simulation. The random values are selected from the probability distribution of variables. The simulation procedure repeated with random scenarios and probability distribution of outcomes is estimated and they can be used to statistical analysis (Erdem, 2008).

Monte Carlo Simulation technique is a valuable tool in risk assessment field because the probable outcome and impact of the hazards can be simulated but it requires large number of simulations.

CHAPTER 4

THE DEVELOPED RISK ASSESSMENT METHODOLOGY

The proposed methodology involves two main parts, namely data analysis and risk assessment. Figure 7 illustrates the developed model in this study. Data analysis is

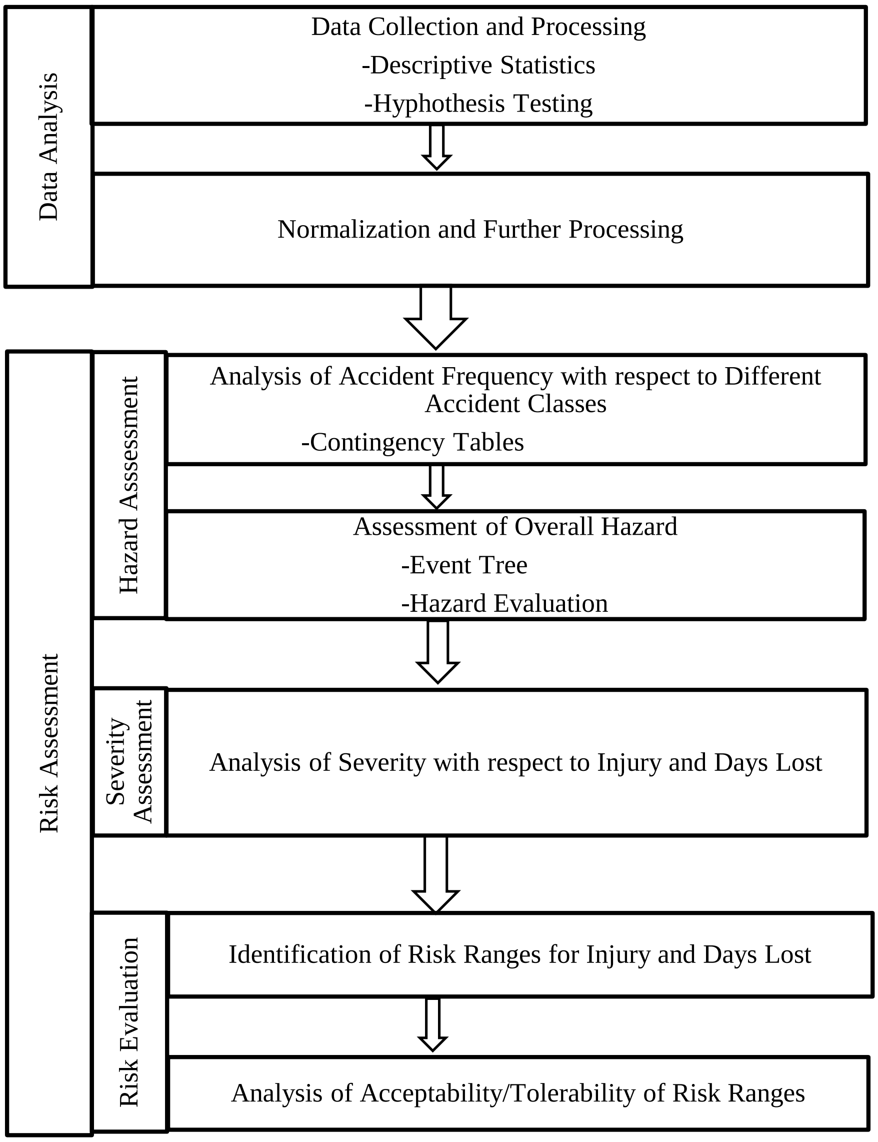


Figure 7 The developed methodology

composed of data collection and processing as well as normalization steps. Risk assessment has three main stages, hazard and severity assessments and risk evaluation (Figure 7).The following subsections describe the details of each stage.

4.1 Data Analysis

The first step of all risk assessment studies is the analysis of existing data. In this study the data analysis is carried out taking into consideration the previous analysis for the occupational accidents for underground mining sector in the literature.

TTK has an excellent data set regarding occupational accident records. The raw data is obtained from the enterprise as data set covering all the accident records for each mine for fifteen year period between 2000 and 2014.

The data set contains many parameters related with the occupational accidents. Hence, they are processed according to the needs of the study. For this purpose, first occupational accidents on the surface are extracted from the set. In the second step, fatal underground accidents are separated from the overall data set to analyze them separately. In this context, all columns in the data set are scrutinized one by one and all related variables like type of accident, location of accident, main duty and assigned duty of casualty, age, experience and education level of casualty, injury and days lost values are extracted and tabulated for accidents resulting injury or fatality in all mines for the period of 2000 and 2014. The mines are compared with respect to all variables. Underground occupational accidents are analyzed for abovementioned variables.

After completing the data collection and obtaining all the necessary variables, basic statistical analysis are carried out on the filtered data to evaluate the underground occupational accidents in TTK. All variables are evaluated for each mine including the yearly changes. These analysis provide comparison of the mines in the basin.

All the data is normalized using run of mine coal production, number of workers and unit production in order to remove the effect of the production and the number of workers on the number of accidents. With normalization of the number of accident and days lost data it becomes possible to compare the mines having different number of workers and different productions with respect to these variables. Additionally, it is also possible by normalization to evaluate the changes in these variables through years by eliminating the changes in the number of workers and amount of productions between years.

4.2 Risk Assessment

It is the second step in the proposed methodology. As shown in Figure 7, hazard and severity assessments are two important parts of risk assessment study. Hazards are determined and categorized according to their characteristics. Later, severities in terms of the injury and days lost are calculated. At the last step injury and days lost for each mine are determined and risks are evaluated.

Hazard is the probability of a danger that may cause to an adverse event (Düzgün, 2005) which is accident in this case. Hazard assessment is carried out mainly in two stages. Firstly, using contingency tables related accident frequencies and probabilities are determined for each category and for each mine. Secondly, the event trees for each hazard category are prepared.

Using contingency tables the probabilities of accidents for each type of variable are found. The hazards are grouped into three as individual, operational and locational in the study. The hazards resulting from the individual characteristics (e.g. age, experience) are named as individual hazard, the hazards directly related with the operations (e.g. transportation, material handling, demontage, mechanical/electrical) in the mine are handled as operational hazard and the hazards regarding to the working environment (e.g. working places) are called as locational hazards. All hazards are calculated using the discrete probability concept and all cross probabilities covering more than one variable are calculated with conditional probability theorem.

After analyzing the hazard profile with respect to defined categories the second step in hazard assessment is the calculation of total hazard for each mine. Total probability theorem is applied in the calculation of total hazard. After the calculation of total hazard for each mine the lower and upper limits of the hazards for the mines are determined as minimum and maximum hazards.

In this study as mentioned earlier, since only the available quantitative data are used and since no assumption or any estimation is done throughout the study, the injuries and the days lost for each underground occupational accident are handled as consequences (severities) of related accidents. Within this context two types of severities are calculated. One is the severity for injury and other is severity for days lost. Severity for injury is calculated from the contingency tables showing the injuries in each mine. By this context, severities in the form of probability for each type of injury are taken into account and these severities are calculated for each mine also. Moreover, severity for days lost is also calculated as the probability of days lost for the related mine considering the average yearly days lost values.

After the determination of severities with respect to injury and days lost risks are calculated and evaluated for two severities. Maximum and minimum risks are defined for each mine for injury and days lost. The acceptability or tolerability of determined risk levels are also evaluated at this stage. Risk evaluation is carried out regarding the calculated risk values which are the minimum and maximum injury and days lost risks. For this purpose the range between minimum and maximum risks is divided into three region linearly. Risks in the lower part are evaluated as acceptable, the risks falling to the middle area are accepted as tolerable and risk values in the upper side is regarded as unacceptable. At this stage mines are compared in terms of risks they involve.

CHAPTER 5

THE CASE STUDY: TURKISH HARD COAL ENTERPRISES

The proposed methodology is implemented for TTK. A brief description of TTK and reason of selecting TTK for the implementation is given in the following subsections. TTK is a state owned organization which is responsible for the operation and administration of all hard coal and coal bed methane activities in Turkey. Coal production is performed in five different mines in TTK namely Amasra, Armutçuk, Karadon, Kozlu and Üzülmez mines.

The structural geology of Zonguldak coal basin is very complex due to existence of various faults, anticlines and synclines (Duzgun, 2005). The geological position of Zonguldak coal basin and the locations of each mine in the basin are illustrated in Figure 8. The Longwall mining method is applied in all of the five mines of the basin. Changing roof and floor conditions and the dip of the coal seams makes the working conditions difficult especially for some of the mines.

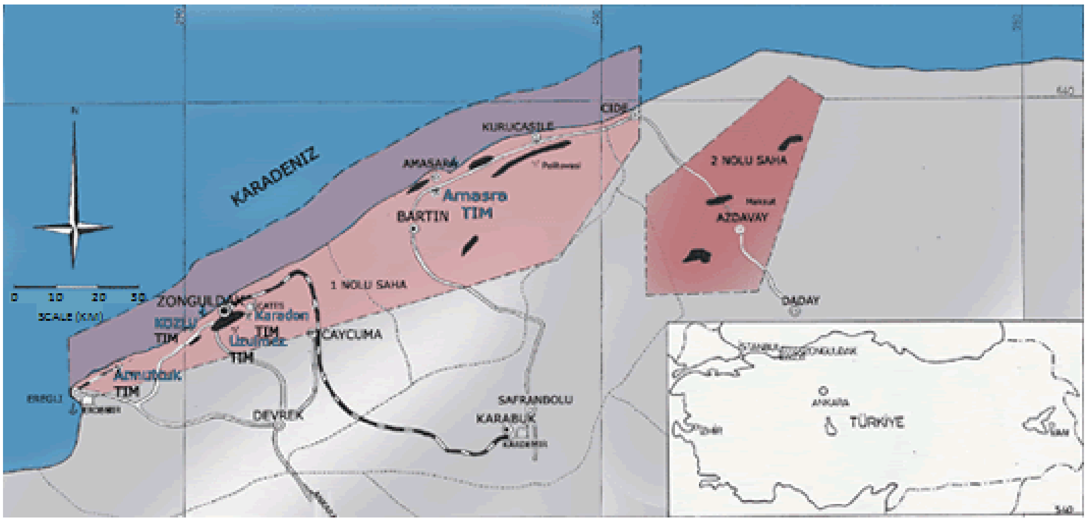


Figure 8 Working area and location of establishments of TTK (Source TTK)

Amasra mine is at very east of the basin. The production activities continue at two coal seams with a thickness ranging from 2.5 to 3.5 meters. The elevation of the coal seams changes between -175 and -300 meters (Annual Report of TTK, 2015).

Armutçuk mine is at the very west of the basin and semi coking coal is extracted at Kandilli-Alacaağzı department of Armutçuk mine. Coal production is performed between -460 and -560 elevations. The seam thickness ranges from three to nine meters and the extracted coal is processed to eliminate tailings and increase its calorific value (Annual Report of TTK, 2015). The nine meters seam thickness is higher than that of other mines.

Karadon mine is at 15 km east of Zonguldak city in the basin and production is performed in the coal fields covering 32 km^2. Coking coal production is performed in Kilimli and Gelik sites. Production activities are carried out at different seven coal seams having elevations ranging from -150 to -490 meters. Coal seams in Karadon mine have slight to moderate dip. Coal seams' thickness ranges from 1.6 to 3.5 meters and the produced coal is processed in Çatalağzı preparation plant (Annual Report of TTK, 2015). In terms of geological structure, the coal field is not faulty and the strata condition is relatively good. However, the moisture content of the coal seam is relatively high which is not desired for mining activities.

Kozlu mine is located in the 8 km west of the Zonguldak city in the basin and the production activities are performed in approximately 12 km^2 area. In this mine, coking coal is produced at -380/-560 elevations with a coal seam thickness of 2.3 to 2.9 meters in five different coal seams (Annual Report of TTK, 2015). Coal seam dip changes between 10-80 degrees in Kozlu mine. Moreoever, the bad roof conditions and existing of faults results in difficult mining operation in the field.

Üzülmez mine is 7 km far from the city of Zonguldak and coal production is performed covering 28 km^2 area. Coal is produced at five different coal seams with thickness ranging from 1.5 to 3.3 meters. In this region coal seams have a gentle slope at north and steep slopes at south. In Üzülmez mine, the elevation of production panels ranges from -35 to -220 meters and the produced coal is processed in

Zonguldak coal preparation plant (Annual Report of TTK, 2015). In Üzülmez mine, faults are not frequent which is good for mining planning and activities. However, at Çaydamar, roof is relatively weak and there is high amount of methane content which are risky in terms of safety issues.

The total hard coal reserve of the region is 1.3 billion tonnes. As illustrated in Table 4 the amount of proven reserve in the region is about 500 million tonnes and 7.5 million tonnes of coal is ready production as of February 2016 (Table 4). Amasra and Karadon mines are two mines having the highest hard coal reserves of 406 and 409 million tonnes of coal, respectively. There is only 32 million tonnes of hard coal reserve in Armutçuk mine and the amount of coal reserve in Üzülmez mine is 303 million tonnes (Table 4).

Table 4 Coal reserves in the region (x1000 tonnes)(Source TTK)

	ARMUTÇUK	AMASRA	ÜZÜLMEZ	KARADON	KOZLU	TOTAL
Possible	7,883	121,535	74,020	119,034	47,975	**370,447**
Probable	15,860	115,052	94,342	159,162	40,539	**424,955**
Proven	6,875	169,015	134,508	129,184	64,276	**503,858**
Ready for Production	1,580	424	399	2,366	2,795	**7,564**
TOTAL	**32,197**	**406,026**	**303,269**	**409,747**	**155,585**	**1,306,824**

5.1 Production and Productivity of the Mines

Although the quality of coal produced in the mines differs this difference is not taken into consideration in this study in order to compare the mines in terms of production and productivity. Table 5 shows the run of mine (ROM) production of all five mines and TTK in total between 2000 and 2014. In terms of production, Karadon mine is at the top with nearly 14 million tons of coal in 15 years among the five mines. Kozlu and Üzülmez mines follow Karadon mine with approximately 9 million tons production. The total production of Amasra and Armutçuk mines are 3.7 and 4.8 million tonnes respectively for the corresponding time interval (Table 5).

Table 5 ROM coal production of the TTK mines between 2000 and 2014 (1000 tonnes)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
AMASRA	277	294	261	234	234	215	211	195	203	240	288	290	250	261	222	3,674
ARMUTÇUK	359	382	382	349	373	378	331	342	332	327	266	252	252	214	214	4,754
KARADON	1,147	1,324	1,124	1,052	974	921	796	810	815	1,044	905	803	806	757	680	13,957
KOZLU	639	665	658	602	541	510	507	555	518	654	683	691	647	519	485	8,873
ÜZÜLMEZ	776	826	822	717	683	597	453	522	467	569	586	571	486	440	482	8,997
TTK	3,197	3,492	3,247	2,954	2,804	2,621	2,297	2,424	2,335	2,833	2,727	2,607	2,441	2,191	2,084	40,255

Figure 9 clearly shows how the production changes through the years in the mines. In general during this interval (2000-2014) the production has decreased in all five mines. But it is not difficult to say that the rate of decrease is not same for all mines.

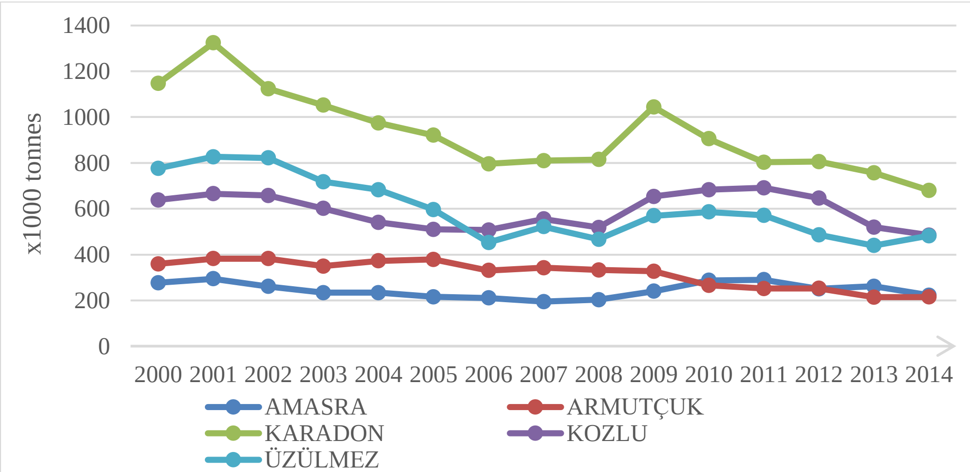


Figure 9 ROM coal production of mines between 2000 and 2014

The production in Karadon mine has decreased more sharply. On the other hand, the amount of decrease in production is relatively small in Kozlu and Üzülmez mines. However, the level of decrease regarding the ROM production is much steadier for Amasra and Armutçuk mines between 2000 and 2014.

Table 6 shows the number of underground workers in the mines between 2000 and 2014. When Table 6 is analyzed the first recognized point is that there are two major dates that show an increase in the number of underground workers. First, there is a slight increase in the number of workers in 2001 in all the mines. There is an increase of 200 workers in total. The second increase is in the year 2009. This increase is more significant than 2001. The total number of underground workers increases approximately 2500 in 2009. The majority of the increase in the number of underground workers belongs to Karadon mine (about 1100 workers). Apart from these two years the number of underground workers decreases steadily from 2000 to 2014 from 13,238 to 7,375, respectively. The change in the number of underground workers is clearly seen on Figure 10. The sharp increase in 2009 especially for Karadon mine is very clear, the second mine in this respect is Kozlu mine with the increase of approximately 600 workers. From now on, throughout the thesis, TTK used in the graphs and tables refers to the total values of five mines.

Table 6 Number of underground workers of TTK mines between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
AMASRA	1,123	1,158	997	890	795	783	625	613	570	718	704	672	625	609	530	11,412
ARMUTÇUK	1,401	1,406	1,300	1,152	1024	1,050	1,056	1,066	983	1,240	1,185	1,154	1,077	1,006	952	17,052
KARADON	4,893	4,968	4,354	3,817	3,321	3,246	3,071	3,045	2,673	3,771	3,597	3,406	3,144	2,924	2,819	53,049
KOZLU	2,447	2,506	2,201	1,975	1,658	1,637	1,544	1,528	1,367	1,980	1,920	1,856	1,707	1,652	1,595	27,573
ÜZÜLMEZ	3,374	3,387	2,909	2,505	2,134	2,111	1,879	1,813	1,649	2,000	1,924	1,874	1,649	1,568	1,479	32,255
TTK	13,238	13,425	11,761	10,339	8,932	8,827	8,175	8,065	7,242	9,709	9,330	8,962	8,202	7,759	7,375	141,341

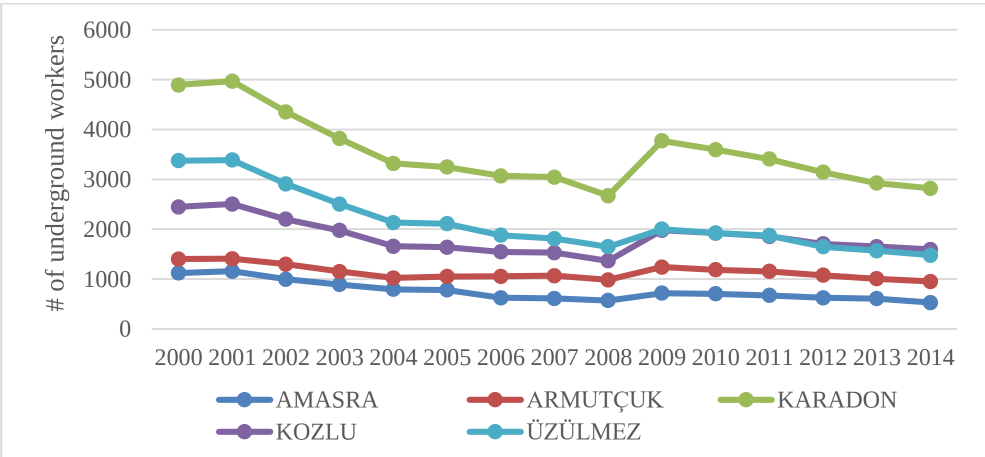


Figure 10 Number of underground workers of TTK mines between 2000 and 2014

The productivity is an average efficiency measure of production. It can be expressed as the ratio of output to inputs used in the production process. If all outputs and inputs are considered the measure is called total productivity. When only one factor is taken into account as input, the productivity is called as partial productivity. Here the labor productivity is examined in terms of unit production of mines regarding underground workers. Labor Productivity is calculated as follows:

$$LP = P / NOW \quad [3]$$

Where; LP : Labor Productivity

P : Yearly ROM Production

NOW : Number of Underground Workers

Table 7 and Figure 11 show the annual labor productivity of the mines between 2000 and 2014. The highest value in labor productivity is seen in 2011 with 431 tonnes/worker in Amasra mine (Table 7). On the other hand, the lowest value appears as 213 tonnes/worker in Armutçuk mine in the year 2013. Till 2008, there is a steady increase in labor productivity for all five mines. After this year, it changes from mine to mine. For example, Armutçuk and Karadon mines are two significant mines with decreasing productivity after 2008 (Figure 11). There is not any change in the labor productivity of Üzülmez mine from 2008 to 2014, even the number of workers increases in 2008. In Kozlu mine, there is an increase in the productivity till 2012. However, there is a sharp decrease in the last two years 2013 and 2014.

Table 7 Annual labor productivity of underground workers of TTK mines between 2000 and 2014 (tonnes/worker/year)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
AMASRA	246	254	262	263	294	275	337	318	356	334	409	431	400	429	420	322
ARMUTÇUK	256	272	294	303	364	360	313	321	338	264	224	218	234	213	225	279
KARADON	234	267	258	276	293	284	259	266	305	277	252	236	256	259	241	263
KOZLU	261	265	299	305	326	311	328	364	379	330	356	372	379	314	304	322
ÜZÜLMEZ	230	244	283	286	320	283	241	288	283	285	304	305	295	280	326	279
TTK	241	260	276	286	314	297	281	301	322	292	292	291	298	282	283	285

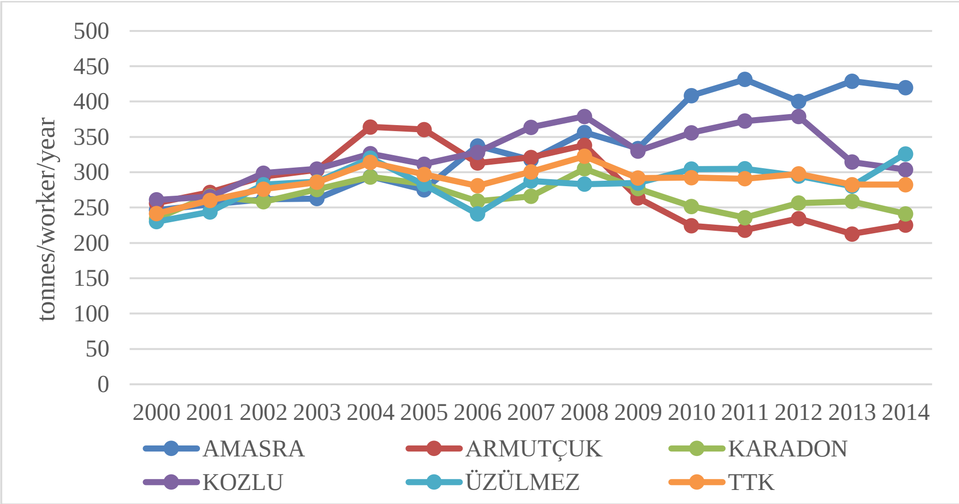


Figure 11 Productivity of underground workers in TTK mines between 2000 and 2014

Figure 12 shows the overall labor productivity between 2000 and 2014. The highest labor productivity belongs to Amasra and Kozlu mines with 322 tonnes/worker (Figure 12). The average labor productivity for TTK is 285 tonnes/worker for this period. The labor productivity of Armutçuk and Üzülmez mines are close to the average with 279 tonnes/worker (Figure 12). The labor productivity of Karadon mine having the highest production and maximum number of underground worker in all the mines is the lowest with 263 tonnes/worker. Amasra mine is the only mine increasing its labor productivity continuously starting from 2000.

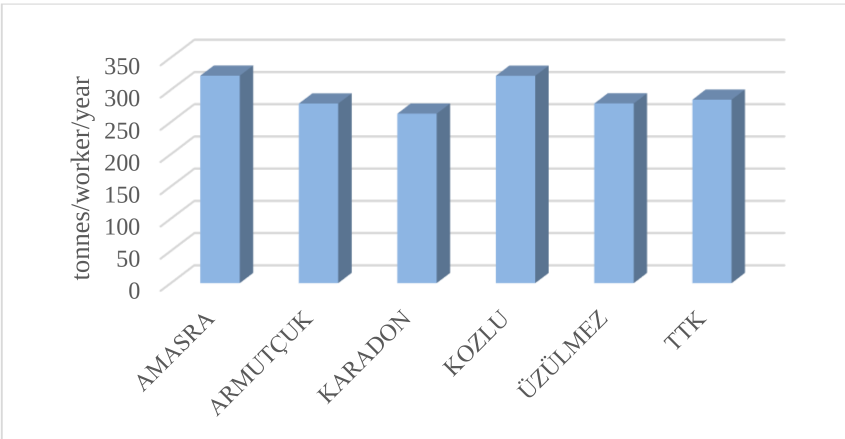


Figure 12 Average productivity in TTK mines

5.2 Production Cost and Sale Prices of Coal in TTK

Due to geological conditions in the region and due to structural geology of coal seams in the region, coal production in the mines is based on labor force. For this reason high labor cost directly affects the production cost in the mines. According to the data existing in sectoral reports, the web site of TTK and evaluation reports prepared by TTK the production costs and the related sale prices between 2002 and 2014 varies as illustrated Figure 13. The difference between the cost and sale price of coal, which is the deficit, in fact increases especially after 2010 (Figure 13).

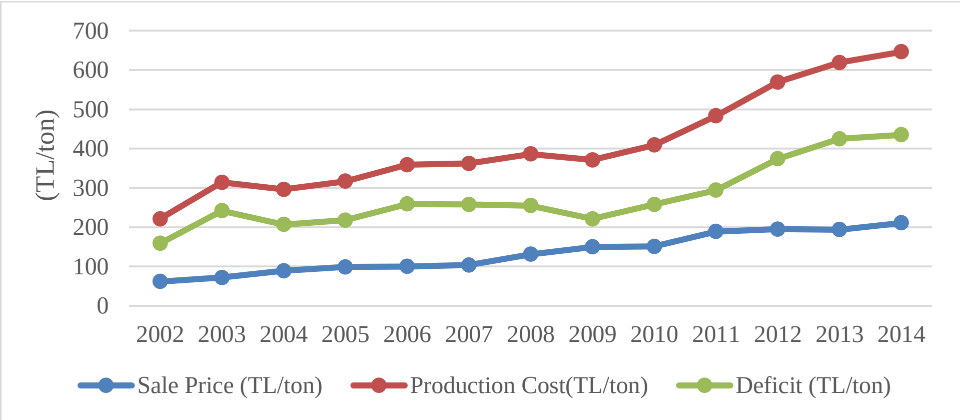


Figure 13 Production cost and sale price of coal between 2000 and 2014

As clearly seen from Figure 14, the highest share of production cost belongs to the labor cost. Its share varies from 60% and 68%. This high share shows the production characteristics of TTK and at the same time points out the importance of days lost in occupational accidents.

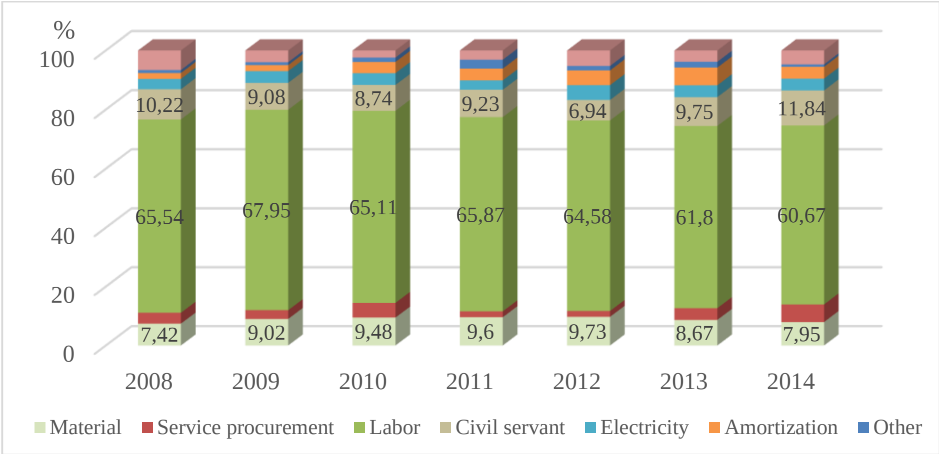


Figure 14 Share of production cost components between 2008 and 2014 (Source TTK)

In order to decrease the existing deficit, TTK should increase the productivity to decrease the production cost which is closely related to occupational accidents and their costs.

The costs of an occupational accident can be categorized as direct and indirect costs in working environments. Amount of the indirect cost category contains more considerations than direct costs. In some studies, direct cost is called as insured cost and indirect cost is called as uninsured cost. Days lost is one of the direct cost of occupational accidents for the mines. Hence, risk analysis and risk assessment for TTK is utmost importance.

Number of accidents is the most important factor directly related with the number of injuries and number of fatalities in a mine. If the number of accidents is high, the fatality rate and number of injured workers increases. Therefore, it should be kept low. In order to decrease the number of occupational accidents, some important measures must be taken. Additionally, the damages and financial losses are also directly proportional with the number of accidents.

Fatality can be considered as one of the most important parameters in the risk analyses related with occupational accidents. However, predicting cost of a fatality, although it is performed for insurance analysis, contains some controversial issues. For this reason, fatalities are not taken into consideration for the risk assessment part in this thesis. However, descriptive statistics are performed to provide information about causes, places and some other details to decision makers.

Days lost is a direct result of an occupational accident and is measurable. Thus, it is used as the major cost indicator of an occupational accident in this thesis.

5.3 Occupational Accident Data Set in TTK

Occupational accidents data set in TTK includes so much information about the accidents occurring in the enterprises. For the record of the accidents there exist at least one personnel (engineer or technician) responsible from the preparing accident reports about the occupational accidents in each mine. This employee prepares the detailed reports and summit it to the General Directorate. All detail information in these reports is entered to the data base. The date, time, location and type of the accident, a short explanation for the location of the accident, name, surname, main duty, education level and birthday of the casualty, and, the consequence of the accident (fatality or injury) are some of the information existing in the data set. Notification date and time, source of the accident, assigned duty to the casualty and the job done during the accident, injured body parts, short explanation about the occurrence of the accident, starting date of the employment and rest days of casualty (days lost) for the accident are the other parameters existing in the data set. All headings of the existing information in the data set is given in Appendix A.

It is very comprehensive and it gives the opportunity to carry out quantitative risk analysis on it. TTK could be a model for all mining entities regarding the recording and keeping such a comprehensive data set for the occupational accidents.

CHAPTER 6

DATA ANALYSIS FOR TTK

The data covering underground accidents causing injury or fatality have been analyzed in details. First, all the data is classified on a yearly basis. Then the existing data is examined for each mine separately regarding the number of accidents/injuries, type of accidents, location of accidents, main duty of casualty, injured body part, education level, age and experience of casualty and days lost.

The mine accident data set has been gathered from TTK. The data includes many details for each accident occurring in the mines. As mentioned in the previous chapter, the data set includes the information about the type and location of the accident. The results of the accident whether it resulted in injury or fatality also exist in the data. The name, surname and birthday of the casualty, main duty and education level of casualty, assigned duty to the casualty and the job done during the accident are other details. Injured body parts due to the accidents, short explanation about the occurrence of the accident, starting date of employment and rest days of the casualty (days lost) for the accident are also given. The ages and experiences of the casualties are derived from the existing data set in order to use in further analysis.

The data analysis includes the analysis of accident categories for both row and normalized data and hypothesis testing for some variables. Figure 15 illustrates the steps followed in the data analysis. Number, type and location of accidents, age, experience and education level of casualties, injured body parts and days lost are the parameters statistically analyzed in this stage. Fatality is the other parameter analyzed separately from other variables (Figure 15).

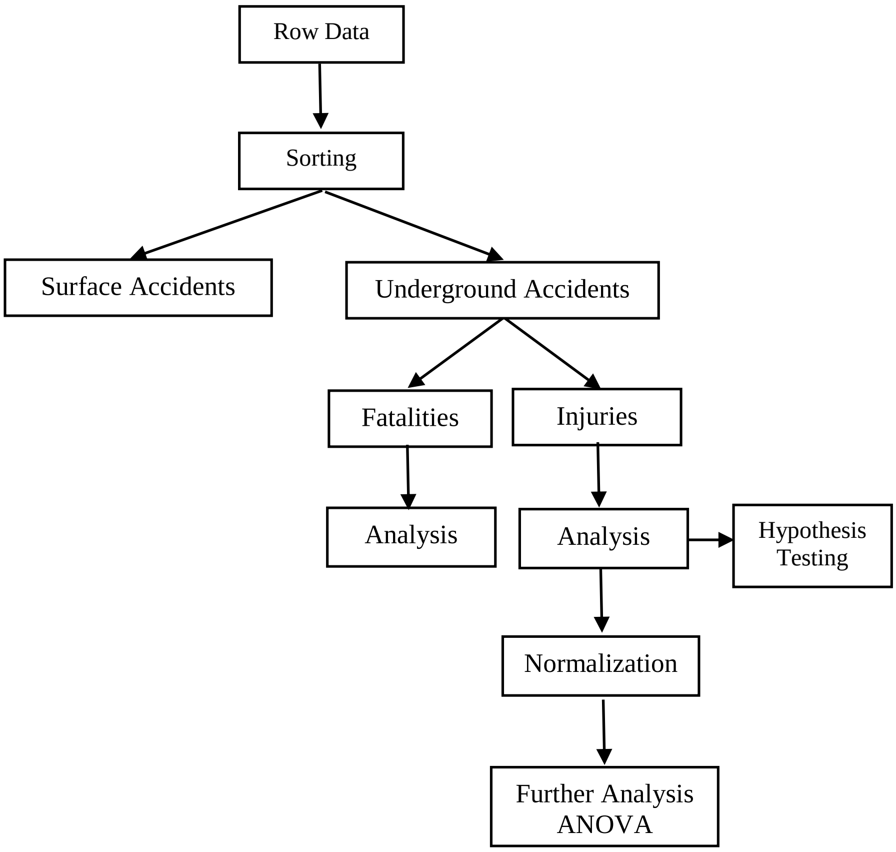


Figure 15 Data analysis flowchart

6.1 Data Analysis for Row Data of Injuries

All analysis have been carried out only for the underground mine accidents. The data set covers the accidents occurred in the period of fifteen year (2000-2014). After eliminating surface accidents in the data set the accidents resulted in fatality have been extracted to another data set in order to carry out analysis precisely on the injury resulted accidents. The days lost values for the fatalities is very high when compared with that of injuries. For this reason the accidents causing fatalities have been examined and analyzed separately. Then, all data was separated and grouped according to years for each mine to evaluate the changes by years for each mine.

6.1.1 Annual Number of Accidents

The total number of accidents occurring annually in the mines have been determined. Table 8 shows the total number of underground accidents occurred in TTK mines between the years 2000 and 2014. As can be seen from the Table 8 during fifteen years period 39,738 accidents have occurred in the underground mines of TTK.

Table 8 Number of underground accidents in TTK mines between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
AMASRA	542	545	414	317	227	218	203	162	142	217	295	268	185	221	145	**4,101**
ARMUTÇUK	297	312	245	246	272	188	163	244	196	238	304	333	345	273	233	**3,889**
KARADON	1,410	1,532	912	878	774	667	661	966	960	1,946	1,684	1,177	1,165	1,178	917	**16,827**
KOZLU	950	887	570	501	442	384	354	392	264	609	590	484	488	343	298	**7,556**
ÜZÜLMEZ	752	881	444	472	445	372	287	288	352	490	488	578	521	438	557	**7,365**
TTK	**3,951**	**4,157**	**2,585**	**2,414**	**2,160**	**1,829**	**1,668**	**2,052**	**1,914**	**3,500**	**3,361**	**2,840**	**2,704**	**2,453**	**2,150**	**39,738**

The number of accidents varies from mine to mine and also from year to year. At first look, it can be said that Karadon mine is the mine having the highest annual number of accidents. Kozlu and Üzülmez mines follow Karadon mine with 7,569 and 7,385 accidents during fifteen years. 4,101 and 3,889 accidents have occurred during this period in Amasra and Armutçuk mines, respectively. It can roughly be said that Kozlu and Üzülmez mines have similar characteristics. In the same way, Amasra and Armutçuk mines are similar in terms of the number of underground accidents between 2000 and 2014. On the other hand, Karadon mine has distinct accident numbers (Table 8).

Figure 16 shows the changes in the number of accidents in the mines through the years. Starting from the year 2000 the number of underground accidents has decreased till 2006 (Figure 16). This trend is also valid for all mines. As it can be seen both from the Table 8 and Figure 16, although totally 3,951 underground mine accidents occurred in 2000 this number has dropped to 1,668 in 2006. Between 2006 and 2008 the number of accidents fluctuated in all mines without a significant increase or decrease. However, in 2009 in all mines the number of accidents increased suddenly and reached to 3,500. This value is the top after the year 2006.

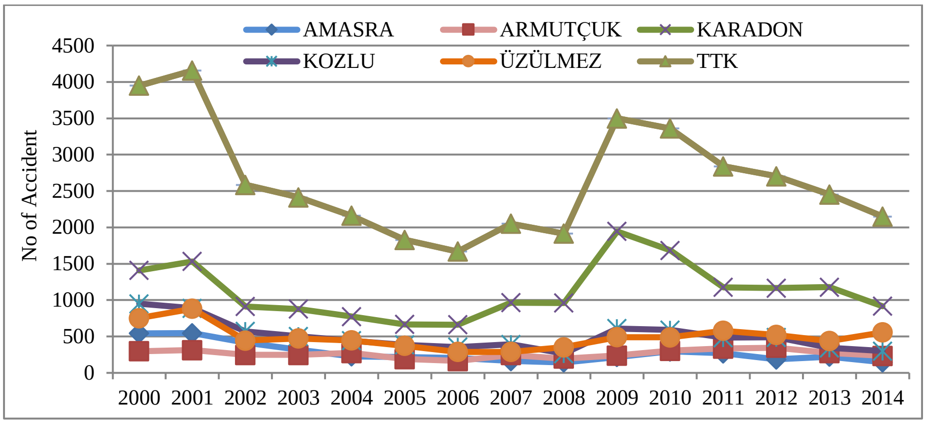


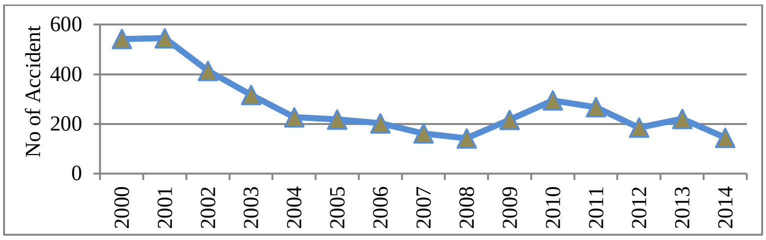
Figure 16 Number of underground accidents in TTK mines between 2000 and 2014

The change in the number of accidents/casualties for all five mines can be seen in the Figure 17. Starting from the year 2010 the number of accidents in most of the mines started to decrease gradually till 2014 Figure 17.

The steady decrease between 2000 and 2014 without significant undulations is clear in Amasra mine (Figure 17). The decrease in Karadon and Kozlu mines is also apparent together with fluctuations (Figure 17).

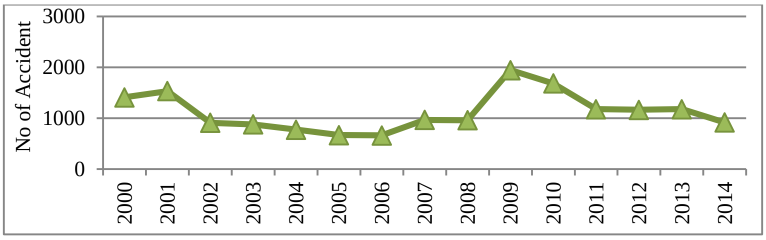
The situation is a little bit different for Armutçuk and Üzülmez mines. Apart from other mines, especially for Armutçuk mine, the number of accidents in the mine has increased till 2012 then started to decline in 2013 (Figure 17).

In Üzülmez mine, the number of accidents has fluctuated between 2006 and 2014. It increased till 2011, then decreased till 2013 and then increased again in 2014 (Figure 17).

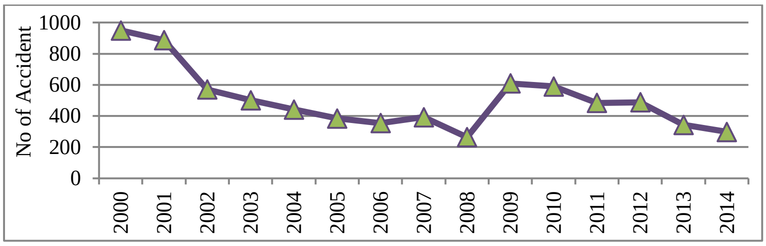


(a) Amasra mine

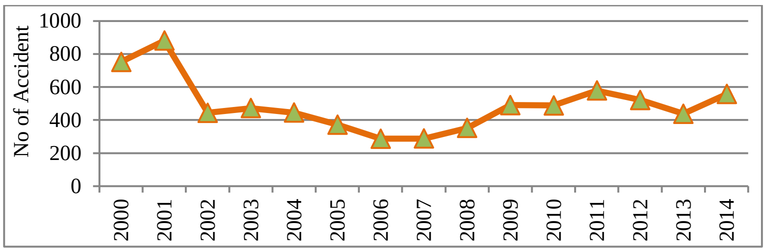
(b) Armutçuk mine



(c) Karadon mine



(d) Kozlu mine



(e) Üzülmez mine

Figure 17 Number of accidents in the mines

6.1.2 Type of Accidents

After having analyzed the number of accidents for all mines, the accidents occurring in the underground mines have been classified according to their types. During this classification the classes used in previous studies (Duzgun, 2005; Sari et al., 2005; Paul, 2009; Onder and Adiguzel, 2010; Eratak, 2014,) have been taken into account. All the accidents has been grouped to seven categories as;

- Roof Fall
- Transportation
- Material Handling
- Slip/Fall
- Struck by Objects
- Mechanical and Electrical
- Others

The type of accidents have been categorized considering the “KAZA SEBEBİ” column in data set. In order to decide the actual cause of the accidents correctly, the accidents which the reason is not clearly defined (defines as “various”) in this column has been filtered in the “KAZA KAYNAK” column and the cause of the accident has been determined for each type of accidents. This operation has been repeated for all accident types in all cases.

Table 9 shows the distribution of all underground mine accidents considering their types occurred in TTK Mines between the years 2000 and 2014. The changes in the number of accidents in TTK is illustrated in Figure 18. The number of roof fall accidents is always the highest. Material accident is the second common accident type in TTK between 2000 and 2014 (Figure 18).

Table 9 Number of type of accidents in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	1709	1923	1169	910	852	748	652	842	765	1282	1165	1240	1232	915	598	16002
Transport.	155	139	75	33	72	108	40	52	68	116	132	119	111	100	90	1410
Mat. Hand.	848	806	476	509	429	374	358	353	392	853	671	561	554	503	510	8197
Slip/Fall	399	434	291	310	291	248	206	273	229	403	428	331	303	396	347	4889
Struck Obj.	409	415	249	287	191	108	172	244	277	652	740	359	312	345	446	5206
Mech. Electr.	133	128	99	61	72	69	57	52	54	96	124	128	128	127	104	1432
Others	298	312	226	304	253	174	183	236	129	98	101	102	64	67	55	2602
TOTAL	3951	4157	2585	2414	2160	1829	1668	2052	1914	3500	3361	2840	2704	2453	2150	39738

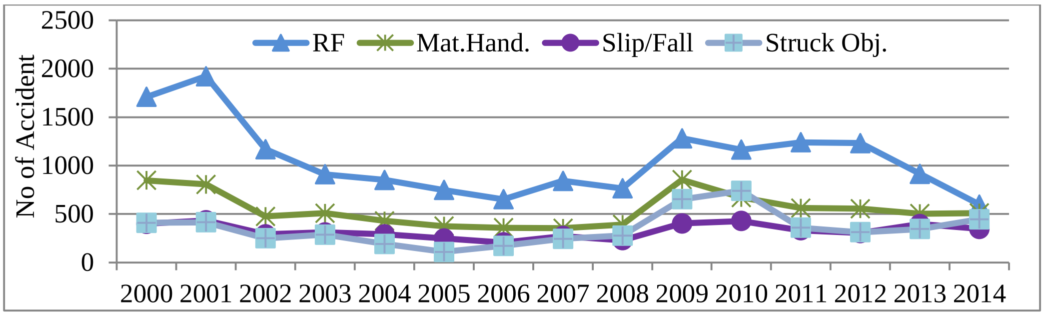


Figure 18 Type of accidents in TTK between 2000 and 2014

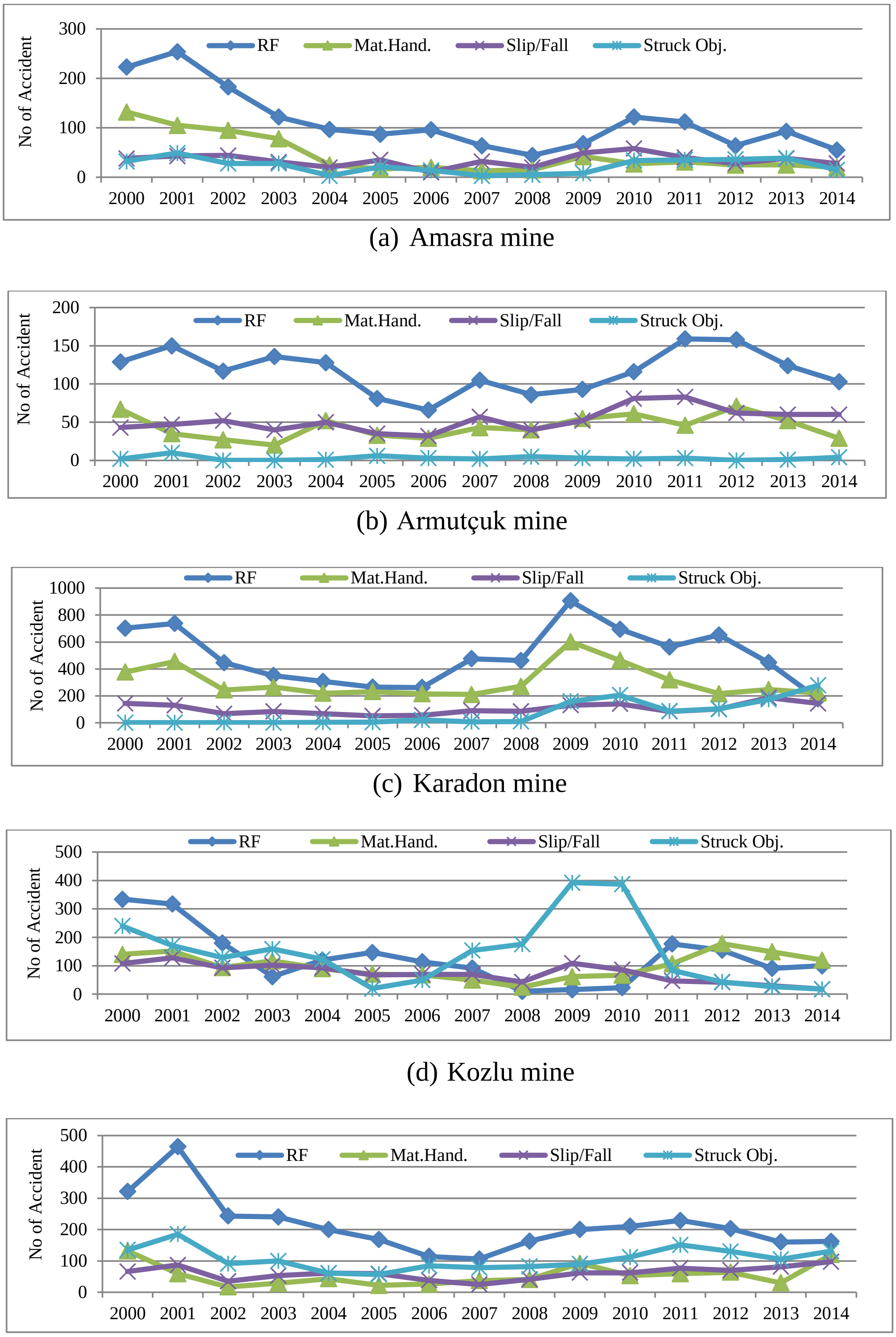
Table 10 shows the distribution of type of all accidents occurred in Amasra, Armutçuk, Karadon, Kozlu and Üzülmez mines. Table 10 shows that Roof Fall is most frequently occurring accident type for TTK and for all five mines.

Among all the 39,738 accidents occurred in the TTK Mines for the years between 2000 and 2014, 16,002 of them are due to Roof Falls. Approximately 40% of the accidents in TTK mines has occurred as a result of roof failure whether small or large scale. The second important accident type is Material Handling. The share of this accident type is approximately 20%. Accidents due to Struck by Objects and Slip/Fall are the next frequently occurring accident types with 5,206 (13%) and 4,889 (12%) accidents.

Table 10 Number of type of accidents in the mines between 2000 and 2014

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
AMASRA	Roof Fall	223	254	183	122	97	87	96	64	44	68	122	112	64	93	55	1684
	Transport.	18	19	19	11	10	23	7	3	6	9	11	17	11	5	11	180
	Mat. Hand.	132	105	95	78	25	17	20	13	15	42	27	31	25	25	20	670
	Slip/Fall	38	43	44	31	20	35	10	32	20	49	58	40	28	38	28	514
	Struck Obj.	32	49	28	28	3	21	14	3	5	8	34	35	36	39	15	350
	Mech. Electr.	24	27	16	2	13	14	5	5	4	12	12	11	10	12	10	177
	Others	75	48	29	45	59	21	51	42	48	29	31	22	11	9	6	526
	TOTAL	542	545	414	317	227	218	203	162	142	217	295	268	185	221	145	4101
ARMUTÇUK	RF	129	150	117	136	128	81	66	105	86	93	116	159	158	124	103	1751
	Trans.	14	7	7	10	7	1	4	10	13	21	14	10	18	8	14	158
	Mat. Hand.	67	35	27	20	52	33	29	43	40	55	61	46	71	52	29	660
	Slip/Fall	43	47	52	40	50	35	32	57	40	52	81	83	62	60	60	794
	Struck Obj.	2	10	0	0	1	6	3	2	5	3	2	3	0	1	4	42
	Mech. Electr.	17	15	8	8	12	10	10	6	6	7	14	11	15	13	8	160
	Others	25	48	34	32	22	22	19	21	6	7	16	21	21	15	15	324
	TOTAL	297	312	245	246	272	188	163	244	196	238	304	333	345	273	233	3889
KARADON	RF	702	738	446	350	307	265	262	475	462	905	694	563	652	447	178	7446
	Trans.	1	0	1	0	11	0	5	20	36	70	80	43	43	50	27	387
	Mat. Hand.	377	455	243	265	219	231	215	210	271	602	463	318	216	247	221	4553
	Slip/Fall	144	129	67	84	67	51	56	89	85	131	141	84	101	187	144	1560
	Struck Obj.	0	0	1	0	3	4	21	7	9	159	205	86	103	173	278	1049
	Mech. Electr.	0	2	13	2	3	1	8	11	29	45	70	33	31	45	45	338
	Others	186	208	141	177	164	115	94	154	68	34	31	50	19	29	24	1494
	TOTAL	1410	1532	912	878	774	667	661	966	960	1946	1684	1177	1165	1178	917	16827
KOZLU	RF	334	317	180	62	120	147	114	92	10	16	23	177	155	91	100	1938
	Trans.	86	83	33	1	4	50	14	6	1	1	0	22	18	11	17	347
	Mat. Hand.	140	152	94	117	90	71	68	50	25	62	67	107	178	149	120	1490
	Slip/Fall	108	128	93	102	93	68	70	70	43	109	86	47	42	30	18	1107
	Struck Obj.	240	171	129	159	123	20	50	154	176	392	387	84	43	27	18	2173
	Mech. Electr.	38	32	24	13	4	16	21	9	4	6	9	42	43	25	18	304
	Others	4	4	17	47	8	12	17	11	5	23	18	5	9	10	7	197
	TOTAL	950	887	570	501	442	384	354	392	264	609	590	484	488	343	298	7556
ÜZÜLMEZ	RF	321	464	243	240	200	168	114	106	163	200	210	229	203	160	162	3183
	Trans.	36	30	15	11	40	34	10	13	12	15	27	27	21	26	21	338
	Mat. Hand.	132	59	17	29	43	22	26	37	41	92	53	59	64	30	120	824
	Slip/Fall	66	87	35	53	61	59	38	25	41	62	62	77	70	81	97	914
	Struck Obj.	135	185	91	100	61	57	84	78	82	90	112	151	130	105	131	1592
	Mech. Electr.	54	52	38	36	40	28	13	21	11	26	19	31	29	32	23	453
	Others	8	4	5	3	0	4	2	8	2	5	5	4	4	4	3	61
	TOTAL	752	881	444	472	445	372	287	288	352	490	488	578	521	438	557	7365

Figure 19 shows the portions of each accident type and their changes through years. All accidents regarding their types for the fifteen years period for each mine are also given in Figure 19. In Figure 19 in order to make it clearer only first four major accident types are illustrated for the mines although all types are tabulated in the Table 10.



(a) Amasra mine

(b) Armutçuk mine

(c) Karadon mine

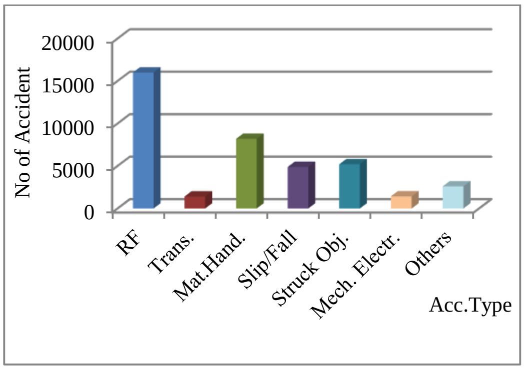
(d) Kozlu mine

(e) Üzülmez mine

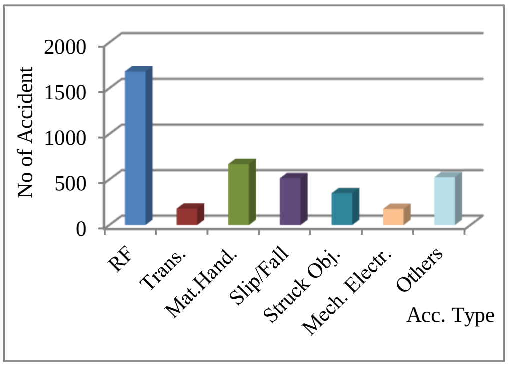
Figure 19 Type of accidents in the mines between 2000 and 2014

It can easily be seen from Figure 19 that the changes in the number of each type of accidents are similar with the changes of total number of accidents in general. As can be derived from the Table 10 also, the most important accident type for TTK is roof fall for all years which is also valid for each mine. When the distribution of accident types for each mine is examined it is seen that while the roof fall is the most important cause, transportation and mechanical and electrical related accidents are the the least important ones for TTK and for all five mines, the proportion of accidents resulted from material handling, struck by objects and slip/fall varies from mine to mine. For example, in Kozlu mine the proportion of accidents resulting from struck by objects is even higher than roof fall accidents. Especially between 2007 and 2010 the number of accidents resulting from struck by objects bursts. The situation is not so different for the accidents resulting from material handling and slip/fall. In other words, the ratios of these accident types are comparatively higher than that of other mines. The main reason for this may be the errors in the data entry for the related accident information to the system. Similarly, in Üzülmez mine, the accidents caused by struck by objects take place in the second order after roof fall. On the other hand, in Armutçuk mine the number of accidents due to struck by objects is the smallest.

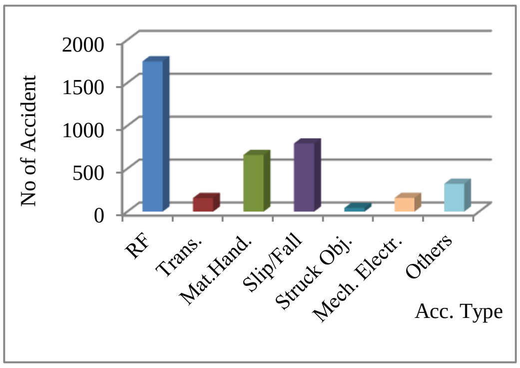
When the Table 10 and Figure 19 are examined, it can easily be concluded that in terms of accident type, roof fall, material handling, slip/fall and struck by objects are the major accident types in TTK Mines in general. Figure 20 illustrates the distributions of all accident types of the considered period in TTK and the mines. The picture is clearer in Figure 20 since it shows the total number of accidents with respect to accident types. As mentioned previously, it is seen in Figure 20 that roof fall is the most common accident type in all five mines. On the other hand, the transportation and the mechanical and electrical accidents are the least frequent accidents in all mines (Figure 20).



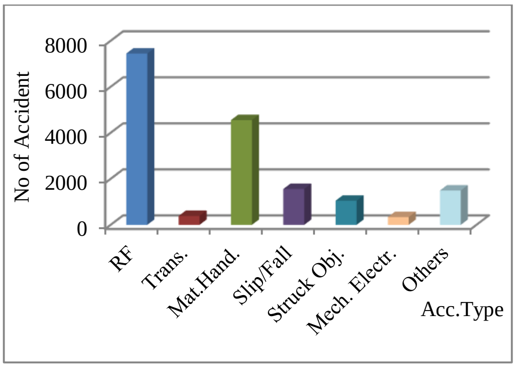
(a) TTK



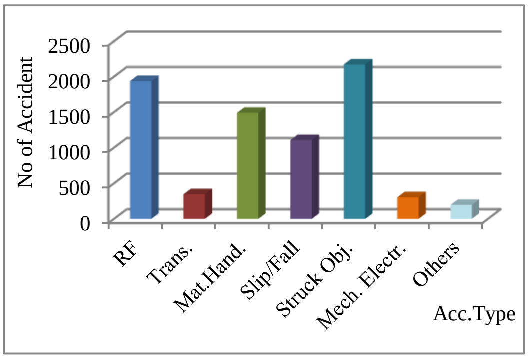
(b) Amasra mine



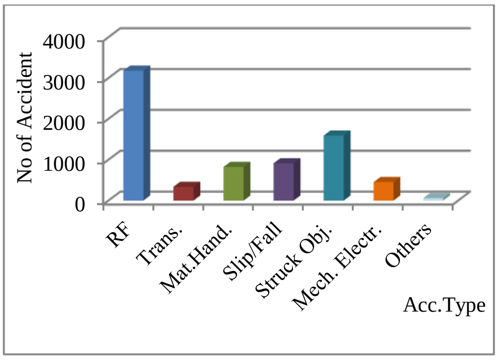
(c) Armutçuk mine



(d) Karadon mine



(e) Kozlu mine



(f) Üzülmez mine

Figure 20 Total number of accidents with respect to accident types in TTK mines between 2000 and 2014

6.1.3 Location of Accidents

Location of accident is one of the important factors for risk assessment. Thus, all data has been examined in terms of their locations. For this purpose, working places in the mines are classified in four regions and all remaining other regions are categorized as others. The main regions are:

- Production face
- Development face
- Gate road (Main and Tail Gates)
- Roadways and galleries (Other than gate roads)
- Others

In this analysis the "İŞYERİ" column has mainly used in deciding the location of the accident. The accidents occurring directly in the production places apart from development faces are put into the production face group. Similarly, the accidents occurring directly at development face are grouped as development face. The accidents occurring at the roadways related with development face were regarded as Roadways and galleries. In the case of conflicts the "KY ACIKLAMA" column was examined to determine precisely the correct place of the accident. The location has been regarded as Gate road only for the accidents occurred at main and tail gates. The underground openings including transportation galleries, development roadways, main entry and exit galleries have been categorized as Roadways and Galleries. Accidents in all other places have been classified as others. This operation has been carried out for all fifteen years and for all five mines.

Table 11 shows that where all the accidents occurred in TTK between 2000 and 2014. Most of the accidents (22,982 accidents) in TTK occurred in production faces (Table 11). The second important place for the accidents in TTK is roadways and galleries where all material and human transportation take place (Table 11). Development faces where the opening activities of new roadways and galleries have been carried out comes the (Table 11).

Table 11 Distribution of number of accidents with respect to locations in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
Prod. Face	2,474	2,627	1,378	1,414	1,274	1,021	932	1,319	1,164	2,051	1,566	1,521	1,482	1,457	1,302	**22,982**
Dev. Face	635	618	423	402	368	438	340	300	284	242	296	253	343	265	262	**5,469**
Gate Roads	101	125	90	130	94	40	47	78	91	237	204	142	156	117	59	**1,711**
Roadw, Gall.	447	559	564	249	238	200	208	181	227	823	1,112	777	564	496	397	**7,042**
Others	294	228	130	219	186	130	141	174	148	147	183	147	159	118	130	**2,534**
TOTAL	**3,951**	**4,157**	**2,585**	**2,414**	**2,160**	**1,829**	**1,668**	**2,052**	**1,914**	**3,500**	**3,361**	**2,840**	**2,704**	**2,453**	**2,150**	**39,738**

Figure 21 shows the changes in the number of accidents occurred at each location. The change is similar to the changes in the number of accidents shown in Figure 16 and Figure 18. Figure 21 shows that most of the accidents occurred in production faces for all years. However, although till the year 2009 development faces were the second common location for accidents except 2002, after 2009 roadways and galleries were the second important place after production faces for the accidents till 2014. The reason for this may be vigorous material transportation for the development faces during this period.

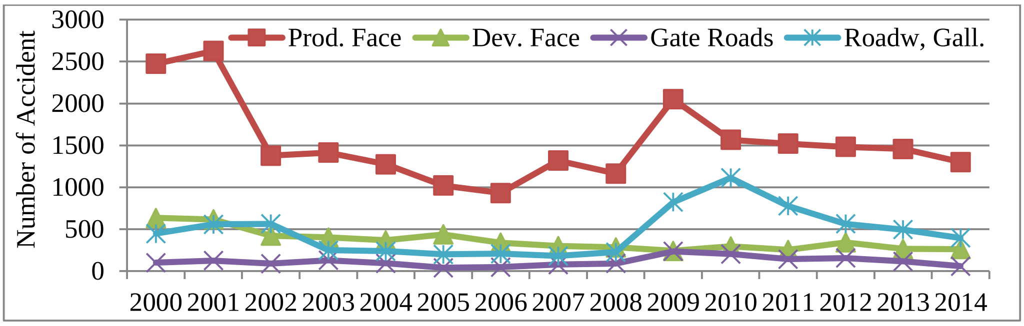


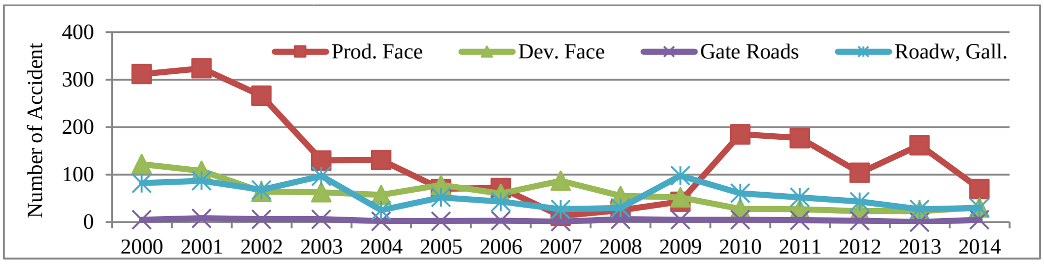
Figure 21 Accident locations in TTK between 2000 and 2014

As previously mentioned, Table 11 is a consolidated form of Table 12. Table 12 shows the distribution of location of the accidents between 2000 and 2014 in Amasra, Armutçuk, Karadon, Kozlu and Üzülmez mines. The graphical illustration of the changes in the location of accidents through the years can be seen in Figure 22. In Figure 22 all the changes are illustrated for each mine separately.

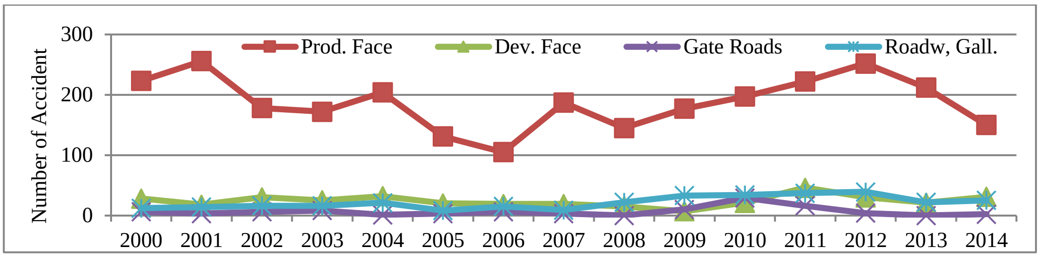
Table 12 Distribution of number of accidents with respect to locations in the mines

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
AMASRA	Prod. Face	312	324	266	130	131	70	72	13	25	43	185	177	104	162	70	2,084
	Dev. Face	122	108	64	63	57	78	60	87	55	52	28	27	23	23	31	878
	Gate Roads	5	8	6	6	2	2	3	1	6	5	5	4	3	0	5	61
	Roadw, Gall.	82	87	68	97	25	52	43	27	30	98	61	52	43	27	30	822
	Others	21	18	10	21	12	16	25	34	26	19	16	8	12	9	9	256
	TOTAL	542	545	414	317	227	218	203	162	142	217	295	268	185	221	145	4,101
ARMUTÇUK	Prod. Face	223	256	178	172	204	131	105	187	145	177	197	222	252	212	150	2,811
	Dev. Face	28	18	30	25	32	20	19	19	15	7	21	46	30	21	31	362
	Gate Roads	6	3	6	8	1	3	6	3	0	10	29	16	4	0	2	97
	Roadw, Gall.	12	14	16	16	21	8	15	9	22	33	34	37	39	22	25	323
	Others	28	21	15	25	14	26	18	26	14	11	23	12	20	18	25	296
	TOTAL	297	312	245	246	272	188	163	244	196	238	304	333	345	273	233	3,889
KARADON	Prod. Face	1118	1218	530	639	543	515	473	770	625	1154	562	457	510	635	522	10,271
	Dev. Face	126	147	95	102	125	81	75	66	128	101	137	66	174	97	84	1,604
	Gate Roads	4	3	1	0	5	2	7	10	18	35	32	9	20	41	6	193
	Roadw, Gall.	41	56	226	34	34	38	60	61	127	585	886	577	404	367	273	3,769
	Others	121	108	60	103	67	31	46	59	62	71	67	68	57	38	32	990
	TOTAL	1410	1532	912	878	774	667	661	966	960	1946	1684	1177	1165	1178	917	16,827
KOZLU	Prod. Face	332	228	85	101	100	62	143	190	130	314	292	238	253	155	138	2,761
	Dev. Face	223	194	188	178	117	207	113	67	29	32	52	62	57	65	57	1,641
	Gate Roads	63	73	69	109	70	15	16	53	55	169	118	79	104	47	36	1,076
	Roadw, Gall.	254	340	203	64	98	69	56	57	28	63	83	76	43	44	27	1,505
	Others	78	52	25	49	57	31	26	25	22	31	45	29	31	32	40	573
	TOTAL	950	887	570	501	442	384	354	392	264	609	590	484	488	343	298	7,556
ÜZÜLMEZ	Prod. Face	489	601	319	372	296	243	139	159	239	363	330	427	363	293	422	5,055
	Dev. Face	136	151	46	34	37	52	73	61	57	50	58	52	59	59	59	984
	Gate Roads	23	38	8	7	16	18	15	11	12	18	20	34	25	29	10	284
	Roadw, Gall.	58	62	51	38	60	33	34	27	20	44	48	35	35	36	42	623
	Others	46	29	20	21	36	26	26	30	24	15	32	30	39	21	24	419
	TOTAL	752	881	444	472	445	372	287	288	352	490	488	578	521	438	557	7,365

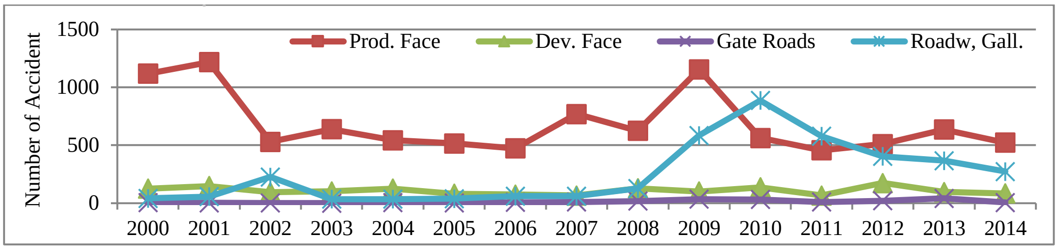
Figure 22 shows how the location of the accidents in the mines varies throughout the years. As mentioned previously, regarding accident locations in TTK, till 2009 the second important place for accidents was development face, after 2009 roadways and galleries become the second important location for accidents. Figure 22 points out that this change mainly results from the accidents in Karadon mine. Because especially after 2009 there has been a great increase in the number of accidents in roadways and galleries in Karadon mine.



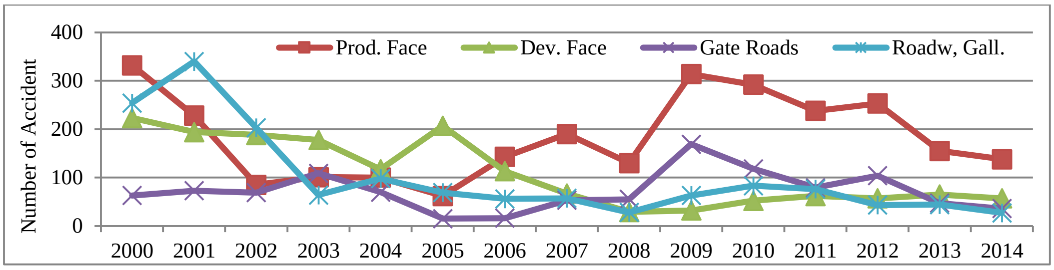
(a) Amasra mine



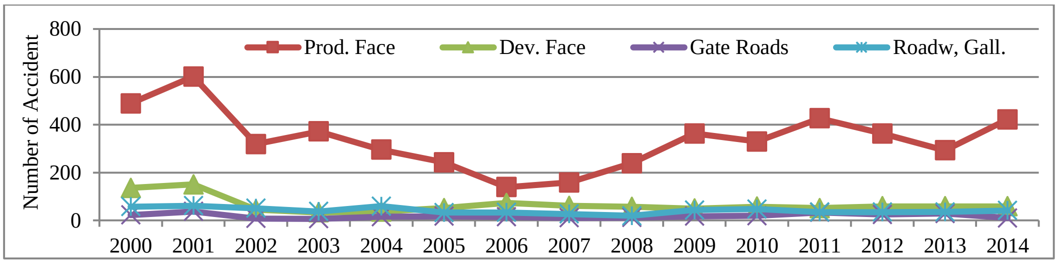
(b) Armutçuk mine



(c) Karadon mine



(d) Kozlu mine



(e) Üzülmez mine

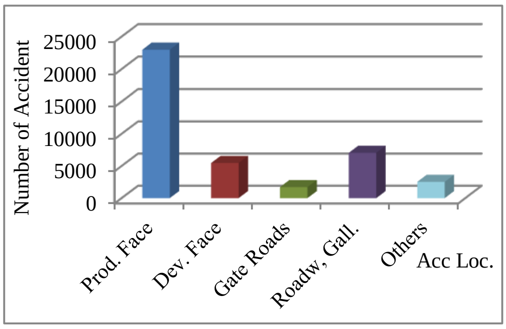
Figure 22 Locations of accidents in the mines between 2000 and 2014

Figure 22 shows that in Amasra mine, the share of production faces in accidents has decreased significantly between 2005 and 2009. Another important point that could be driven from Figure 22 is that the production faces are almost the most probable accident places in Armutçuk and Üzülmez mines for all years without significant change.

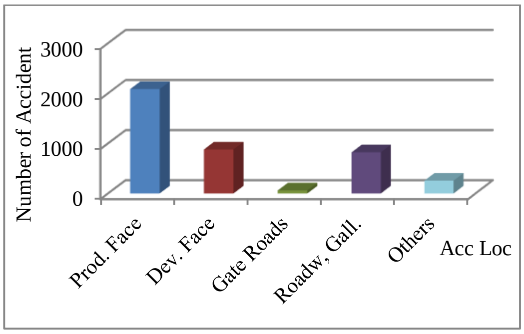
Figures 23 illustrates the distribution of all accident locations in TTK and all five mines between 2000 and 2014. Figure 23 points out that the most of the accidents have occurred in production faces both TTK and all five mines. The second common places are the development faces and roadways and galleries but their shares varies from mine to mine due to nature and operational characteristics of the mines. For example, in Amasra and Armutçuk mines, the number of accidents occurred in the development faces are slightly more than the number of accidents in roadways and galleries (Figure 23).

The situation is similar for Kozlu and Üzülmez mines. In other words, the number of accidents in development faces is also greater than the number of accidents in roadways and galleries but the difference is a bit higher in these mines.

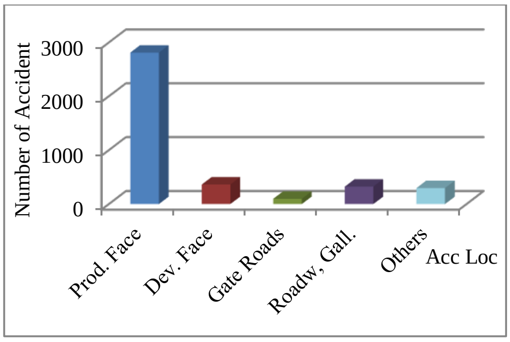
Considering all the accidents in TTK mines, the number of accidents occurred in roadways and galleries is slightly higher than the number of accidents occurred in development faces. This mainly results from the Karadon mine. Because the number of accidents in roadways and galleries is much higher than the number of accidents in development faces in Karadon mine (Figure 23).



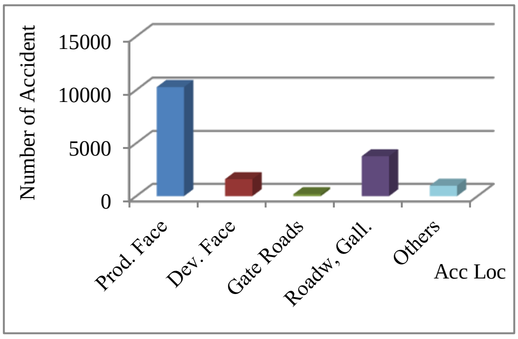
(a) TTK



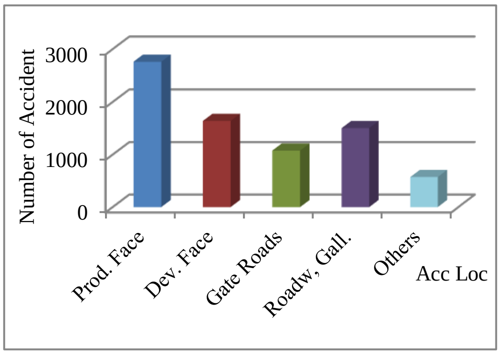
(b) Amasra mine



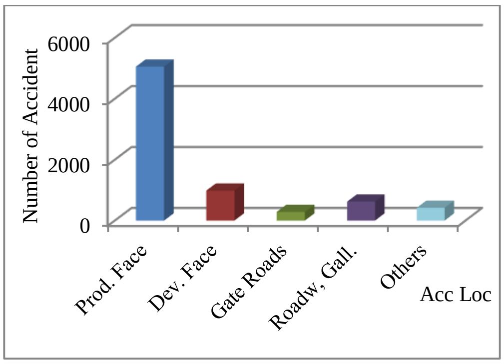
(c) Armutçuk mine



(d) Karadon mine



(e) Kozlu mine



(f) Üzülmez mine

Figure 23 Total number of accidents with respect to accident locations in TTK mines between 2000 and 2014

6.1.4 Main Duty of Casualties

Main duty of workers is also an important factor in mine accidents since the workers are given tasks according to their main duties. Thus, main duty of a worker is an important factor affecting the accident risks. For this reason, after analyzing the total number of accidents, type and location of accidents, main duty of casualties in the accidents between 2000 and 2014 has been analyzed in this study.

The main duties have been grouped into five main categories. Any other duty other than defined categories has been classified as others. These categories are:

- Production worker
- Development worker
- Transportation worker
- Mechanics, Electrician and Repairman
- Demontage worker
- Others

In this analysis "ASIL GÖREV" column is scrutinized for the determination of casualties in the accidents. All underground accident data resulting injury excluding fatality has been examined in terms of main duty of casualties for each mine in yearly basis.

Table 13 shows main duties of casualties between 2000 and 2014 in TTK. 30,010 of 39,738 casualties are production workers working mainly in faces and production areas as shown in Table 13. Although the number of production workers is relatively higher than that of other workers, the portion of production worker is not as high as in the case of casualty distribution. The development workers working mainly for the opening new roadways and galleries are the second duty category with 3,680 casualties (Table 13).

Table 13 Main duty of casualties in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. W.	2,965	3,195	1,946	1,781	1,572	1,223	1,175	1,536	1,333	2,948	2,709	2,259	2,028	1,824	1,516	**30,010**
Dev. W.	374	384	265	267	268	279	207	189	174	143	199	219	226	241	245	**3,680**
Trans. W.	139	151	98	88	99	120	112	130	160	166	194	149	185	184	174	**2,149**
Mech.,Elect.	114	116	84	90	82	83	69	92	120	97	104	85	100	87	70	**1,393**
Demont. W.	123	125	68	89	53	62	58	53	67	57	74	64	90	56	60	**1,099**
Others	133	140	124	99	84	62	47	52	60	89	81	64	75	61	85	**1,256**
Unknown	103	46	0	0	2	0	0	0	0	0	0	0	0	0	0	**151**
TOTAL	**3,951**	**4,157**	**2,585**	**2,414**	**2,160**	**1,829**	**1,668**	**2,052**	**1,914**	**3,500**	**3,361**	**2,840**	**2,704**	**2,453**	**2,150**	**39,738**

Figure 24 shows how the main duty of the casualties in the accidents changes through years. It is clear from the Figure 24 that the production workers in TTK have the great share in the accidents between 2000 and 2014. Additionally, it can easily be said that although the number of accidents varies from year to year the high share of production workers has not changed. The number of development workers injured in the accidents comes second in order after production workers although this is not the case in actual main duty distribution of TTK underground workers.

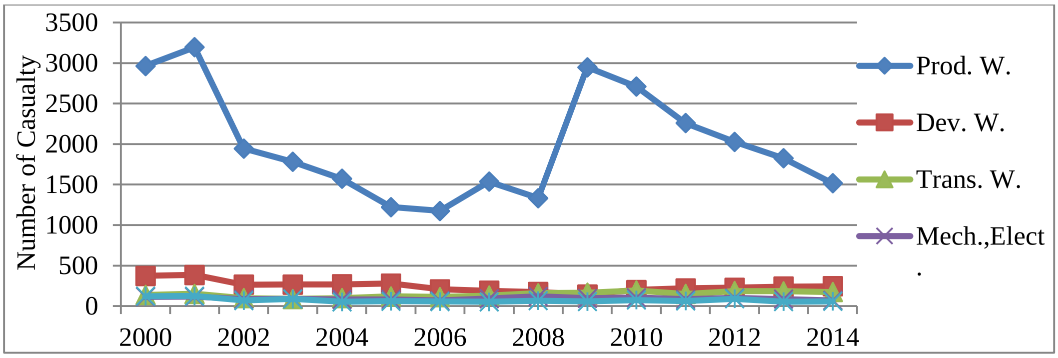


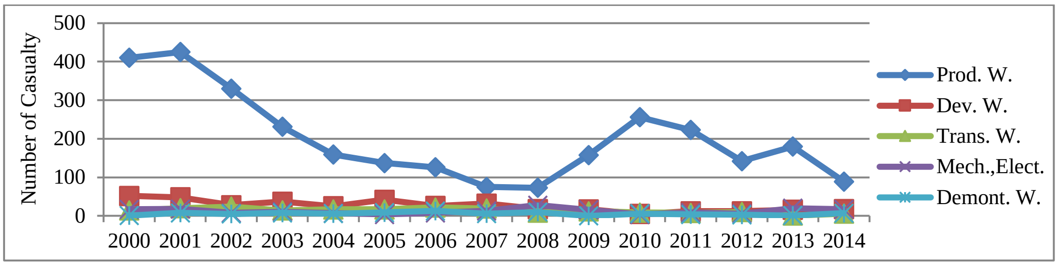
Figure 24 Main duty of casualties in TTK between 2000 and 2014

Table 14 shows that for each mine the situation is almost the same. For all mines most of the workers subjected to accidents have been production workers. The share of production workers in injured population is extremely high compared to other duties (Table 14). This fact is not valid for only a specific period, but also valid for all fifteen years and in total.

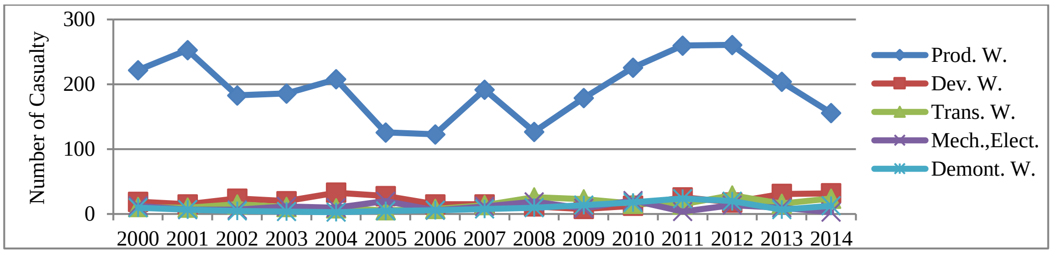
Table 14 Main duty of casualties in the mines between 2000 and 2014

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
AMASRA	Prod. W.	410	425	330	231	159	137	126	75	73	158	256	223	142	180	89	3014
	Dev. W.	52	48	28	37	25	42	26	32	18	17	5	12	12	16	18	388
	Trans. W.	14	20	24	14	17	17	22	19	9	12	9	8	10	1	6	202
	Mech.,Elect.	17	18	8	11	7	4	8	13	28	16	4	9	6	20	17	186
	Demont. W.	1	8	5	8	6	9	13	6	10	0	6	4	3	1	7	87
	Others	25	17	19	16	13	9	8	17	4	14	15	12	12	3	8	192
	Unknown	23	9	0	0	0	0	0	0	0	0	0	0	0	0	0	32
	TOTAL	542	545	414	317	227	218	203	162	142	217	295	268	185	221	145	4101
ARMUTÇUK	Prod. W.	222	253	183	186	208	126	123	192	127	179	226	260	261	204	156	2906
	Dev. W.	19	15	24	20	33	28	15	15	12	8	13	26	18	31	32	309
	Trans. W.	11	10	15	11	9	6	8	14	26	23	16	15	29	16	24	233
	Mech.,Elect.	13	7	7	12	10	20	6	12	19	9	21	4	14	10	3	167
	Demont. W.	10	7	5	4	3	5	6	8	10	14	18	24	20	7	13	154
	Others	7	14	11	13	7	3	5	3	2	5	10	4	3	5	5	97
	Unknown	15	6	0	0	2	0	0	0	0	0	0	0	0	0	0	23
	TOTAL	297	312	245	246	272	188	163	244	196	238	304	333	345	273	233	3889
KARADON	Prod. W.	1110	1206	686	625	564	451	477	765	694	1701	1423	967	904	924	679	13176
	Dev. W.	128	145	91	105	94	96	79	66	56	44	39	61	59	63	67	1193
	Trans. W.	30	33	21	21	38	45	38	57	93	88	101	62	83	97	78	885
	Mech.,Elect.	18	28	26	37	28	19	20	33	42	38	46	39	49	31	20	474
	Demont. W.	55	63	36	55	29	33	31	27	37	36	39	23	41	35	32	572
	Others	53	49	52	35	21	23	16	18	38	39	36	25	29	28	41	503
	Unknown	16	8	0	0	0	0	0	0	0	0	0	0	0	0	0	24
	TOTAL	1410	1532	912	878	774	667	661	966	960	1946	1684	1177	1165	1178	917	16827
KOZLU	Prod. W.	702	643	407	358	320	263	276	305	173	505	428	355	340	214	183	5472
	Dev. W.	100	104	78	69	65	58	32	39	42	38	92	63	76	73	71	1000
	Trans. W.	33	41	23	24	16	26	22	22	16	29	37	36	36	30	23	414
	Mech.,Elect.	24	26	21	20	14	17	12	13	20	16	17	13	15	14	13	255
	Demont. W.	28	19	15	8	7	4	4	3	6	5	6	3	6	2	0	116
	Others	22	37	26	22	20	16	8	10	7	16	10	14	15	10	8	241
	Unknown	41	17	0	0	0	0	0	0	0	0	0	0	0	0	0	58
	TOTAL	950	887	570	501	442	384	354	392	264	609	590	484	488	343	298	7556
ÜZÜLMEZ	Prod. W.	521	668	340	381	321	246	173	199	266	405	376	454	381	302	409	5442
	Dev. W.	75	72	44	36	51	55	55	37	46	36	50	57	61	58	57	790
	Trans. W.	51	47	15	18	19	26	22	18	16	14	31	28	27	40	43	415
	Mech.,Elect.	42	37	22	10	23	23	23	21	11	18	16	20	16	12	17	311
	Demont. W.	29	28	7	14	8	11	4	9	4	2	5	10	20	11	8	170
	Others	26	23	16	13	23	11	10	4	9	15	10	9	16	15	23	223
	Unknown	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	14
	TOTAL	752	881	444	472	445	372	287	288	352	490	488	578	521	438	557	7365

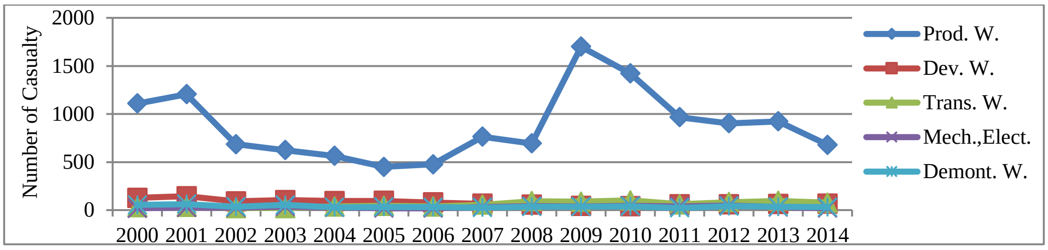
Figure 25 shows the changes in the number of casualties throughout the years regarding for main duties. Figure 25 clearly indicates that the number of casualties fluctuates between 2000 and 2014. However, the share of the production workers in casualties has been top (Figure 25).



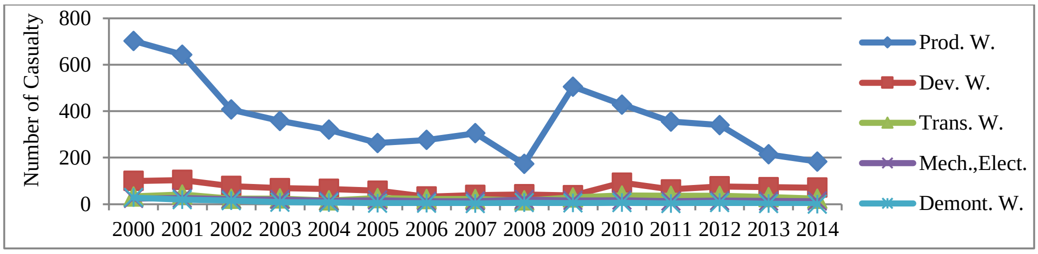
(a) Amasra mine



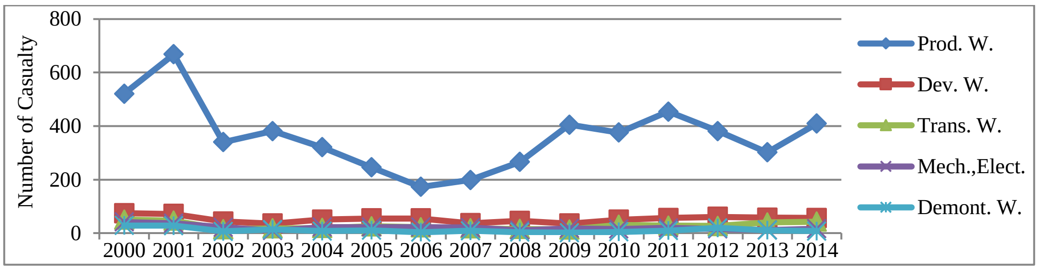
(b) Armutçuk mine



(c) Karadon mine



(d) Kozlu mine



(e) Üzülmez mine

Figure 25 Main duty of casualties in the mines between 2000 and 2014

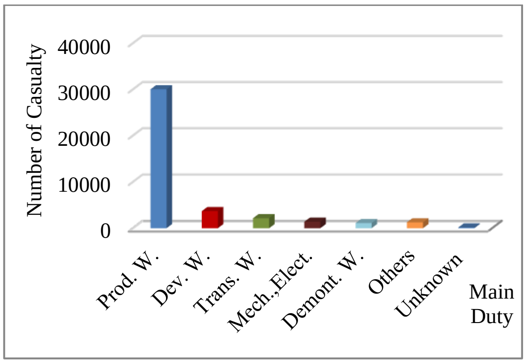
Figure 26 shows the total number of casualties in TTK and all its five mines for fifteen year period. The number of production workers subjected to accidents much greater than of all others (Figure 26).

In terms of the main duties of casualties, Amasra and Armutçuk mines have similar characteristics with approximately 3,000 casualties belonging to production workers (Figure 26). Kozlu and Üzülmez mines show similar characteristics with totally 5,500 production worker casualties out of approximately 7,500 injuries (Figure 26).

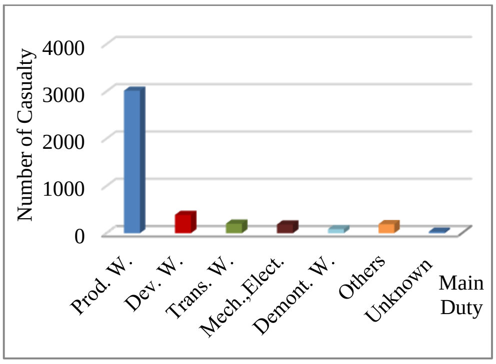
Table 14 and Figure 26 show that in Amasra mine 3,014 casualties out of 4,101 casualty belong to production worker category. In Amasra mine, the number of development workers exposed to occupational accidents during fifteen years period is 388. The number of casualties is similar for Armutçuk mine with 2,906 and 309 casualties for production workers and development workers, respectively. The number of production workers subjected to accidents in Karadon mine is high with 13,176 casualties. The similarity with respect to distribution of casualties according to main duties between Amasra and Armutçuk mines is also valid for Kozlu and Üzülmez mines.

Apart from the differences between the mines, the number of production workers subjected to occupational accidents is the highest value in all mines. The ratio of injured production workers in the accidents is much higher than all other injured duty group of workers. Similarly, although the ratio is considerably lower compared to production workers, the number of injured development workers in the accidents is the second highest value in all mines (Figure 26).

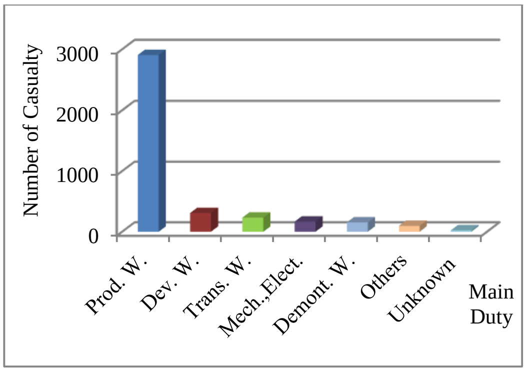
Transportation workers are the third group with respect to accident proneness. Because, the number of injured transportation workers in the accidents comes third in all mines. The smallest value for the number of casualty belongs to demontage workers in all mines.



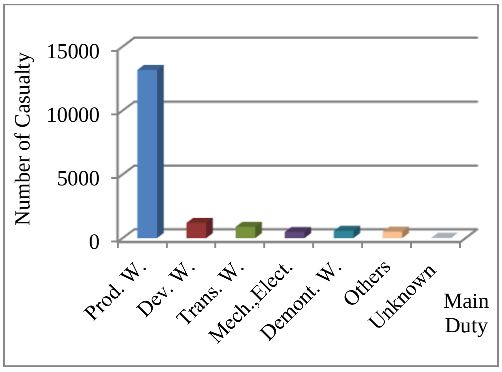
(a) TTK



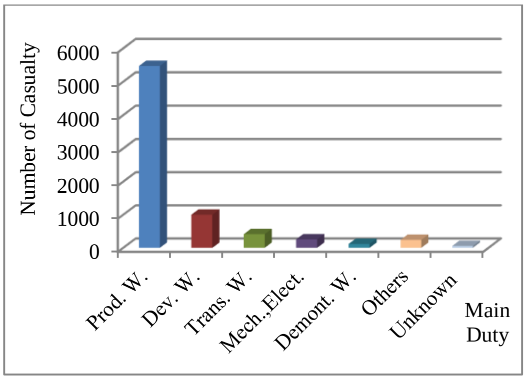
(b) Amasra mine



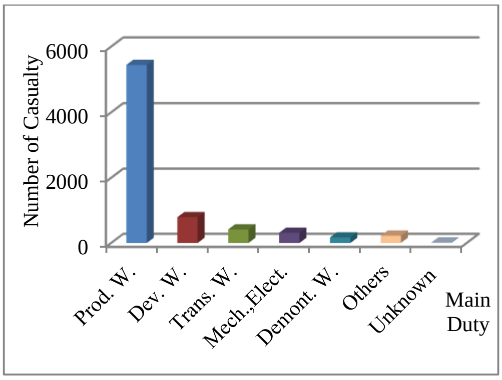
(c) Armutçuk mine



(d) Karadon mine



(e) Kozlu mine



(f) Üzülmez mine

Figure 26 Total number of accidents with respect to main duty of casualties in TTK mines between 2000 and 2014

6.1.5 Age of Casualties

The age of workers is also an important factor in occupational accidents. Therefore, in this study all accidents are analyzed in terms of casualties' ages. Considering the age categorization in the previous studies (Eratak, 2104; Sari et al., 2004, Onder, 2014) all casualties has been grouped as follows:

- ≤ 25
- 26-30
- 31-35
- 36-40
- 41-45
- 46≤
- Unknown

In this analysis in data set "KAZA TARİHİ" and "DOĞUM TARİHİ" columns have been used to calculate the ages of casualties when the accident occurred. This calculation has been carried out for all casualties in all mines for all years.

Table 15 and Figure 27 show the distribution of ages of casualties in TTK between 2000 and 2014. Most of the casualties are in the 26-30 age range (Table 15 and Figure 27). Total number of accidents in this age group is 15,735. The second age group is 31-35 with 9,587 casualties. The casualties under 25 years old come the third. The sharp increase in the number of casualties of younger than 25 years old and in the group of 25-30 years old in the year 2009 is an important issue that should be taken into account. There has been a huge number of employment in TTK in 2009. This may be attributed to inexperienced workers starting to work in the Mines in 2009.

Table 15 Ages of casualties in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
≤ 25	1,183	1,128	494	228	62	1	111	310	228	1,031	771	387	181	75	19	**6,209**
26-30	1,383	1,672	1,082	1,052	927	672	561	813	642	1,584	1,556	1,225	1,082	890	594	**15,735**
31-35	325	327	348	479	621	679	625	574	629	523	595	821	965	1,038	1,038	**9,587**
36-40	664	575	350	322	237	145	135	184	257	259	356	316	354	331	380	**4,865**
41-45	286	360	248	262	268	288	195	144	107	58	38	57	95	100	102	**2,608**
46≤	37	65	62	67	43	44	41	27	50	45	46	34	26	18	14	**619**
Unknown	73	30	1	4	2	1	0	0	1	0	0	0	1	1	1	**115**
TOTAL	**3,951**	**4,157**	**2,585**	**2,414**	**2,160**	**1,830**	**1,668**	**2,052**	**1,914**	**3,500**	**3,362**	**2,840**	**2,704**	**2,453**	**2,148**	**39,738**

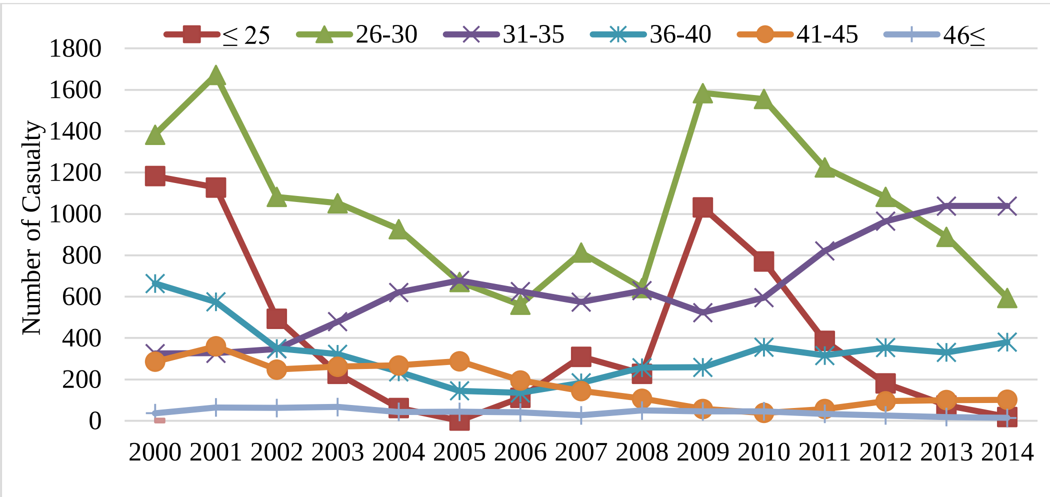
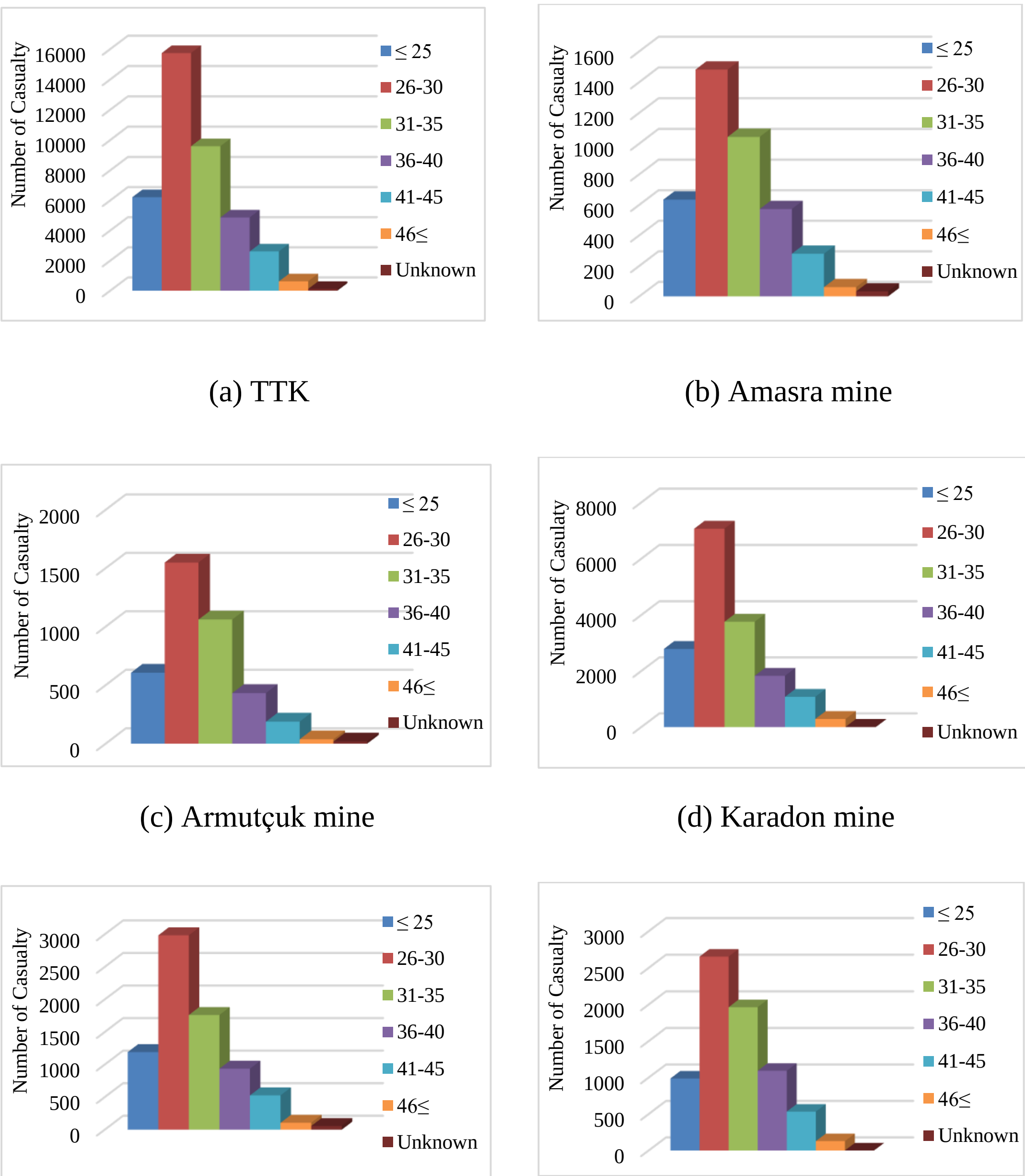


Figure 27 Ages of casualties in TTK between 2000 and 2014

Figure 28 illustrates the distributions of age of casualties in Amasra, Armutçuk, Karadon, Kozlu and Üzülmez mines and TTK. The share of each corresponding age group are similar. The most vulnerable group is 26-30 age group (Figure 28). The second is the 31-35 age group. The third group regarding vulnerability to accidents is the group of workers under 25 years old. The reason of having similar share of each group in all mines is that the age category is an independent variable. In other words, age factor is an individual characteristics independent from others. One interesting point is that with aging, the vulnerability of the workers in terms of being exposed to accidents decreases. In other words, the older workers are less exposed to the accidents, this may be attributed to experience.

The proportion of the injured age group in the total injured worker population and the proportion of corresponding age group in total number of workers are important. This is analyzed in hypothesis testing part.



(a) TTK (b) Amasra mine

(c) Armutçuk mine (d) Karadon mine

(e) Kozlu mine (f) Üzülmez mine

Figure 28 Total number of accidents with respect to ages of casualties in TTK mines between 2000 and 2014

6.1.6 Experience of Casualties

Accident exposure is also related to experience (Bennett and Passmore, 1984). Thus, experience of casualties the grouped as:

- 0-1 Year
- 2-5 Years
- 6-10 Years
- 11-15 Years
- 16-20 Years
- 21≤ Years
- Unknown

In carrying out this analysis the columns of "GIR_TARIHI" and "KAZA TARIHI" have been used to calculate the experience of workers when they had an accident. Again, as in the case of age analysis, this calculation has been carried out for all accidents in all five mines for fifteen years. Then, the results are tabulated and grouped to above mentioned categories.

Table 16 and Figure 29 show that the workers having experience between 2-5 years are likely to prone to more accidents than other groups. The number of casualties having 2-5 years of experience is 14,613. The second group is the workers with 0-1 years of experience. From Table 16 and Figure 29, it can be concluded that with increasing experience of workers the possibility of being injured by accidents in TTK decreases.

Table 16 Experience of casualties in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
0-1 Year	2,395	2,801	362	1	0	2	268	890	610	2,208	2,178	81	8	39	59	**11,902**
2-5 Years	161	176	1,499	1,728	1,499	1,261	198	1	244	512	460	2,122	1,940	1,555	1,293	**14,649**
6-10 Years	509	294	169	173	93	97	878	928	885	622	584	98	134	381	384	**6,229**
11-15 Years	601	479	303	318	274	250	151	101	69	36	43	470	569	446	384	**4,494**
16-20 Years	243	364	216	151	269	197	147	104	72	64	47	29	21	7	9	**1,940**
21≤	40	40	36	43	25	21	26	27	34	58	49	40	30	24	21	**514**
Unknown	2	3	0	0	0	1	0	1	0	0	0	0	2	1	0	**10**
TOTAL	**3,951**	**4,157**	**2,585**	**2,414**	**2,160**	**1,829**	**1,668**	**2,052**	**1,914**	**3,500**	**3,361**	**2,840**	**2,704**	**2,453**	**2,150**	**39,738**

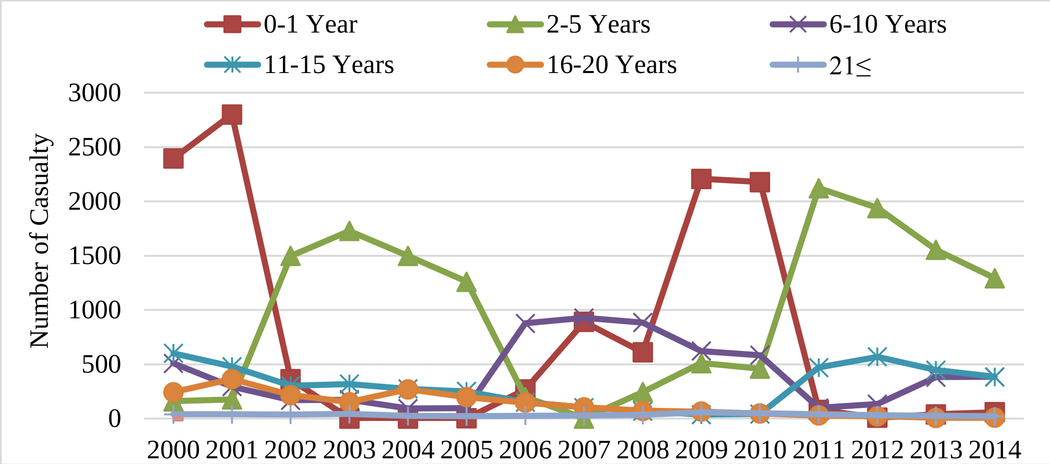
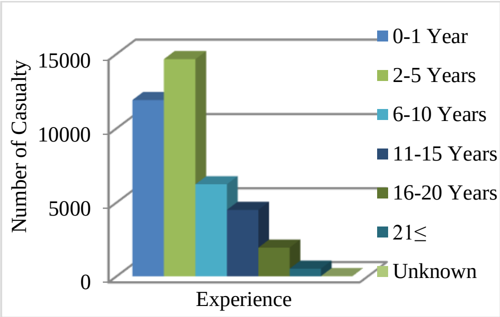
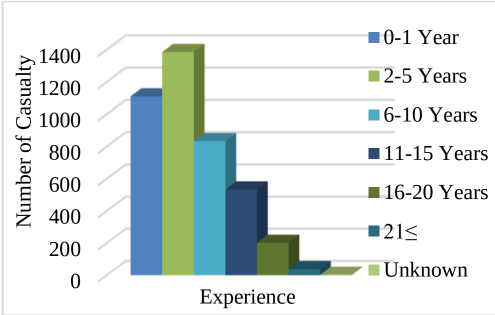


Figure 29 Experience of casualties in TTK between 2000 and 2014

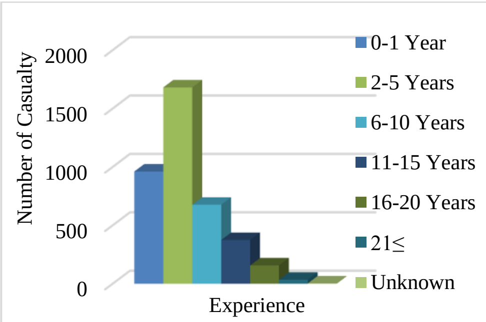
Figure 30 illustrates the distribution of experience of casualties in TTK and in the five mines. One interesting point is that the situation is almost the same for age distribution. This is an expected result. Age and experience is dependent on each other to some extent. The vulnerability of exposing to an accident decreases with increasing experience (Figure 30). However, there is a contradiction for the workers having 0-1 year of experience. This group has less share then 2-5 year group. There may be several reasons for that. First, this result may be due to the lower proportion of the corresponding group in the population of workers, second and more probable one is that at the beginning of their work life (at least for these mines) relatively lower risky jobs assigned to the first group by their chiefs especially for 1 or 2 years, third and the most important one is that at the beginning, the workers work with more experienced worker(s) till getting enough experience for the related job. The reasons behind the high portion of accident exposure for 2-5 year group is that experienced workers may be in transition from the inexperienced period to the experienced one. The feeling of having enough experience and ignoring some safety measurements may yield to exposing more accidents. However, after getting more than five years of experience the probability of having accidents decreases together with increasing experience (Figure 30).



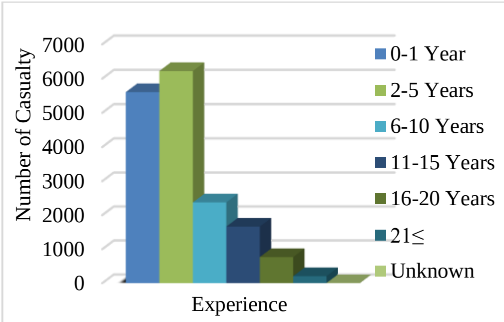
(a) TTK



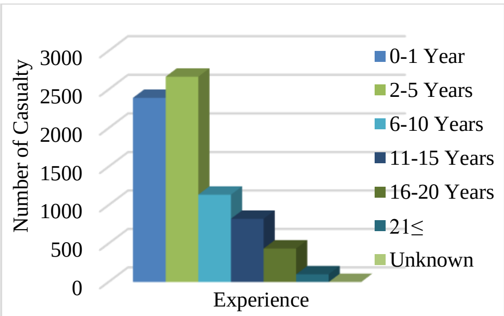
(b) Amasra mine



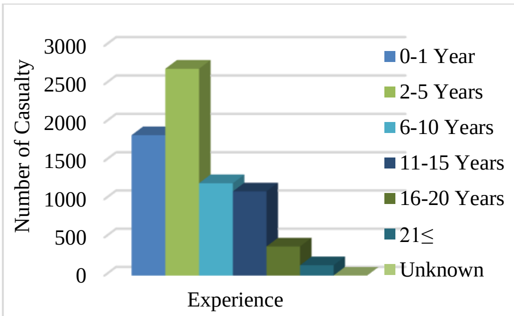
(c) Armutçuk mine



(d) Karadon mine



(e) Kozlu mine



(f) Üzülmez mine

Figure 30 Total number of accidents with respect to experience of casualties in TTK mines between 2000 and 2014

6.1.7 Education Level of Casualties

Education is important in struggling with occupational accidents. Education level of workers is also related with occurrence of accidents. Regarding this fact the education level of workers has been analyzed in this study. The educational level categories used in the analysis are:

- Primary School
- Secondary School
- High School
- University (2 or 4 years)
- Unknown

In the analysis of education level of casualties "TAHSIL" column has been examined. All casualties have been grouped according to their education levels. The results have been tabulated for each mine and then for TTK in yearly basis between the years 2000 and 2014.

Table 17 and Figure 31 show that in TTK the majority of the casualties' education level is Primary School with 25,351 casualties. The number of injured workers graduated from high school is 7,818, while the number of injured workers graduated from mid high school is 6,030.

Table 17 Education level of casualties in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
Primary Sch.	2,924	3,094	1,947	1,801	1,646	1,371	1,159	1,302	1,121	1,837	1,808	1,528	1,422	1,279	1,112	**25,351**
Secondary Sch.	502	523	324	333	248	230	253	327	365	616	555	501	457	423	373	**6,030**
High Sch.	423	484	297	266	258	222	244	390	402	995	944	760	789	713	631	**7,818**
University	1	0	0	2	0	0	3	5	6	6	1	8	3	2	2	**39**
Unknown	101	56	17	12	8	6	9	28	20	46	53	43	33	36	32	**500**
TOTAL	**3,951**	**4,157**	**2,585**	**2,414**	**2,160**	**1,829**	**1,668**	**2,052**	**1,914**	**3,500**	**3,361**	**2,840**	**2,704**	**2,453**	**2,150**	39,738

The increase in the total number of accidents in the year 2009 is mainly resulted from the increase in the number of accidents which workers graduated from primary school and high school were exposed (Figure 31).

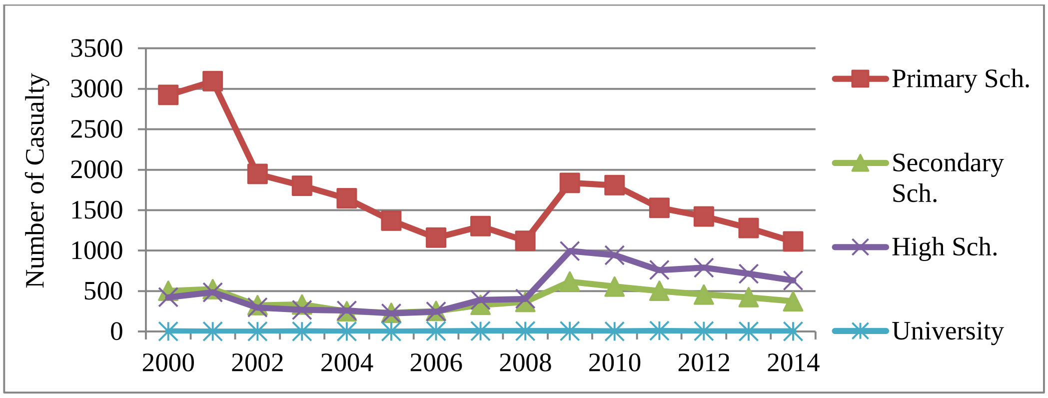
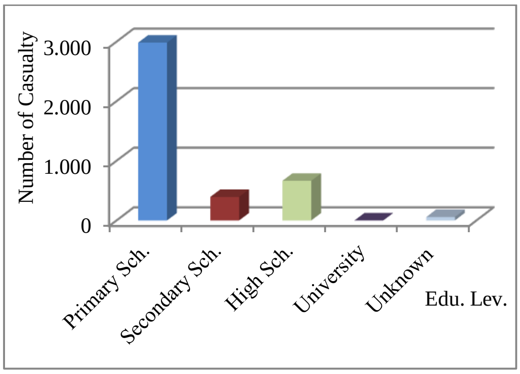


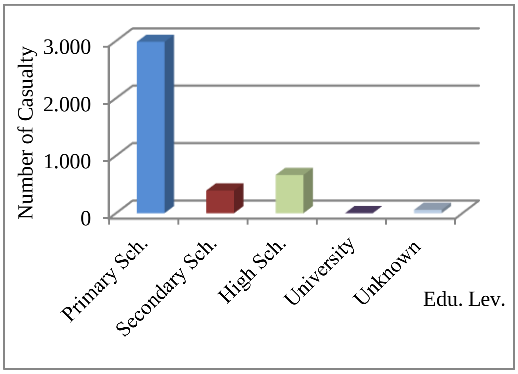
Figure 31 Education level of casualties in TTK between 2000 and 2014

Figure 32 illustrates the distribution of all casualties according to education level. The situation does not differ from mine to mine regarding the education level of casualties (Figure 32). In all mines workers graduated from primary school have the highest portion in terms of having occupational accident (Figure 32). As in the case of TTK the portion of casualties graduated from high school is a little bit higher than that of injured workers graduated from secondary school. Additionally, the number of casualties graduated from universities having two or four years of education period is considerably small compared to the other groups. This is valid for both TTK and all the five mines (Figure 32).

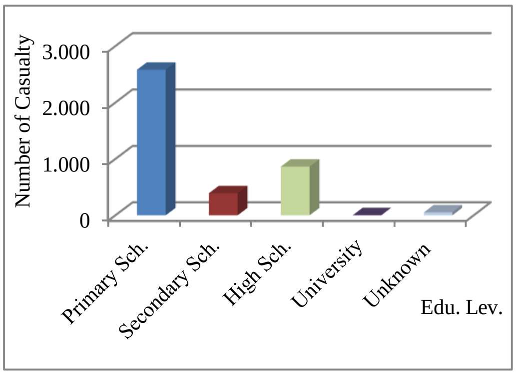
As in the case of analysis of age, experience and main duty variables, the share of the populations of educational level of injured groups in the total injured population and the share of the each group in the whole worker population must be significantly different. Hence, these proportions should be compared to make the results of the analysis meaningful. The most suitable method for this comparison is hypothesis testing which is applied in the study.



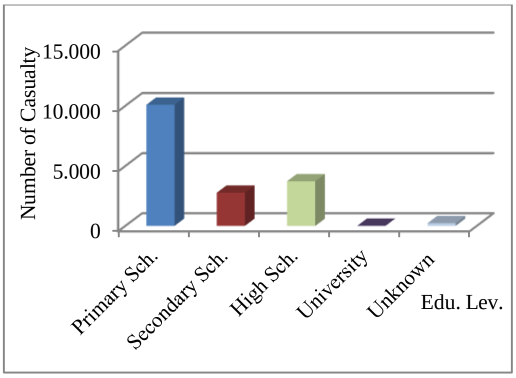
(a) TTK



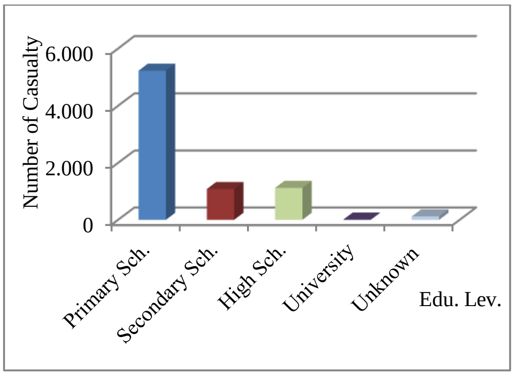
(b) Amasra mine



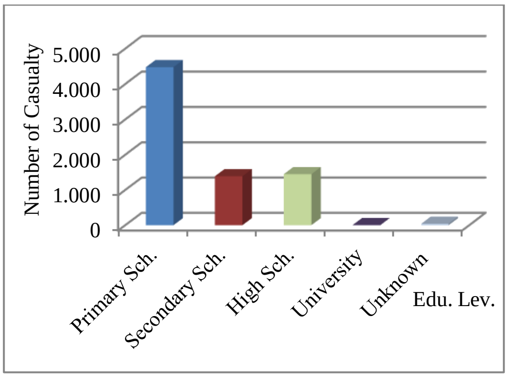
(c) Armutçuk mine



(d) Karadon mine



(e) Kozlu mine



(f) Üzülmez mine

Figure 32 Total number of accidents with respect to education level of casualties in TTK mines between 2000 and 2014

6.1.8 Injured Body Parts

Depending on the type and location of the accident, different parts of the body may be injured in underground accidents. All the other parameters up to now could be considered as the factors affecting the results of an accident. However, injury is one of the results of the accidents. The severity of the accident depends on the other parameters. In this analysis the injured body parts has been examined for all 39,738 underground accidents in TTK mines during fifteen years. This analysis may be useful especially for the selection of protective equipment in the mines. For this purpose the injured body parts was defined as:

- Head
- Hands
- Feet
- Arms
- Legs
- Main Body
- Various

In this analysis "KAZA ORGAN" column has mainly used in determining the injured body part of casualty in the accidents. In the case of more than one injury, the one stated in the first column of the database has been taken into account in the analysis.

Table 18 and Figure 33 show the distribution of injured body parts due to underground accidents in TTK between 2000 and 2014. Hands are the most affected body part in the underground accidents for all fifteen years (Figure 33). The ratios of hand, feet and main body injuries in total are always higher than that of other injuries during fifteen year period (Figure 33). The total number of casualties due to hand injuries is 11,825 in TTK. Feet and main body are the other more affected parts of the body in accidents with 8,673 and 7,241 accidents, respectively. (Table 18). Legs and head are the less affected body parts in underground accidents in TTK. The least injured body part in the accidents is arms with 2,657 injuries in TTK (Table 18).

Table 18 Injured body parts of casualties in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
Head	374	428	284	288	250	182	169	230	190	316	315	291	296	290	229	**4,132**
Hands	1,155	1,225	768	696	592	518	513	594	542	994	1,037	903	846	753	705	**11,841**
Feet	768	895	587	528	525	427	366	470	439	819	797	596	564	467	429	**8,677**
Arms	214	236	140	141	135	111	88	126	129	237	264	212	211	226	189	**2,659**
Legs	431	361	254	203	164	156	148	222	191	410	286	319	304	344	257	**4,050**
Main Body	924	933	502	498	439	395	323	358	349	575	533	418	402	309	290	**7,248**
Various	85	79	50	60	55	40	61	52	74	149	129	101	81	64	51	**1,131**
TOTAL	**3,951**	**4,157**	**2,585**	**2,414**	**2,160**	**1,829**	**1,668**	**2,052**	**1,914**	**3,500**	**3,361**	**2,840**	**2,704**	**2,453**	**2,150**	**39,738**

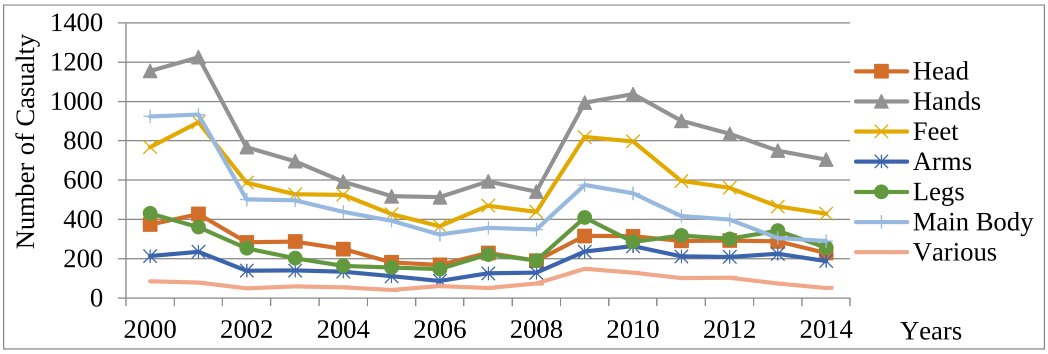
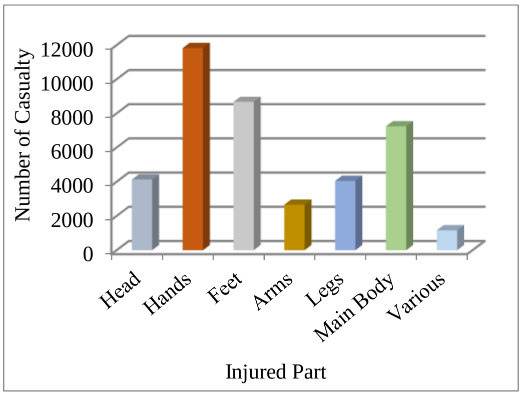


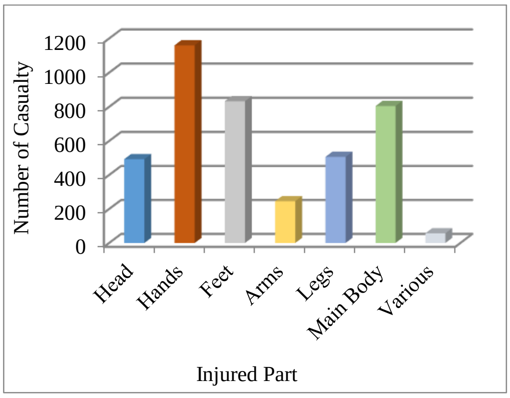
Figure 33 Injured body parts of casualties in TTK between 2000 and 2014

Figure 34 show the distribution of total injuries in TTK, Amasra, Armutçuk, Karadon, Kozlu and Üzülmez mines. When the number of casualties between 2000 and 2014 are examined in terms of injured body parts in all mines, it is seen that the injured body parts in the accidents in Amasra, Armutçuk, Karadon, Kozlu and Üzülmez mines are not so different from each other and similar to the case in TTK (Figure 34). Hands and feet are the main injured body parts in the accidents for all mines (Figure 34). The number of casualties injured from hands in the accidents is the highest for all mines. The number of injury from feet and main body are very close to each other especially in Amasra, Karadon and Kozlu mines.

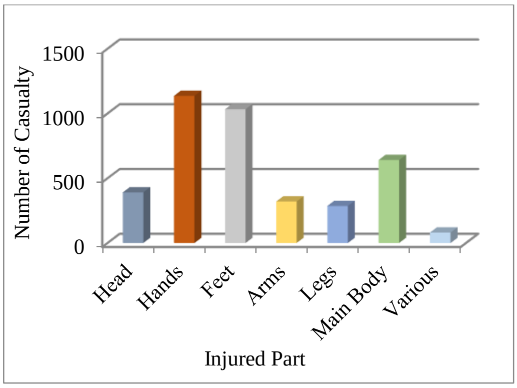
Figure 33 and 34 show that the ratios of injured body parts change from year to year and from mine to mine. However, in general for all mines and for all years hands and feet are the most injured parts in accidents. The main body injuries are also important in the accidents.



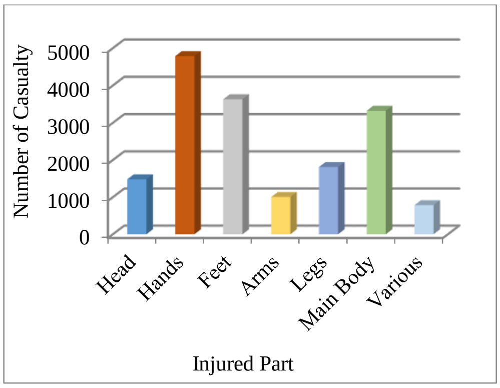
(a) TTK



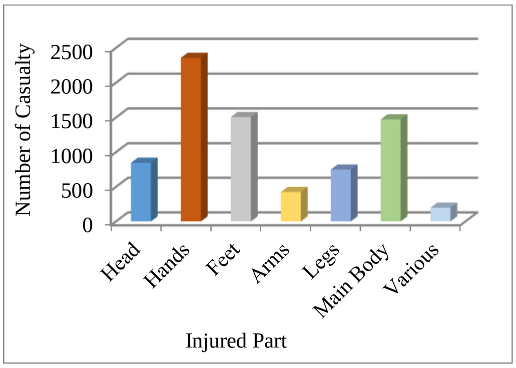
(b) Amasra mine



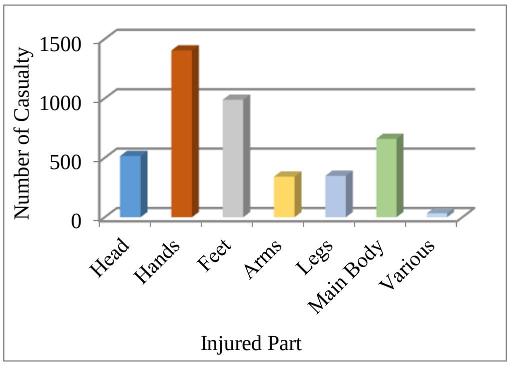
(c) Armutçuk mine



(d) Karadon mine



(e) Kozlu mine



(f) Üzülmez mine

Figure 34 Total number of accidents with respect to injured body part of casualties in TTK mines between 2000 and 2014

6.1.9 Days Lost

One of the most important consequences of occupational accidents is days lost. Days lost is directly related with the economies of enterprises since labor cost is an important item in business. Loosing days after an accident causes the decreasing power of labor and at the same time increasing the labor cost for the job. Days lost is also important to carry out the risk analysis study. Most enterprises suffer from the costs of days lost in the occupational injuries. For the fatalities the situation is much more dramatic. Moreover, apart from the dramatic side of the issue, the corresponding assumed days lost values in the fatalities are extremely high. In this study days lost have been analyzed on the basis of accident types. The days lost for each type of accident have been examined for all five mines and for each year.

Table 19 and Figure 35 show that the days lost due to Roof Falls has the highest value for TTK. Although the values varies through years for all types, TTK has lost more days due to roof fall accidents. TTK has lost 263,187 days during fifteen years due to roof fall accidents (Table 19). The decrease in the days lost resulting from roof fall accidents is significant for the years 2013 and 2014 (Figure 35). Moreover, the increase in the amount of days lost due to the occupational accidents caused by struck by objects is also clear in 2009 and 2010 (Figure 35). Between the years 2000 and 2014 totally 666,061 days have been lost in 39,738 occupational accidents excluding accidents causing fatalities. The average days lost per accident is 16.761 days. It means that TTK lost 16.8 days in an occupational accident on the average.

Table 19 Days lost for each type of accidents in TTK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
Roof Fall	22,479	26,711	18,811	14,707	18,310	17,678	14,184	15,524	16,415	21,578	18,486	17,920	18,122	13,928	8,334	**263,187**
Transport.	1,396	1,379	1,195	892	1,832	2,631	916	3,169	2,605	3,215	2,970	3,419	1,720	2,140	2,085	**31,564**
Mat Hand.	11,009	10,247	5,954	7,742	8,485	11,374	8,812	5,639	6,764	11,579	9,657	7,802	8,328	7,893	7,372	**128,657**
Slip/Fall	4,565	6,005	3,480	5,427	7,771	5,926	5,119	7,879	4,422	7,184	7,123	5,465	4,797	6,430	5,350	**86,943**
Struck Obj.	2,364	4,286	3,134	4,474	3,807	2,166	3,605	6,380	5,513	12,208	13,587	6,341	5,164	5,346	6,882	**85,257**
Mech. Electr.	1,218	1,459	1,452	1,579	1,725	1,900	1,222	1,134	1,111	1,437	2,737	2,935	2,119	1,927	1,604	**25,559**
Others	4,949	4,952	2,690	3,298	4,810	6,941	4,099	4,518	2,226	1,415	1,360	1,576	575	976	509	**44,894**
TOTAL	**47,980**	**55,039**	**36,716**	**38,119**	**46,740**	**48,616**	**37,957**	**44,243**	**39,056**	**58,616**	**55,920**	**45,458**	**40,825**	**38,640**	**32,136**	**666,061**

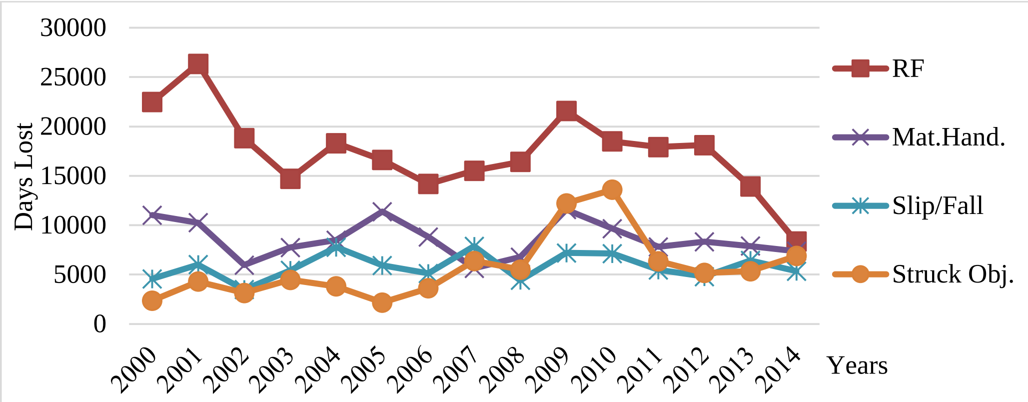


Figure 35 Days lost for type of accidents in TTK

Figure 36 indicates the relation between the total number of accidents and related days lost in TTK between 2000 and 2014. It is very clear that there is no direct relation between the two. Although the number of accidents in 2009 is not the highest, the days lost for this year is the highest for all years (58,616 days). Especially, considering the lack of days lost data for Armutçuk (2000-2004) and Kozlu (2000-2002) mines, no direct correlation between the number of accident and the related days lost can be established.

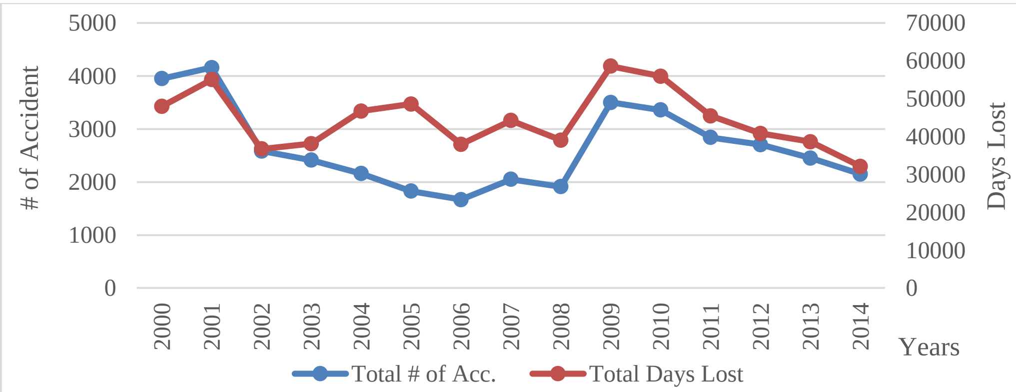


Figure 36 Number of accidents and corresponding days lost in TTK

Table 20 shows the days lost values on yearly basis for the mines. TTK losses 46,889 days due to occupational underground accidents and Karadon is the mine having maximum days lost value per year with 21,513 days/year (Table 20). Approximately, 43% of this value belongs to the days lost resulting from roof fall accidents in Karadon mine. This value is approximately, 50% of the yearly days lost value due to roof falls (18,872 days lost/year) for TTK. (Table 20). Üzülmez mine follows Karadon mine with 11,845 days lost/year. The third mine in this manner is Kozlu mine with 7,316 days/year. The least number of days lost belongs to Amasra and Armutçuk mines with 3,149 and 3,066 days per years, respectively.

Table 20 Yearly days dost for each type of accident in the mines

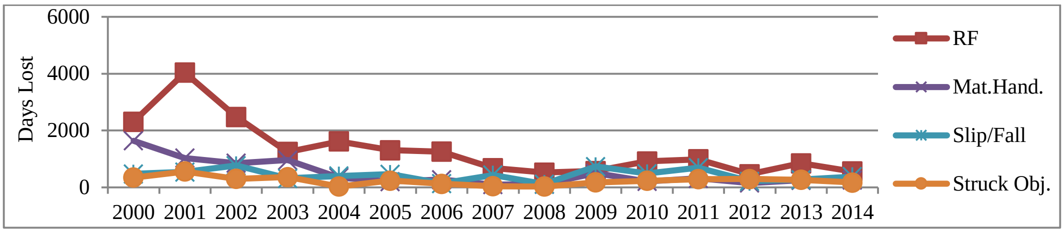
	AMASRA	ARMUTÇUK	KARADON	KOZLU	ÜZÜLMEZ	TOTAL
RF	1,321	1,216	9,326	1,603	4,806	18,272
Trans.	217	249	570	350	871	2,257
Mat. Hand.	482	529	5,498	1,224	1,266	8,998
Slip/Fall	430	692	2,288	1,286	1,588	6,284
Struck Obj.	233	31	1,119	2,373	2,413	6,169
Mech. Electr.	140	188	438	267	787	1,820
Others	326	162	2,274	212	115	3,089
TOTAL	3,149	3,066	21,513	7,316	11,845	46,889

Tables 21 show the distribution of days lost values for each mine for each type of accident between 2000 and 2014. Karadon minehas the highest values of days lost. In Karadon mine during fifteen years totally 322,693 days have been lost. The second highest days lost value is in Üzülmez mine with 177,673 days lost. Kozlu and Amasra mines follow these mines with 82,794 and 47,238 days lost, respectively. Armutçuk mine has the least number of days lost. Between 2000 and 2014 totally 30,663 days have been lost in Armutçuk mine (Table 21). Actually, the days lost data for Armutçuk mine does not exist for the years 2000 to 2004. Additionally for 2000, 2001 and 2002 the days lost data does not exist for Kozlu mine. Considering the absence of days lost data for some of the mines for some years, the yearly days lost values for the mines is more meaningful.

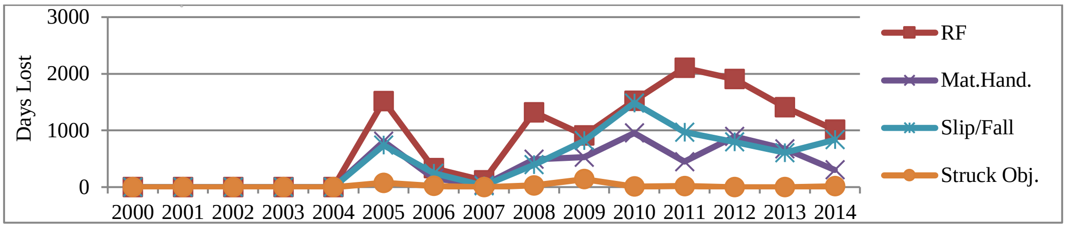
Table 21 Days lost for each type of accidents in the mines

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
AMASRA	Roof Fall	2310	4042	2480	1247	1617	1308	1257	681	522	576	914	989	467	846	562	19818
	Transport.	132	428	222	137	129	425	348	14	135	196	193	674	51	28	149	3261
	Mat. Hand.	1639	1031	851	961	349	205	273	101	117	500	211	317	158	253	260	7226
	Slip/Fall	478	542	771	316	402	466	137	437	115	733	489	697	218	273	379	6453
	Struck Obj.	348	559	301	366	33	238	129	44	32	176	236	291	294	266	175	3488
	Mech. Electr.	246	334	345	9	245	189	58	41	47	87	138	98	58	44	157	2096
	Others	684	571	393	414	432	182	461	314	553	265	307	125	58	38	99	4896
	TOTAL	5837	7507	5363	3450	3207	3013	2663	1632	1521	2533	2488	3191	1304	1748	1781	47238
ARMUTÇUK	Roof Fall	0	0	0	0	0	1519	332	117	1319	913	1525	2104	1906	1411	1013	12159
	Transport.	0	0	0	0	0	71	0	19	638	394	373	239	364	188	199	2485
	Mat. Hand.	0	0	0	0	0	807	154	39	491	527	956	449	894	674	303	5294
	Slip/Fall	0	0	0	0	0	741	246	23	395	818	1485	970	798	606	836	6918
	Struck Obj.	0	0	0	0	0	74	21	0	30	141	10	19	0	0	17	312
	Mech. Electr.	0	0	0	0	0	454	47	0	91	52	285	143	342	379	87	1880
	Others	0	0	0	0	0	334	225	12	77	48	229	220	232	128	110	1615
	TOTAL	0	0	0	0	0	4000	1025	210	3041	2893	4863	4144	4536	3386	2565	30663
KARADON	Roof Fall	13844	13627	10580	7000	9456	8358	6363	9000	9995	13973	10556	8308	9838	6823	2166	139887
	Transport.	3	0	1	0	397	0	112	936	912	1762	1505	817	589	705	811	8550
	Mat. Hand.	5816	7856	4697	5417	5827	7732	6375	3908	5037	7168	6603	4941	3682	4370	3035	82464
	Slip/Fall	2466	2370	1601	2168	3787	1921	1293	4596	1594	1876	1988	1460	1533	3431	2236	34320
	Struck Obj.	0	0	113	0	78	350	513	68	78	3132	2736	1060	1473	3144	4038	16783
	Mech. Electr.	0	226	185	28	103	6	98	198	644	528	1789	966	714	561	528	6574
	Others	4146	4355	2259	2628	4262	5676	2887	3804	1403	452	253	1139	140	527	184	34115
	TOTAL	26275	28434	19436	17241	23910	24043	17641	22510	19663	28891	25430	18691	17969	19561	12998	322693
KOZLU	Roof Fall	0	0	0	549	1910	2555	2531	2200	374	527	851	2451	2106	1534	1652	19240
	Transport.	0	0	0	0	116	883	227	767	0	32	0	884	245	452	597	4203
	Mat. Hand.	0	0	0	705	1130	1389	1512	701	326	866	746	1350	2012	1903	2050	14690
	Slip/Fall	0	0	0	858	1515	1057	2447	1855	1569	2126	1555	971	748	419	310	15430
	Struck Obj.	0	0	0	841	1853	94	670	3481	3428	6701	7894	1723	1066	406	321	28478
	Mech. Electr.	0	0	0	121	62	126	461	270	92	89	200	543	515	419	310	3208
	Others	0	0	0	208	116	110	291	139	176	519	456	72	117	236	105	2545
	TOTAL	0	0	0	3282	6702	6214	8139	9413	5965	10860	11702	7994	6809	5369	5345	87794
ÜZÜLMEZ	Roof Fall	6325	9042	5751	5911	5327	3938	3701	3526	4205	5589	4640	4068	3805	3314	2941	72083
	Transport.	1261	951	972	755	1190	1252	229	1433	920	831	899	805	471	767	329	13065
	Mat. Hand.	3554	1360	406	659	1179	1241	498	890	793	2518	1141	745	1582	693	1724	18983
	Slip/Fall	1621	3093	1108	2085	2067	1741	996	968	749	1631	1606	1367	1500	1701	1589	23822
	Struck Obj.	2016	3727	2720	3267	1843	1410	2272	2787	1945	2058	2711	3248	2331	1530	2331	36196
	Mech. Electr.	972	899	922	1421	1315	1125	558	625	237	681	325	1185	490	524	522	11801
	Others	119	26	38	48	0	639	235	249	17	131	115	20	28	47	11	1723
	TOTAL	15868	19098	11917	14146	12921	11346	8489	10478	8866	13439	11437	11438	10207	8576	9447	177673

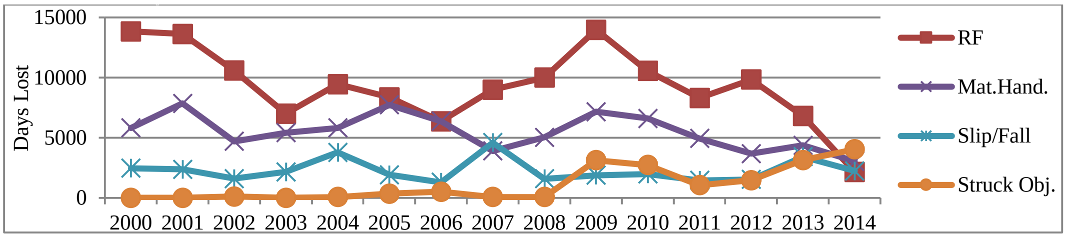
Figure 37 illustrates the days lost for each mine in terms of type of accidents. There is also lack of days lost data for the years 2006 and 2007 for Armutçuk mine. As in the case of number of accidents, the main reasons of days lost in terms of types of accident varies from mine to mine. For example, roof fall and slip/fall are the two major accidents types causing days lost in Armutçuk mine. On the other hand, in Karadon mine, Material handling is the type of accident causing the second highest days lost value following roof fall. Main cause of days lost in Kozlu and Üzülmez mines is struck by objects following roof fall (Figure 37).



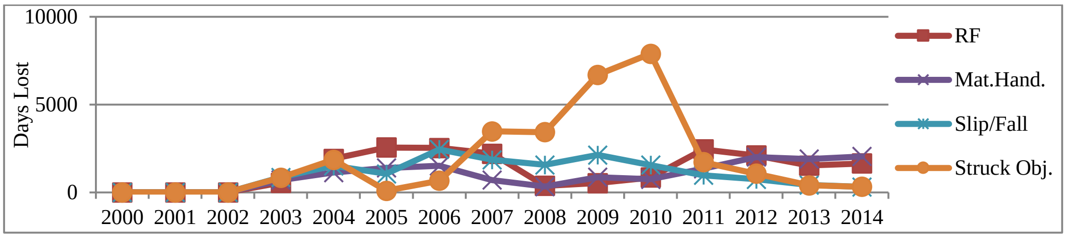
(a) Amasra mine



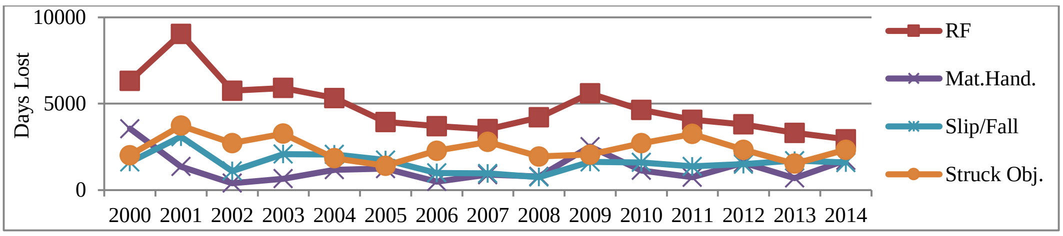
(b) Armutçuk mine



(c) Karadon mine



(d) Kozlu mine



(e) Üzülmez mine

Figure 37 Days lost for type of accidents in the mines

6.1.10 Different Job Allocation

In the analysis of accidents the difference between the main duty and assigned duty to the worker as a factor for accident occurrence has been examined "ASIL GÖREV" and "KAZA GÖREVİ" columns have been compared and the different allocation of job during accident occurrence determined. In the mines, workers are assigned job at every shift considering the current conditions in the mine. Due to this fact, sometimes workers might be assigned to any job other than his/her main duty considering the existing conditions in the mine. This may be an important factor for an occupational accident. A job performed by a worker who is not experienced enough induces more accident risk. In fact, there are two important aspects of this issue. One is that, assigning a more dangerous duty to a worker in the less dangerous main duty group, the other one is assigning a less dangerous duty to a worker in the more dangerous main duty group. The first one is much more dangerous and increases the related hazard. The second one may be considered more innocent but this alternative should also be avoided and every worker should be assigned to his/her main duty according to his/her competence and experience.

Table 22 illustrates the different job assignment and their ratios in all the accidents in the mines. The Karadon Mine is the first mine in this respect with 904 different assignments. This means that in the 904 of 16,287 occupational accidents, casualties have been assigned different duties other than their main duties (Table 22).

Table 22 Different job assignment in the accidents in TTK mines

	Total No of Acc.	Same Job	Different Job	Unknown	% of Diff. Job
Amasra	4,101	3,942	127	32	3.1
Armutçuk	3,889	3,645	221	23	5.7
Karadon	16,827	15,862	904	61	5.4
Kozlu	7,556	6,714	784	58	10.4
Üzülmez	7,365	7,092	257	16	3.5
TOTAL	39,738	37,255	2,293	190	5.8

The second mine in this analysis is Kozlu mine with 784 accidents. However, when the ratios are investigated, Kozlu mine comes the first with 10.4% which is a great share when compared with the others. Armutçuk and Karadon mines follows Kozlu mine with 5.7% and 5.4%, respectively (Figure 38). The ratio of different job assignment in the accidents occurred in Üzülmez mine is 3.5% (Figure 38). The smallest ratio belongs to Amasra mine with 3.1%. The overall ratio for TTK containing five mines is 5.8% which is not so small. This means that in TTK 5.8% of 39,738 accidents casualties have been assigned to another duty different from their main duty.

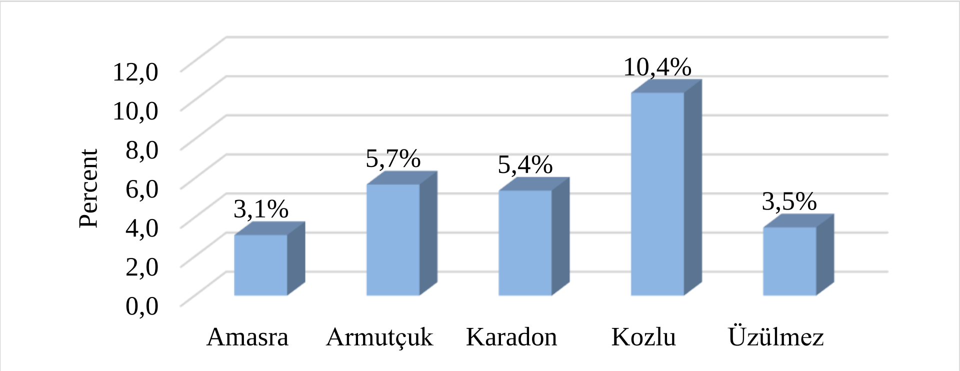


Figure 38 Different job assignment ratios in the mines

6.1.11 Accidents Resulting in Fatality

One of the dramatic results of occupational accidents is fatality. In an occupational accident in case of fatality not only the mine but also the family of the casualty is terribly affected. The effects of a fatality continues for a long time especially for his/her family members. For this reason fatalities are examined separately.

Table 23 and Figure 39 illustrate the number of fatalities through years 2000-2014 in TTK mines. In fifteen years totally 70 workers lost their lives in all the TTK Mines (Table 23). The highest number belongs to the year 2005 with 10 fatalities (Figure 39). Karadon mine has the highest value in the number of fatalities with 28 workers in fifteen years.

Table 23 Fatalities in TTK mines between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
AMASRA			1	2									1	1		**5**
ARMUTÇUK						1			1				1		1	**4**
KARADON			3	3	2	6	1	2	2	4	2	1	1	1		**28**
KOZLU				2		3		2	1	2	1		2			**13**
ÜZÜLMEZ	1	1	4	2			2	1	3		2	3	1			**20**
TTK	**1**	**1**	**8**	**9**	**2**	**10**	**3**	**5**	**7**	**6**	**5**	**4**	**6**	**2**	**1**	**70**

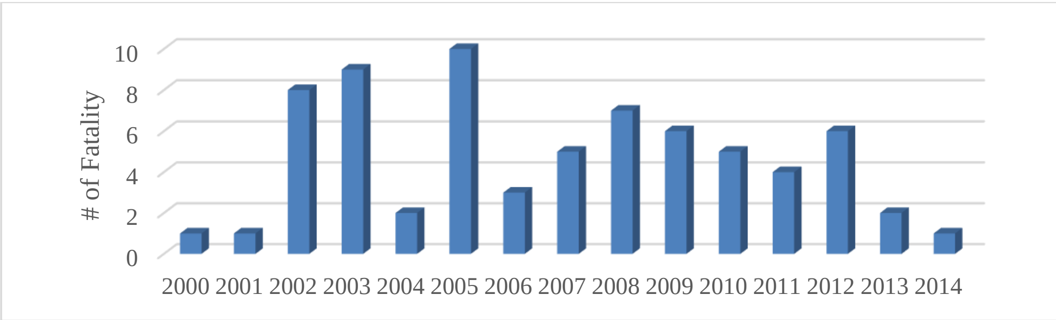


Figure 39 Fatalities in TTK mines between 2000 and 2014

Üzülmez mine comes the second with 20 fatalities (Figure 40). In the fifteen year period, 13 workers lost their lives due to occupational accidents in Kozlu mine. There is at least one fatality in each year in TTK mines.

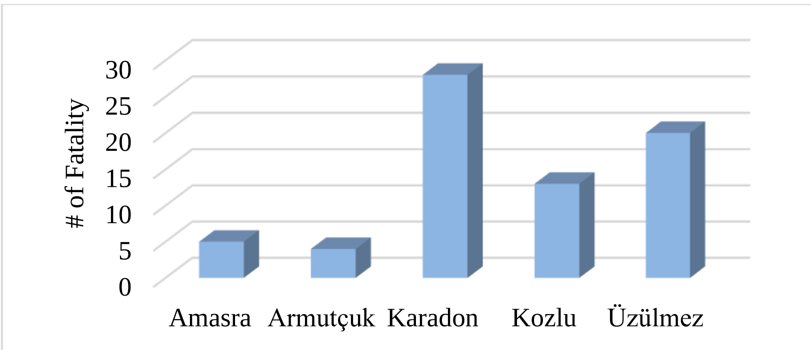


Figure 40 Total number of fatalities in the mines

Table 24 and Figure 41 show the number of fatalities and related accident types. According to the Table 24 and the Figure 39, roof falls are the most fatal accidents. 28 of 70 fatalities belong to the occupational accidents resulting from roof falls (Table 24). The second accident type responsible for the fatalities in this period is transportation with eight fatalities (Figure 41). The highest number of fatalities due to roof fall belongs to Üzülmez mine with 12 fatalities, although the mine has totally 20 fatalities. It means that a great portion (60%) of fatalities in Üzülmez mine occurs due to roof falls.

Table 24 Distribution of fatalities according to type of accidents

	AMASRA	ARMUTÇUK	KARADON	KOZLU	ÜZÜLMEZ	**TOTAL**
Roof Fall	2	0	9	5	12	**28**
Transportation	3	1	1	0	3	**8**
Material Handling	0	0	3	0	0	**3**
Slip/Fall	0	1	1	1	1	**4**
Struck by Objects	0	0	0	1	1	**2**
Mechanical and Electrical	0	0	0	0	0	**0**
Others	0	2	14	6	3	**25**
TOTAL	**5**	**4**	**28**	**13**	**20**	**70**

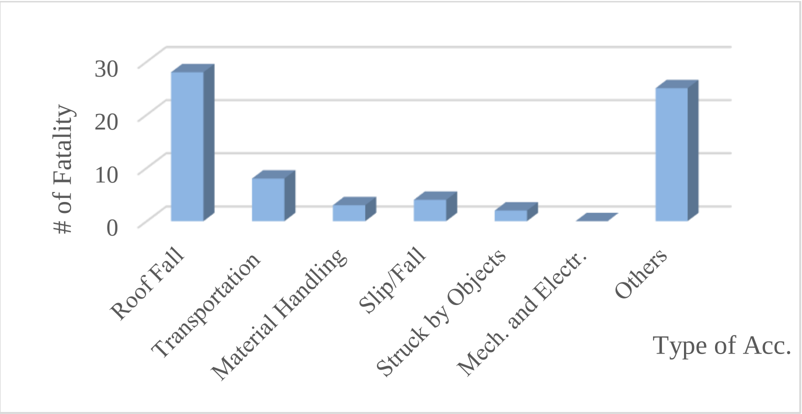


Figure 41 Total number of fatalities with respect to type of accidents

Considering the location of accidents causing fatality the analysis points out that most of the fatal accidents occur in the production faces. 26 of 70 fatal accidents occur in production faces (Table 25). Roadways and galleries and development faces are the two major accident locations causing fatality with 21 and 14 fatalities, respectively in the fifteen years period (Table 25 and Figure 42).

Table 25 Distribution of fatalities according to location of accidents

	AMASRA	ARMUTÇUK	KARADON	KOZLU	ÜZÜLMEZ	**TOTAL**
Production Face	2	1	11	2	10	**26**
Development Face	0	0	4	4	6	**14**
Gate Roads	1	1	0	5	0	**7**
Roadways, Galleries	2	1	13	2	3	**21**
Others	0	1	0	0	1	**2**
TOTAL	**5**	**4**	**28**	**13**	**20**	**70**

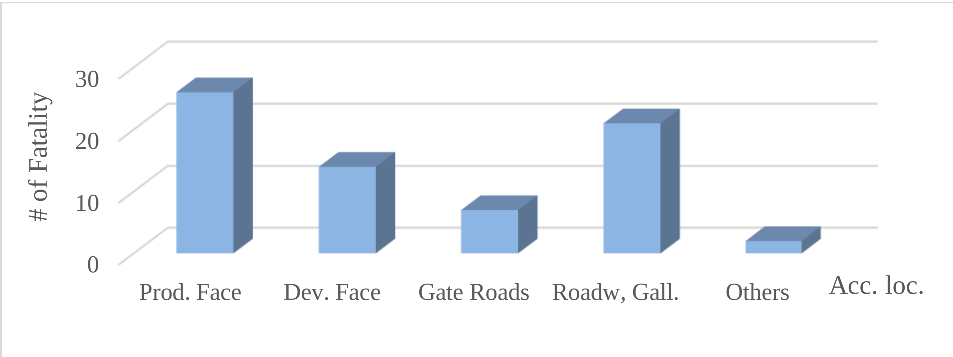


Figure 42 Total number of fatalities with respect to accidents locations

The distribution of fatalities according to the main duties of workers is tabulated and illustrated in Table 26 and Figure 43. Totally 41 production workers lost their lives in TTK mines between 2000 and 2014 (Table 26). The ratio of production workers in fatalities is approximately 58% which is a very high ratio. The following two main duties in the fatalities are transportation workers and development workers with nine and eight fatalities, respectively (Figure 43).

Table 26 Distribution of fatalities according to main duty

	AMASRA	ARMUTÇUK	KARADON	KOZLU	ÜZÜLMEZ	**TOTAL**
Production Worker	2	3	21	6	9	**41**
Development Worker	0	0	1	0	7	**8**
Transporting Worker	2	1	1	4	1	**9**
Mech.,Electrician,Rep.	0	0	1	1	0	**2**
Demontage Worker	1	0	0	0	0	**1**
Others	0	0	4	2	1	**7**
Unknown	0	0	0	0	2	**2**
TOTAL	**5**	**4**	**28**	**13**	**20**	**70**

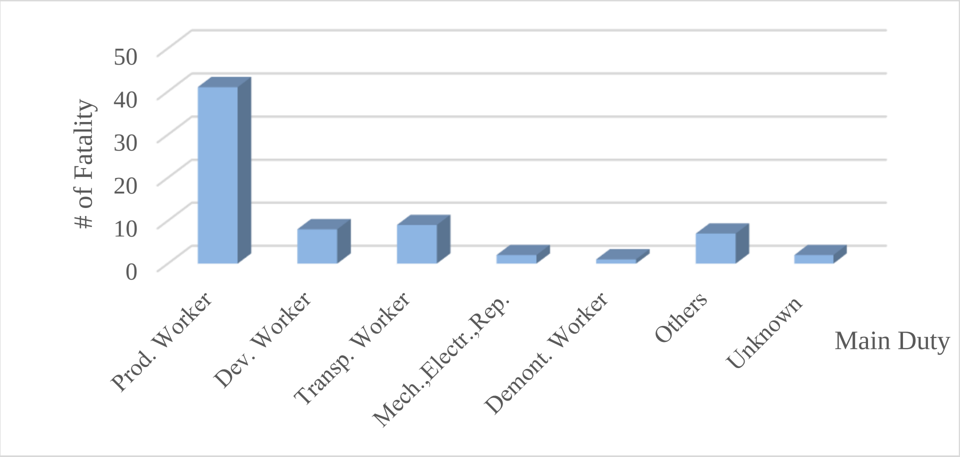


Figure 43 Total number of fatalities with respect to main duties

6.1.12 Hypothesis Testing

In previous section, the accident data analyzed and evaluated with general simple statistical methods. During the evaluation, there are some important points that should be taken into account. One of them is the portion of any injured group in the all injured population and the portion of the corresponding group of workers in the population of workers. These portions must be completely different to be able to make correct evaluations on the results. To eliminate this problem in the analysis the t-test has been applied to "Main Duty", "Education level" and "Age" of casualties. For this purpose, the share of all main duties of workers employed between 2005 and 2014 in all mines are gathered from the institution and the proportions of each main duty group in the analysis have been calculated considering the ten years interval. During the calculation the sum of 10 year data has been taken into account for both injured group and for all workers.

A t-test is a statistical examination of two population means. A two-sample t-test examines whether two samples are different and is commonly used when the variances of two normal distributions are unknown and when an experiment uses a small sample size.

6.1.12.1 Main Duty

Table 27 shows the t-test results for main duty of workers in TTK mines. The confidence interval is taken as %95. In other words α=0.05 is accepted as significance value for the injured group. Hear Hypothesis in the test are as follows:

H_0 : There is no difference between two proportions (π=p)

H_1 : The difference between two proportions is significant ($\pi \neq p$)

For this confidence interval the Z table value is found as 1.96 from Z tables. P values are calculated for each t ratio.

For main duty of workers t-test results show that for all TTK mines except some group of workers the proportion of injured main duty groups are completely different from proportions of corresponding group in worker population (Table 27). For development workers in Amasra, Armutçuk and Üzülmez mines and demontage workers in Amasra mine, since H_0 is accepted no evaluation could be done about the vulnerability of these groups (Table 27).

Table 27 T-Test results for the main duty of injured workers

Amasra

Main Duty	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
Prod. W.	0.710	0.438	0.272	0.000381	0.0195	13.92	0.0001	H_1
Dev. W.	0.096	0.117	-0.021	0.000161	0.0127	-1.67	0.0956	H_0
Trans. W.	0.055	0.119	-0.064	0.000162	0.0127	-5.01	0.0001	H_1
Mech.,Elect.	0.061	0.130	-0.069	0.000175	0.0132	-5.20	0.0001	H_1
Demont. W.	0.029	0.041	-0.012	0.000061	0.0078	-1.57	0.1177	H_0
Others	0.050	0.155	-0.106	0.000203	0.0143	-7.42	0.0001	H_1

Armutçuk

Main Duty	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
Prod. W.	0.737	0.388	0.349	0.000220	0.0148	23.49	0.0001	H_1
Dev. W.	0.079	0.070	0.009	0.000060	0.0078	1.11	0.2673	H_0
Trans. W.	0.070	0.182	-0.112	0.000138	0.0118	-9.50	0.0001	H_1
Mech.,Elect.	0.047	0.130	-0.083	0.000105	0.0103	-8.12	0.0001	H_1
Demont. W.	0.050	0.080	-0.030	0.000068	0.0082	-3.63	0.0003	H_1
Others	0.018	0.150	-0.132	0.000119	0.0109	-12.16	0.0001	H_1

Karadon

Main Duty	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
Prod. W.	0.794	0.387	0.406	0.000075	0.0087	46.98	0.0001	H_1
Dev. W.	0.056	0.093	-0.037	0.000027	0.0052	-7.21	0.0001	H_1
Trans. W.	0.066	0.178	-0.112	0.000046	0.0068	-16.52	0.0001	H_1
Mech.,Elect.	0.030	0.149	-0.119	0.000040	0.0063	-18.86	0.0001	H_1
Demont. W.	0.030	0.060	-0.031	0.000018	0.0042	-7.24	0.0001	H_1
Others	0.026	0.133	-0.107	0.000036	0.0060	-17.78	0.0001	H_1

Kozlu

Main Duty	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
Prod. W.	0.723	0.405	0.318	0.000144	0.0120	26.54	0.0001	H_1
Dev. W.	0.139	0.121	0.018	0.000063	0.0080	2.26	0.0240	H_1
Trans. W.	0.066	0.168	-0.102	0.000083	0.0091	-11.17	0.0001	H_1
Mech.,Elect.	0.036	0.154	-0.118	0.000078	0.0088	-13.41	0.0001	H_1
Demont. W.	0.009	0.019	-0.009	0.000011	0.0033	-2.84	0.0046	H_1
Others	0.027	0.134	-0.107	0.000069	0.0083	-12.83	0.0001	H_1

Üzülmez

Main Duty	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
Prod. W.	0.735	0.393	0.342	0.000133	0.0115	29.68	0.0001	H_1
Dev. W.	0.117	0.130	-0.013	0.000063	0.0079	-1.64	0.1013	H_0
Trans. W.	0.061	0.187	-0.126	0.000085	0.0092	-13.73	0.0001	H_1
Mech.,Elect.	0.040	0.137	-0.097	0.000066	0.0081	-11.91	0.0001	H_1
Demont. W.	0.019	0.030	-0.011	0.000016	0.0040	-2.64	0.0084	H_1
Others	0.028	0.123	-0.095	0.000060	0.0078	-12.30	0.0001	H_1

TTK

Main Duty	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
Prod. W.	0.758	0.396	0.362	0.000029	0.0053	67.73	0.0001	H_1
Dev. W.	0.087	0.105	-0.019	0.000011	0.0034	-5.57	0.0001	H_1
Trans. W.	0.064	0.174	-0.109	0.000017	0.0041	-26.41	0.0001	H_1
Mech.,Elect.	0.037	0.144	-0.106	0.000015	0.0038	-27.77	0.0001	H_1
Demont. W.	0.026	0.046	-0.020	0.000005	0.0023	-8.75	0.0001	H_1
Others	0.028	0.135	-0.107	0.000014	0.0037	-28.76	0.0001	H_1

Although the proportion of production workers is 44% in Amasra mine, the proportion of injured production workers in the accidents is 70% (Table 27). This points out that production workers are the most vulnerable group. On the other hand, for transportation workers and mechanics and electricians the situation is different. Although their proportions in the total worker population are 12% and 13%, respectively, the ratios of injured transportation workers and mechanics and electricians among injured population are only 5.5% and 6%, respectively (Table 38). The risk of exposing an accident is lower for these group of workers. The evaluations could be done for each mine separately and for TTK from the Table 27. The results of the hypothesis testing for the main duty supports the results obtained from the descriptive statistics.

6.1.12.2 Age

The results of the hypothesis testing for age of casualties are tabulated in Table 28. Apart from the 31-35 age group in Amasra and Üzülmez mines, all groups are significant (H_1 is accepted) (Table 28). In other words, a conclusive result cannot be obtained regarding 31-35 age group in Amasra and Üzülmez mines, since the proportion of these groups in the mines are very similar with the proportions of the injured workers of the group in the injured population. For general evaluation, the most risky group for all mines is 26-30 age group. For example, in Amasra mine, although the percentage of 26-30 age group in the worker population is 8%, the proportion of injured 26-30 age group in the injured population is 36% (Table 28). Although the hypothesis H_1 is rejected for the 31-35 age group in the Amasra mine, the accident proneness of this group is relatively low in other mines except Karadon Mine (Table 28). Although the proportion of 36-40 age group in the worker population is 38% in the Amasra mine, the proportion of injured 36-40 age group in the injured population is only 14% percent (Table 28). It means that this group has relatively low risk. The risk decreases for the older workers. The vulnerability of higher age workers gets smaller as their age gets older.

Table 28 T-Test results for age of injured workers

Amasra

Age	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
≤ 25	0.156	0.006	0.150	0.000012	0.0035	43.21	0.0001	H_1
26-30	0.364	0.080	0.284	0.000148	0.0122	23.30	0.0001	H_1
31-35	0.256	0.281	-0.025	0.000406	0.0201	-1.23	0.2190	H_0
36-40	0.141	0.378	-0.237	0.000472	0.0217	-10.91	0.0001	H_1
41-45	0.069	0.203	-0.134	0.000325	0.0180	-7.45	0.0001	H_1
46≤	0.015	0.052	-0.037	0.000099	0.0100	-3.76	0.0002	H_1

Armutçuk

Age	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
≤ 25	0.166	0.006	0.160	0.000007	0.0026	61.43	0.0001	H_1
26-30	0.420	0.102	0.318	0.000098	0.0099	32.21	0.0001	H_1
31-35	0.224	0.293	-0.069	0.000220	0.0148	-4.65	0.0001	H_1
36-40	0.109	0.361	-0.252	0.000245	0.0157	-16.08	0.0001	H_1
41-45	0.064	0.177	-0.112	0.000155	0.0124	-9.03	0.0001	H_1
46≤	0.017	0.062	-0.045	0.000062	0.0078	-5.68	0.0001	H_1

Karadon

Age	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
≤ 25	0.134	0.004	0.130	0.000001	0.0012	111.54	0.0001	H_1
26-30	0.360	0.075	0.286	0.000026	0.0051	56.37	0.0001	H_1
31-35	0.267	0.321	-0.054	0.000081	0.0090	-6.03	0.0001	H_1
36-40	0.149	0.336	-0.188	0.000083	0.0091	-20.62	0.0001	H_1
41-45	0.073	0.190	-0.117	0.000057	0.0075	-15.53	0.0001	H_1
46≤	0.018	0.075	-0.057	0.000026	0.0051	-11.32	0.0001	H_1

Kozlu

Age	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
≤ 25	0.023	0.011	0.012	0.000007	0.0027	4.69	0.0001	H_1
26-30	0.302	0.097	0.205	0.000057	0.0075	27.16	0.0001	H_1
31-35	0.466	0.314	0.153	0.000140	0.0118	12.93	0.0001	H_1
36-40	0.185	0.303	-0.118	0.000137	0.0117	-10.10	0.0001	H_1
41-45	0.020	0.198	-0.178	0.000103	0.0102	-17.55	0.0001	H_1
46≤	0.003	0.077	-0.074	0.000046	0.0068	-10.86	0.0001	H_1

Üzülmez

Age	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
≤ 25	0.134	0.006	0.129	0.000004	0.0020	65.65	0.0001	H_1
26-30	0.360	0.061	0.299	0.000040	0.0063	47.41	0.0001	H_1
31-35	0.267	0.255	0.012	0.000132	0.0115	1.03	0.3033	H_0
36-40	0.149	0.359	-0.210	0.000160	0.0126	-16.65	0.0001	H_1
41-45	0.073	0.228	-0.155	0.000122	0.0111	-14.05	0.0001	H_1
46≤	0.018	0.092	-0.074	0.000058	0.0076	-9.75	0.0001	H_1

TTK

Age	p	π	p-π	π(1-π)/n	SE	t-ratio	p-value	H_0/H_1
≤ 25	0.156	0.006	0.150	0.000001	0.0009	161.53	0.0001	H_1
26-30	0.396	0.081	0.315	0.000010	0.0032	97.39	0.0001	H_1
31-35	0.241	0.299	-0.059	0.000029	0.0054	-10.82	0.0001	H_1
36-40	0.122	0.340	-0.217	0.000031	0.0056	-38.70	0.0001	H_1
41-45	0.066	0.198	-0.133	0.000022	0.0047	-28.11	0.0001	H_1
46≤	0.016	0.075	-0.060	0.000010	0.0031	-19.11	0.0001	H_1

6.1.12.3 Education Level

Regarding the t-test results for education level of casualties Table 29 indicates that only the casualty group with education level of secondary school in Üzülmez mine is not significant. All other groups in all mines are significant. In other words, only for this group the proportions are very similar and the accident results belonging to this group is not so meaningful since the proportion of injured workers graduated from secondary school in all casualties in Üzülmez mine is very close to the proportion of workers graduated from secondary school in all workers in Üzülmez mine.

From this point of view, when the results are examined it is not difficult to recognize that for all mines and for TTK in total the proportions of casualties in the injured workers (p) is greater than the proportions of workers in all workers(π) for primary school. This means that the workers graduated from primary school is more vulnerable in terms of being exposed to occupational accidents. The likelihood of having accident is smaller for all other groups for all mines (Table 29).

6.2 Data Analysis for Normalized Injury Data

Normalization means adjusting values measured on different scales to a notionally common scale, often prior to averaging. In more complicated cases, normalization may refer to more sophisticated adjustments where the intention is to bring the entire probability distributions of adjusted values into alignment. It also refers to the creation of shifted and scaled versions of statistics, where the intention is that these normalized values allow the comparison of corresponding normalized values for different datasets in a way that eliminates the effects of certain gross influences.

In this analysis all values belonging to occupational accidents in TTK are normalized with the run of mine coal production and number of workers in order to equalize the effect of production and worker population on occupational accidents. For this purpose data values are divided by run of mine production and total number of workers of related mine for the corresponding year. In the third stage all

Table 29 T-Test results for age of injured workers

Amasra

Education Level	p	π	p-π	π(1-π)/n	SE	t-ratio	p value	H_0/H_1
Prim. Sch.	0.7276	0.4079	0.3198	0.000500	0.0224	14.30	0.0001	H_1
Secondary Sch.	0.0961	0.1781	-0.0820	0.000303	0.0174	-4.71	0.0001	H_1
High Sch.	0.1619	0.3810	-0.2190	0.000488	0.0221	-9.91	0.0001	H_1
Univ.(2 or 4 y)	0.0002	0.0331	-0.0329	0.000066	0.0081	-4.04	0.0001	H_1

Armutçuk

Education Level	p	π	p-π	π(1-π)/n	SE	t-ratio	p value	H_0/H_1
Prim. Sch.	0.6634	0.4092	0.2542	0.000260	0.0161	15.77	0.0001	H_1
Secondary Sch.	0.1008	0.1665	-0.0657	0.000149	0.0122	-5.38	0.0001	H_1
High Sch.	0.2219	0.3899	-0.1680	0.000256	0.0160	-10.51	0.0001	H_1
Univ.(2 or 4 y)	0.0005	0.0344	-0.0339	0.000036	0.0060	-5.67	0.0001	H_1

Karadon

Education Level	p	π	p-π	π(1-π)/n	SE	t-ratio	p value	H_0/H_1
Prim. Sch.	0.5994	0.3762	0.2232	0.000087	0.0093	23.90	0.0001	H_1
Secondary Sch.	0.1647	0.2323	-0.0677	0.000066	0.0081	-8.31	0.0001	H_1
High Sch.	0.2212	0.3569	-0.1357	0.000085	0.0092	-14.69	0.0001	H_1
Univ.(2or4 y)	0.0012	0.0346	-0.0334	0.000012	0.0035	-9.48	0.0001	H_1

Kozlu

Education Level	p	π	p-π	π(1-π)/n	SE	t-ratio	p value	H_0/H_1
Prim. Sch.	0.6915	0.4262	0.2653	0.000160	0.0126	20.99	0.0001	H_1
Secondary Sch.	0.1432	0.2200	-0.0768	0.000112	0.0106	-7.25	0.0001	H_1
High Sch.	0.1482	0.3087	-0.1605	0.000139	0.0118	-13.60	0.0001	H_1
Univ.(2or4 y)	0.0012	0.0450	-0.0438	0.000028	0.0053	-8.28	0.0001	H_1

Üzülmez

Education Level	p	π	p-π	π(1-π)/n	SE	t-ratio	p value	H_0/H_1
Prim. Sch.	0.6077	0.4199	0.1878	0.000172	0.0131	14.33	0.0001	H_1
Secondary Sch.	0.1889	0.2040	-0.0151	0.000115	0.0107	-1.41	0.1589	H_0
High Sch.	0.1967	0.3458	-0.1491	0.000160	0.0126	-11.80	0.0001	H_1
Univ.(2or4 y)	0.0010	0.0303	-0.0294	0.000021	0.0046	-6.45	0.0001	H_1

TTK

Education Level	p	π	p-π	π(1-π)/n	SE	t-ratio	p value	H_0/H_1
Prim. Sch.	0.6380	0.4024	0.2356	0.000034	0.0058	40.34	0.0001	H_1
Secondary Sch.	0.1517	0.2115	-0.0598	0.000024	0.0049	-12.30	0.0001	H_1
High Sch.	0.1967	0.3502	-0.1535	0.000032	0.0057	-27.02	0.0001	H_1
Univ.(2or4 y)	0.0010	0.0359	-0.0349	0.000005	0.0022	-15.76	0.0001	H_1

occupational injury data is normalized with unit production (ton of ROM coal/worker) and obtained results are analyzed, separately. The normalization process is carried out to be able to examine to exact trend of accident behavior in the mines through years.

6.2.1 Analysis of Data Normalized with ROM Production

In this analysis all obtained values belonging to occupational accidents are divided by ROM coal production of the mines for each year. In all the calculations the Equation 4 is used.

$$NV(ROM) = N*10^3/P \qquad [4]$$

NV(ROM) : Normalized Value of Number of Accident with ROM Coal Production

N : Number of accident/casualty

P : Run of Mine Coal production (tonnes)

In Equation 4 the multiplier 10^3 is used not to struggle too many small decimals during calculations. For example, in the Amasra mine the number of casualty in 2000 is 542 and 276,727 tons of ROM coal was produced in this mine in 2000. Then the normalized number of casualty for Amasra mine in 2000 is calculated as follows:

N=542

P=276,727 tonnes

$$NV(ROM) = N*10^3/P$$
$$= 542*1000/276,727$$
$$=1.96$$

In Amasra mine there was 1.96 casualty per ton of coal production in the year 2000. This normalization calculation is carried out for all categories and in all mines for fifteen years. For the case of normalization of days lost data the value of N (Number of Accident/Casualty) is replaced by Days Lost (DL) value. Then Equation 4 takes the form of $NV(ROM)= DL*10^3/P$ where DL is the days lost value for the related injury in the accident.

6.2.1.1 Number of Accidents/Casualties

All the number of accident values are normalized using Equation 4 (Table 30 and Figure 44). When the Table 30 and Figure 44 are examined it can be seen that during this fifteen year interval the number of accident per ton of coal production increases although the production decreases through years. Figure 44 indicates that the previous analysis is not sufficient to investigate the change of number of accidents in the mines through years. Because raw data shows that the number of accidents in all mines decreases in fifteen years with some fluctuations, however, actually, as the normalized values point out, the unit number of accidents increases for TTK (Figure 44). The situation is different for each mine of TTK.

Table 30 NV(ROM) number of casualties

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
AMASRA	1.96	1.85	1.59	1.36	0.97	1.01	0.96	0.83	0.70	0.91	1.03	0.92	0.74	0.85	0.65	**1.12**
ARMUTÇUK	0.83	0.82	0.64	0.70	0.73	0.50	0.49	0.71	0.59	0.73	1.14	1.32	1.37	1.28	1.09	**0.82**
KARADON	1.23	1.16	0.81	0.83	0.79	0.72	0.83	1.19	1.18	1.86	1.86	1.47	1.45	1.56	1.35	**1.21**
KOZLU	1.49	1.33	0.87	0.83	0.82	0.75	0.70	0.71	0.51	0.93	0.86	0.70	0.75	0.66	0.62	**0.85**
ÜZÜLMEZ	0.97	1.07	0.54	0.66	0.65	0.62	0.63	0.55	0.75	0.86	0.83	1.01	1.07	1.00	1.16	**0.82**
TTK	**1.24**	**1.19**	**0.80**	**0.82**	**0.77**	**0.70**	**0.73**	**0.85**	**0.82**	**1.24**	**1.23**	**1.09**	**1.11**	**1.12**	**1.03**	**0.99**

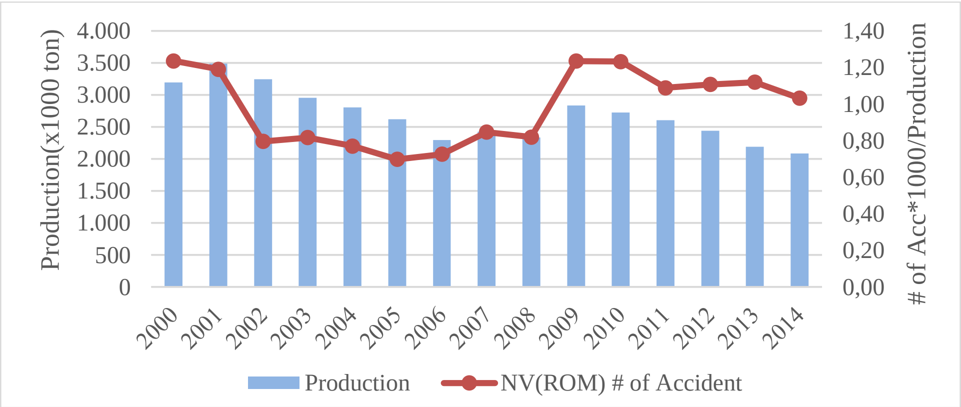


Figure 44 Production and NV(ROM) # of casualties in TTK between 2000 and 2014

Figures 45-49 illustrate the change of production and related normalized number of accidents in each mine. It can be concluded from the Figures 45-49 that although the normalized number of accidents decreases in Amasra and Kozlu mines, the Armutçuk, Karadon and Üzülmez mines behave like TTK. In Armutçuk, Karadon and Üzülmez mines, the NV(ROM) number of accidents increases although the production decreases. One attention should be given to the point that the decrease in normalized value of number of accidents is more apparent considering the production increase in Amasra (Figure 45).

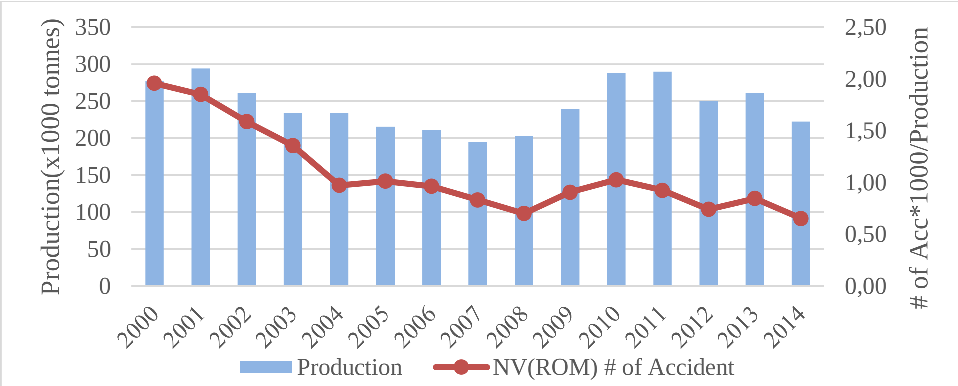


Figure 45 Production and NV(ROM) # of casualties in Amasra mine between 2000 and 2014

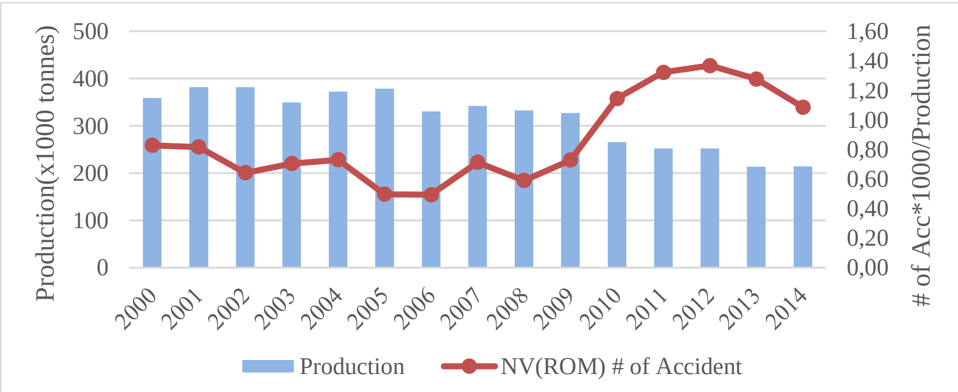


Figure 46 Production and NV(ROM) # of casualties in Armutçuk mine between 2000 and 2014

Figure 50 illustrates the NV(ROM) for all mines considering the total production and total number of accidents for the fifteen year's data. The Karadon and Amasra mine's normalized values are the highest with 1.21 and 1.12, respectively. Kozlu mine has the third highest normalized value of 0.85, Armutçuk and Üzülmez mines are the mines having the least normalized value of 0.82 (Figure 50). The main reason for Amasra mine having the second highest value is that it has the considerably high NV(ROM) values in 2000, 2001 and 2002 (Figure 45). Although the mine increases its production and the number of accidents decreases in the mine through years, overall values places the Amasra mine to the second. The situation for Karadon mine is completely different from Amasra mine. The NV(ROM) value for Karadon mine in 2000 is considerably low and smaller than Amasra and Kozlu mines, however, the NV(ROM) value for Karadon mine in 2014 is higher than the value in 2000, which means that the safety conditions for Karadon mine gets worse through the years (Figure 47). The trend of NV(ROM) values for Armutçuk and Üzülmez mines are similar to Karadon mine (Figures 46 and 49).

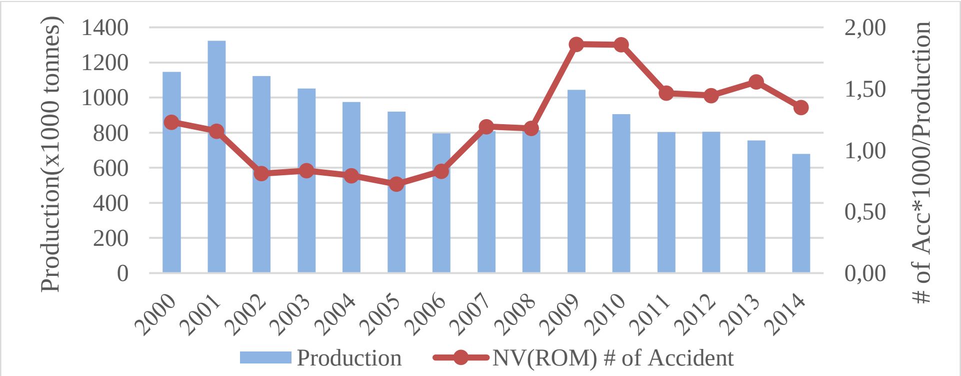


Figure 47 Production and NV(ROM) # of casualties in Karadon mine between 2000 and 2014

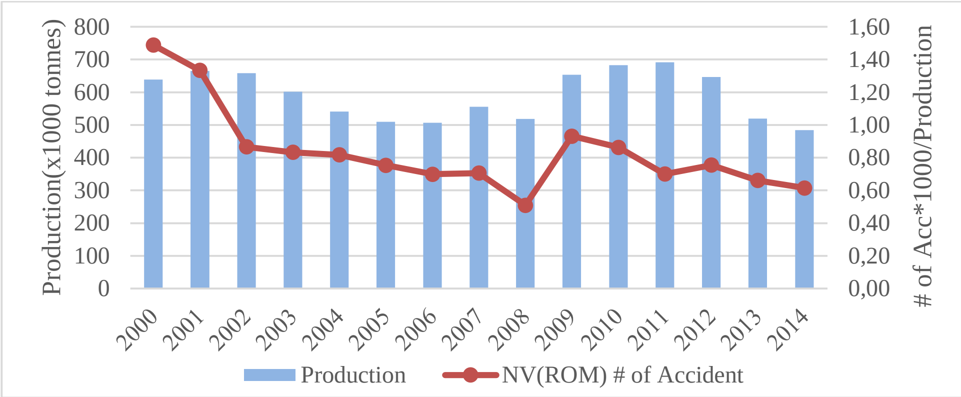


Figure 48 Production and NV(ROM) # of casualties in Kozlu mine between 2000 and 2014

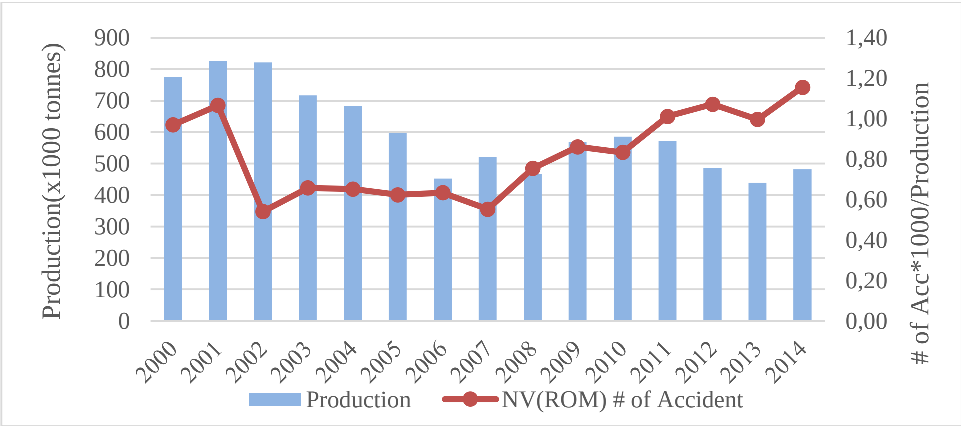


Figure 49 Production and NV(ROM) # of casualties in Üzülmez mine between 2000 and 2014

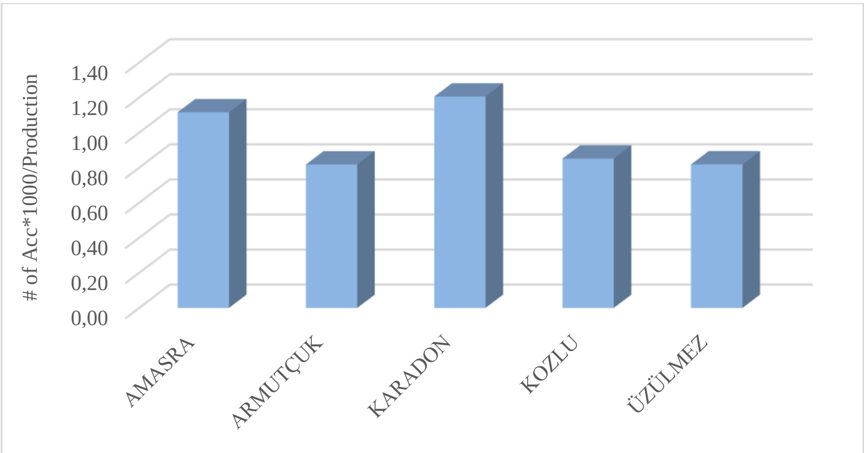


Figure 50 Total NV(ROM) # of casualties in the mines

6.2.1.2 Days Lost

The days lost data is analyzed after normalization. Table 31 shows the distribution of days lost according to the type of accidents for TTK mines in total for the fifteen years period. The total days lost for the accidents undulates through years, however it is not directly proportional to the ROM production (Figure 51).

Table 31 NV(ROM) days lost for TTK with respect to accident types

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
RF	7.03	7.65	5.79	4.98	6.53	6.75	6.18	6.41	7.03	7.62	6.78	6.87	7.42	6.36	4.00	**6.54**
Trans.	0.44	0.39	0.37	0.30	0.65	1.00	0.40	1.31	1.12	1.13	1.09	1.31	0.70	0.98	1.00	**0.78**
Mat. Hand.	3.44	2.93	1.83	2.62	3.03	4.34	3.84	2.33	2.90	4.09	3.54	2.99	3.41	3.60	3.54	**3.20**
Slip/Fall	1.43	1.72	1.07	1.84	2.77	2.26	2.23	3.25	1.89	2.54	2.61	2.10	1.96	2.93	2.57	**2.16**
Struck Obj.	0.74	1.23	0.97	1.51	1.36	0.83	1.57	2.63	2.36	4.31	4.98	2.43	2.12	2.44	3.30	**2.12**
Mech. Electr.	0.38	0.42	0.45	0.53	0.62	0.72	0.53	0.47	0.48	0.51	1.00	1.13	0.87	0.88	0.77	**0.63**
Others	1.55	1.42	0.83	1.12	1.72	2.65	1.78	1.86	0.95	0.50	0.50	0.60	0.24	0.45	0.24	**1.12**
TOTAL	**15.01**	**15.76**	**11.31**	**12.90**	**16.67**	**18.55**	**16.53**	**18.25**	**16.72**	**20.69**	**20.50**	**17.44**	**16.72**	**17.64**	**15.42**	**16.55**

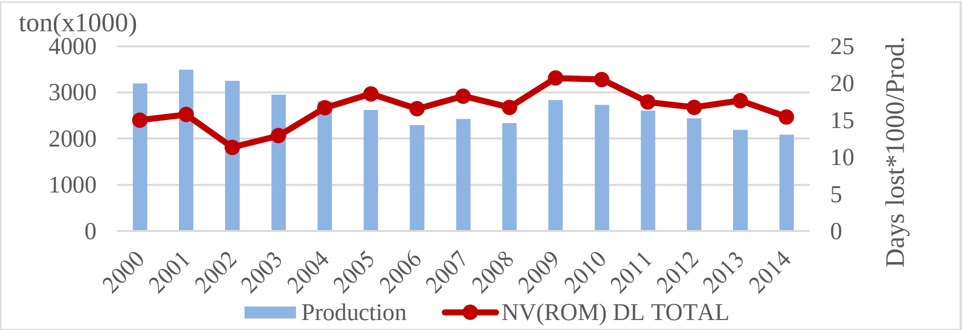


Figure 51 Production and NV(ROM) days lost in TTK between 2000 and 2014

Although the proportions of accidents types in days lost in TTK varies between years, roof fall and material handling have the highest shares (Figure 52). The relatively high share of struck by objects for days lost for 2009 and 2010 results from the corresponding values for Kozlu mine in these years. The overall distribution of all days lost data for the accident types is illustrated in Figure 52.

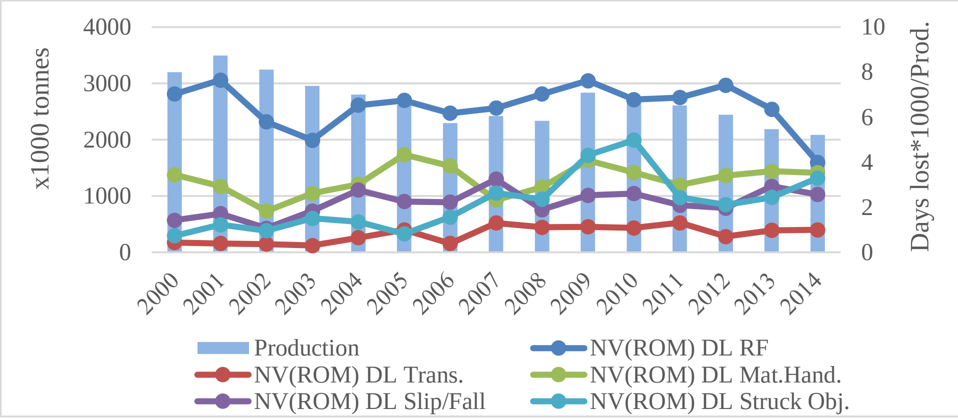


Figure 52 Production and NV(ROM) days lost with respect to the type of accidents in TTK between 2000 and 2014

Roof fall has the highest NV(ROM) days lost value with 6.54 (Figure 53) . Material handling and slip fall follows roof fall with 3.2 and 2.16 values (Figure 53). The smallest share belong to accidents resulting from transportation and mechanical and electrical works with 0.78 and 0.63, respectively. Regarding the share of total days lost among mines due to underground occupational accidents, Karadon mine is the first mine with a value of 23.12. Armutçuk mine has the lowest total normalized days lost value (Figure 54).

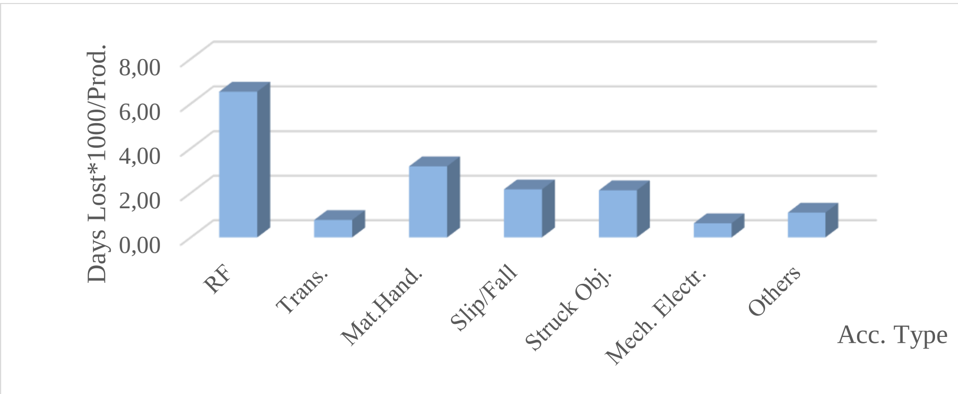


Figure 53 Total NV(ROM) days lost in TTK with respect to type of accidents between 2000 and 2014

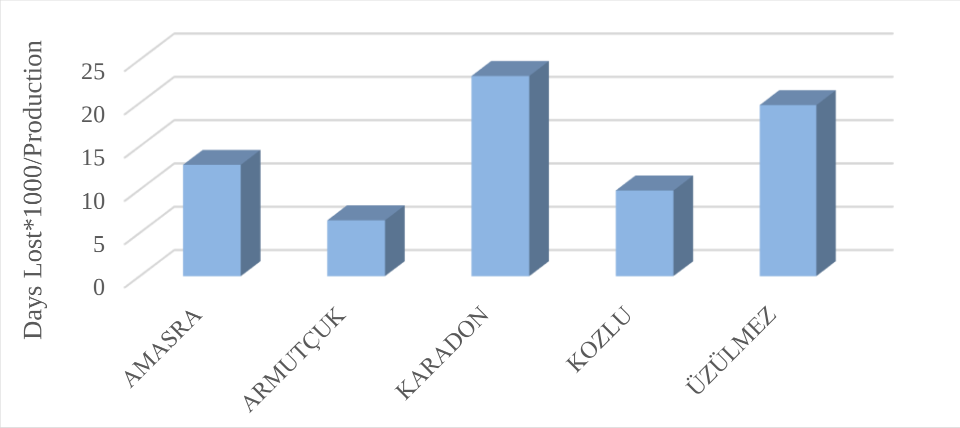


Figure 54 Total NV(ROM) days lost in TTK mines

The normalized values of days lost considering the type of accidents through years for five mines are tabulated in Tables 32-36. Figures 55-59 illustrate how the normalized value of total days lost in the mines changes throughout the years together with production changes in these mines. Roof fall is the first accident type having the highest normalized days lost value for all mines. However, the ratio of roof fall changes from mine to mine. For example, the ratios of normalized value of days lost resulting from roof fall in Karadon and Üzülmez mines are almost 50 percent although this ratio is relatively small in the other mines. In Amasra mine, the NV(ROM) DL decreases through years till 2012, with a slight increase in 2013 and 2014 (Figure 55). The maximum NV(ROM) DL is seen in the year 2001 as 25.50, and the minimum NV(ROM) DL of 5.21 occurs in 2012 in Amasra mine (Table 32).

Table 32 NV(ROM) Total days lost in Amasra mine for accident types between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
RF	8.35	13.73	9.51	5.33	6.92	6.07	5.96	3.50	2.57	2.40	3.18	3.41	1.87	3.24	2.53	5.39
Trans.	0.48	1.45	0.85	0.59	0.55	1.97	1.65	0.07	0.66	0.82	0.67	2.33	0.20	0.11	0.67	0.89
Mat. Hand.	5.92	3.50	3.26	4.11	1.49	0.95	1.29	0.52	0.58	2.09	0.73	1.09	0.63	0.97	1.17	1.97
Slip/Fall	1.73	1.84	2.96	1.35	1.72	2.16	0.65	2.24	0.57	3.06	1.70	2.40	0.87	1.05	1.70	1.76
Struck Obj.	1.26	1.90	1.15	1.57	0.14	1.10	0.61	0.23	0.16	0.73	0.82	1.00	1.18	1.02	0.79	0.95
Mech. Electr.	0.89	1.13	1.32	0.04	1.05	0.88	0.28	0.21	0.23	0.36	0.48	0.34	0.23	0.17	0.71	0.57
Others	2.47	1.94	1.51	1.77	1.85	0.84	2.19	1.61	2.72	1.11	1.07	0.43	0.23	0.15	0.45	1.33
TOTAL	**21.09**	**25.50**	**20.56**	**14.75**	**13.73**	**13.99**	**12.63**	**8.38**	**7.49**	**10.57**	**8.65**	**11.01**	**5.21**	**6.69**	**8.01**	**12.86**

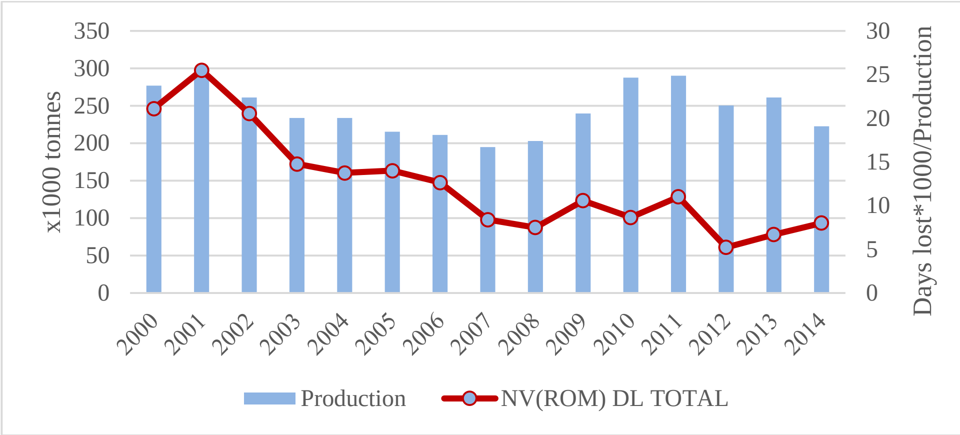


Figure 55 Production and NV(ROM) days lost in Amasra mine between 2000 and 2014

As mentioned before there is a lack of data for days lost till 2005 in Armutçuk mine. In 2005, there is a sharp increase as illustrated in the Figure 56. Sharp undulations in the graph points that the days lost data in Armutçuk mine is not reliable till 2008. After 2008, although the production decreases the NV(ROM) DL increases in Armutçuk mine (Figure 56). The highest NV(ROM) DL in Armutçuk mine is observed in the year as 17.98 (Table 33).

Table 33 NV(ROM) days lost in Armutçuk mine with respect to accident types between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
RF	0.00	0.00	0.00	0.00	0.00	4.01	1.00	0.34	3.97	2.79	5.74	8.36	7.55	6.60	4.72	2.56
Trans.	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.06	1.92	1.21	1.40	0.95	1.44	0.88	0.93	0.52
Mat. Hand.	0.00	0.00	0.00	0.00	0.00	2.13	0.47	0.11	1.48	1.61	3.60	1.78	3.54	3.15	1.41	1.11
Slip/Fall	0.00	0.00	0.00	0.00	0.00	1.96	0.74	0.07	1.19	2.50	5.59	3.85	3.16	2.83	3.89	1.46
Struck Obj.	0.00	0.00	0.00	0.00	0.00	0.20	0.06	0.00	0.09	0.43	0.04	0.08	0.00	0.00	0.08	0.07
Mech. Electr.	0.00	0.00	0.00	0.00	0.00	1.20	0.14	0.00	0.27	0.16	1.07	0.57	1.36	1.77	0.41	0.40
Others	0.00	0.00	0.00	0.00	0.00	0.88	0.68	0.04	0.23	0.15	0.86	0.87	0.92	0.60	0.51	0.34
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**10.57**	**3.10**	**0.61**	**9.15**	**8.85**	**18.31**	**16.46**	**17.98**	**15.84**	**11.94**	**6.45**

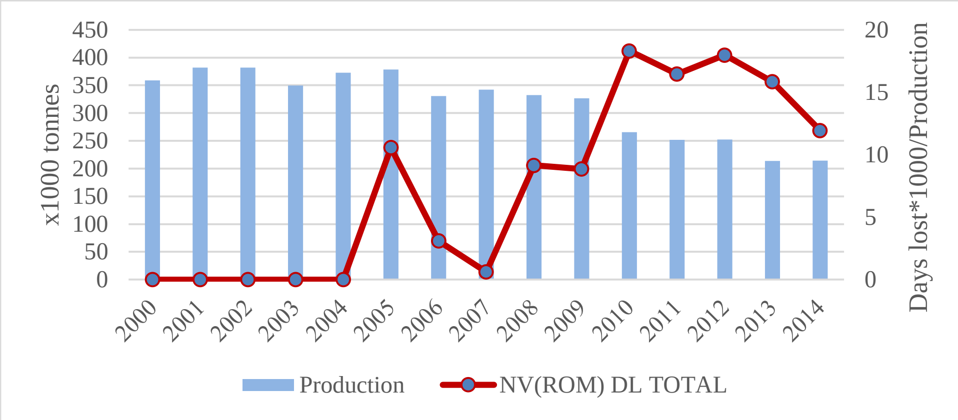


Figure 56 Production and NV(ROM) days lost in Armutçuk mine between 2000 and 2014

NV(ROM) DL values are relatively high for Karadon mine when compared with the other mines. The values varies between 16 and 28. The highest value belongs to the year 2010 with 28.09 (Table 34). As mentioned before one important point that could be driven from the table is the value belonging to roof fall (10.02) is 43% of total. (Table 34). The accident type having the second highest value is material handling with 5.91 (Table 34). The total NV(ROM) DL values fluctuate through years. There is no significant continuous increase or decrease. But the range of values is relatively high (Figure 57).

Table 34 NV(ROM) days lost in Karadon mine for accident types between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
RF	12.07	10.29	9.41	6.65	9.70	9.08	8.00	11.11	12.27	13.39	11.66	10.35	12.21	9.02	3.18	10.02
Trans.	0.00	0.00	0.00	0.00	0.41	0.00	0.14	1.16	1.12	1.69	1.66	1.02	0.73	0.93	1.19	0.61
Mat. Hand.	5.07	5.93	4.18	5.15	5.98	8.40	8.01	4.83	6.18	6.87	7.29	6.15	4.57	5.78	4.46	5.91
Slip/Fall	2.15	1.79	1.42	2.06	3.89	2.09	1.62	5.68	1.96	1.80	2.20	1.82	1.90	4.53	3.29	2.46
Struck Obj.	0.00	0.00	0.10	0.00	0.08	0.38	0.64	0.08	0.10	3.00	3.02	1.32	1.83	4.16	5.94	1.20
Mech. Electr.	0.00	0.17	0.16	0.03	0.11	0.01	0.12	0.24	0.79	0.51	1.98	1.20	0.89	0.74	0.78	0.47
Others	3.62	3.29	2.01	2.50	4.37	6.17	3.63	4.70	1.72	0.43	0.28	1.42	0.17	0.70	0.27	2.44
TOTAL	**22.91**	**21.47**	**17.29**	**16.39**	**24.54**	**26.12**	**22.17**	**27.80**	**24.13**	**27.68**	**28.09**	**23.27**	**22.30**	**25.85**	**19.11**	**23.12**

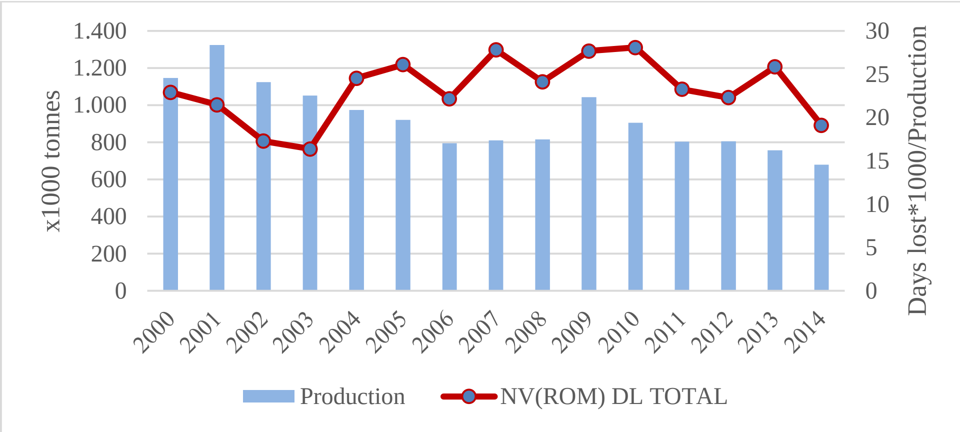


Figure 57 Production and NV(ROM) days lost in Karadon mine between 2000 and 2014

Kozlu mine is one of the mines having the lowest NV(ROM) DL values. The values range from 5.46 to 17.13 (Table 35). Like Armutçuk mine, there is no data for days lost in the data set for years 2000, 2001 and 2003 in Kozlu mine (Table 35). NV(ROM) DL value increases between 2003 and 2007 and reaches its highest value of 16.95 in 2007 (Figure 58) . There are some sudden drops in 2008 and 2011. Later on there is no significant change till 2014 (Figure 58).

Table 35 NV(ROM) days lost in Kozlu mine for accident types between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
RF	0.00	0.00	0.00	0.91	3.53	5.01	4.99	3.96	0.72	0.81	1.25	3.55	3.26	2.95	3.41	2.17
Trans.	0.00	0.00	0.00	0.00	0.21	1.73	0.45	1.38	0.00	0.05	0.00	1.28	0.38	0.87	1.23	0.47
Mat. Hand.	0.00	0.00	0.00	1.17	2.09	2.73	2.98	1.26	0.63	1.32	1.09	1.95	3.11	3.66	4.23	1.66
Slip/Fall	0.00	0.00	0.00	1.43	2.80	2.07	4.83	3.34	3.03	3.25	2.28	1.40	1.16	0.81	0.64	1.74
Struck Obj.	0.00	0.00	0.00	1.40	3.43	0.18	1.32	6.27	6.61	10.25	11.56	2.49	1.65	0.78	0.66	3.21
Mech. Electr.	0.00	0.00	0.00	0.20	0.11	0.25	0.91	0.49	0.18	0.14	0.29	0.79	0.80	0.81	0.64	0.36
Others	0.00	0.00	0.00	0.35	0.21	0.22	0.57	0.25	0.34	0.79	0.67	0.10	0.18	0.45	0.22	0.29
TOTAL	**0.00**	**0.00**	**0.00**	**5.46**	**12.39**	**12.19**	**16.06**	**16.95**	**11.51**	**16.61**	**17.13**	**11.57**	**10.53**	**10.34**	**11.03**	**9.89**

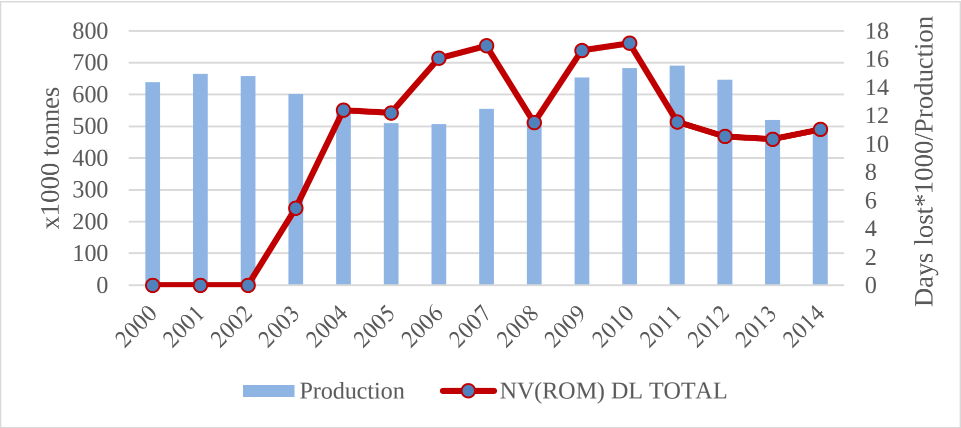


Figure 58 Production and NV(ROM) days lost in Kozlu mine between 2000 and 2014

Üzülmez mine is the second mine having the highest NV(ROM) DL values after Karadon mine (Table 36). The minimum NV(ROM) DL value is 14.5 in 2002 and the maximum value is 23.61 in 2009 (Table 36). In Üzülmez mine, apart from the sudden decrease in 2002 and a sharp increase in 2009, there is no significant change regarding NV(ROM) DL values(Figure 59). The values are relatively high.

Table 36 NV(ROM) days lost in Üzülmez mine for accident types between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
RF	8.15	10.94	7.00	8.24	7.80	6.60	8.17	6.76	9.01	9.82	7.92	7.12	7.83	7.54	6.10	8.01
Trans.	1.63	1.15	1.18	1.05	1.74	2.10	0.51	2.75	1.97	1.46	1.54	1.41	0.97	1.74	0.68	1.45
Mat. Hand.	4.58	1.65	0.49	0.92	1.73	2.08	1.10	1.71	1.70	4.42	1.95	1.30	3.25	1.58	3.58	2.11
Slip/Fall	2.09	3.74	1.35	2.91	3.03	2.92	2.20	1.86	1.60	2.87	2.74	2.39	3.09	3.87	3.30	2.65
Struck Obj.	2.60	4.51	3.31	4.55	2.70	2.36	5.02	5.34	4.17	3.62	4.63	5.69	4.80	3.48	4.84	4.02
Mech. Electr.	1.25	1.09	1.12	1.98	1.93	1.89	1.23	1.20	0.51	1.20	0.55	2.07	1.01	1.19	1.08	1.31
Others	0.15	0.03	0.05	0.07	0.00	1.07	0.52	0.48	0.04	0.23	0.20	0.04	0.06	0.11	0.02	0.19
TOTAL	**20.45**	**23.11**	**14.50**	**19.72**	**18.93**	**19.02**	**18.74**	**20.09**	**18.99**	**23.61**	**19.53**	**20.02**	**21.00**	**19.50**	**19.60**	**19.75**

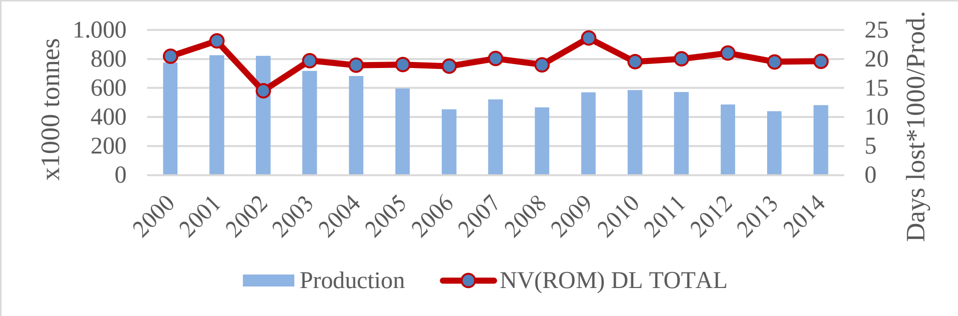


Figure 59 Production and NV(ROM) days lost in Üzülmez mine between 2000 and 2014

Considering the NV(ROM) DL values, Karadon and Üzülmez mines can be categorized as first group of mines having relatively high values. On the other hand, the Armutçuk and Kozlu mines can be placed into the same group having relatively low values. Amasra mine has the lowest NV(ROM) DL values especially for the last years.

6.2.2 Analysis of Data Normalized with NOW

In the previous analysis all obtained values belonging to occupational accidents are divided by ROM coal production for each mines for each year. Number of workers is another variable having an effect on occupational accidents. For this reason in order perform a comprehensive evaluation, all results are normalized with number of workers working in underground. By this way the effect of changes or differences in the number of workers on occupational accidents would be eliminated. In the calculations the Equation 5 is used.

$$NV(NOW) = N/NOW \qquad [5]$$

Where; NV(NOW): Normalized Value of Number of Accident with Number of Workers

N : Number of accident/casualty

NOW : Total number of underground workers in the mine

For example, in the Amasra mine, the previous normalized value for the number of casualty in 2000 is 1.96 and total number of underground workers in the mine for the year is 1,123. The NV(NOW) number of accident for the same year is calculated using Equation 4 as follows:

N = 542

NOW = 1,123

NV(NOW) = N/NOW

= 542/1123

= 0.48

This means that in Amasra mine, there was 0.48 casualty per worker in the year 2000. In other words almost one of two workers was injured in 2000 in Amasra mine. This normalization calculation is carried out for all categories and in all mines for fifteen years. For the case of normalization of days lost data the value of N (Number of Accident/Casualty) is replaced by Days Lost (DL) value. Then, Equation 5 takes the form of NV(NOW)= DL/NOW where DL is the days lost value for the related injury in the accident.

6.2.2.1 Number of Accidents/Casualties

All the number of accident values are normalized using Equation 5 and the results are tabulated. The NV(NOW) number of accident values for TTK fluctuates between 0.2 and 0.36 between 2000 and 2014 (Table 37). The significant decrease in 2002 and the continuous increase after 2006 is recognizable from Figure 60. Especially after the year 2006, although the number of workers decreases till 2008, the NV(NOW) number of accidents increases as illustrated in Figure 60. This increase becomes sharper in 2009 together with the increase in the number of workers.

Table 37 NV(NOW) number of accidents in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
AMASRA	0.48	0.47	0.42	0.36	0.29	0.28	0.32	0.26	0.25	0.30	0.42	0.40	0.30	0.36	0.27	**0.36**
ARMUTÇUK	0.21	0.22	0.19	0.21	0.27	0.18	0.15	0.23	0.20	0.19	0.26	0.29	0.32	0.27	0.24	**0.23**
KARADON	0.29	0.31	0.21	0.23	0.23	0.21	0.22	0.32	0.36	0.52	0.47	0.35	0.37	0.40	0.33	**0.32**
KOZLU	0.39	0.35	0.26	0.25	0.27	0.23	0.23	0.26	0.19	0.31	0.31	0.26	0.29	0.21	0.19	**0.27**
ÜZÜLMEZ	0.22	0.26	0.15	0.19	0.21	0.18	0.15	0.16	0.21	0.25	0.25	0.31	0.32	0.28	0.38	**0.23**
TTK	**0.30**	**0.31**	**0.22**	**0.23**	**0.24**	**0.21**	**0.20**	**0.25**	**0.26**	**0.36**	**0.36**	**0.32**	**0.33**	**0.32**	**0.29**	**0.28**

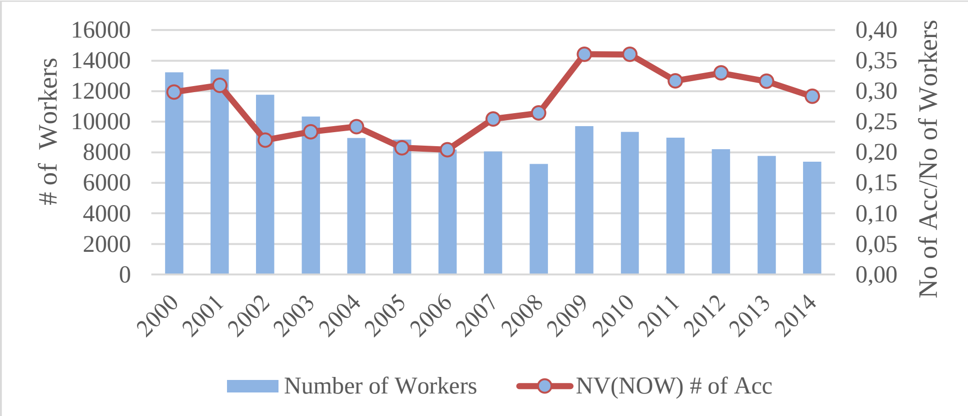


Figure 60 Production and NV(NOW) # of accidents in TTK between 2000 and 2014

Figures 61-65 illustrate the changes in the number of underground workers and also change in NV(NOW) the number of accidents. The situation for Amasra mine is similar to TTK. NV(NOW) number of accidents moves parallel with number of workers till 2009. However, there is a slight increase in the NV(NOW) number of accident in spite of the decrease in the number of workers in 2010 (Figure 61). The improvement in overall safety conditions is recognizable for Amasra mine in Figure 61. The decrease in the NV(NOW) number of accidents from 0.48 to 0.27 is a key indicator to this fact.

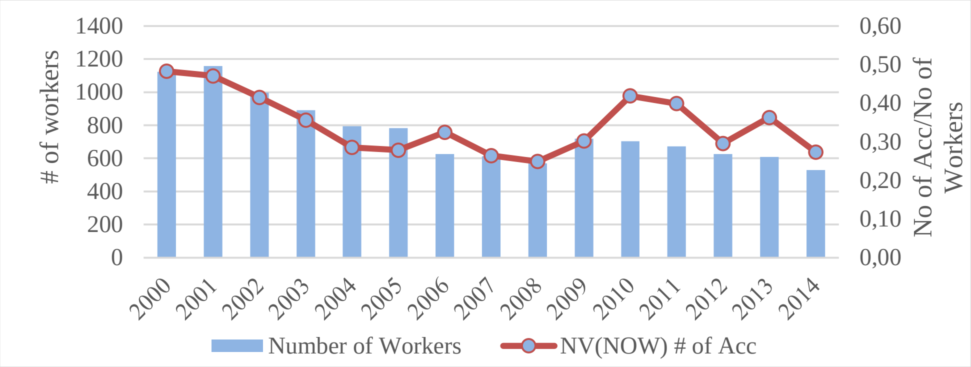


Figure 61 Production and NV(NOW) # of Accidents in Amasra mine

The NV(NOW) number of accidents in Armutçuk mine undulates through the years (Figure 62). The lowest NV(NOW) number of accident is 0.15 in 2006. The increase in the NV(NOW) number of accident is significant between the years 2009 and 2012 and it reaches the highest value of 0.32 2012 (Figure 62).

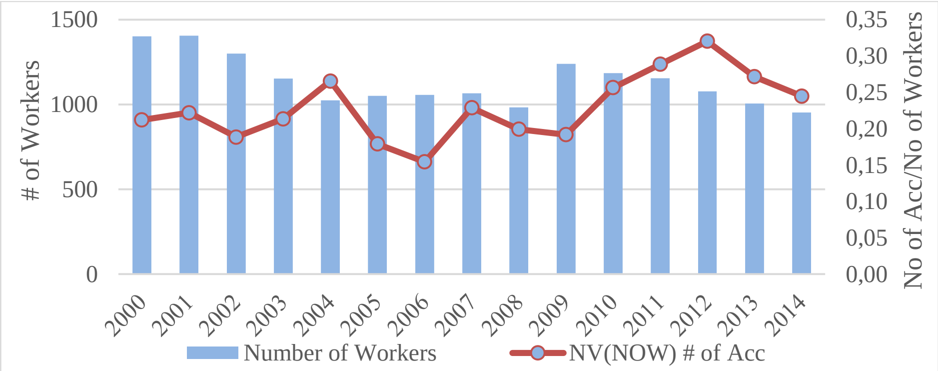


Figure 62 Production and NV(NOW) # of accidents in Armutçuk mine

For Karadon and Üzülmez mines, the NV(NOW) number of accidents increases especially after 2006 (Figure 63 and Figure 64). The increase is much more significant in Üzülmez mine (Figure 64). The NV(NOW) number of accident reaches the highest value of 0.52 in 2009 in Karadon mine (Figure 63). In Üzülmez mine the increase in the NV(NOW) number of accident continues till 2014 and the highest value of 0.38 is seen in 2014 (Figure 64).

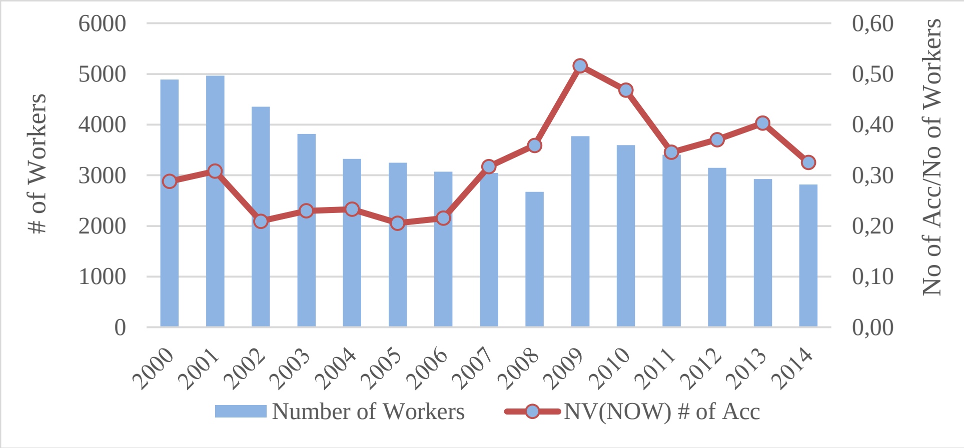


Figure 63 Production and NV(NOW) # of accidents in Karadon mine

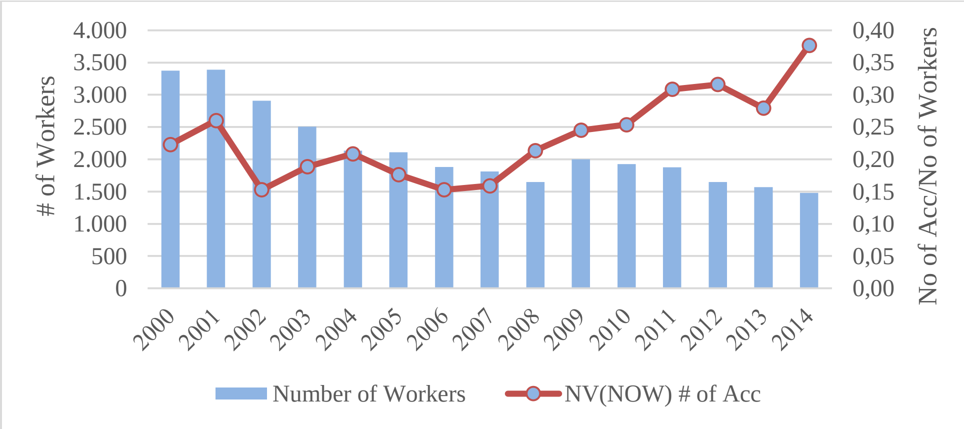


Figure 64 Production and NV(NOW) # of accidents in Üzülmez mine

Figure 65 shows that the number of accident and the number of underground workers are directly proportional in Kozlu mine. It means that the number of accidents increases as the number of workers increase and vice versa. The situation is the same for the production. As illustrated in Figure 48 NV(ROM) the number of accident/casualty fluctuates with production in Kozlu mine.

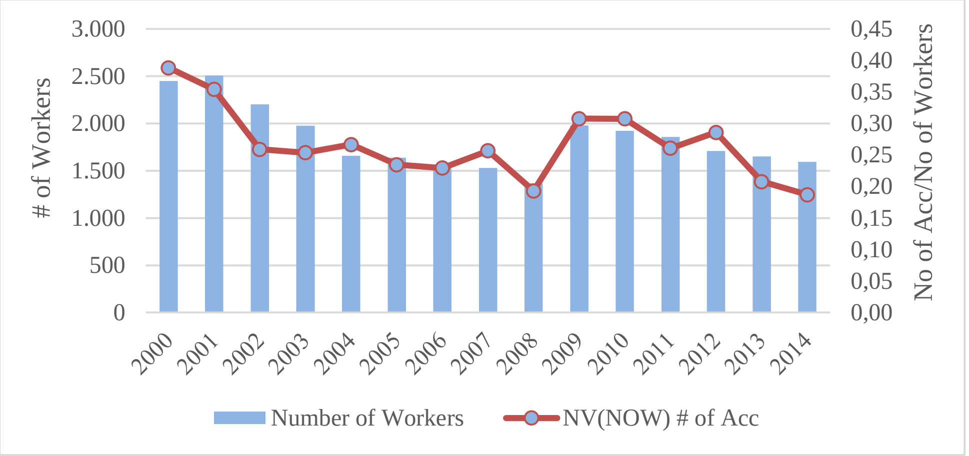


Figure 65 Production and NV(NOW) # of accidents in Kozlu mine

Figure 66 shows the differences between mines in terms of NV(NOW) for number of accidents (casualties). When the mines are compared regarding NV(NOW) number of accidents for the total values, Amasra mine is the mine having the highest NV(NOW) number of accident value of 0.36 and Karadon mine is the second mine with NV(NOW) number of accident value of 0.32. The lowest value of 0.23 belongs to Armutçuk and Üzülmez mines (Figure 66). As in the case of NV(ROM) number of accidents, NV(NOW) number of accidents clearly points the improvement in safety conditions in the Amasra mine.

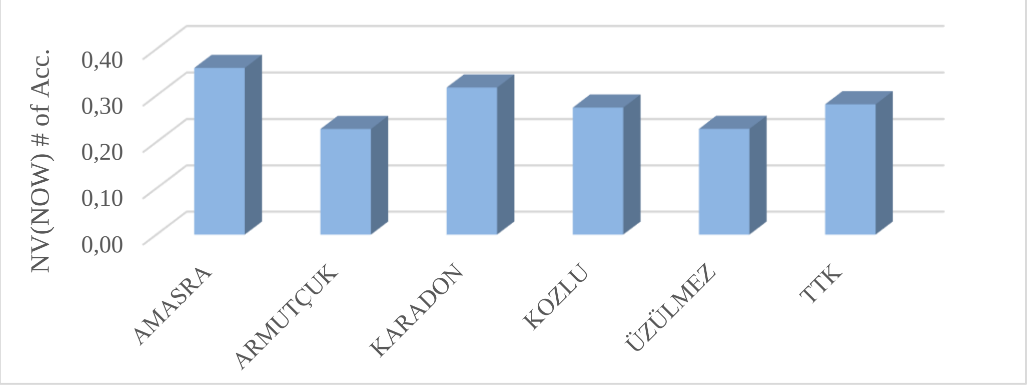


Figure 66 Total NV(NOW) # of accidents in mines

6.2.2.2 Days Lost

Days lost row data is normalized with number of workers using Equation 5. The results of normalization are tabulated in Table 38 for TTK. Roof fall is the major type of accident causing days lost. The NV(NOW) DL for roof fall in TTK is 1.86 which is the highest value (Table 38). The second accident type causing days lost is material handling with 0.91 as shown in Table 38. As compatible with previous normalization results the highest value in terms of days lost belong to the year 2009 with the NV(NOW) DL value of 6.04 (Table 38).

Table 38 NV(NOW) DL in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
RF	1.70	1.99	1.60	1.42	2.05	2.00	1.74	1.92	2.27	2.22	1.98	2.00	2.21	1.80	1.13	**1.86**
Trans.	0.11	0.10	0.10	0.09	0.21	0.30	0.11	0.39	0.36	0.33	0.32	0.38	0.21	0.28	0.28	**0.22**
Mat. Hand.	0.83	0.76	0.51	0.75	0.95	1.29	1.08	0.70	0.93	1.19	1.04	0.87	1.02	1.02	1.00	**0.91**
Slip/Fall	0.34	0.45	0.30	0.52	0.87	0.67	0.63	0.98	0.61	0.74	0.76	0.61	0.58	0.83	0.73	**0.62**
Struck Obj.	0.18	0.32	0.27	0.43	0.43	0.25	0.44	0.79	0.76	1.26	1.46	0.71	0.63	0.69	0.93	**0.60**
Mech. Electr.	0.09	0.11	0.12	0.15	0.19	0.22	0.15	0.14	0.15	0.15	0.29	0.33	0.26	0.25	0.22	**0.18**
Others	0.37	0.37	0.23	0.32	0.54	0.79	0.50	0.56	0.31	0.15	0.15	0.18	0.07	0.13	0.07	**0.32**
TOTAL	**3.62**	**4.10**	**3.12**	**3.69**	**5.23**	**5.51**	**4.64**	**5.49**	**5.39**	**6.04**	**5.99**	**5.07**	**4.98**	**4.98**	**4.36**	**4.71**

NV(NOW) DL for TTK undulates between 2000 and 2014 (Figure 67). As illustrated in Figure 67, there is no direct relation between the number of workers and days lost due to accidents. For example, although the number of workers in TTK decreases between 2002 and 2008 the NV(NOW) DL increases.

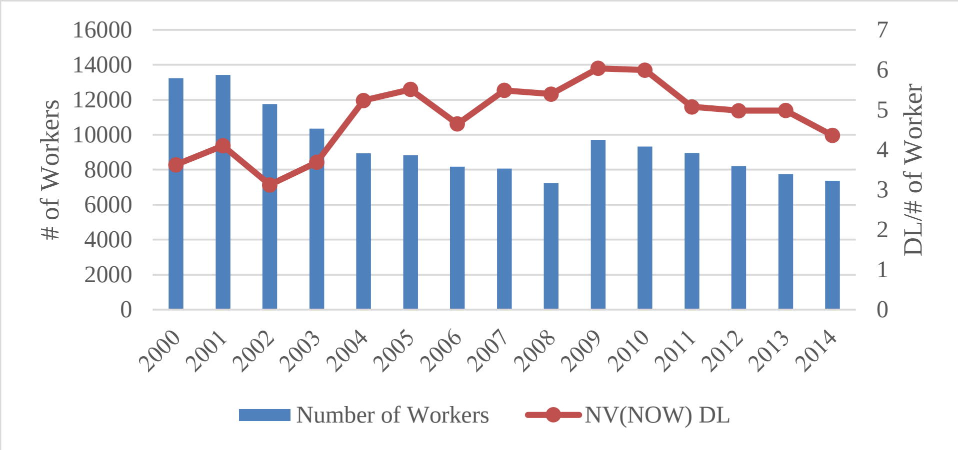


Figure 67 NOW and NV(NOW) DL in TTK between 2000 and 2014

Figure 68 illustrates how the NV(NOW) DL changes through years considering accident types. The results of this normalization are absolutely compatible with the previous results. Although the shares undulates, the main effective accident type is roof fall and material handling comes the second after it which is valid for TTK.

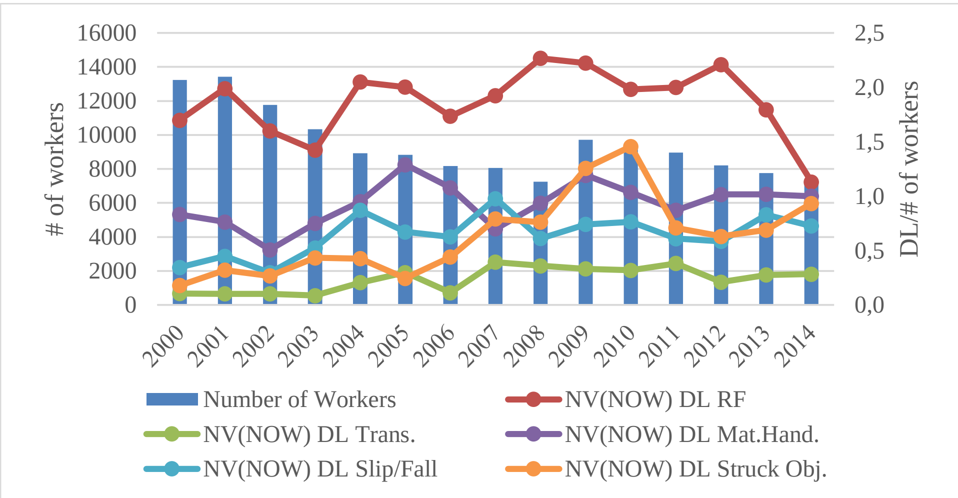


Figure 68 NOW and NV(NOW) DL according to the type of accidents in TTK

The total NV(NOW) DL values are illustrated in Figure 69. Slip fall and struck by objects are the accident types following material handling with 0.62 and 0.60 values, respectively. The smallest share belongs to mechanical and electrical accidents and its value is 0.18. The corresponding value for the transportation accidents is 0.22 which is comparatively low.

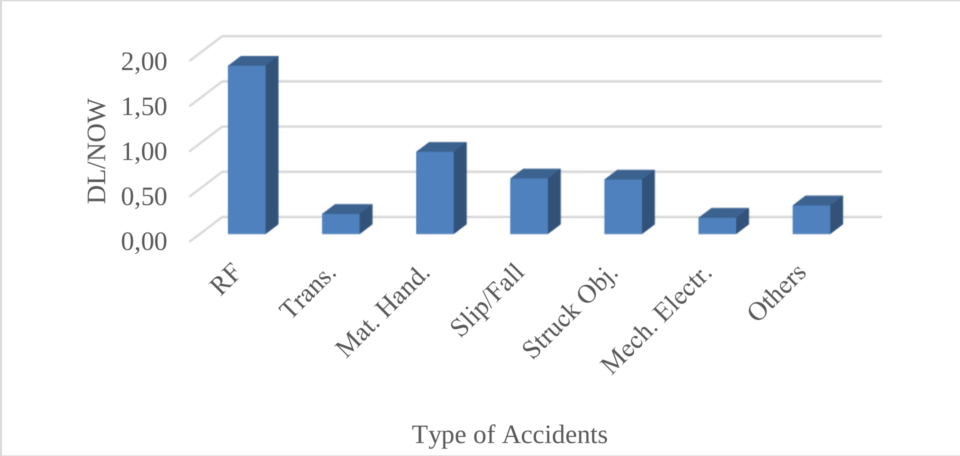


Figure 69 Total NV(NOW) DL in the mines according to type of accidents

The results of normalization of days lost values with NOW for each mine are tabulated in Tables 39-43 and illustrated at Figures 70-74. In each table the details regarding accident types are shown but in the figures mainly the correlation between NOW and total yearly NV(NOW) DL are illustrated.

For Amasra Mine, it can be said that the NV(NOW) DL is relatively related with NOW. Figure 70 illustrates the NV(NOW) DL correlated with NOW through years except 2006, 2011 and 2014. Roof fall again the most effective type regarding days lost in Amasra Mine (Table 39). As in the case of previous analysis the improvement is recognizable in Amasra Mine in terms of decreasing days lost values between 2000 and 2014.

Table 39 NV(NOW) DL in Amasra mine between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
RF	2.06	3.49	2.49	1.40	2.03	1.67	2.01	1.11	0.92	0.80	1.30	1.47	0.75	1.39	1.06	**1.74**
Trans.	0.12	0.37	0.22	0.15	0.16	0.54	0.56	0.02	0.24	0.27	0.27	1.00	0.08	0.05	0.28	**0.29**
Mat. Hand.	1.46	0.89	0.85	1.08	0.44	0.26	0.44	0.16	0.21	0.70	0.30	0.47	0.25	0.42	0.49	**0.63**
Slip/Fall	0.43	0.47	0.77	0.36	0.51	0.60	0.22	0.71	0.20	1.02	0.69	1.04	0.35	0.45	0.72	**0.57**
Struck Obj.	0.31	0.48	0.30	0.41	0.04	0.30	0.21	0.07	0.06	0.25	0.34	0.43	0.47	0.44	0.33	**0.31**
Mech. Electr.	0.22	0.29	0.35	0.01	0.31	0.24	0.09	0.07	0.08	0.12	0.20	0.15	0.09	0.07	0.30	**0.18**
Others	0.61	0.49	0.39	0.47	0.54	0.23	0.74	0.51	0.97	0.37	0.44	0.19	0.09	0.06	0.19	**0.43**
TOTAL	**5.20**	**6.48**	**5.38**	**3.88**	**4.03**	**3.85**	**4.26**	**2.66**	**2.67**	**3.53**	**3.53**	**4.75**	**2.09**	**2.87**	**3.36**	**4.14**

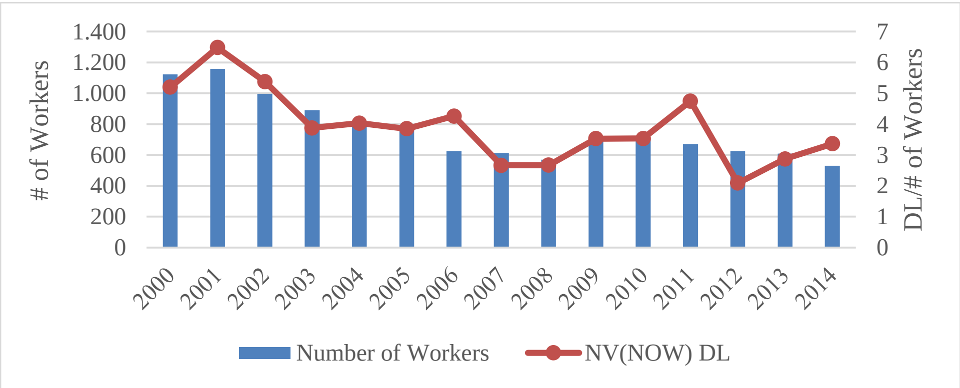


Figure 70 NOW and NV(NOW) DL in Amasra mine between 2000 and 2014

Since the days lost data for the period 2000-2005 is not available in the data set it is not possible to make an evaluation for fifteen year period Table 40). As previously mentioned the corresponding values in 2006 and 2007 also point that there is missing days lost data for the years 2006 and 2007. It is not possible to evaluate the existing data and to reach some comprehensive results. The NV(NOW) DL value for roof fall in Armutçuk mine for the fifteen years period is 0.71 which is the highest value among others (Table 40). It can only be concluded that roof fall is also the most effective accident type causing days lost in Armutçuk mine. The highest NV(NOW) DL values for Armutçuk mine are seen in 2010 and 2012 (Figure 71).

Table 40 NV(NOW) DL in Armutçuk mine between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
RF	0.00	0.00	0.00	0.00	0.00	1.45	0.31	0.11	1.34	0.74	1.29	1.82	1.77	1.40	1.06	**0.71**
Trans.	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.02	0.65	0.32	0.31	0.21	0.34	0.19	0.21	**0.15**
Mat. Hand.	0.00	0.00	0.00	0.00	0.00	0.77	0.15	0.04	0.50	0.43	0.81	0.39	0.83	0.67	0.32	**0.31**
Slip/Fall	0.00	0.00	0.00	0.00	0.00	0.71	0.23	0.02	0.40	0.66	1.25	0.84	0.74	0.60	0.88	**0.41**
Struck Obj.	0.00	0.00	0.00	0.00	0.00	0.07	0.02	0.00	0.03	0.11	0.01	0.02	0.00	0.00	0.02	**0.02**
Mech. Electr.	0.00	0.00	0.00	0.00	0.00	0.43	0.04	0.00	0.09	0.04	0.24	0.12	0.32	0.38	0.09	**0.11**
Others	0.00	0.00	0.00	0.00	0.00	0.32	0.21	0.01	0.08	0.04	0.19	0.19	0.22	0.13	0.12	**0.09**
TOTAL	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**3.81**	**0.97**	**0.20**	**3.09**	**2.33**	**4.10**	**3.59**	**4.21**	**3.37**	**2.69**	**1.80**

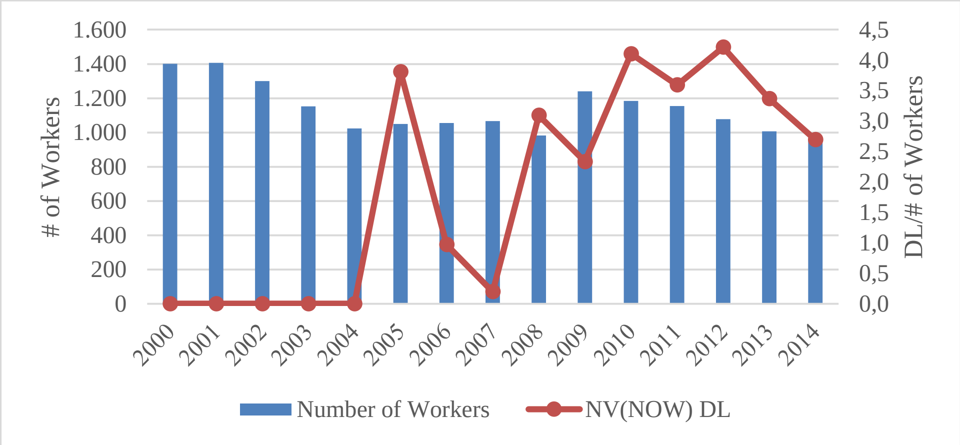


Figure 71 NOW and NV(NOW) DL in Armutçuk mine between 2000 and 2014

The NV(NOW) DL values between 2004 and 2010 is relatively high for Karadon mine when compared with other years (Figure 72). Although NV(NOW) DL values for accident types undulates through years roof fall again the first accident type with respect to days lost share (Table 41). The NV(NOW) DL value for roof fall of 2.64 is very high compared to other mines. The value is even much higher than the average value of 1.86 for TTK. Like other mines material handling is the second accident type causing days lost (Table 41). The NV(NOW) DL value for material handling is 1.55 (Table 41). The smallest share belongs to mechanical and electrical accidents.

Table 41 NV(NOW) DL in Karadon mine between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
RF	2.83	2.74	2.43	1.83	2.85	2.57	2.07	2.96	3.74	3.71	2.93	2.44	3.13	2.33	0.77	**2.64**
Trans.	0.00	0.00	0.00	0.00	0.12	0.00	0.04	0.31	0.34	0.47	0.42	0.24	0.19	0.24	0.29	**0.16**
Mat. Hand.	1.19	1.58	1.08	1.42	1.75	2.38	2.08	1.28	1.88	1.90	1.84	1.45	1.17	1.49	1.08	**1.55**
Slip/Fall	0.50	0.48	0.37	0.57	1.14	0.59	0.42	1.51	0.60	0.50	0.55	0.43	0.49	1.17	0.79	**0.65**
Struck Obj.	0.00	0.00	0.03	0.00	0.02	0.11	0.17	0.02	0.03	0.83	0.76	0.31	0.47	1.08	1.43	**0.32**
Mech. Electr.	0.00	0.05	0.04	0.01	0.03	0.00	0.03	0.07	0.24	0.14	0.50	0.28	0.23	0.19	0.19	**0.12**
Others	0.85	0.88	0.52	0.69	1.28	1.75	0.94	1.25	0.52	0.12	0.07	0.33	0.04	0.18	0.07	**0.64**
TOTAL	**5.37**	**5.72**	**4.46**	**4.52**	**7.20**	**7.41**	**5.74**	**7.39**	**7.36**	**7.66**	**7.07**	**5.49**	**5.72**	**6.69**	**4.61**	**6.08**

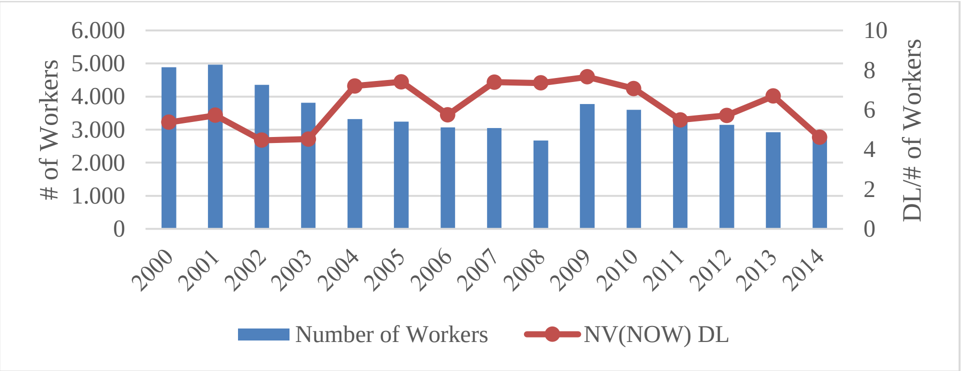


Figure 72 NOW and NV(NOW) DL in Karadon mine between 2000 and 2014

Like Armutçuk mine, the days lost data of the accidents for 2000-2003 period is not available in Kozlu mine (Table 42). The NV(NOW) DL values between 2006 and 2010 is relatively high in Kozlu mine (Figure 73). However, the decrease starting from the year 2010 is also significant in Kozlu mine.

Table 42 NV(NOW) DL in Kozlu mine between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
RF	0.00	0.00	0.00	0.28	1.15	1.56	1.64	1.44	0.27	0.27	0.44	1.32	1.23	0.93	1.04	0.70
Trans.	0.00	0.00	0.00	0.00	0.07	0.54	0.15	0.50	0.00	0.02	0.00	0.48	0.14	0.27	0.37	0.15
Mat. Hand.	0.00	0.00	0.00	0.36	0.68	0.85	0.98	0.46	0.24	0.44	0.39	0.73	1.18	1.15	1.29	0.53
Slip/Fall	0.00	0.00	0.00	0.43	0.91	0.65	1.58	1.21	1.15	1.07	0.81	0.52	0.44	0.25	0.19	0.56
Struck Obj.	0.00	0.00	0.00	0.43	1.12	0.06	0.43	2.28	2.51	3.38	4.11	0.93	0.62	0.25	0.20	1.03
Mech. Electr.	0.00	0.00	0.00	0.06	0.04	0.08	0.30	0.18	0.07	0.04	0.10	0.29	0.30	0.25	0.19	0.12
Others	0.00	0.00	0.00	0.11	0.07	0.07	0.19	0.09	0.13	0.26	0.24	0.04	0.07	0.14	0.07	0.09
TOTAL	**0.00**	**0.00**	**0.00**	**1.66**	**4.04**	**3.80**	**5.27**	**6.16**	**4.36**	**5.48**	**6.09**	**4.31**	**3.99**	**3.25**	**3.35**	**3.18**

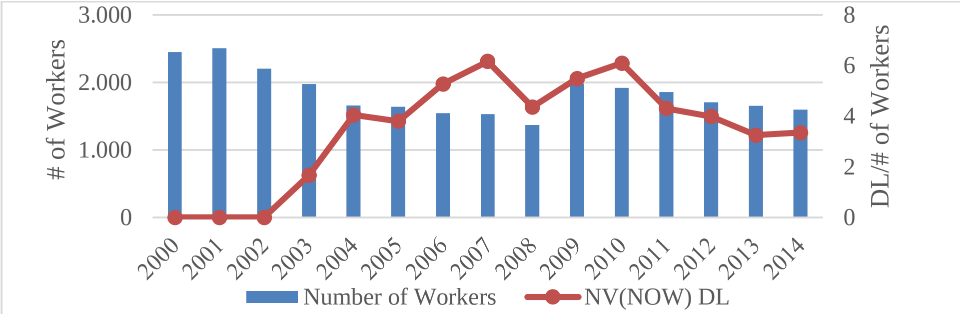


Figure 73 NOW and NV(NOW) DL in Kozlu mine between 2000 and 2014

Üzülmez mine comes the second after Karadon mine in terms of NV(NOW) DL values. In spite of decreasing NOW the continuous increase between 2006 and 2009 and staying at these high levels is very apparent (Figure 74). The total value of 5.51 is even higher than the value for TTK (Table 43). The most important accident type is roof fall with 2.23 NV(NOW) DL value in Üzülmez mine (Table 43). Struck by objects has the second highest share in Üzülmez mine with 1.12 value (Table 43).

Table 43 NV(NOW) DL in Üzülmez mine between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
RF	1.87	2.67	1.98	2.36	2.50	1.87	1.97	1.94	2.55	2.79	2.41	2.17	2.31	2.11	1.99	2.23
Trans.	0.37	0.28	0.33	0.30	0.56	0.59	0.12	0.79	0.56	0.42	0.47	0.43	0.29	0.49	0.22	0.41
Mat. Hand.	1.05	0.40	0.14	0.26	0.55	0.59	0.27	0.49	0.48	1.26	0.59	0.40	0.96	0.44	1.17	0.59
Slip/Fall	0.48	0.91	0.38	0.83	0.97	0.82	0.53	0.53	0.45	0.82	0.83	0.73	0.91	1.08	1.07	0.74
Struck Obj.	0.60	1.10	0.94	1.30	0.86	0.67	1.21	1.54	1.18	1.03	1.41	1.73	1.41	0.98	1.58	1.12
Mech. Electr.	0.29	0.27	0.32	0.57	0.62	0.53	0.30	0.34	0.14	0.34	0.17	0.63	0.30	0.33	0.35	0.37
Others	0.04	0.01	0.01	0.02	0.00	0.30	0.13	0.14	0.01	0.07	0.06	0.01	0.02	0.03	0.01	0.05
TOTAL	**4.70**	**5.64**	**4.10**	**5.65**	**6.05**	**5.37**	**4.52**	**5.78**	**5.38**	**6.72**	**5.94**	**6.10**	**6.19**	**5.47**	**6.39**	**5.51**

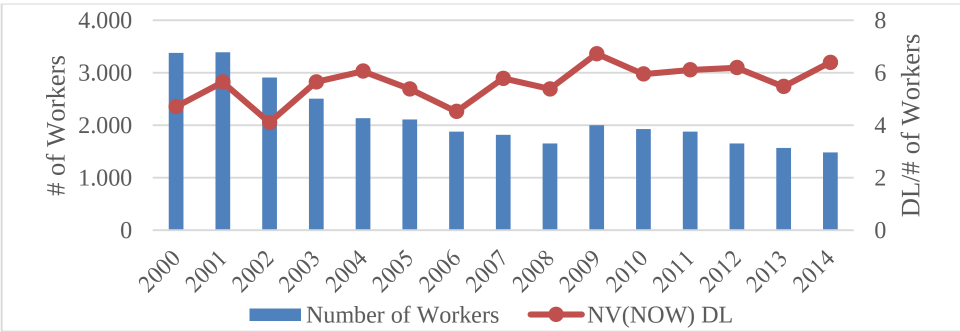


Figure 74 NOW and NV(NOW) DL in Üzülmez mine between 2000 and 2014

Karadon, Üzülmez and Amasra mines are three mines having the highest days lost shares with 6.08, 5.51 and 4.14 NV(NOW) DL, respectively. The smallest share belongs to Armutçuk mine with 1.80 NV(NOW) DL (Figure 75). The lack of days lost data for Armutçuk and Kozlu mines have to be taken into consideration in this evaluation.

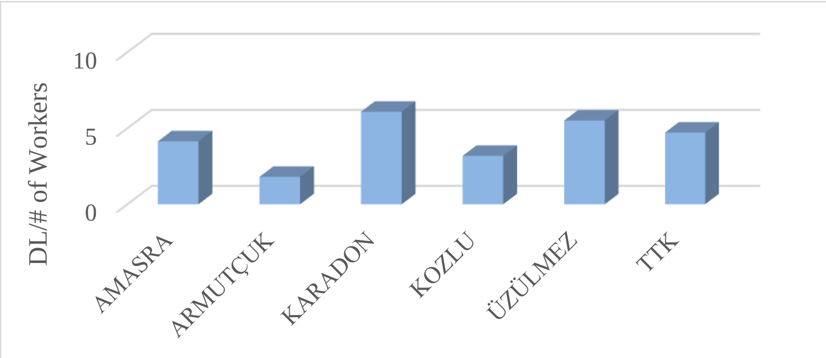


Figure 75 Total NV(NOW) DL in the mines

6.2.3 Analysis of Data Normalized with Labor Productivity

In the previous analysis all obtained values belonging to occupational accidents are divided by run of mine coal production of the mines for each year. In the second step obtained values are normalized with the number of underground workers. In that case all analyzed data would be normalized both production and number of workers. In other words all data are normalized by Unit Production (UP). By this way the effect of changes or differences in amount of production and number of workers would be eliminated together in the analysis. In all the calculations Equation 6 is used.

$$NV(UP) = N/UP \qquad [6]$$

Where; NV(UP) : Normalized Value with Unit Production

N : Number of accident/casualty

UP : Unit production per worker (P/NOW)

In the Amasra mine, the number of accident in 2000 is 542. The amount of run of mine production in Amasra mine in this year is 276,727 tons and the total number of underground workers in Amasra mine in the related year is 1123. The normalized value with unit production of number of casualty in 2000 in Amasra mine could be calculated using formula 6 as follows:

N=542
P=276,727
NOW=1123

First, we should calculate the unit production in Amasra mine for the year 2000.

UP =P/NOW
=276,727/1123
=246 tons/worker
NV(UP) = N/UP
NV(UP) = 542/246
=2.20

The normalized value of 542 accidents with unit production in Amasra mine for the year 2000 is 2.2. The unit of this value is # of casualty/ton of production/worker. In other words we can say that the number of accident/casualty in Amasra mine in 2000 per unit production is 2.20. This normalization calculation is carried out for all categories and in all mines for fifteen years. For the normalization of days lost data, the N is replaced by DL and the Equation 6 takes the form of NV(UP) = DL/UP where DL is the days lost value for the related accident. All NV(UP) tables are listed in Appendix A.

6.2.3.1 Number of Accidents/Casualties

Although the change in UP is not so significant, the NV(UP) # of accidents changes apparently through years. At the beginning, the NV(UP) # of accidents is 16.86 and it decreases to 5.94 in 2008 in TTK (Table 44). The NV(UP) # of accidents increases almost 100% in 2009 (Table 44). Then a steady decrease in the NV(UP) # of accidents for TTK is clear till 2014 (Figure 76).

Table 44 NV(UP) NOW in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
AMASRA	2.20	2.14	1.58	1.21	0.77	0.79	0.60	0.51	0.40	0.65	0.72	0.62	0.46	0.52	0.35	**12.74**
ARMUTÇUK	1.16	1.15	0.83	0.81	0.75	0.52	0.52	0.76	0.58	0.90	1.36	1.53	1.47	1.28	1.03	**13.95**
KARADON	6.02	5.75	3.53	3.19	2.64	2.35	2.55	3.63	3.15	7.03	6.69	4.99	4.55	4.55	3.80	**63.96**
KOZLU	3.64	3.34	1.91	1.64	1.36	1.23	1.08	1.08	0.70	1.84	1.66	1.30	1.29	1.09	0.98	**23.48**
ÜZÜLMEZ	3.27	3.61	1.57	1.65	1.39	1.32	1.19	1.00	1.24	1.72	1.60	1.90	1.77	1.56	1.71	**26.41**
TTK	**16.36**	**15.98**	**9.36**	**8.45**	**6.88**	**6.16**	**5.94**	**6.83**	**5.94**	**11.99**	**11.50**	**9.76**	**9.08**	**8.69**	**7.61**	**139.53**

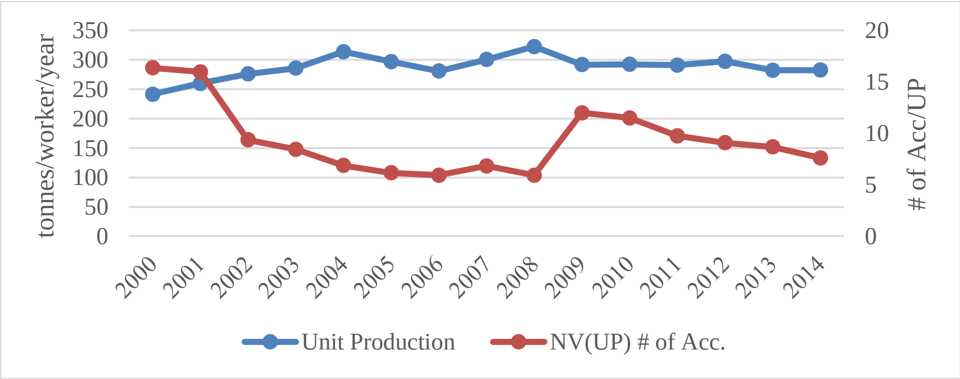


Figure 76 Unit production and NV(UP) # of accidents in TTK

The NV(UP) # of accident in Amasra mine decreases between 2000 and 2014. The increase in UP during this period is also clear (Figure 77). In other words, in Amasra mine, the NV(UP) # of accident decreases while UP increases from 250 tons/worker to more than 400 tons/worker. The NV(UP) # of accident was 2.2, which is the highest value for Amasra mine, in the year 2000. However, this value decrease to 0.35, which is the lowest value for all the mines in this period, in 2014 (Figure 77). It can be concluded that the safety conditions in Amasra mine has been improved in this period.

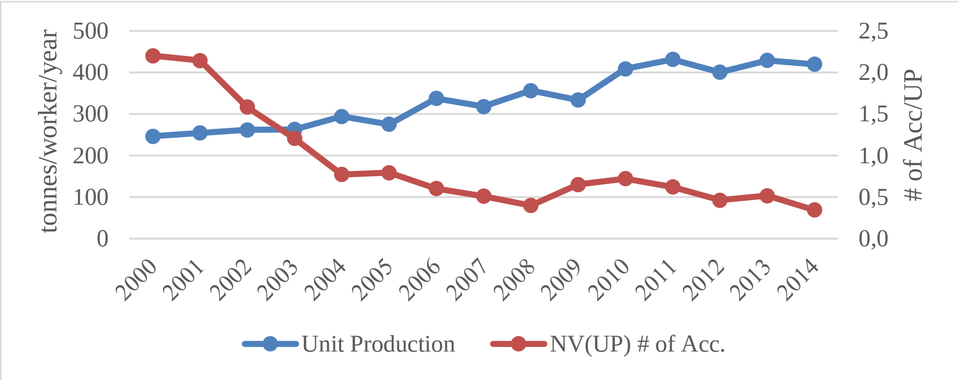


Figure 77 Unit production and NV(UP) # of accidents in Amasra mine

Until 2008 the NV(UP) # of Accident in Armutçuk mine decreases and UP increases like Amasra mine (Figure 78). However, after 2008 the increase in NV(UP) # of accident and decrease in UP is clear in Armutçuk mine (Figure 78).

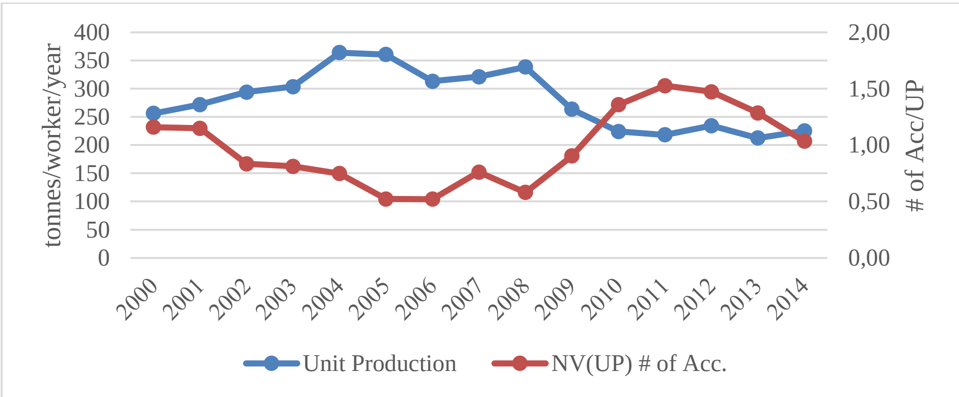


Figure 78 Unit Production and NV(UP) # of accident in Armutçuk mine

The trend of NV(UP) # of accident line in the graph in Karadon mine is similar to Armutçuk mine (Figure 79). However, the NV(UP) # of accident values for Karadon mine are relatively high compared to other mines. The sharp increase in NV(UP) # of accident in 2009 can easily be recognized in Figure 79.

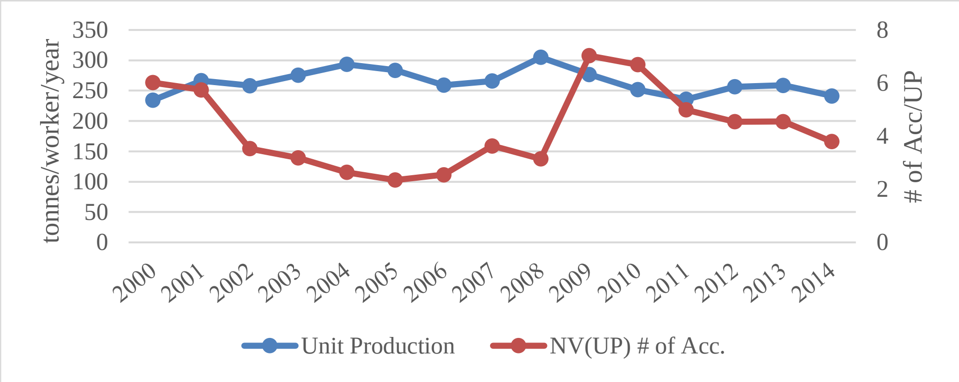


Figure 79 Unit production and NV(UP) # of accident in Karadon mine

The NV(UP) # of accident value in Kozlu mine decreases between 2000 and 2014 except the increase in 2009 (Figure 80). Moreover, the UP increases during this period (Figure 80). Kozlu mine, considering the decrease in the NV(UP) # of accident value and increase in the UP, is similar to Amasra mine.

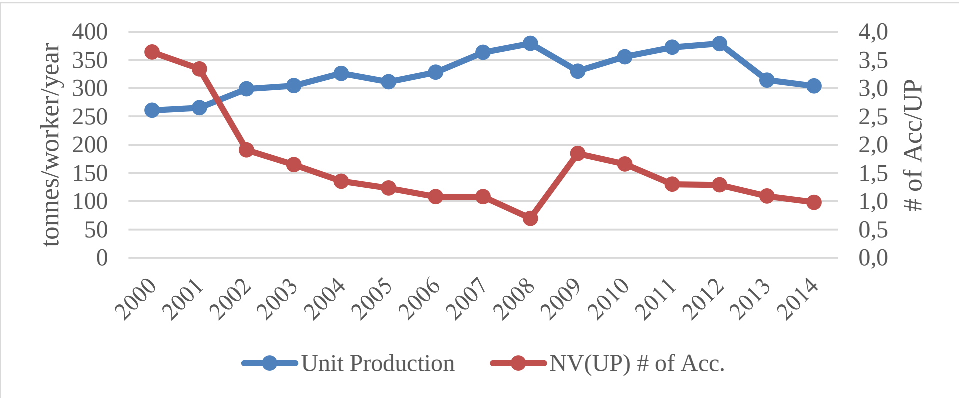


Figure 80 Unit production and NV(UP) # of accident in Kozlu mine

There is a different situation for Üzülmez mine. After the great decrease in 2002 the NV(UP) # of accident moves almost parallel with the UP line. There is no significant positive or negative change in the overall safety conditions in Üzülmez mine (Figure 81).

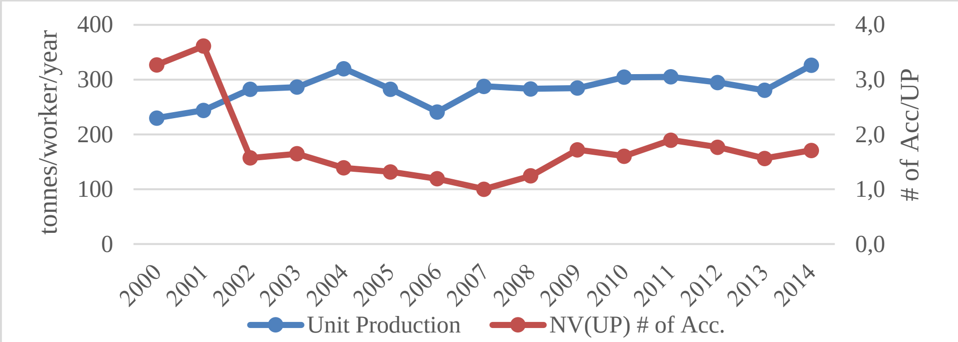


Figure 81 Unit production and NV(UP) # of accident in Üzülmez mine

In Figure 82 the Mines are compared with respect to their total NV(UP) # of accident for fifteen years. Karadon mine is the mine having the highest NV(UP) # of accident value which is 63.96 in fifteen years. Üzülmez and Kozlu mines have the NV(UP) # of accident values of 26.41 and 23.48, respectively follows Karadon mine. Amasra and Armutçuk mines have the lowest NV(UP) # of accident values of 12.74 and 13.95, respectively.

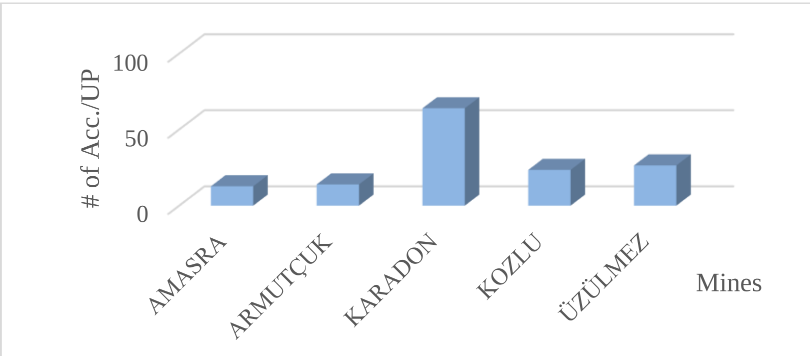


Figure 82 Total NV(UP) # of accident in the mines

6.2.3.2 Days Lost

The NV(UP) DL in TTK drops from 212 to 133 in 2002 (Table 45). There is no significant increase or decrease in the NV(UP) DL values for TTK up to 2009

(Figure 83). However, the NV(UP) DL value in TTK increases suddenly from 121 to 201 in 2009 (Table 45). After 2010 the decrease in the NV(UP) DL value till 2014 is clear (Figure 83). A steady increase from 2000 to 2014 in the UP of TTK is also illustrated in Figure 83.

Table 45 NV(UP) DL in TTK between 2000 and 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
RF	93.1	102.7	68.1	51.5	58.3	59.5	50.5	51.7	50.9	73.9	63.2	61.6	60.9	49.3	29.5	**924**
Trans.	5.8	5.3	4.3	3.1	5.8	8.9	3.3	10.5	8.1	11.0	10.2	11.8	5.8	7.6	7.4	**111**
Mat. Hand.	45.6	39.4	21.6	27.1	27.0	38.3	31.4	18.8	21.0	39.7	33.0	26.8	28.0	28.0	26.1	**452**
Slip/Fall	18.9	23.1	12.6	19.0	24.8	20.0	18.2	26.2	13.7	24.6	24.4	18.8	16.1	22.8	18.9	**305**
Struck Obj.	9.8	16.5	11.4	15.7	12.1	7.3	12.8	21.2	17.1	41.8	46.5	21.8	17.3	18.9	24.4	**299**
Mech. Electr.	5.0	5.6	5.3	5.5	5.5	6.4	4.3	3.8	3.4	4.9	9.4	10.1	7.1	6.8	5.7	**90**
Others	20.5	19.0	9.7	11.5	15.3	23.4	14.6	15.0	6.9	4.8	4.7	5.4	1.9	3.5	1.8	**158**
TOTAL	**199**	**212**	**133**	**133**	**149**	**164**	**135**	**147**	**121**	**201**	**191**	**156**	**137**	**137**	**114**	**2,339**

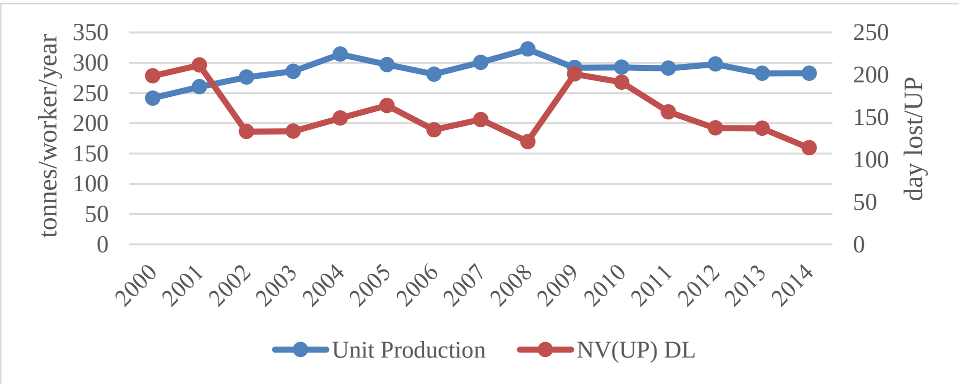


Figure 83 Unit production and NV(UP) DL in TTK between 2000 and 2014

The shares of accident types in NV(UP) DL value through the years is illustrated in Figure 84. Roof fall is the accident type having the highest share in NV(UP) DL value in every years without exception (Figure 84). Moreover, material handling is the other accident type having high percentages in NV(UP) DL value through the years.

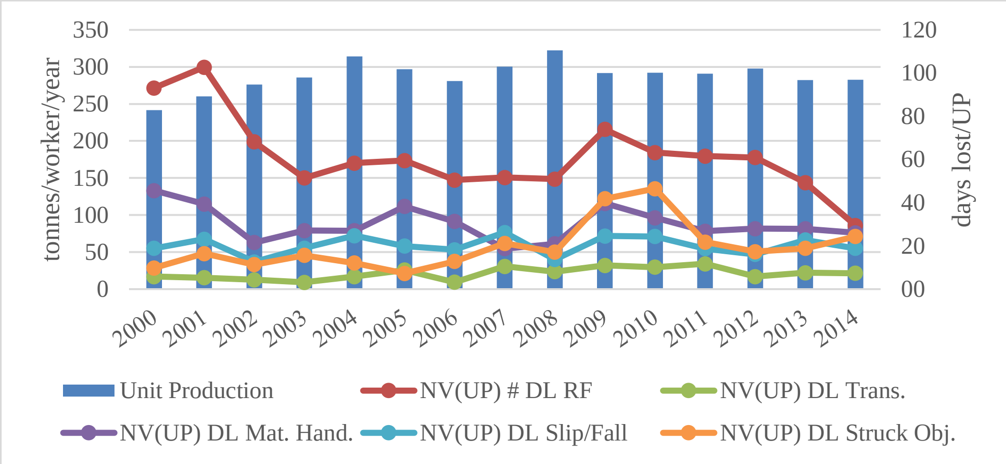


Figure 84 Unit production and NV(UP) DL according to the type of accidents in TTK between 2000 and 2014

As in the case of other normalized data analysis, in the evaluation of the share of accident types in the NV(UP) DL values the order does not change. Roof fall is the first and material handling is the second accident types with 954 and 452 NV(UP) DL values, respectively. Slip fall and struck by objects are the accident types following roof fall (Figure 85). The share of accidents resulting from transportation works and mechanical and electrical works in the NV(UP) DL values are relatively low (Figure 85).

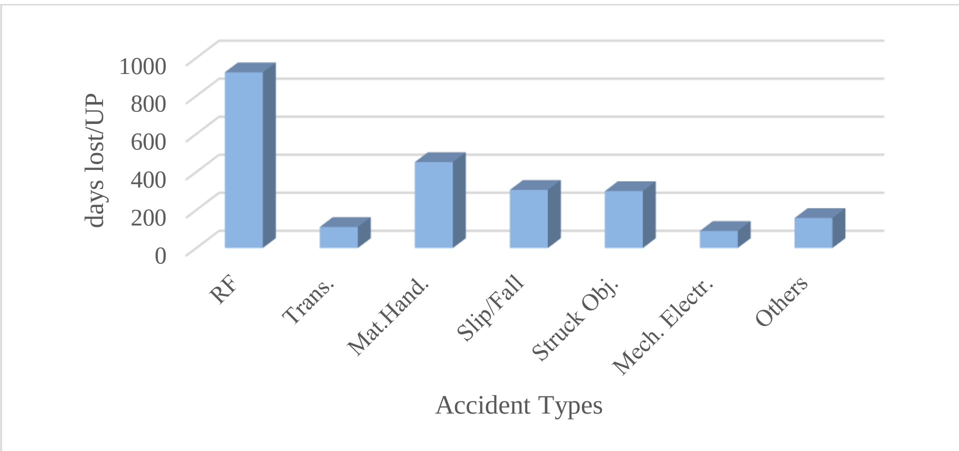


Figure 85 Total NV(UP) DL in the mines

Figure 86-90 illustrate the changes in NV(UP) DL values between 2000 and 2014 in each mine. The trend of NV(UP) DL is almost same with NV(UP) # of accident for Amasra mine (Figure 86). Both NV(UP) DL and the NV(UP) # of accident values decreases continuously, however, the decrease between 2001 and 2007 is more apparent (Figure 86).

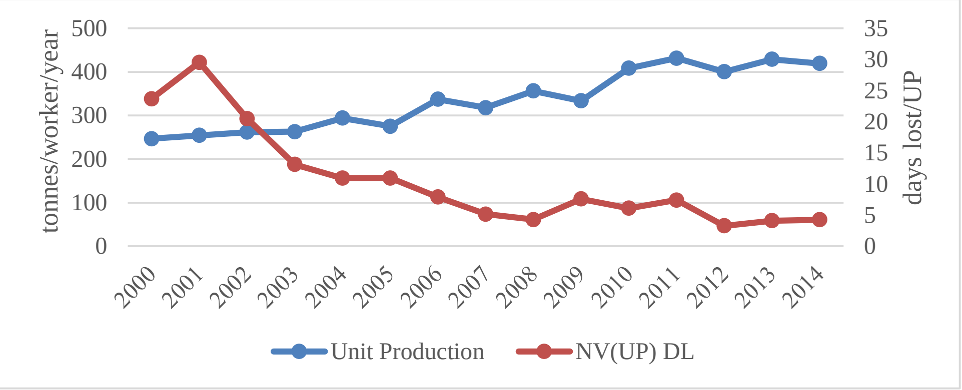


Figure 86 Unit production and NV(UP) DL in Amasra mine

In Armutçuk mine, the increase in NV(UP) DL between 2007 and 2010 is very sharp (Figure 87). The NV(UP) DL values decreases between 2010 and 2014 (Figure 87).

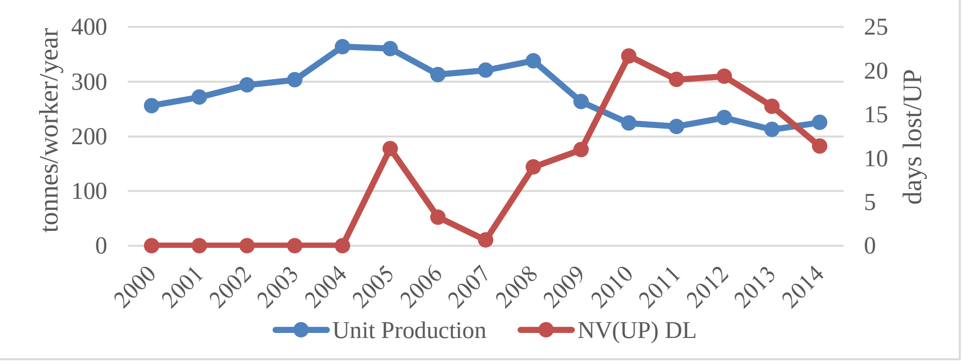


Figure 87 Unit production and NV(UP) DL in Armutçuk mine

Although there exist small fluctuations there is no significant change in the NV(UP) DL in Karadon Mine during fifteen years period (Figure 88). The decrease in the NV(UP) DL between 2000 and 2003 and a sharp increase in 2009 is clear in the Figure 88.

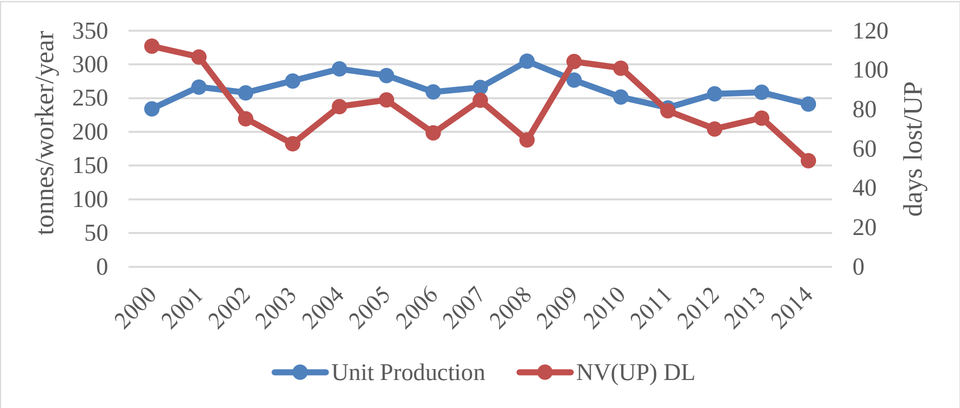


Figure 88 Unit production and NV(UP) DL in Karadon mine

The situation is different for Kozlu mine. Although the NV(UP) # of accident decreases through years in Kozlu mine, the NV(UP) DL increases especially between 2002 and 2009 except the single drop in 2008 (Figure 89). This shows that the severity of accidents in Kozlu mine increases during this period.

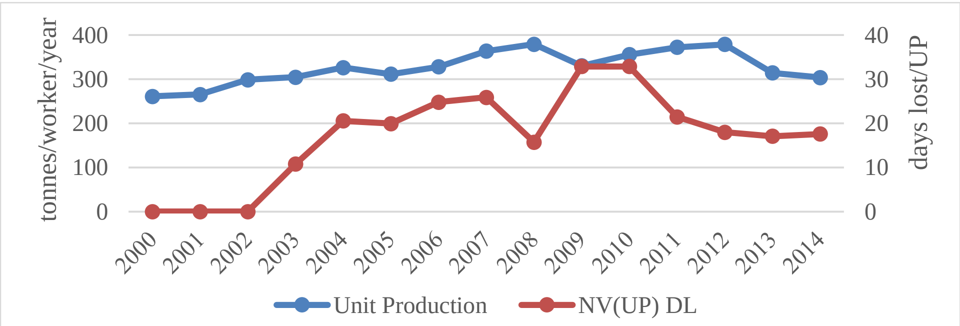


Figure 89 Unit production and NV(UP) DL in Kozlu mine

Except the sudden decrease in 2002 the NV(UP) DL behaves like NV(UP) # of accident in Üzülmez mine. It means that the severity of occupational accidents regarding days lost does not change in Üzülmez mine between 2002 and 2014 (Figure 90).

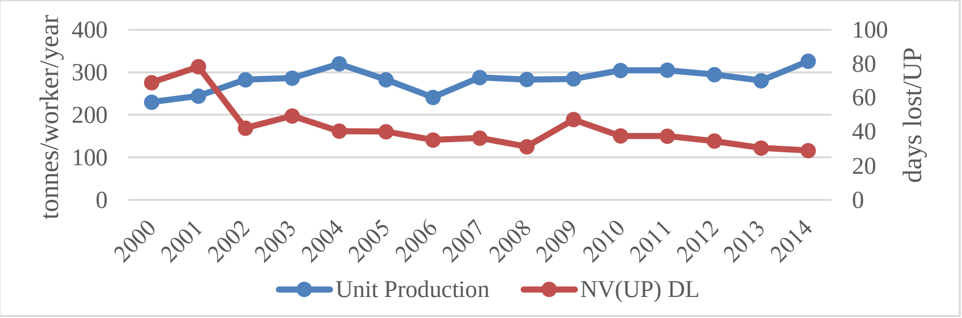


Figure 90 Unit production and NV(UP) DL in Üzülmez mine

6.2.4 Comparison of Mines with Analysis of Variance (ANOVA)

All normalized data regarding the number, type and location of accidents, and days lost is tested for normality. Kruskal Wallis Tests are also applied for the data which is not supplying assumptions and the null hypothesis is rejected for all data set. Therefore, in order to determine main differences between means of related variables, it is continued to ANOVA test.

6.2.4.1 Number of Accidents

The normalized number of accidents values with unit production are tabulated in Table 46. This table supply data for the entry to the ANOVA regarding number of accidents in each mine.

Table 46 NV(UP) NOA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
AMASRA	2.20	2.14	1.58	1.21	0.77	0.79	0.60	0.51	0.40	0.65	0.72	0.62	0.46	0.52	0.35
ARMUTÇUK	1.16	1.15	0.83	0.81	0.75	0.52	0.52	0.76	0.58	0.90	1.36	1.53	1.47	1.28	1.03
KARADON	6.02	5.75	3.53	3.19	2.64	2.35	2.55	3.63	3.15	7.03	6.69	4.99	4.55	4.55	3.80
KOZLU	3.64	3.34	1.91	1.64	1.36	1.23	1.08	1.08	0.70	1.84	1.66	1.30	1.29	1.09	0.98
ÜZÜLMEZ	3.27	3.61	1.57	1.65	1.39	1.32	1.19	1.00	1.24	1.72	1.60	1.90	1.77	1.56	1.71

Since the Significance Value (“sig”) is smaller than 0.05, the null hypothesis is rejected for the homogeneity of variances (Table 47). In other words, there is a significant difference between the variances of each variable (%95).

Table 47 Test of homogeneity of variances for NV(UP) NOA data

Test of Homogeneity of Variances			
Levene Statistic	df1	df2	Sig.
20.405	4	220	0.000

As in the case of homogeneity table "Sig." value which is lower than 0.05 in Table 48 points that there is a significant difference between the means of variables considering 0.95 confidence interval.

Table 48 ANOVA Table for NV(UP) NOA data

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	298.592	4	74.648	90.846	0.000
Within Groups	180.773	220	0.822		
Total	479.365	224			

In order to determine the variables having difference with respect to their means, the Table 49 is examined in detail. Since generally "Tamhane's" Test is preferred to get more comprehensive results in the analyses of variances which are not homogenous, "Tamhane's" Test is applied for further analysis in this study.

Table 49 Multiple comparisons for NV(UP) NOA data

Multiple Comparisons							
Dependent Variable: Number of Accident							
	(I) Mine	(J) Mine	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tamhane	Amasra	Armutcuk	-0.07566	0.168	1.000	-0.608	0.457
		Karadon	-3.39281*	0.271	0.000	-4.182	-2.603
		Kozlu	-0.70763*	0.188	0.008	-1.279	-0.136
		Uzulmez	-0.86518*	0.176	0.001	-1.412	-0.318
	Armutcuk	Amasra	0.07566	0.168	1.000	-0.457	0.609
		Karadon	-3.31715*	0.229	0.000	-3.988	-2.646
		Kozlu	-0.63197*	0.121	0.000	-0.980	-0.284
		Uzulmez	-0.78952*	0.101	0.000	-1.079	-0.500
	Karadon	Amasra	3.39281*	0.271	0.000	2.603	4.182
		Armutcuk	3.31715*	0.229	0.000	2.646	3.988
		Kozlu	2.68517*	0.245	0.000	1.975	3.395
		Uzulmez	2.52763*	0.236	0.000	1.841	3.214
	Kozlu	Amasra	0.70763*	0.188	0.008	0.136	1.279
		Armutcuk	0.63197*	0.121	0.000	0.284	0.980
		Karadon	-2.68517*	0.245	0.000	-3.395	-1.975
		Uzulmez	-0.15755	0.133	0.934	-0.536	0.221
	Uzulmez	Amasra	0.86518*	0.176	0.001	0.318	1.412
		Armutcuk	0.78952*	0.101	0.000	0.500	1.079
		Karadon	-2.52763*	0.236	0.000	-3.214	-1.841
		Kozlu	0.15755	0.133	0.934	-0.221	0.536
*Mean difference is significant at the 0.05 level.							

In the Multiple Comparison Table (Table 49) the mines are compared with each other with respect to the number of accidents between 2000 and 2014. In the Table the differences between the means of each mine are tabulated. A row having a sig value smaller than 0.05 and with a (*) sign near the mean difference value points that there is a significant difference between the means of the NV(UP) NOA values of corresponding mines. For example, there is a statistically significant difference between Amasra mine and Karadon-Kozlu-Uzulmez mines regarding the NV(UP) NOA values for 2000-2014 period. However, there is no significant difference between Amasra and Armutçuk mines regarding the NV(UP) NOA for the same period since the sig value is equal to 1.0. (Table 49). The same is valid for Kozlu and Üzülmez mines as can be seen from Table 49 ("sig"=0.934). The results of the Table 49 show that Karadon mine is the worst mine in terms of number of accident between the years 2000 and 2014. On the other hand, the best mine is Amasra mine in this respect. The mines could be ordered from worst to best as Karadon-Üzülmez-Kozlu-Armutçuk-Amasra mines considering the NV(UP) NOA for the 2000-2014 period.

6.2.4.2 Type of Accident

Table 50 illustrates the NV(UP) number of accidents with respect to types considering the fifteen years period for each mine. These values are used in the ANOVA in order to examine the correlation between the types of accidents and to compare the mines in term of accident types for fifteen years.

Table 50 NV(UP) type of accidents (2000-2014)

	Amasra	Armutçuk	Karadon	Kozlu	Üzülmez
RF	5.23	6.28	28.30	6.02	11.41
Trans.	0.56	0.57	1.47	1.08	1.21
Mat.Hand.	2.08	2.37	17.31	4.63	2.95
Slip/Fall	1.60	2.85	5.93	3.44	3.28
Struck Obj.	1.09	0.15	3.99	6.75	5.71
Mech. Electr.	0.55	0.57	1.28	0.94	1.62
Others	1.63	1.16	5.68	0.61	0.22

The sig values in the Table 51 and Table 52 point that the differences between the means of the variables are statistically significant. Therefore further analysis would be comprehensive.

Table 51 Test of homogeneity of variances for NV(UP) type of accidents data

Test of Homogeneity of Variances			
Levene Statistic	df1	df2	Sig.
6.840	6	53	0.000

Table 52 ANOVA for NV(UP) type of accidents data

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	476.855	6	79.476	6.086	0.000
Within Groups	692.112	53	13.059		
Total	1,168.967	59			

Table 53 reveals that there is no significant difference for most of the accident types. For example, for roof fall accidents, since significance value is higher than 0.05 for all other type of accidents, there is no significant difference between the roof fall accidents and any other accident types regarding their distributions through years. This is valid for material handling and struck by object accidents. On the other hand, since significance value is smaller than 0.05, there is a significant difference between slip/fall, transportation and mechanical electrical accident types (Table 53). In other words, the distribution of number of these accidents differs from each other in the mines through the years. There is no statistically difference between other types of accidents regarding the distribution of these accident types among the mines. In other words, the ratios of type of accidents in the mines are close to each other through the years.

Table 53 Multiple comparisons for NV(UP) type of accidents data

Multiple Comparisons							
Dependent Variable: number of accident							
	(I) Type of accident	(J) Type of accident	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tamhane	rf	trans	10.47198	4.356	0.800	-19.061	40.005
		mat.hand	5.58170	5.226	1.000	-18.608	29.772
		slip/fall	8.03116	4.378	0.957	-21.094	37.157
		struck	7.91228	4.435	0.962	-20.242	36.066
		mech	10.45392	4.354	0.802	-19.110	40.017
		other	9.58832	4.384	0.868	-19.422	38.599
	trans	rf	-10.47198	4.356	0.800	-40.005	19.061
		mat.hand	-4.89028	2.899	0.978	-24.464	14.683
		slip/fall	-2.44082*	0.504	0.010	-4.397	-0.484
		struck	-2.55970	0.872	0.275	-6.088	0.969
		mech	-0.01806	0.227	1.000	-0.975	0.939
		other	-0.88366	0.556	0.947	-2.867	1.099
	mat.hand	rf	-5.58170	5.226	1.000	-29.772	18.608
		trans	4.89028	2.899	0.978	-14.683	24.464
		slip/fall	2.44946	2.931	1.000	-16.543	21.442
		struck	2.33058	3.016	1.000	-15.456	20.117
		mech	4.87222	2.897	0.979	-14.746	24.491
		other	4.00662	2.941	0.997	-14.828	22.841
	slip/fall	rf	-8.03116	4.378	0.957	-37.157	21.094
		trans	2.44082*	0.504	0.010	0.484	4.397
		mat.hand	-2.44946	2.931	1.000	-21.442	16.543
		struck	-0.11888	0.974	1.000	-3.709	3.471
		mech	2.42276*	0.491	0.011	0.482	4.364
		other	1.55716	0.706	0.555	-0.849	3.963
*Mean difference is significant at the 0.05 level.							

Table 53 (continued)

Multiple Comparisons							
Dependent Variable: number of accident							
	(I) Type of accident	(J) Type of accident	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tamhane	struck	rf	-7.91228	4.435	0.962	-36.066	20.242
		trans.	2.55970	0.872	0.275	-0.969	6.088
		mat.hand	-2.33058	3.016	1.000	-20.117	15.456
		slip/fall	0.11888	0.974	1.000	-3.471	3.709
		mech	2.54164	0.864	0.281	-0.992	6.075
		other	1.67604	1.002	0.922	-1.936	5.288
	mech	rf	-10.45392	4.354	0.802	-40.017	19.110
		trans	0.01806	0.227	1.000	-0.939	0.975
		mat.hand	-4.87222	2.897	0.979	-24.491	14.746
		slip/fall	-2.42276*	0.491	0.011	-4.364	-0.482
		struck	-2.54164	0.864	0.281	-6.075	0.992
		other	-0.86560	0.544	0.948	-2.822	1.091
	other	rf	-9.58832	4.384	0.868	-38.599	19.422
		trans	0.88366	0.556	0.947	-1.099	2.867
		mat.hand	-4.00662	2.941	0.997	-22.841	14.828
		slip/fall	-1.55716	0.706	0.555	-3.963	0.849
		struck	-1.67604	1.002	0.922	-5.288	1.936
		mech	0.86560	0.544	0.948	-1.091	2.822
*Mean difference is significant at the 0.05 level							

6.2.4.3 Location of Accident

Table 54 shows the NV(UP) Location of Accidents between 2000 and 2014 in the mines. These values are used as entry in the ANOVA.

Table 54 NV(UP) location of accidents (2000-2014)

	Amasra	Armutçuk	Karadon	Kozlu	Üzülmez
Prod. Face	6.47	10.08	39.04	8.58	18.12
Dev. Face	2.73	1.30	6.10	5.10	3.53
Gate Roads	0.19	0.35	0.73	3.34	1.02
Roadw, Gall.	2.55	1.16	14.33	4.68	2.23
Others	0.80	1.06	3.76	1.78	1.50

The results of homogeneity and Anova tests show that it is possible to carry out further analysis on the normalized location of accident data (Table 55 and Table 56).

Table 55 Test of homogeneity of variances for NV(UP) location of accidents data

Test of Homogeneity of Variances			
Levene Statistic	df1	df2	Sig.
6.745	4	30	0.001

Table 56 ANOVA for NV(UP) location of accidents data

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	843.073	4	210.768	6.465	0.001
Within Groups	977.975	30	32.599		
Total	1,821.048	34			

The results of the Table 57 clearly show that there is statistically significant difference between the means of production face and the means of other remaining accident locations among the mines. In other words, the proportions of each accident location is very close to each other in each mine. Production face has the greatest share in the accidents between 2000 and 2014 in all mines. On the contrary, gate road has the lowest share in all mines. When the results of Anova test is examined in detail, it can be seen that all the other accident locations except production face have proportions which are very close to each other and much smaller than production face (Table 57). These results are consistent with the other statistical analysis.

Table 57 Multiple comparisons for NV(UP) location of accidents data

Multiple Comparisons							
Dependent Variable: Number of Accident							
	(I)Location of Accident	(J)Location of Accident	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tamhane	prodface	devface	12.70962*	3.611	0.025	0.865	24.554
		gateroad	15.33290*	3.611	0.004	3.489	27.177
		roadways	11.47000*	3.127	0.028	1.213	21.728
		others	14.67900*	3.127	0.002	4.422	24.937
	devface	prodface	-12.70962*	3.611	0.035	-24.554	-0.865
		gateroad	2.62328	3.611	0.879	-9.221	14.468
		roadways	-1.23962	3.127	0.667	-11.497	9.018
		others	1.96938	3.127	0.582	-8.288	12.227
	gateroad	prodface	-15.33290*	3.611	0.006	-27.177	-3.489
		devface	-2.62328	3.611	0.887	-14.468	9.221
		roadways	-3.86290	3.127	0.625	-14.120	6.395
		others	-0.65390	3.127	1.000	-10.911	9.604
	roadways	prodface	-11.47000*	3.127	0.012	-21.728	-1.213
		devface	1.23962	3.127	0.957	-9.018	11.497
		gateroad	3.86290	3.127	0.850	-6.395	14.120
		others	3.20900	2.553	0.911	-5.166	11.584
	others	prodface	-14.67900*	3.127	0.001	-24.937	-4.422
		devface	-1.96938	3.127	0.782	-12.227	8.288
		gateroad	0.65390	3.127	1.000	-9.604	10.911
		roadways	-3.20900	2.553	0.611	-11.584	5.166
*Mean difference is significant at the 0.05 level							

6.2.4.4 Days Lost

As mentioned before, since there is lack of data for some years till 2005 in the analysis of days lost the data between 2005 and 2014 is used. The Table 58 shows the normalized days lost values of Mines with UP.

Table 58 NV(UP) DL

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Amasra	10.95	7.89	5.14	4.27	7.59	6.09	7.40	3.26	4.08	4.25
Armutçuk	11.10	3.27	0.65	8.99	10.98	21.70	18.99	19.36	15.93	11.37
Karadon	84.77	68.08	84.65	64.50	104.37	101.03	79.27	70.10	75.60	53.87
Kozlu	19.96	24.80	25.90	15.74	32.89	32.89	21.47	17.97	17.08	17.59
Üzülmez	40.15	35.22	36.42	31.32	47.22	37.57	37.52	34.63	30.58	28.99

Since the “Sig.” value (0.00) is smaller than 0.05, the null hypothesis for the variance homogeneity is rejected. That is, the means are significantly different %95 (Table 59).

Table 59 Test of homogeneity of variances for NV(UP) DL data

Test of Homogeneity of Variances			
Levene Statistic	df1	df2	Sig.
12.930	4	105	0.000

As mentioned before since the sig value in Table 60 is smaller than 0.05, the means are significantly different and the further analysis could be carried out on the days lost data.

Table 60 ANOVA for NV(UP) DL data

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	57,596.994	4	14,399.249	214.868	0.000
Within Groups	7036.499	105	67.014		
Total	64,633.494	109			

Table 61 shows the differences between means of the days lost of the mines. There is a significant difference between the means of days lost of the mines for the period 2005-2014 (Table 61). All mines differs from each other regarding the NV(UP) DL values. Karadon mine appears as the mine having the worst score in terms of NV(UP) DL value. On the other hand, Amasra mine is the mine having the least NV(UP) DL values according to the results (Table 61).

Amasra and Armutçuk mines are very similar with respect to NV(UP) DL values according to the multiple comparison results. Kozlu mine is also similar to these mines with respect to NV(UP) DL values (Table 61).

Üzülmez mine differs from Amasra, Armutçuk and Kozlu mines regarding the NV(UP) DL values. The results of the multiple comparison show that Üzülmez mine has the second worst NV(UP) DL values.

Table 61 points that Karadon completely different from other mines considering the NV(UP) DL values. The mines could be ordered as Amasra, Armutçuk, Kozlu, Üzülmez and Karadon mine from best to worst score with respect to NV(UP) DL values (Table 61).

Table 61 Multiple comparisons for NV(UP) DL data

Multiple Comparisons							
Dependent Variable: days lost							
	(I) Mine	(J) Mine	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tamhane	Amasra	Armutcuk	-7.88945*	1.827	0.004	-13.668	-2.111
		Karadon	-72.53418*	3.518	0.000	-83.543	-61.525
		Kozlu	-16.53681*	1.343	0.000	-20.534	-12.539
		Uzulmez	-29.56863*	1.124	0.000	-32.945	-26.192
	Armutcuk	Amasra	7.88945*	1.827	0.004	2.111	13.668
		Karadon	-64.64473*	3.820	0.000	-76.285	-53.004
		Kozlu	-8.64736*	2.004	0.002	-14.760	-2.535
		Uzulmez	-21.67919*	1.865	0.000	-27.494	-15.864
	Karadon	Amasra	72.53418*	3.518	0.000	61.525	83.543
		Armutcuk	64.64473*	3.820	0.000	53.004	76.285
		Kozlu	55.99737*	3.613	0.000	44.819	67.176
		Uzulmez	42.96555*	3.538	0.000	31.927	54.005
	Kozlu	Amasra	16.53681*	1.343	0.000	12.539	20.534
		Armutcuk	8.64736*	2.004	0.002	2.535	14.760
		Karadon	-55.99737*	3.613	0.000	-67.176	-44.819
		Uzulmez	-13.03182*	1.394	0.000	-17.094	-8.970
	Uzulmez	Amasra	29.56863*	1.124	0.000	26.192	32.945
		Armutcuk	21.67919*	1.865	0.000	15.864	27.494
		Karadon	-42.96555*	3.538	0.000	-54.005	-31.927
		Kozlu	13.03182*	1.394	0.000	8.970	17.094
*Mean difference is significant at the 0.05 level							

CHAPTER 7

RISK ANALYSIS FOR TTK

Risk Analysis involves quantification of hazard and its severity. Hence, in this chapter stages of risk assessment for TTK accidents is explained.

7.1 Hazard Assessment

Hazard is the first component of risk. There are variables affecting hazard. In the study; age, experience and main duty of casualties, type and location of the accident are considered to be the main factors that contribute the occurrence of accidents. Considering this fact, these variables are used in the calculation of related hazard.

In order to quantify the hazards, first contingency tables for factors affecting the accidents are utilized. Then, based on the results of the contingency tables, overall hazard for TTK and each Mine are assessed taking individual, operational and locational aspects of hazards.

7.1.1 Contingency Tables

Contingency tables are the tables in the form of matrixes showing the relationships between the variables. In this study, in order to determine the related probabilities, contingency tables are prepared for each variable. Contingency tables show the share of accidents related with crossing variable among all. Within this context cross tables given in Figure 91 are established.

- Type of Accident
  - Location of Accident
  - Injured body part
  - Age
  - Experience
  - Main Duty
- Location of Accident
  - Injured body part
  - Experience
  - Age
- Experience
  - Age
  - Injured body part
- Age
  - Injured body part
- Days Lost
  - Type of Accident
  - Age
  - Injured body part
  - Experience
  - Location of Accident
  - Main Duty

Figure 91 Contingency tables between variables

The cross tables in Figure 91 are prepared for all the data covering the accidents between 2000 and 2014. The contingency tables for the variables are prepared for each mine separately and for TTK in total. Tables for TTK are given. The contingency tables for all types of cross variables for each mine are given in Appendix B. In the color scale used for the contingency tables dark red points the highest probability and the lowest probability value is illustrated as dark green.

7.1.1.1 Contingency Tables for Type of Accident

The roof fall in the production faces in TTK mines are the most probable occupational accidents (Table 62 and Table 63). 16,002 of 39,738 accidents are roof fall accidents and 11,385 of them occurs in production faces as shown in Table 62. The probability of a roof fall in a production face is 0.287 which is very high (Table 63). On the other hand the smallest probability belongs to the mechanical and electrical accidents in gate roads, with the probability is 0.001 (Table 63). During evaluations the categories "Others", "Various" and "Unknown" are excluded due to unavailability of the data for these categories.

Table 62 Distribution of accidents according to type and location in TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	11,385	185	4,472	2,275	2,667	766	1,232	**22,982**
Dev. Face	2,233	143	1,071	740	656	187	439	**5,469**
Gate Roads	151	281	378	345	416	56	84	**1,711**
Roadw, Gall.	1,766	590	1,786	1,081	1,156	212	451	**7,042**
Others	467	211	490	448	311	211	396	**2,534**
TOTAL	**16,002**	**1,410**	**8,197**	**4,889**	**5,206**	**1,432**	**2,602**	**39,738**

Table 63 Accident probabilities with respect to type and location in TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.287	0.005	0.113	0.057	0.067	0.019	0.031	**0.578**
Dev. Face	0.056	0.004	0.027	0.019	0.017	0.005	0.011	**0.138**
Gate Roads	0.004	0.007	0.010	0.009	0.010	0.001	0.002	**0.043**
Roadw, Gall.	0.044	0.015	0.045	0.027	0.029	0.005	0.011	**0.177**
Others	0.012	0.005	0.012	0.011	0.008	0.005	0.010	**0.064**
TOTAL	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

4,770 of 11,841 hand injuries are due to the accidents resulting from roof falls (Table 64). Regarding the type of injury and accident, hand injury in a roof fall is the most probable event. (Table 65). Its probability is 0.12. The smallest probability belongs to the arms and main body injuries in mechanical and electrical accidents (Table 65).

Table 64 Distribution of accidents according to type and injury in TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Head	1,895	106	462	368	818	179	304	**4,132**
Hands	4,770	504	2,525	954	1,908	432	748	**11,841**
Feet	3,610	287	1,551	980	1,116	496	637	**8,677**
Arms	1,388	61	289	448	287	77	109	**2,659**
Legs	1,692	117	535	797	567	137	205	**4,050**
Main Body	2,237	296	2,653	1,144	349	78	491	**7,248**
Various	410	39	182	198	161	33	108	**1,131**
TOTAL	**16,002**	**1,410**	**8,197**	**4,889**	**5,206**	**1,432**	**2,602**	**39,738**

Table 65 Accident probabilities with respect to type and injury in TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Head	0.048	0.003	0.012	0.009	0.021	0.005	0.008	**0.104**
Hands	0.120	0.013	0.064	0.024	0.048	0.011	0.019	**0.298**
Feet	0.091	0.007	0.039	0.025	0.028	0.012	0.016	**0.218**
Arms	0.035	0.002	0.007	0.011	0.007	0.002	0.003	**0.067**
Legs	0.043	0.003	0.013	0.020	0.014	0.003	0.005	**0.102**
Main Body	0.056	0.007	0.067	0.029	0.009	0.002	0.012	**0.182**
Various	0.010	0.001	0.005	0.005	0.004	0.001	0.003	**0.028**
TOTAL	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

As clearly shown in Tables 66 and 67 the workers within the 26-30 age group are mostly exposed to roof fall accidents with a probability of 0.175 and the smallest probability is 0.001 which belongs to the mechanical and electrical accidents and older than 46 years old age group.

Table 66 Distribution of accidents according to type and age in TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	Total
≤ 25	2,766	59	1,437	640	850	188	269	**6,209**
26-30	6,944	205	3,423	1,754	2,101	485	823	**15,735**
31-35	3,863	346	1,780	1,262	1,282	408	646	**9,587**
36-40	1,575	424	920	703	616	209	418	**4,865**
41-45	683	275	512	413	280	102	343	**2,608**
46≤	142	83	104	101	62	34	93	**619**
Unknown	29	18	21	16	15	6	10	**115**
Total	**16,002**	**1,410**	**8,197**	**4,889**	**5,206**	**1,432**	**2,602**	**39,738**

Table 67 Accident probabilities with respect to type and age in TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	Total
≤ 25	0.070	0.001	0.036	0.016	0.021	0.005	0.007	**0.156**
26-30	0.175	0.005	0.086	0.044	0.053	0.012	0.021	**0.396**
31-35	0.097	0.009	0.045	0.032	0.032	0.010	0.016	**0.241**
36-40	0.040	0.011	0.023	0.018	0.016	0.005	0.011	**0.122**
41-45	0.017	0.007	0.013	0.010	0.007	0.003	0.009	**0.066**
46≤	0.004	0.002	0.003	0.003	0.002	0.001	0.002	**0.016**
Unknown	0.001	0.000	0.001	0.000	0.000	0.000	0.000	**0.003**
Total	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

Similarly, the highest probability belongs to the roof fall accidents with having 2-5 years of experience. On the other hand, the least probable event is the mechanical and electrical accident with workers having more than 21 years of experience (Table 68 and Table 69).

Table 68 Distribution of accidents according to type and experience in TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
0-1 Year	5,181	122	2,764	1,221	1,767	320	527	**11,902**
2-5 Years	6,470	239	3,077	1,761	1,778	531	793	**14,649**
6-10 Years	2,440	323	1,044	808	857	253	504	**6,229**
11-15 Years	1,330	462	864	699	522	192	425	**4,494**
16-20 Years	486	198	363	301	212	97	283	**1,940**
21≤	93	65	84	97	70	39	66	**514**
Unknown	2	1	1	2	0	0	4	**10**
TOTAL	**16,002**	**1,410**	**8,197**	**4,889**	**5,206**	**1,432**	**2,602**	**39,738**

Table 69 Accident probabilities with respect to type and experience in TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
0-1 Year	0.130	0.003	0.070	0.031	0.044	0.008	0.013	**0.300**
2-5 Years	0.163	0.006	0.077	0.044	0.045	0.013	0.020	**0.369**
6-10 Years	0.061	0.008	0.026	0.020	0.022	0.006	0.013	**0.157**
11-15 Years	0.033	0.012	0.022	0.018	0.013	0.005	0.011	**0.113**
16-20 Years	0.012	0.005	0.009	0.008	0.005	0.002	0.007	**0.049**
21≤	0.002	0.002	0.002	0.002	0.002	0.001	0.002	**0.013**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

Regarding main duty, the injury of a production worker in a roof fall accident is the most probable event with a probability value of 0.344 (Table 70 and 71). The probability of injury in demontage workers exposed to a mechanical and electrical accident is the smallest with a value of 0.001.

Table 70 Distribution of accidents according to type and main duty in TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. W.	13,674	314	6,378	3,297	4,010	907	1,430	**30,010**
Dev. W.	1,312	129	741	555	469	128	346	**3,680**
Trans. W.	155	685	326	302	283	78	320	**2,149**
Mech.,Elect.	169	84	288	245	197	225	185	**1,393**
Demont. W.	380	60	250	151	103	36	119	**1,099**
Others	278	119	181	310	128	52	188	**1,256**
Unknown	34	19	33	29	16	6	14	**151**
TOTAL	**16,002**	**1,410**	**8,197**	**4,889**	**5,206**	**1,432**	**2,602**	**39,738**

Table 71 Accident probabilities with respect to type and main duty in TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. W.	0.344	0.008	0.161	0.083	0.101	0.023	0.036	**0.755**
Dev. W.	0.033	0.003	0.019	0.014	0.012	0.003	0.009	**0.093**
Trans. W.	0.004	0.017	0.008	0.008	0.007	0.002	0.008	**0.054**
Mech.,Elect.	0.004	0.002	0.007	0.006	0.005	0.006	0.005	**0.035**
Demont. W.	0.010	0.002	0.006	0.004	0.003	0.001	0.003	**0.028**
Others	0.007	0.003	0.005	0.008	0.003	0.001	0.005	**0.032**
Unknown	0.001	0.000	0.001	0.001	0.000	0.000	0.000	**0.004**
TOTAL	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

7.1.1.2 Contingency Tables for Location of Accident

The contingency tables for the distribution of accidents regarding their location are prepared. Tables 72-77 show the number and the probabilities of the accidents with respect to accident location and the injured body part, age and experience of casualties. The maximum probabilities belong to the accidents in production faces and the corresponding probabilities in these accidents for hand injury, workers having 2-5 years of experience and workers 26-30 years old are 0.173, 0.239, and 0.261, respectively. On the other hand, the accidents in gate roads have the minimum probability and the related probabilities for arm injury, workers having more than 21 years of experience and workers older than 46 years old are 0.002, 0.001 and 0.002, respectively. (Tables 72-77).

Table 72 Distribution of accidents according to location and injury in TTK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
Head	2,383	605	168	670	306	4,132
Hands	6,885	1,605	567	1,997	787	11,841
Feet	5,213	1,148	386	1,423	507	8,677
Arms	1,644	342	94	435	144	2,659
Legs	2,446	489	138	798	179	4,050
Main Body	3,911	1,115	329	1,357	536	7,248
Various	500	165	29	362	75	1,131
TOTAL	**22,982**	**5,469**	**1,711**	**7,042**	**2,534**	**39,738**

Table 73 Accident probabilities with respect to location and injury in TTK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
Head	0.060	0.015	0.004	0.017	0.008	**0.104**
Hands	0.173	0.040	0.014	0.050	0.020	**0.298**
Feet	0.131	0.029	0.010	0.036	0.013	**0.218**
Arms	0.041	0.009	0.002	0.011	0.004	**0.067**
Legs	0.062	0.012	0.003	0.020	0.005	**0.102**
Main Body	0.098	0.028	0.008	0.034	0.013	**0.182**
Various	0.013	0.004	0.001	0.009	0.002	**0.028**
TOTAL	**0.578**	**0.138**	**0.043**	**0.177**	**0.064**	**1.000**

Table 74 Distribution of accidents according to location and experience in TTK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
0-1 Year	8,140	1,033	339	2,191	199	11,902
2-5 Years	9,483	1,727	460	2,564	415	14,649
6-10 Years	3,231	1,183	354	915	546	6,229
11-15 Years	1,540	1,003	354	849	748	4,494
16-20 Years	498	435	153	395	459	1,940
21≤	85	88	51	128	162	514
Unknown	5	0	0	0	5	10
TOTAL	**22,982**	**5,469**	**1,711**	**7,042**	**2,534**	**39,738**

Table 75 Accident probabilities with respect to location and experience in TTK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
0-1 Year	0.205	0.026	0.009	0.055	0.005	**0.300**
2-5 Years	0.239	0.043	0.012	0.065	0.010	**0.369**
6-10 Years	0.081	0.030	0.009	0.023	0.014	**0.157**
11-15 Years	0.039	0.025	0.009	0.021	0.019	**0.113**
16-20 Years	0.013	0.011	0.004	0.010	0.012	**0.049**
21≤	0.002	0.002	0.001	0.003	0.004	**0.013**
Unknown	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.578**	**0.138**	**0.043**	**0.177**	**0.064**	**1.000**

Table 76 Distribution of accidents according to location and age in TTK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
≤ 25	4,289	515	170	1,128	107	**6,209**
26-30	10,354	1,739	489	2,727	426	**15,735**
31-35	5,485	1,509	418	1,616	559	**9,587**
36-40	1,921	981	350	871	742	**4,865**
41-45	760	575	215	524	534	**2,608**
46≤	142	130	60	146	141	**619**
Unknown	31	20	9	30	25	**115**
TOTAL	**22,982**	**5,469**	**1,711**	**7,042**	**2,534**	**39,738**

Table 77 Accident probabilities with respect to location and age in TTK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	Total
≤ 25	0.108	0.013	0.004	0.028	0.003	**0.156**
26-30	0.261	0.044	0.012	0.069	0.011	**0.396**
31-35	0.138	0.038	0.011	0.041	0.014	**0.241**
36-40	0.048	0.025	0.009	0.022	0.019	**0.122**
41-45	0.019	0.014	0.005	0.013	0.013	**0.066**
46≤	0.004	0.003	0.002	0.004	0.004	**0.016**
Unknown	0.001	0.001	0.000	0.001	0.001	**0.003**
Total	**0.578**	**0.138**	**0.043**	**0.177**	**0.064**	**1.000**

7.1.1.3 Contingency Tables for Experience and Age

Tables 78-83 show the distribution of occupational accidents and related probabilities regarding the experience and age of casualties. When the injury and experience are regarded, according to the results, the probability of injuring from hands for a worker having 2-5 years of experience has the highest value (0.108) and the smallest probability (0.001) belongs to the injury from arms and legs for the workers experienced more than 21 years (Table 78 and Table 79).

Table 78 Distribution of accidents according to experience and injury in TTK

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	TOTAL
Head	1,023	1,618	708	510	222	51	0	**4,132**
Hands	3,525	4,305	1,920	1,380	546	164	1	**11,841**
Feet	2,659	3,214	1,345	936	412	107	4	**8,677**
Arms	821	1,076	378	265	91	28	0	**2,659**
Legs	1,341	1,541	584	388	145	51	0	**4,050**
Main Body	2,171	2,479	1,112	918	473	93	2	**7,248**
Various	362	416	182	97	51	20	3	**1,131**
TOTAL	**11,902**	**14,649**	**6,229**	**4,494**	**1,940**	**514**	**10**	**39,738**

Table 79 Accident probabilities with respect to experience and injury in TTK

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	TOTAL
Head	0.026	0.041	0.018	0.013	0.006	0.001	0.000	**0.104**
Hands	0.089	0.108	0.048	0.035	0.014	0.004	0.000	**0.298**
Feet	0.067	0.081	0.034	0.024	0.010	0.003	0.000	**0.218**
Arms	0.021	0.027	0.010	0.007	0.002	0.001	0.000	**0.067**
Legs	0.034	0.039	0.015	0.010	0.004	0.001	0.000	**0.102**
Main Body	0.055	0.062	0.028	0.023	0.012	0.002	0.000	**0.182**
Various	0.009	0.010	0.005	0.002	0.001	0.001	0.000	**0.028**
TOTAL	**0.300**	**0.369**	**0.157**	**0.113**	**0.049**	**0.013**	**0.000**	**1.000**

Regarding the age and experience, the maximum probability of accident is obtained for workers having 2-5 years of experience and 26-30 years old (0.202) and the smallest probability (0.00008) is obtained for the workers of 31-35 years old and having more than 21 years of experience (Table 80 and Table 81).

Table 80 Distribution of accidents according to experience and age in TTK

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	Total
≤ 25	4,702	1,503	0	0	0	0	4	**6,209**
26-30	6,647	8,014	985	85	0	0	4	**15,735**
31-35	528	5,042	3,204	716	93	3	1	**9,587**
36-40	15	73	1,948	2,375	362	92	0	**4,865**
41-45	3	9	83	1,206	1,134	172	1	**2,608**
46≤	0	0	5	97	284	233	0	**619**
Unknown	7	8	4	15	67	14	0	**115**
Total	**11,902**	**14,649**	**6,229**	**4,494**	**1,940**	**514**	**10**	**39,738**

Table 81 Accident probabilities with respect to experience and age in TTK

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	Total
≤ 25	0.118	0.038	0.000	0.000	0.000	0.000	0.000	**0.156**
26-30	0.167	0.202	0.025	0.002	0.000	0.000	0.000	**0.396**
31-35	0.013	0.127	0.081	0.018	0.002	0.000	0.000	**0.241**
36-40	0.000	0.002	0.049	0.060	0.009	0.002	0.000	**0.122**
41-45	0.000	0.000	0.002	0.030	0.029	0.004	0.000	**0.066**
46≤	0.000	0.000	0.000	0.002	0.007	0.006	0.000	**0.016**
Unknown	0.000	0.000	0.000	0.000	0.002	0.000	0.000	**0.003**
Total	**0.300**	**0.369**	**0.157**	**0.113**	**0.049**	**0.013**	**0.000**	**1.000**

For the age of casualty and injured part, injury from hands for 26-30 years old workers has the highest probability, on the other hand the smallest probability in that respect belongs to the injury from main body for the workers older than 46 years old (Table 82 and Table 83).

Table 82 Distribution of accidents according to age and injury in TTK

	Head	Hands	Feet	Arms	Legs	Main Body	Various	Total
≤ 25	554	1,862	1,372	435	708	1,107	171	**6,209**
26-30	1,548	4,604	3,589	1,083	1,666	2,778	467	**15,735**
31-35	1,093	2,905	1,983	682	1,011	1,634	279	**9,587**
36-40	556	1,489	1,018	297	398	979	128	**4,865**
41-45	290	759	563	133	205	598	60	**2,608**
46≤	74	197	129	24	52	120	23	**619**
Unknown	17	25	23	5	10	32	3	**115**
Total	**4,132**	**11,841**	**8,677**	**2,659**	**4,050**	**7,248**	**1,131**	**39,738**

Table 83 Accident probabilities with respect to injury and age in TTK

	Head	Hands	Feet	Arms	Legs	Main Body	Various	Total
≤ 25	0.014	0.047	0.035	0.011	0.018	0.028	0.004	**0.156**
26-30	0.039	0.116	0.090	0.027	0.042	0.070	0.012	**0.396**
31-35	0.028	0.073	0.050	0.017	0.025	0.041	0.007	**0.241**
36-40	0.014	0.037	0.026	0.007	0.010	0.025	0.003	**0.122**
41-45	0.007	0.019	0.014	0.003	0.005	0.015	0.002	**0.066**
46≤	0.002	0.005	0.003	0.001	0.001	0.003	0.001	**0.016**
Unknown	0.000	0.001	0.001	0.000	0.000	0.001	0.000	**0.003**
Total	**0.104**	**0.298**	**0.218**	**0.067**	**0.102**	**0.182**	**0.028**	**1.000**

7.1.1.4 Contingency Tables for Days Lost

Days lost is one of the most serious consequences of occupational accidents. Days lost is an important variable in the calculation of risk in the mines. For this reason, all contingency tables for days lost for the accidents in the mines are prepared. Tables 84-89 show the distribution of yearly days lost values considering all the other variables. As previously mentioned, since in some of the mines the days lost data for some years are missing the contingency tables for days lost are prepared in yearly basis.

Table 84 shows that 21,513 days are lost every year on the average in Karadon mine considering data between 2000 and 2014. The biggest share of this lost belongs to roof fall accidents with 9,326 days/year. The best mine in that respect is Armutçuk mine. The average yearly days lost is 3,066 days in this mine. The yearly average days lost for TTK due to accidents is 46,889 days. The number of days lost in a year due to accidents resulting from material handling works is approximately 9,000 days. The share of transportation and mechanical and electrical accidents are relatively low (Table 84).

Table 84 Yearly days lost for type of accidents (days/year)

	AMASRA	ARMUTÇUK	KARADON	KOZLU	ÜZÜLMEZ	TOTAL
RF	1,321	1,216	9,326	1,603	4,806	**18,272**
Trans.	217	249	570	350	871	**2,257**
Mat. Hand.	482	529	5,498	1,224	1,266	**8,998**
Slip/Fall	430	692	2,288	1,286	1,588	**6,284**
Struck Obj.	233	31	1,119	2,373	2,413	**6,169**
Mech. Electr.	140	188	438	267	787	**1,820**
Others	326	162	2,274	212	115	**3,089**
TOTAL	**3,149**	**3,066**	**21,513**	**7,316**	**11,845**	**46,889**

Considering the age of casualties the great portion lost in TTK belongs to the accidents in which the casualties are 26-30 years old (Table 85). On the other hand, the share of days lost for the accidents which are the casualties are older than 46 years old is the smallest with only 973 days/year.

Table 85 Yearly days lost for age of casualties (days/year)

	AMASRA	ARMUTÇUK	KARADON	KOZLU	ÜZÜLMEZ	TOTAL
≤ 25	425	307	2,615	715	1,256	**5,317**
26-30	1,059	1,097	8,244	2,571	3,998	**16,969**
31-35	743	1,051	5,345	2,300	3,237	**12,675**
36-40	580	444	2,820	1,082	1,932	**6,858**
41-45	257	148	2,018	529	1,118	**4,070**
46≤	72	20	463	119	299	**973**
Unknown	14	0	6	0	6	**27**

The injuries of hands and feet have the highest values with 15,426 and 12,093 days/year, respectively. The smallest value is 2,609 days for head injuries (Table 86).

Table 86 Yearly days lost for injured part of casualties (days/year)

	AMASRA	ARMUTÇUK	KARADON	KOZLU	ÜZÜLMEZ	TOTAL
Head	201	206	1,049	435	717	**2,609**
Hands	932	942	6,789	2,754	4,019	**15,436**
Feet	811	887	5,360	1,805	3,231	**12,093**
Arms	143	334	1,261	451	932	**3,120**
Legs	484	259	2,485	645	1,430	**5,303**
Main Body	545	394	4,021	1,047	1,457	**7,464**
Various	33	44	549	181	58	**864**

The days lost resulting from the accidents of casualties having more than 21 years of experience is the smallest among others with only 971 days/year (Table 87). On the other hand, as shown on the Table 87, in TTK days are lost yearly due to the accidents having casualties with 2-5 years and 6-10 years of experiences (16,973 and 12,677 days/year, respectively).

Table 87 Yearly days lost for experience of casualties (days/year)

	AMASRA	ARMUTÇUK	KARADON	KOZLU	ÜZÜLMEZ	TOTAL
0-1 Year	425	307	2,615	715	1,256	**5,317**
2-5 Years	1,059	1,097	8,251	2,569	3,997	**16,973**
6-10 Years	746	1,051	5,342	2,304	3,234	**12,677**
11-15 Years	580	444	2,819	1,082	1,934	**6,859**
16-20 Years	253	148	2,016	529	1,120	**4,066**
21≤	72	20	463	117	299	**971**
Unknown	14	0	6	0	6	**27**

27,749 days are lost yearly due to the accidents occurring in production faces in TTK. On the other hand the corresponding days lost value for the gate road accidents is only 2,409 days/year (Table 88).

Table 88 Yearly days lost for location of accidents (days/year)

	AMASRA	ARMUTÇUK	KARADON	KOZLU	ÜZÜLMEZ	TOTAL
Prod. Face	1,525	1,924	13,516	2,998	7,787	**27,749**
Dev. Face	642	324	2,058	1,246	1,661	**5,930**
Gate Roads	91	95	261	1,387	574	**2,409**
Roadw, Gall.	689	432	4,303	1,148	1,166	**7,737**
Others	202	291	1,376	538	657	**3,064**

Similarly, when the main duty of the casualties are taken into account, the great share belongs to the accidents in which the production workers are exposed (Table 89). The accidents in which demontage workers included are the least ones in terms of day lost in all mines excluding Karadon mine. In Karadon mine, the days lost values due to mechanical and electrical accidents are smaller (Table 89).

Table 89 Yearly Days Lost for Main Duty of Casualties (days/year)

	AMASRA	ARMUTÇUK	KARADON	KOZLU	ÜZÜLMEZ	TOTAL
Prod. W.	2,268	1,996	16,389	5,096	8,489	**34,237**
Dev. W.	284	276	1,482	915	1,226	**4,183**
Trans. W.	232	318	1,420	619	852	**3,441**
Mech.,Elect.	130	224	561	344	508	**1,767**
Demont. W.	70	190	984	65	296	**1,605**
Others	152	64	622	276	449	**1,562**
Unknown	14	0	53	0	27	**94**

7.1.2 Assessment of Overall Hazard

Hazard is the probability of a danger or accident to occur. On the other hand, risk covers the consequences of the corresponding hazard. Considering the structure of the variables and the causes, three main hazard categories are defined. These are:

1. Individual Hazard : Hazard related directly with the properties of casualties
2. Operational Hazard : Hazard related directly with the operational activities carried out in the mines during working
3. Locational hazard : Hazard related with the mine environment especially structural condition of the working area

Table 90 shows the defined hazard categories and related variables. The hazard related with the age and experience of casualty is categorized as individual hazard since these parameters are directly related with the individual characteristics of the workers. The hazard related with the main duty of casualty, type of accidents like transportation material handling, slip/fall, mechanical and electrical and struck by objects are handled as operational hazards since these variables cover the operational activities in the mine. Finally, the hazard related to accident location and roof fall accidents are categorized as locational hazard since accidents location and roof falls are directly related with the mine environment.

Table 90 Hazard classification and related variables

Individual Hazard	Operational Hazard	Locational hazard
Age	Main Duty	Accident Location
Experience	Transportation	Roof Fall
	Material Handling	
	Slip/Fall	
	Mechanical and Electrical	
	Struck by Objects	

7.1.2.1 Calculation of Individual Hazards

As previously mentioned since the hazard is the probability of an accident, in order to determine the hazards for the related categories all probabilities are calculated using the contingency tables. Later, Total and Conditional Probability Theorems are applied in calculation of each hazard category and total hazard.

In calculating the hazards, the contingency tables in the previous section are used. For the calculation of individual hazard the Age versus Experience table is used. In the calculation Equation 7 is used.

$$H_I = P_{age} + P_{exp} - P_{age} \times P_{exp} \qquad [7]$$

Where;

H_I : Individual Hazard

P_{age} : Probability of accidents regarding the age of casualties

P_{exp} : Probability of accidents regarding the experience of casualties

Applying the Equation 7 on the age versus experience contingency table, the related probabilities are calculated. Although in previous contingency tables only the values belonging to TTK are taken into account, since one of the most important objectives of this study is to compare each mine regarding occupational hazards and risks, in this section all calculations carried out for each mine are given. After calculating the related hazards the minimum and maximum individual hazards are determined for each mine. Tables 91-96 show all the individual hazards for each mine and TTK in total value. The hazard values are graded by red- white- green color scale. The highest hazard is shown in dark red and the smallest hazard value is illustrated in dark green. During color scaling the unknown categories are excluded both on the row and the column due to availability problems. The most hazardous groups are the workers between 26-30 age group having 6-10 years of experience in Amasra mine. The related hazard value for this group of workers is 0.530 (Table 91). On the other hand, the least hazardous group is the group of workers older than 46 years old and having more than 21 years of experience. The corresponding hazard value is 0.02 as shown in the Table 91). When all the tables are examined, it is recognized that apart from the Amasra mine, the groups of workers having maximum and minimum hazard are the same. In these mines maximum hazard value belongs to the group of workers in 26-30 years age having 2-5 years of experience. Additionally, the group of workers older than 46 years old and having more than 21 years of experience have the minimum hazard values (Tables 92-95). The situation is the same for TTK in total (Table 96). Only in Amasra mine, as mentioned above, the most hazardous group is different from others mines. Although the age of this group is the same as the other mines, the experience of this group is 6-10 years. It can easily be said that the hazard decreases with increasing age and experience.

Table 91 Individual hazards for Amasra mine

Exp. / Age	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown
≤ 25	0.308	0.454	0.358	0.285	0.204	0.164	0.155
26-30	0.495	0.509	**0.530**	0.490	0.410	0.370	0.362
31-35	0.509	0.483	0.361	0.353	0.301	0.264	0.255
36-40	0.409	0.475	0.272	0.213	0.179	0.148	0.140
41-45	0.339	0.406	0.269	0.161	0.092	0.074	0.068
46≤	0.285	0.352	0.218	0.142	0.056	**0.020**	0.015
Unknown	0.278	0.345	0.211	0.136	0.053	0.016	0.008

Table 92 Individual hazards for Armutçuk mine

Age \ Exp.	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown
≤ 25	0.301	0.535	0.330	0.252	0.196	0.165	0.156
26-30	0.511	**0.600**	0.543	0.491	0.438	0.407	0.399
31-35	0.509	0.558	0.356	0.348	0.309	0.281	0.273
36-40	0.358	0.542	0.233	0.163	0.142	0.117	0.112
41-45	0.295	0.481	0.221	0.121	0.069	0.054	0.049
46≤	0.257	0.442	0.184	0.104	0.044	**0.017**	0.010
Unknown	0.251	0.437	0.178	0.100	0.043	0.013	0.005

Table 93 Individual hazards for Karadon mine

Age \ Exp.	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown
≤ 25	0.372	0.496	0.307	0.265	0.211	0.178	0.166
26-30	0.560	**0.586**	0.539	0.518	0.466	0.432	0.420
31-35	0.544	0.469	0.292	0.310	0.267	0.236	0.224
36-40	0.441	0.477	0.206	0.154	0.145	0.120	0.109
41-45	0.397	0.434	0.203	0.133	0.081	0.073	0.064
46≤	0.350	0.387	0.158	0.113	0.056	**0.022**	0.017
Unknown	0.333	0.370	0.141	0.099	0.046	0.013	0.001

Table 94 Individual hazards for Kozlu mine

Age \ Exp.	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown
≤ 25	0.348	0.479	0.308	0.266	0.215	0.171	0.157
26-30	0.538	**0.550**	0.525	0.500	0.453	0.408	0.395
31-35	0.534	0.464	0.303	0.329	0.289	0.246	0.233
36-40	0.440	0.474	0.227	0.171	0.172	0.135	0.124
41-45	0.386	0.422	0.218	0.150	0.094	0.078	0.070
46≤	0.331	0.367	0.164	0.121	0.064	**0.022**	0.014
Unknown	0.324	0.360	0.158	0.116	0.060	0.020	0.007

Table 95 Individual hazards for Üzülmez mine

Age \ Exp.	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown
≤ 25	0.283	0.468	0.298	0.284	0.186	0.152	0.134
26-30	0.474	**0.535**	0.497	0.506	0.412	0.379	0.360
31-35	0.504	0.495	0.345	0.389	0.315	0.285	0.267
36-40	0.398	0.513	0.264	0.216	0.191	0.161	0.149
41-45	0.322	0.439	0.234	0.189	0.094	0.084	0.073
46≤	0.267	0.384	0.181	0.164	0.061	**0.030**	0.018
Unknown	0.250	0.367	0.164	0.150	0.052	0.019	0.001

Table 96 Individual hazards for TTK

Age \ Exp.	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown
≤ 25	0.337	0.487	0.313	0.269	0.205	0.169	0.156
26-30	0.528	**0.563**	0.528	0.507	0.445	0.409	0.396
31-35	0.527	0.483	0.317	0.336	0.288	0.254	0.241
36-40	0.422	0.489	0.230	0.176	0.162	0.133	0.123
41-45	0.365	0.434	0.220	0.148	0.086	0.074	0.066
46≤	0.315	0.384	0.172	0.126	0.057	**0.023**	0.016
Unknown	0.302	0.371	0.160	0.116	0.050	0.015	0.003

The minimum and maximum individual hazard values are tabulated in Table 97. When the mines compared in terms of maximum and minimum individual hazards, the most hazardous mine is Armutçuk mine and the most hazardous group is, as mentioned before, workers 26-30 years old having 2-5 years of experience (Table 97). Regarding the minimum individual hazards, similarly in the Armutçuk mine, the group of workers older than 46 years old and having more than 21 years of experience is the least hazardous group among all mines. The minimum and maximum individual hazard values for TTK is 0.023 and 0.563, respectively for the same groups.

Table 97 Maximum and minimum individual hazards in the mines

	Maximum Hazard			Minimum Hazard		
	Age	**Experience**	**Likelihood**	**Age**	**Experience**	**Likelihood**
Amasra	26-30	6-10 Years	**0.530**	46≤	21≤	**0.020**
Armutçuk	26-30	2-5 Years	**0.600**	46≤	21≤	**0.017**
Karadon	26-30	2-5 Years	**0.586**	46≤	21≤	**0.022**
Kozlu	26-30	2-5 Years	**0.550**	46≤	21≤	**0.022**
Üzülmez	26-30	2-5 Years	**0.535**	46≤	21≤	**0.030**
TTK	26-30	2-5 Years	**0.563**	46≤	21≤	**0.023**

The event tree of individual hazard is illustrated in Figure 92. The red color shows the maximum individual hazard for TTK and green color on the tree illustrates corresponding minimum hazard.

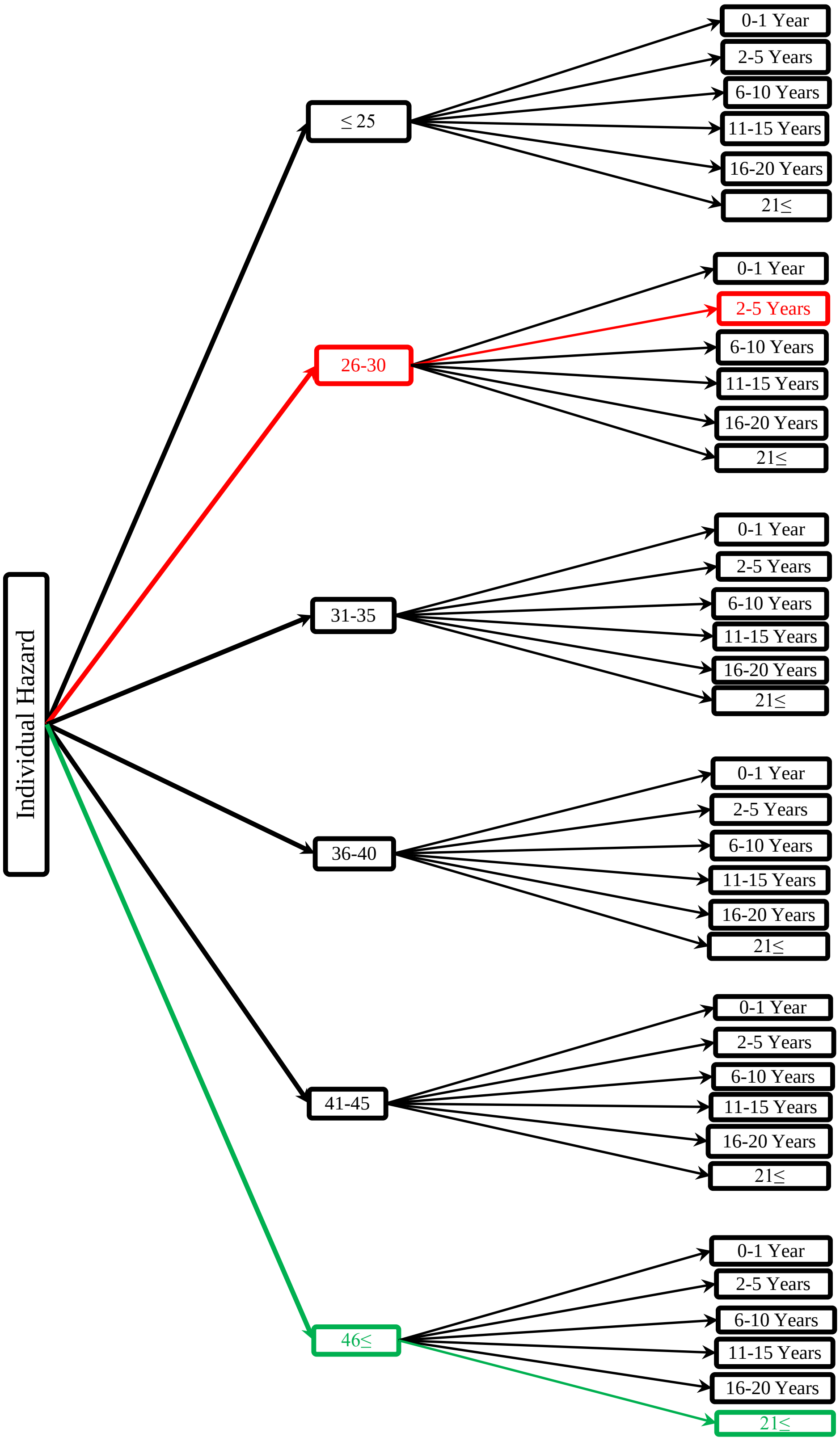


Figure 92 Event tree of individual hazard for TTK mines

7.1.2.2 Calculation of Operational Hazards

For the calculation of operational hazard the Main Duty and Type of Accident are considered and the corresponding contingency tables are used accordingly. Equation 8 is used for calculating operational hazard.

$$H_O = P_{duty} + P_{type} - P_{duty} \times P_{type} \quad [8]$$

Where;

H_O : Operational Hazard

P_{duty} : Probability of accidents regarding the duty of casualties

P_{type} : Probability of accidents regarding their type

Using Equation 8 for the duty x type contingency table, the related probabilities are calculated and tabulated (Tables 98-103). During calculation the roof fall column is excluded in the calculation of operational hazards since it is handled in the calculation of locational hazards. In this section, the others and unknown rows and columns are not scaled to be able to make a precise evaluation for each group. In Amasra mine, the greatest operational hazard belongs to production workers having accidents types of slip and fall with a value is 0.732 (Table 98). In this mine, the smallest operational hazard is 0.097, which belongs to demontage workers experiencing mechanical or electrical related accidents.

Table 98 Operational hazards for Amasra mine

Duty \ Type	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others
Prod. W.	0.721	0.727	**0.732**	0.695	0.693	0.742
Dev. W.	0.162	0.347	0.281	0.230	0.156	0.288
Trans. W.	0.123	0.351	0.281	0.220	0.152	0.276
Mech.,Elect.	0.136	0.332	0.265	0.200	0.129	0.268
Demont. W.	0.103	0.298	0.236	0.170	**0.097**	0.240
Others	0.119	0.324	0.260	0.198	0.130	0.267
Unknown	0.084	0.284	0.221	0.155	0.083	0.225

For Armutçuk mine, the maximum operational hazard is 0.768 and the group is the same as Amasra mine's production workers having accident type of slip/fall. However, for the minimum operational hazard, although the duty of the group is the same as demontage workers, in terms of accident type is struck by objects (Table 99).

Table 99 Operational hazards for Armutçuk mine

Type / Duty	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others
Prod. W.	0.724	0.730	**0.768**	0.665	0.673	0.710
Dev. W.	0.157	0.370	0.423	0.103	0.157	0.217
Trans. W.	0.124	0.395	0.449	0.115	0.175	0.242
Mech.,Elect.	0.136	0.362	0.422	0.087	0.131	0.208
Demont. W.	0.114	0.340	0.398	**0.063**	0.117	0.191
Others	0.109	0.344	0.391	0.059	0.114	0.182
Unknown	0.080	0.313	0.377	0.027	0.082	0.158

The situation is a little bit different for Karadon mine. The probability of having material handling accidents for production workers is the highest among all (Table 100). On the other hand, the probability of exposing to accident in demontage workers for mechanical or electrical related accident is the smallest (Table 100). The situation for Kozlu mine is exactly the same as Karadon mine (Table 101).

Table 100 Operational hazards for Karadon mine

Type / Duty	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others
Prod. W.	0.754	**0.801**	0.768	0.731	0.737	0.797
Dev. W.	0.113	0.528	0.226	0.182	0.107	0.211
Trans. W.	0.096	0.555	0.241	0.193	0.119	0.224
Mech.,Elect.	0.084	0.517	0.204	0.156	0.0711	0.192
Demont. W.	0.076	0.505	0.196	0.147	**0.0707**	0.186
Others	0.081	0.519	0.196	0.150	0.074	0.185
Unknown	0.043	0.487	0.168	0.114	0.038	0.161

Table 101 Operational hazards for Kozlu mine

Duty \ Type	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others
Prod. W.	0.724	**0.780**	0.748	0.774	0.706	0.698
Dev. W.	0.192	0.353	0.309	0.482	0.185	0.169
Trans. W.	0.114	0.319	0.257	0.439	0.119	0.098
Mech.,Elect.	0.102	0.297	0.231	0.420	0.092	0.078
Demont. W.	0.076	0.277	0.211	0.399	**0.071**	0.052
Others	0.094	0.293	0.222	0.415	0.089	0.071
Unknown	0.068	0.272	0.204	0.393	0.062	0.043

Table 102 indicates the operational hazard values for Üzülmez mine. The minimum and maximum operational hazards are different from other mines. The highest hazard belongs to the group of production workers for the accident type of struck by objects (Table 102). The smallest hazard is 0.105 which is a relatively high value for minimum hazard, is for transportation accidents in which demontage workers involved (Table 102).

Table 102 Operational hazards for Üzülmez mine

Duty \ Type	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others
Prod. W.	0.717	0.705	0.743	**0.773**	0.687	0.669
Dev. W.	0.187	0.301	0.302	0.459	0.220	0.130
Trans. W.	0.147	0.280	0.295	0.446	0.197	0.104
Mech.,Elect.	0.137	0.247	0.267	0.418	0.156	0.074
Demont. W.	**0.105**	0.221	0.242	0.397	0.136	0.042
Others	0.111	0.230	0.242	0.409	0.144	0.052
Unknown	0.083	0.199	0.220	0.383	0.110	0.017

When TTK is considered, the probability of struck by objects accidents which production workers involved is the highest. On the other hand, the smallest probability belongs to the transportation accidents for demontage workers. The minimum and maximum operational hazard values for TTK are 0.087 and 0.765, respectively (Table 103).

Table 103 Operational hazards for TTK

Duty \ Type	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others
Prod. W.	0.734	**0.765**	0.755	0.739	0.710	0.738
Dev. W.	0.154	0.414	0.282	0.299	0.155	0.195
Trans. W.	0.115	0.416	0.277	0.291	0.141	0.180
Mech.,Elect.	0.107	0.385	0.247	0.263	0.102	0.153
Demont. W.	**0.087**	0.365	0.230	0.245	0.089	0.135
Others	0.096	0.379	0.234	0.255	0.099	0.143
Unknown	0.064	0.349	0.210	0.224	0.065	0.114

Minimum and maximum operational hazards are listed in Table 104. When the mines are compared in terms of maximum and minimum operational hazards the most hazardous mine is Karadon mine and the most hazardous group is production workers and accident type is material handling (Table 104). Regarding the minimum operational hazards, in Armutçuk mine, the group of demontage workers for the struck by object accidents is the least hazardous group among all the mines (Table 104).

Table 104 Maximum and minimum operational hazards in the mines

	Maximum Hazard			**Minimum Hazard**		
	Main Duty	**Accident Type**	**Likelihood**	**Main Duty**	**Accident Type**	**Likelihood**
Amasra	Prod. W.	Slip/Fall	**0.732**	Demont. W.	Mech. Electr.	**0.097**
Armutçuk	Prod. W.	Slip/Fall	**0.768**	Demont. W.	Struck Obj.	**0.063**
Karadon	Prod. W.	Mat. Hand.	**0.801**	Demont. W.	Mech. Electr.	**0.071**
Kozlu	Prod. W.	Mat. Hand.	**0.780**	Demont. W.	Mech. Electr.	**0.071**
Üzülmez	Prod. W.	Struck Obj.	**0.773**	Demont. W.	Trans.	**0.105**
TTK	Prod. W.	Mat. Hand.	**0.765**	Demont. W.	Trans.	**0.087**

Figure 93 is the illustration of Operational hazards for TTK Mines. The maximum operational hazard which is in red belongs to the production workers for material handling in Karadon mine (Figure 93). On the other hand, as illustrated in the Figure 91 in green, the minimum operational hazard is for demontage workers having struck by object accidents in Armutçuk mine.

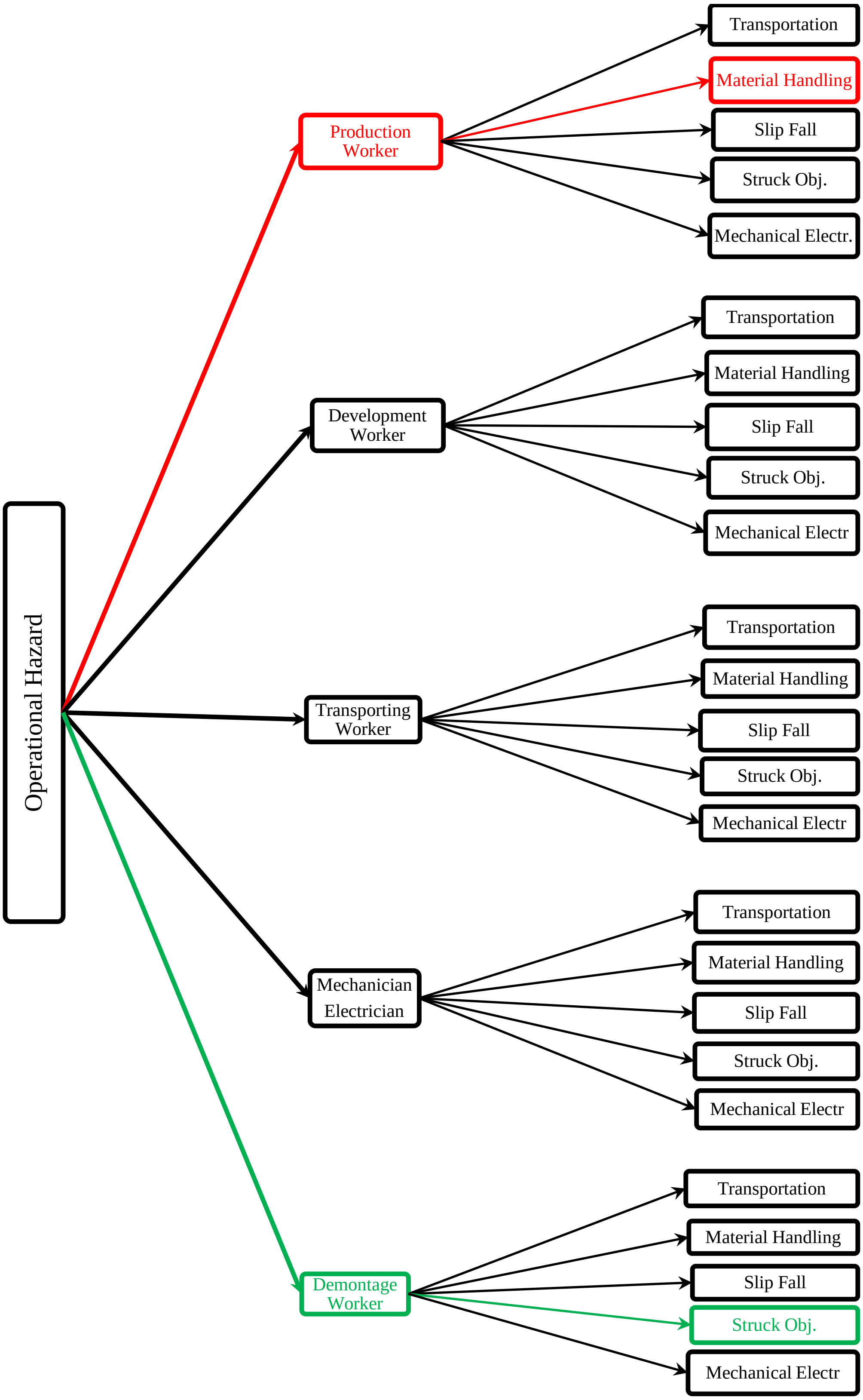


Figure 93 Event tree of operational hazard for TTK Mines

7.1.2.3 Calculation of Locational Hazards

Since all the other accident types are taken into account in operational hazards, here only roof fall accidents are explained as accident type together with location of accidents. Therefore the roof fall column in the location of accident versus type of accident contingency tables are considered as the locational hazard directly. In all mines the most probable accident locations are production faces. The smallest value in this respect belongs to gate roads in all mines. Tables 105-110 show the locational hazards in the mines.

Table 105 Locational hazards for Amasra mine

Location \ Type	RF	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.238	0.006	0.081	0.049	0.059	0.021	0.055	**0.508**
Dev. Face	0.116	0.004	0.027	0.025	0.007	0.010	0.025	**0.214**
Gate Roads	0.001	0.006	0.003	0.002	0.001	0.000	0.001	**0.015**
Roadw, Gall.	0.048	0.023	0.041	0.036	0.015	0.006	0.030	**0.200**
Others	0.008	0.005	0.011	0.012	0.003	0.006	0.017	**0.062**
TOTAL	**0.411**	**0.044**	**0.163**	**0.125**	**0.085**	**0.043**	**0.128**	**1.000**

Table 106 Locational hazards for Armutçuk mine

Location \ Type	RF	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.374	0.002	0.127	0.131	0.006	0.031	0.053	**0.723**
Dev. Face	0.041	0.001	0.016	0.020	0.002	0.002	0.011	**0.093**
Gate Roads	0.007	0.003	0.006	0.008	0.000	0.000	0.001	**0.025**
Roadw, Gall.	0.016	0.019	0.010	0.028	0.001	0.003	0.006	**0.083**
Others	0.012	0.016	0.012	0.018	0.002	0.005	0.012	**0.076**
TOTAL	**0.450**	**0.041**	**0.170**	**0.204**	**0.011**	**0.041**	**0.083**	**1.000**

Table 107 Locational hazards for Karadon mine

Location \ Type	RF	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.335	0.003	0.154	0.045	0.023	0.006	0.043	**0.610**
Dev. Face	0.036	0.001	0.026	0.011	0.005	0.003	0.014	**0.095**
Gate Roads	0.002	0.005	0.001	0.001	0.000	0.000	0.001	**0.011**
Roadw, Gall.	0.059	0.012	0.076	0.025	0.033	0.005	0.015	**0.224**
Others	0.011	0.003	0.014	0.010	0.001	0.006	0.015	**0.059**
TOTAL	**0.443**	**0.023**	**0.271**	**0.093**	**0.062**	**0.020**	**0.089**	**1.000**

Table 108 Locational hazards for Kozlu mine

Location \ Type	RF	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.110	0.003	0.064	0.042	0.125	0.015	0.006	**0.365**
Dev. Face	0.072	0.007	0.049	0.028	0.047	0.008	0.006	**0.217**
Gate Roads	0.008	0.012	0.038	0.029	0.043	0.005	0.007	**0.142**
Roadw, Gall.	0.052	0.017	0.029	0.038	0.052	0.007	0.004	**0.199**
Others	0.014	0.006	0.018	0.009	0.021	0.005	0.002	**0.076**
TOTAL	**0.256**	**0.046**	**0.197**	**0.147**	**0.288**	**0.040**	**0.026**	**1.000**

Table 109 Locational hazards for Üzülmez mine

Location \ Type	RF	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.338	0.011	0.077	0.065	0.146	0.046	0.004	**0.686**
Dev. Face	0.061	0.007	0.013	0.021	0.025	0.004	0.002	**0.134**
Gate Roads	0.002	0.010	0.005	0.009	0.011	0.001	0.000	**0.039**
Roadw, Gall.	0.018	0.013	0.012	0.015	0.019	0.006	0.002	**0.085**
Others	0.014	0.005	0.005	0.013	0.015	0.004	0.001	**0.057**
TOTAL	**0.432**	**0.046**	**0.112**	**0.124**	**0.216**	**0.062**	**0.008**	**1.000**

Table 110 Locational hazards for TTK

Location \ Type	RF	Trans.	Mat.Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.287	0.005	0.113	0.057	0.067	0.019	0.031	**0.578**
Dev. Face	0.056	0.004	0.027	0.019	0.017	0.005	0.011	**0.138**
Gate Roads	0.004	0.007	0.010	0.009	0.010	0.001	0.002	**0.043**
Roadw, Gall.	0.044	0.015	0.045	0.027	0.029	0.005	0.011	**0.177**
Others	0.012	0.005	0.012	0.011	0.008	0.005	0.010	**0.064**
TOTAL	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

The minimum and maximum locational hazards are tabulated in Table 111. The maximum locational hazard belongs to production faces for roof fall accidents and the minimum locational hazard belongs to gate roads (Figure 94).

When the mines are compared, regarding locational hazards, Armutçuk mine has the highest hazard with 0.3739 and Amasra mine has the lowest locational hazard with 0.0012 (Table 111).

Table 111 Maximum and minimum locational hazards in the mines

	Maximum Hazard			Minimum Hazard		
	Acc. Location	**Acc. Type**	**Likelihood**	**Acc. Location**	**Acc. Type**	**Likelihood**
Amasra	Prod. Face	RF	**0.2377**	Gate Roads	RF	**0.0012**
Armutçuk	Prod. Face	RF	**0.3739**	Gate Roads	RF	**0.0072**
Karadon	Prod. Face	RF	**0.3349**	Gate Roads	RF	**0.0023**
Kozlu	Prod. Face	RF	**0.1100**	Gate Roads	RF	**0.0085**
Üzülmez	Prod. Face	RF	**0.3381**	Gate Roads	RF	**0.0022**
TTK	Prod. Face	RF	**0.2865**	Gate Roads	RF	**0.0038**

The maximum locational hazard is in the production faces for roof fall accidents which is illustrated as red in Figure 94. On the other hand, as illustrated in Figure 94 in green, the minimum operational hazard belongs to the roof fall accidents in gate roads.

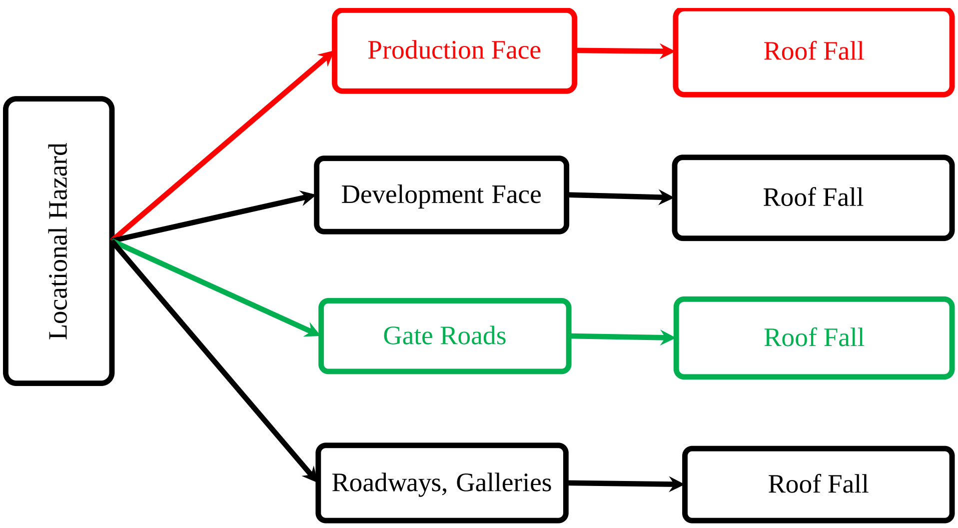


Figure 94 Event tree of locational hazard for TTK Mines

7.1.2.4 Calculation of Total Hazard

After calculating the individual, operational and locational hazards for the mines, the total hazard for each mine is calculated using Equation 9.

$$H_T = \sum_{i=1}^{n} H_i - \sum_{i=1}^{n}\sum_{j=1}^{n} H_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{n} H_{ijk} \qquad [9]$$

Considering the hazard categories, Equation 9 takes the following form.

$$H_T = H_I + H_O + H_L - H_I H_O - H_I H_L - H_O H_L + H_I H_O H_L \qquad [10]$$

Where;

H_T : Total Hazard

H_I : Individual Hazard

H_O : Operational Hazard

H_L : Locational Hazard

After the implementation of Equation 10, maximum and minimum total hazards are obtained (Table 112). According to the results, Karadon mine is found as the most hazardous mine and Armutçuk mine is found as the least hazardous mine with respect to total hazard (Table 112).

Table 112 Maximum and minimum total hazard in TTK mines

	Total Hazard	
	Maximum	Minimum
Amasra	0.9040	0.1161
Armutçuk	0.9419	0.0852
Karadon	0.9451	0.0928
Kozlu	0.9117	0.0995
Üzülmez	0.9299	0.1335
TTK	0.9267	0.1112

7.2 Severity Assessment

Severity assessment is the second essential component of risk assessment. For this purpose, severities in terms of in terms of injured body parts and days lost are calculated.

The contingency table related with injuries is given in Table 113. It shows the probabilities of injured body parts during the accidents for the fifteen year period in the mines. The highest probabilities are seen for the hands and feet injuries. The highest probability belongs to hand injury in Üzülmez mine. The smallest probability is seen in Amasra mine for arms injury (Table 113).

Table 113 Probabilities of injuries in the mines

	Head	Hands	Feet	Arms	Legs	Main Body	Various	Total
Amasra	0.120	0.283	0.203	0.060	0.124	0.196	0.014	1.000
Armutçuk	0.101	0.292	0.266	0.083	0.074	0.165	0.021	1.000
Karadon	0.088	0.285	0.216	0.060	0.108	0.198	0.045	1.000
Kozlu	0.112	0.312	0.199	0.056	0.099	0.195	0.026	1.000
Üzülmez	0.124	0.324	0.227	0.090	0.094	0.136	0.006	1.000
TTK	0.104	0.298	0.218	0.067	0.102	0.182	0.028	1.000

For the calculation of probabilities in terms of days lost in the mines, the total working days of a worker in a year is assumed as 287 days (Table 114). Available days lost values and the number of underground workers in the mines are also other parameters used in the calculation. To get rid of the negative effects of the absence of days lost data for some years in some of the mines, the average annual values are used in the calculations.

The highest probability in terms of days lost is seen in Karadon mine while the least days lost probability belongs to Armutçuk mine. The highest and the lowest probabilities for these mines are 0.021 and 0.009 respectively (Table 114).

Table 114 Probabilities of days lost in the mines

	Days Lost (days/year)	Total # of Workers	Yearly Av. # of Workers	Work Days per Year	Total Work Days per Year	Probability of Days Lost
Amasra	3,149	11,412	761	287	218,350	0.014
Armutçuk	3,066	17,052	1,137	287	326,262	0.009
Karadon	21,513	53,049	3,537	287	1,015,004	0.021
Kozlu	7,316	27,573	1,838	287	527,563	0.014
Üzülmez	11,845	32,255	2,150	287	617,146	0.019
TTK	46,889	141,341	9,423	287	2,704,324	0.017

7.3 Risk Assessment

As mentioned earlier, the risk is the combination of hazard and the severity of the hazard. It is also expressed as the multiplication of hazard and severity.

$$\text{Risk} = \text{Hazard x Severity} \qquad [11]$$

In Equation 11, hazard is the total hazard, covering the individual, operational and locational hazard categories, which is calculated using the total probability theorem. In risk calculation, the severity of accidents are considered for injuries of casualties during accidents and related days lost after accidents.

Since the total hazard and severities have already been determined the next stage in the risk analysis is the calculation of the risks for the mines using Equation 11.

Table 115 shows the maximum and minimum risk values computed for the injury types for each mine. When Table 115 is examined, it is seen that the maximum risk values ranges from 0.062 to 0.276 for TTK. In this calculation the type of “various” injury is excluded since the injuries in this class is not definite. In terms of minimum risks in TTK the risk varies from 0.007 to 0.033 (Table115).

Table 115 Risks for injuries

	AMASRA		ARMUTÇUK		KARADON		KOZLU		ÜZÜLMEZ		TTK	
	Max.Risk	Min.Risk	Max.Risk	Min.Risk	Max.Risk	Min.Risk	Max.Risk	Min.Risk	Max.Risk	Min.Risk	Max.Risk	Min.Risk
Head	0.109	0.014	0.095	0.009	0.083	0.008	0.102	0.011	0.116	0.017	0.096	0.012
Hands	**0.256**	0.033	**0.275**	0.025	**0.270**	0.026	**0.284**	0.031	**0.301**	0.043	**0.276**	0.033
Feet	0.184	0.024	0.250	0.023	0.204	0.020	0.182	0.020	0.211	0.030	0.202	0.024
Arms	0.054	**0.007**	0.078	0.007	0.057	**0.006**	0.051	**0.006**	0.083	**0.012**	0.062	**0.007**
Legs	0.112	0.014	0.069	**0.006**	0.102	0.010	0.090	0.010	0.087	0.013	0.094	0.011
Main Body	0.177	0.023	0.155	0.014	0.187	0.018	0.178	0.019	0.126	0.018	0.169	0.020
Various	0.013	0.002	0.020	0.002	0.042	0.004	0.024	0.003	0.006	0.001	0.026	0.003
TOTAL	0.904	0.116	0.942	0.085	0.945	0.093	0.912	0.099	0.930	0.133	0.927	0.111

The maximum risk for injury type is the same as "Hands" in every mines and it ranges from 0.256 to 0.301 (Table 116). The maximum injury risk appears as 0.301 for hands in Üzülmez mine (Table 116). The second highest value is in Kozlu mine (0.284). The lowest maximum injury risk is 0.256 and it belongs to Amasra mine (Table 116).

The minimum injury risks are found in Karadon and Kozlu mines (0.0056). The highest value for minimum injury risk is found for Üzülmez mine (0.012) (Table 116).

Table 116 Maximum and minimum risks for injuries

	Maximum Risk		Minimum Risk	
	Injured Part	Likelihood	Injured Part	Likelihood
Amasra	Hands	0.2560	Arms	0.0070
Armutçuk	Hands	0.2750	Legs	0.0063
Karadon	Hands	0.2700	Arms	0.0056
Kozlu	Hands	0.2840	Arms	0.0056
Üzülmez	Hands	0.3010	Arms	0.0120
TTK	Hands	0.2760	Arms	0.0074

Table 117 shows the maximum and minimum risk values for days lost. Karadon mine is the mine having the highest maximum risk (0.02). Armutçuk mine has the lowest maximum days lost risk (0.009). For minimum risk, Armutçuk mine again has the lowest minimum risk (0.0008). Üzülmez mine is the mine having the highest minimum risk value (0.0026) (Table 117).

Table 117 Maximum and minimum risks for days lost

	Maximum Risk	Minimum Risk
Amasra	0.0130	0.0017
Armutçuk	0.0089	0.0008
Karadon	0.0200	0.0020
Kozlu	0.0126	0.0014
Üzülmez	0.0178	0.0026
TTK	0.0161	0.0019

7.3.1 Risk Evaluation

The final stage of risk analysis is evaluation of the calculated risk. Risk evaluation involves analyzing the computed risk values according to acceptability and tolerability criteria. In the literature, there are mainly three classes in the risk acceptability/tolerability. These are Broadly Acceptable, Reasonable/Tolerable and Unacceptable Risks. The boundaries changes according to the nature of the risk. The values differentiates from study to study according to the identified and calculated risk levels and values.

In this study, for the determination of the three risk regions, the region between the calculated maximum and minimum risks for all the mines are divided into three linearly equal distinct.

Table 118 shows the three regions for the acceptability levels assigned for the injury risks in TTK mines. According to the results the risk levels for injury up to 0.104 could be regarded as broadly acceptable risks. The risks between 0.105 and 0.203 take place in the tolerable region and can be considered as reasonable risks. On the other hand, the risks equal and greater than 0.204 are unacceptable risks (Table 118).

Table 118 Tolerability of injury risks

Risks for Injuries	
Unacceptable Region	0.204 ≤
Tolerable Region	0.105 - 0.203
Broadly Acceptable Region	≤ 0.104

The evaluation of Mines with respect to the injury risk levels considering the minimum and maximum injury risks determined for the mines is given in Table 119. Although the minimum injury risks for Üzülmez mine and TTK are relatively higher compared to other mines, all injury risks take place in the acceptable region (Table 119). On the other hand, all maximum injury risks are unacceptable.

Table 119 Evaluation of mines with respect to injury risks levels

	Maximum Rısk		Minimum Rısk	
	Injured Part	Risk	Injured Part	Risk
Amasra	Hands	0.2560	Arms	0.0070
Armutçuk	Hands	0.2750	Legs	0.0063
Karadon	Hands	0.2700	Arms	0.0056
Kozlu	Hands	0.2840	Arms	0.0056
Üzülmez	Hands	0.3010	Arms	0.0120
TTK	Hands	0.2760	Arms	0.0074

Regarding injury risks, the risks for the hand injury is the highest value in all the mines. In that respect, for TTK mines the mines having injury risk greater than 0.2 should take immediate measures to decrease this risk level to tolerable levels. This is possible by necessary precautions in the short and medium term. On the other hand, the mines having injury risks between 0.1 and 0.2 should also consider to decrease this risk value lower than 0.1. In general, the entities having injury risks higher than 0.2 should take immediate measures to decrease the available risks. Additionally, the entities having tolerable injury risks should also consider necessary measure in the short or medium term to decrease the risk levels to acceptable levels.

The risks for days lost in TTK mines ranges from 0.0008 to 0.02. The days lost risks up to 0.007 take place in the broadly acceptable region (Table 120). The risk levels for days lost between 0.008 and 0.013 can be regarded as tolerable risks. On the other hand the risk levels greater than 0.014 is unacceptable.

Table 120 Tolerability of days lost risks

Risks for Days Lost	
Unacceptable Region	0.014 ≤
Tolerable Region	0.008 - 0.013
Broadly Acceptable Region	≤ 0.007

Table 121 shows the evaluation of mines regarding the minimum and maximum days lost risks. All minimum days lost risks are acceptable according to the risk levels given in Table 120. On the other hand, for maximum days lost risks, the risk values for Amasra, Armutçuk and Kozlu mines can be considered as tolerable risks even they are the maximum risk values (Table 121).

Table 121 Evaluation of mines with respect to days lost risks levels

	Maximum Risk	Minimum Risk
Amasra	0.0130	0.0017
Armutçuk	0.0089	0.0008
Karadon	0.0200	0.0020
Kozlu	0.0126	0.0014
Üzülmez	0.0178	0.0026
TTK	0.0161	0.0019

The highest days lost risks are in Karadon and Üzülmez mines and these risks are unacceptable risks since they are greater than 0.014. The measures should be immediately taken for these mines. The days lost risks for Amasra, Armutçuk and Kozlu mines are relatively lower than that of other mines. The calculated maximum risks are tolerable risks. These mines should also decrease these risks to acceptable levels by necessary measures in the short and medium term. There is no need to take measures for the mines having days lost risk lower than 0.007 at least immediately or in the short term. However, it should be noted that the measures and precautions for the OHS conditions should be considered at any time continuously whatever the risk levels are.

7.4 Results and Discussions

The results show that the number of accident decreases in TTK mines in general. However, the sharp increase in 2009 is significant especially in Karadon mine. The ROM production and the NOW in TTK mines decreases through years. The productivity of Amasra and Kozlu mines increases steadily in this period. There is no significant change in the labor productivity of Üzülmez mine. However, the decrease in the labor productivity in Karadon and Armutçuk mines is significant. Injury and fatality rates for these mines can be seen in Table 122. The highest value for the annual injury rate is in Karadon mine. The situation is not different for the fatality rate. Amasra and Armutçuk mines are the two mines having relatively low annual injury rates (Table 122). Additionally, Amasra and Kozlu mines have the highest annual labor productivity. In order to evaluate the actual change in the number of accidents the further analysis is carried out for the normalized values.

Table 122 ROM production, productivity, injury and fatality rates in the mines

	Average ROM Prod.(ton/year)	Average # of workers	Average Productivity (ton/year/worker)	Injury Rate (#/year)	Fatality rate (#/year)
Amasra	244,961	761	322	273	0.33
Armutçuk	316,907	1,137	279	259	0.27
Karadon	930,480	3,537	263	1,122	1.87
Kozlu	591,523	1,838	322	504	0.87
Üzülmez	599,771	2,150	279	491	1.33
TTK	2,683,643	9,423	285	2,649	4.67

Although the values point out a decrease in the number of accidents in the considered period, the further analysis shows that the number of accidents in TTK mines increases especially after year 2009. The results show that the great share in the increase of the number of underground occupational accidents belongs to the workers under 30 years old and having experience less than five year. This fact points out that these workers have to be dealt more precisely in struggling with occupational accidents. When the mines are scrutinized, the decrease in the number of accidents is more apparent in Amasra and Kozlu mines, while the increase is more significant in Armutçuk, Karadon and Üzülmez mines.

According to data analysis, the four main accident types are found to, roof fall, material handling, struck by objects and slip/fall. However, their share changes from mine to mine (Table 123). For example the share of struck by object is considerably high in Kozlu mine.

Table 123 Distribution of accidents with respect to accident types

	Amasra		Armutçuk		Karadon		Kozlu		Üzülmez	
	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%
Roof fall	5.230	41.1	6.281	45.0	28.301	44.3	6.022	25.6	11.412	43.2
Transportation	0.559	4.4	0.567	4.1	1.471	2.3	1.078	4.6	1.212	4.6
Material handling	2.081	16.3	2.368	17.0	17.305	27.1	4.630	19.7	2.954	11.2
Slip/Fall	1.596	12.5	2.848	20.4	5.929	9.3	3.440	14.7	3.277	12.4
Struck by objects.	1.087	8.5	0.151	1.1	3.987	6.2	6.753	28.8	5.708	21.6
Mechinery electrical related	0.550	4.3	0.574	4.1	1.285	2.0	0.945	4.0	1.624	6.2
Others	1.634	12.8	1.162	8.3	5.678	8.9	0.612	2.6	0.219	0.8

Production faces are the most common working areas with respect to the location of accidents in TTK. This is valid for all the five mines. Development faces together with roadways and galleries are the second common locations considering underground occupational accidents. Lower and upper gate roads are the third in this respect (Table 124).

Table 124 Distribution of accidents with respect to accident locations

	Amasra		Armutçuk		Karadon		Kozlu		Üzülmez	
	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%
Prod. Face	6.472	50.8	10.083	72.3	39.038	61.0	8.580	36.5	18.123	68.6
Dev. Face	2.727	21.4	1.298	9.3	6.097	9.5	5.100	21.7	3.528	13.4
Gate Roads	0.189	1.5	0.348	2.5	0.734	1.1	3.344	14.2	1.018	3.9
Roadw, Gall.	2.553	20.0	1.159	8.3	14.325	22.4	4.677	19.9	2.234	8.5
Others	0.795	6.2	1.062	7.6	3.763	5.9	1.781	7.6	1.502	5.7

The share of production workers in the accidents is extremely high with respect to other main duties. For all of the mines the share is more than %70 (Table 125). The accident proneness of demontage workers and mechanics and electricians are comparatively low (Table 125).

Table 125 Distribution of accidents with respect to main duties of casualties

	Amasra		Armutçuk		Karadon		Kozlu		Üzülmez	
	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%
Prod. W.	9.361	73.5	10.424	74.7	50.080	78.3	17.005	72.4	19.511	73.9
Dev. W.	1.205	9.5	1.108	7.9	4.534	7.1	3.108	13.2	2.832	10.7
Trans. W.	0.627	4.9	0.836	6.0	3.364	5.3	1.287	5.5	1.488	5.6
Mech. Elect.	0.578	4.5	0.599	4.3	1.802	2.8	0.792	3.4	1.115	4.2
Demont. W.	0.270	2.1	0.552	4.0	2.174	3.4	0.360	1.5	0.609	2.3
Others	0.596	4.7	0.348	2.5	1.912	3.0	0.749	3.2	0.800	3.0
Unknown	0.099	0.8	0.083	0.6	0.091	0.1	0.180	0.8	0.050	0.2

Data analysis indicates that the share of accidents for the workers having age between 26 and 30 is maximum for all mines (Table 126). The second highest share belongs to the group of workers 31-35 years old. The percentage decreases with increasing age. The situation is similar for the variable experience. The highest percentage belongs to the workers having 2-5 years of experience. The second group is the workers having 0-1 year of experience. The share decreases together with increasing experience after 2-5 years of experience which has the highest share (Table 127).

Table 126 Distribution of accidents with respect to age of Casualties

	Amasra		Armutçuk		Karadon		Kozlu		Üzülmez	
	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%
≤ 25	1.969	15.5	2.174	15.6	10.608	16.6	3.698	15.7	3.542	13.4
26-30	4.600	36.1	5.553	39.8	26.864	42.0	9.273	39.5	9.515	36.0
31-35	3.239	25.4	3.802	27.3	14.291	22.3	5.469	23.3	7.041	26.7
36-40	1.777	13.9	1.550	11.1	6.959	10.9	2.909	12.4	3.922	14.9
41-45	0.867	6.8	0.674	4.8	4.109	6.4	1.635	7.0	1.915	7.3
46≤	0.186	1.5	0.133	1.0	1.095	1.7	0.326	1.4	0.462	1.8
Unknown	0.099	0.8	0.065	0.5	0.030	0.0	0.171	0.7	0.007	0.0

Table 127 Distribution of accidents with respect to experience of Casualties

	Amasra		Armutçuk		Karadon		Kozlu		Üzülmez	
	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%
0-1 Year	3.447	27.1	3.447	24.7	21.292	33.3	7.436	31.7	6.583	24.9
2-5 Years	4.298	33.7	6.030	43.2	23.630	36.9	8.285	35.3	9.684	36.7
6-10 Years	2.587	20.3	2.428	17.4	9.019	14.1	3.533	15.0	4.335	16.4
11-15 Years	1.655	13.0	1.345	9.6	6.317	9.9	2.558	10.9	3.947	14.9
16-20 Years	0.624	4.9	0.563	4.0	2.908	4.5	1.355	5.8	1.366	5.2
21≤	0.118	0.9	0.126	0.9	0.779	1.2	0.314	1.3	0.484	1.8
Unknown	0.006	0.0	0.011	0.1	0.011	0.0	0.000	0.0	0.007	0.0

The percentage of casualties having primary school education is very high in all mines (Table 128). The smallest share is %59.9 in Karadon mine. The second vulnerable group in this regard is the group of workers having education level of high school (Table 128).

Table 128 Distribution of accidents with respect to education level of casualties

	Amasra		Armutçuk		Karadon		Kozlu		Üzülmez	
	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%
Primary Sch.	9.268	72.8	9.254	66.3	38.335	59.9	16.237	69.2	16.048	60.8
Secondary Sch.	1.224	9.6	1.406	10.1	10.532	16.5	3.362	14.3	4.987	18.9
High Sch.	2.062	16.2	3.096	22.2	14.147	22.1	3.480	14.8	5.195	19.7
University	0.003	0.0	0.007	0.1	0.076	0.1	0.028	0.1	0.025	0.1
Unknown	0.180	1.4	0.187	1.3	0.867	1.4	0.373	1.6	0.151	0.6

The results show that hands and feet are the most vulnerable organs affected from accidents. The least affected parts of the body in the accidents are arms and legs (Table 129).

Table 129 Distribution of accidents with respect to injuries

	Amasra		Armutçuk		Karadon		Kozlu		Üzülmez	
	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%
Head	1.531	12.0	1.403	10.1	5.648	8.8	2.632	11.2	3.281	12.4
Hands	3.603	28.3	4.075	29.2	18.255	28.5	7.325	31.2	8.551	32.4
Feet	2.587	20.3	3.705	26.6	13.820	21.6	4.680	19.9	5.984	22.7
Arms	0.764	6.0	1.151	8.3	3.827	6.0	1.321	5.6	2.366	9.0
Legs	1.575	12.4	1.026	7.4	6.902	10.8	2.328	9.9	2.481	9.4
Main Body	2.500	19.6	2.299	16.5	12.657	19.8	4.577	19.5	3.582	13.6
Various	0.177	1.4	0.291	2.1	2.847	4.5	0.618	2.6	0.161	0.6

The share of accidents in the days lost variable changes according to their type. The weights of each accident type varies from mine to mine. However, roof fall is the most common accident type for days lost. Its share is around 40% except for Kozlu mine. As mentioned previously the share of struck by objects is greater than roof fall in this mine. However, the main reason for this would be the errors in the data entry for the related accident information to the system. Material handling and slip fall are the other accident types having high shares in days lost (Table 130).

Table 130 Distribution of days lost with respect to accident types

	Amasra		Armutçuk		Karadon		Kozlu		Üzülmez	
	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%	NV(UP)	%
Roof fall	61.55	42.0	43.61	39.7	531.69	43.3	59.79	21.9	258.44	40.6
Transportation	10.13	6.9	8.91	8.1	32.50	2.6	13.06	4.8	46.84	7.4
Material handling	22.44	15.3	18.99	17.3	313.43	25.6	45.65	16.7	68.06	10.7
Slip/Fall	20.04	13.7	24.81	22.6	130.44	10.6	47.95	17.6	85.41	13.4
Struck by objects.	10.83	7.4	1.12	1.0	63.79	5.2	88.50	32.4	129.77	20.4
Machinery electrical related	6.51	4.4	6.74	6.1	24.99	2.0	9.97	3.7	42.31	6.6
Others	15.21	10.4	5.79	5.3	129.67	10.6	7.91	2.9	6.18	1.0

After descriptive statistics, hypothesis testing applied for the variables main duty, age and education levels of casualties. The results show that except for some minor groups which are defined, the null hypothesis H_0 is rejected which means that the proportions in the sample and the population are significantly different regarding 0.95 confidence interval. According to the results of hypothesis testing production workers are the most vulnerable workers and demontage workers, mechanic and electricians are the least vulnerable groups. The workers younger than 30 years old are exposed to accidents more than workers older than 30 years old. This test also validate that the workers having education level of primary school are the most vulnerable group among others.

After data analysis, risk assessment is carried out for TTK. In the assessment, firstly hazards are determined secondly consequences of these hazard are calculated and at the third stage the related risks are calculated and evaluated. The results of hazard assessment shows that individual hazard increases with decreasing age and experience. One interesting point is that the individual hazard for the workers having 0-1 year of experience is lower than that of 2-5 years experienced workers. Maximum individual hazard is 0.600 for the workers 26-30 years old and having 2-5 years of experience. On the other hand the minimum hazard belongs to the workers older than 46 years old having more than 21 years of experience.

The production workers working for a material handling job have the maximum operational hazard and demontage workers doing transporting have the minimum operational hazard in TTK.

The most hazardous working areas are production faces for roof fall accidents in TTK. The smallest locational hazard belongs to gate roads for roof fall. The calculated total hazards shows that with respect to maximum hazard values, Karadon mine is the most hazardous mine while Amasra mine is the least hazardous one.

Risk evaluations shows that the risk of injury of hands in the accidents is maximum and the highest value is obtained in Üzülmez mine. The risk for injury of arms is the minimum. On the other hand, the risk for days lost reaches maximum value in Karadon mine (0.02). The minimum risk in that respect is 0.001 for Armutçuk mine.

When the mines are evaluated with respect to the calculated injury risks, all the minimum injury risks are the acceptable risks and all the maximum injury risks are the unacceptable ones. On the other hand, regarding the days lost risks although the minimum days lost risks are acceptable risks, the maximum days lost risks for Amasra, Armutçuk and Kozlu mines are the tolerable risks despite their highest values.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

In this study, it is focused on the development of a new quantitative risk assessment methodology. The methodology is successfully implemented for the mines of Turkish Hard Coal Enterprises.

Although the number of accidents seems to decrease through years the normalized values shows that this is not the case. Another important result is the significant increase in the number of accidents in 2009 in which a lot of new workers are employed. Another interesting point is that the risk for the workers younger than 25 years old having 0-1 years of experience is lower than the workers 26-30 years old having 2-5 years of experience. The main reason for this would be that inexperienced workers are not assigned to major tasks.

The ANOVA results indicate that Amasra and Armutçuk mines are similar with respect to number of accidents through years and Kozlu and Üzülmez mines are the second group mines having similar characteristics in this respect. On the other hand, Karadon mine differs from all the other mines with respect to number of accidents and changes in some variables through years. Roof fall among accident types and production face among location of accidents differ from others according to the ANOVA results considering the normalized fifteen year data.

Regarding days lost, Karadon mine as in the case of number of accidents differs from all mines according to ANOVA results. Amasra-Armutçuk and Kozlu-Üzülmez mines are two couple of mines having similar characteristics in this respect as well.

The most hazardous working places, accident types and the most hazardous age and experience and the main duty group of workers are determined during the hazard assessment. Contingency tables are utilized together with conditional and total probability theorems in the calculation of hazards, severities and risks. Event trees are also prepared for all defined hazard categories.

The number of workers and the amount of ROM production decreases in all mines at different levels. There is a huge decrease in the production of Armutçuk, Karadon and Üzülmez mines. However, there is no significant production decrease in Amasra and Kozlu mines. As a result of these changes, the Labor productivity of Amasra and Kozlu mines increases between 2000 and 2014. On the other hand, since the rate of decrease in the production is higher than the rate of decrease in NOW, the LP of Karadon decreases also between 2000 and 1014. The LP in Armutçuk and Üzülmez mines do not change since the rate of decreases in NOW and ROM production are very close to each other. The number of accidents and resulting days lost decrease between 2000 and 2014 in Amasra and Kozlu mines according to normalization results. In Armutçuk mine, the number of accidents and days lost increases. In Üzülmez mine, although there is no significant change in the number of accidents, the days lost decreases slightly between 2000 and 2014. For Karadon mine, the number of accident increases but days lost value does not change significantly. However, it should mentioned that the days lost values in Karadon mine is considerably higher than that of other mines.

The workers 26-30 years old experienced 2-5 years and production workers working in production faces should be focused on regarding OHS issues since their accident proneness are higher with respect to others.

Supporting systems in production faces which the coal is produced should be improved since roof failure is the major accident type in production faces. In order to reduce the adverse effects of occupational accidents with respect to injuries, special hand and foot-wear should be made compulsory during workings.

The model uses only existing historical accident data as mentioned before and it is completely quantitative. At last step the risk levels are defined as acceptable, tolerable and unacceptable regarding the calculated risk levels. According to these results, as expected, all minimum injury risks are the acceptable risks and all maximum risks are the unacceptable risks. However, for days lost risk, although the minimum days lost risks are the acceptable risks, the maximum days lost risks for Amasra, Armutçuk and Kozlu mines are the tolerable risks. It seems possible to reduce these risks to acceptable risk level with necessary measures.

The model is developed to get rid of the some drawbacks of conventional risk assessment methodologies. The main advancements provided with development of this model is that utilization of only available data in the assessment. It can be applied at any enterprise having appropriate data set covering accident records.

One of the drawback of the method is that a comprehensive data set is required in order to utilize the developed model. Data set regarding the occupational accident records should cover the details containing the variables to be analyzed. Additionally, the quality of the results obtained by the implementation of the methodology is directly proportional to the quality of the data set. In other words, since the methodology is a quantitative one, the success of the analysis using this methodology is directly based on the quality of data.

The model is developed and the obtained results is tested by different statistical analysis in it and each analysis validates each other. In other words all the outcomes are compatible with each other. Analytical Hierarchy Process utilizing expert opinion could be combined with the developed model especially for the inappropriate or missing data cases.

The improvement in the safety conditions of Amasra mine is a clear output of this assessment. This mine could be scrutinized to be able to analyze the factors affecting this improvement. For this purpose further analysis could be carried out for Amasra mine in future studies. This is also valid for Karadon mine. Further detailed analysis should be performed in order to find the reasons for the conditions getting worse in terms of safety performance and labor productivity taking into account the geological conditions in the mine.

This study could be utilized by TTK, universities and mine owners to enhance their capabilities in risk assessment studies. It could also be beneficial for the studies regarding underground accidents, their hazards, severities and risks. The results could be used to prevent or diminish the adverse effects of related accidents. Mainly, TTK, as an owner, could utilize the results of the study in order to enhance its capacity to evaluate and manage the related risks. Finally, proposed risk assessment methodology will contribute to reduce the rate of accidents and their adverse effects and to increase efficiency of workers and to lessen cost of days lost.

Finally, after taking necessary measures to decrease the determined high risk levels both at injury and days lost, a risk assessment study should be carried out to monitor the effects of the implemented precautions in the mines and to compare the risk levels.

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APPENDIX A

CONTENT OF OCCUPATOIONAL ACCIDENT DATA SET IN TTK

1	NAME OF THE MINE	20	DATE OF FATALITY
2	ACCOUNTANCY	21	TIME OF FATALITY
3	NAME OF THE ENTERPRISE	22	PLACE OF FATALITY
4	NAME OF THE SECTION	23	REASON FOR FATALITY
5	SURFACE/UNDERGROUND	24	DUTY DURING THE ACCIDENT
6	WORKING PLACE	25	WORK DONE
7	DATE OF THE ACCIDENT	26	INJURED ORGAN 1
8	TIME OF THE ACCIDENT	27	INJURED ORGAN 2
9	DATE OF NOTIFICATION	28	INJURED ORGAN 3
10	TIME OF NOTIFICATION	29	INJURED ORGAN 4
11	CAUSE OF THE ACCIDENT	30	INJURED ORGAN 5
12	SOURCE OF THE ACCIDENT	31	MISSING EQUIPMENT 1
13	EXPLANATION TO ACCIDENT LOCATION	32	MISSING EQUIPMENT 2
14	REGISTRY NUMBER	33	MISSING EQUIPMENT 3
15	NAME	34	EXPLANATION
16	SURNAME	35	DATE OF EMPLOYMENT
17	BIRTHDAY	36	START OF RESTING
18	MAIN DUTY	37	END OF RESTING
19	FATALITY/INJURY	38	DAYS LOST

APPENDIX B

NORMALIZED VALUES

Table 131 NV(UP) Type of accident

TTK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	7.08	7.39	4.23	3.18	2.71	2.52	2.32	2.80	2.37	4.39	3.99	4.26	4.14	3.24	2.12	56.19
Transport.	0.64	0.53	0.27	0.12	0.23	0.36	0.14	0.17	0.21	0.40	0.45	0.41	0.37	0.35	0.32	4.95
Mat. Hand.	3.51	3.10	1.72	1.78	1.37	1.26	1.27	1.17	1.22	2.92	2.30	1.93	1.86	1.78	1.81	28.78
Slip/Fall	1.65	1.67	1.05	1.08	0.93	0.84	0.73	0.91	0.71	1.38	1.46	1.14	1.02	1.40	1.23	17.17
Struck Obj.	1.69	1.60	0.90	1.00	0.61	0.36	0.61	0.81	0.86	2.23	2.53	1.23	1.05	1.22	1.58	18.28
Mech. Electr.	0.55	0.49	0.36	0.21	0.23	0.23	0.20	0.17	0.17	0.33	0.42	0.44	0.43	0.45	0.37	5.03
Others	1.23	1.20	0.82	1.06	0.81	0.59	0.65	0.79	0.40	0.34	0.35	0.35	0.22	0.24	0.19	9.14
TOTAL	16.36	15.98	9.36	8.45	6.88	6.16	5.94	6.83	5.94	11.99	11.50	9.76	9.08	8.69	7.61	139.53

AMASRA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	0.90	1.00	0.70	0.46	0.33	0.32	0.28	0.20	0.12	0.20	0.30	0.26	0.16	0.22	0.13	5.23
Transport.	0.07	0.07	0.07	0.04	0.03	0.08	0.02	0.01	0.02	0.03	0.03	0.04	0.03	0.01	0.03	0.56
Mat. Hand.	0.54	0.41	0.36	0.30	0.09	0.06	0.06	0.04	0.04	0.13	0.07	0.07	0.06	0.06	0.05	2.08
Slip/Fall	0.15	0.17	0.17	0.12	0.07	0.13	0.03	0.10	0.06	0.15	0.14	0.09	0.07	0.09	0.07	1.60
Struck Obj.	0.13	0.19	0.11	0.11	0.01	0.08	0.04	0.01	0.01	0.02	0.08	0.08	0.09	0.09	0.04	1.09
Mech. Electr.	0.10	0.11	0.06	0.01	0.04	0.05	0.01	0.02	0.01	0.04	0.03	0.03	0.02	0.03	0.02	0.55
Others	0.30	0.19	0.11	0.17	0.20	0.08	0.15	0.13	0.13	0.09	0.08	0.05	0.03	0.02	0.01	1.63
TOTAL	2.20	2.14	1.58	1.21	0.77	0.79	0.60	0.51	0.40	0.65	0.72	0.62	0.46	0.52	0.35	12.74

ARMUTÇUK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	0.50	0.55	0.40	0.45	0.35	0.22	0.21	0.33	0.25	0.35	0.52	0.73	0.67	0.58	0.46	6.28
Transport.	0.05	0.03	0.02	0.03	0.02	0.00	0.01	0.03	0.04	0.08	0.06	0.05	0.08	0.04	0.06	0.57
Mat. Hand.	0.26	0.13	0.09	0.07	0.14	0.09	0.09	0.13	0.12	0.21	0.27	0.21	0.30	0.24	0.13	2.37
Slip/Fall	0.17	0.17	0.18	0.13	0.14	0.10	0.10	0.18	0.12	0.20	0.36	0.38	0.26	0.28	0.27	2.85
Struck Obj.	0.01	0.04	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.15
Mech. Electr.	0.07	0.06	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.06	0.05	0.06	0.06	0.04	0.57
Others	0.10	0.18	0.12	0.11	0.06	0.06	0.06	0.07	0.02	0.03	0.07	0.10	0.09	0.07	0.07	1.16
TOTAL	1.16	1.15	0.83	0.81	0.75	0.52	0.52	0.76	0.58	0.90	1.36	1.53	1.47	1.28	1.03	13.95

KARADON

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	3.00	2.77	1.73	1.27	1.05	0.93	1.01	1.79	1.52	3.27	2.76	2.39	2.54	1.73	0.74	28.30
Transport.	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.08	0.12	0.25	0.32	0.18	0.17	0.19	0.11	1.47
Mat. Hand.	1.61	1.71	0.94	0.96	0.75	0.81	0.83	0.79	0.89	2.17	1.84	1.35	0.84	0.95	0.92	17.31
Slip/Fall	0.61	0.48	0.26	0.30	0.23	0.18	0.22	0.33	0.28	0.47	0.56	0.36	0.39	0.72	0.60	5.93
Struck Obj.	0.00	0.00	0.00	0.00	0.01	0.01	0.08	0.03	0.03	0.57	0.81	0.36	0.40	0.67	1.15	3.99
Mech. Electr.	0.00	0.01	0.05	0.01	0.01	0.00	0.03	0.04	0.10	0.16	0.28	0.14	0.12	0.17	0.19	1.28
Others	0.79	0.78	0.55	0.64	0.56	0.41	0.36	0.58	0.22	0.12	0.12	0.21	0.07	0.11	0.10	5.68
TOTAL	6.02	5.75	3.53	3.19	2.64	2.35	2.55	3.63	3.15	7.03	6.69	4.99	4.55	4.55	3.80	63.96

Table 131 (continued)

KOZLU

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	1.28	1.19	0.60	0.20	0.37	0.47	0.35	0.25	0.03	0.05	0.06	0.48	0.41	0.29	0.33	6.02
Transport.	0.33	0.31	0.11	0.00	0.01	0.16	0.04	0.02	0.00	0.00	0.00	0.06	0.05	0.03	0.06	1.08
Mat. Hand.	0.54	0.57	0.31	0.38	0.28	0.23	0.21	0.14	0.07	0.19	0.19	0.29	0.47	0.47	0.40	4.63
Slip/Fall	0.41	0.48	0.31	0.33	0.29	0.22	0.21	0.19	0.11	0.33	0.24	0.13	0.11	0.10	0.06	3.44
Struck Obj.	0.92	0.64	0.43	0.52	0.38	0.06	0.15	0.42	0.46	1.19	1.09	0.23	0.11	0.09	0.06	6.75
Mech. Electr.	0.15	0.12	0.08	0.04	0.01	0.05	0.06	0.02	0.01	0.02	0.03	0.11	0.11	0.08	0.06	0.94
Others	0.02	0.02	0.06	0.15	0.02	0.04	0.05	0.03	0.01	0.07	0.05	0.01	0.02	0.03	0.02	0.61
TOTAL	3.64	3.34	1.91	1.64	1.36	1.23	1.08	1.08	0.70	1.84	1.66	1.30	1.29	1.09	0.98	23.48

ÜZÜLMEZ

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	1.40	1.90	0.86	0.84	0.63	0.59	0.47	0.37	0.58	0.70	0.69	0.75	0.69	0.57	0.50	11.41
Transport.	0.16	0.12	0.05	0.04	0.13	0.12	0.04	0.05	0.04	0.05	0.09	0.09	0.07	0.09	0.06	1.21
Mat. Hand.	0.57	0.24	0.06	0.10	0.13	0.08	0.11	0.13	0.14	0.32	0.17	0.19	0.22	0.11	0.37	2.95
Slip/Fall	0.29	0.36	0.12	0.19	0.19	0.21	0.16	0.09	0.14	0.22	0.20	0.25	0.24	0.29	0.30	3.28
Struck Obj.	0.59	0.76	0.32	0.35	0.19	0.20	0.35	0.27	0.29	0.32	0.37	0.50	0.44	0.37	0.40	5.71
Mech. Electr.	0.23	0.21	0.13	0.13	0.13	0.10	0.05	0.07	0.04	0.09	0.06	0.10	0.10	0.11	0.07	1.62
Others	0.03	0.02	0.02	0.01	0.00	0.01	0.01	0.03	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.22
TOTAL	3.27	3.61	1.57	1.65	1.39	1.32	1.19	1.00	1.24	1.72	1.60	1.90	1.77	1.56	1.71	26.41

Table 132 NV(UP) Location of accident

TTK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. Face	10.24	10.10	4.99	4.95	4.06	3.44	3.32	4.39	3.61	7.03	5.36	5.23	4.98	5.16	4.61	80.69
Dev. Face	2.63	2.38	1.53	1.41	1.17	1.48	1.21	1.00	0.88	0.83	1.01	0.87	1.15	0.94	0.93	19.20
Gate Roads	0.42	0.48	0.33	0.45	0.30	0.13	0.17	0.26	0.28	0.81	0.70	0.49	0.52	0.41	0.21	6.01
Roadw, Gall.	1.85	2.15	2.04	0.87	0.76	0.67	0.74	0.60	0.70	2.82	3.80	2.67	1.89	1.76	1.40	24.73
Others	1.22	0.88	0.47	0.77	0.59	0.44	0.50	0.58	0.46	0.50	0.63	0.51	0.53	0.42	0.46	8.90
TOTAL	16.36	15.98	9.36	8.45	6.88	6.16	5.94	6.83	5.94	11.99	11.50	9.76	9.08	8.69	7.61	139.53

AMASRA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. Face	1.27	1.27	1.02	0.49	0.45	0.25	0.21	0.04	0.07	0.13	0.45	0.41	0.26	0.38	0.17	6.47
Dev. Face	0.50	0.42	0.24	0.24	0.19	0.28	0.18	0.27	0.15	0.16	0.07	0.06	0.06	0.05	0.07	2.73
Gate Roads	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.19
Roadw, Gall.	0.33	0.34	0.26	0.37	0.09	0.19	0.13	0.08	0.08	0.29	0.15	0.12	0.11	0.06	0.07	2.55
Others	0.09	0.07	0.04	0.08	0.04	0.06	0.07	0.11	0.07	0.06	0.04	0.02	0.03	0.02	0.02	0.80
TOTAL	2.20	2.14	1.58	1.21	0.77	0.79	0.60	0.51	0.40	0.65	0.72	0.62	0.46	0.52	0.35	12.74

Table 132 (continued)

ARMUTÇUK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. Face	0.87	0.94	0.61	0.57	0.56	0.36	0.34	0.58	0.43	0.67	0.88	1.02	1.08	1.00	0.66	10.08
Dev. Face	0.11	0.07	0.10	0.08	0.09	0.06	0.06	0.06	0.04	0.03	0.09	0.21	0.13	0.10	0.14	1.30
Gate Roads	0.02	0.01	0.02	0.03	0.00	0.01	0.02	0.01	0.00	0.04	0.13	0.07	0.02	0.00	0.01	0.35
Roadw, Gall.	0.05	0.05	0.05	0.05	0.06	0.02	0.05	0.03	0.07	0.13	0.15	0.17	0.17	0.10	0.11	1.16
Others	0.11	0.08	0.05	0.08	0.04	0.07	0.06	0.08	0.04	0.04	0.10	0.05	0.09	0.08	0.11	1.06
TOTAL	1.16	1.15	0.83	0.81	0.75	0.52	0.52	0.76	0.58	0.90	1.36	1.53	1.47	1.28	1.03	13.95

KARADON

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. Face	4.77	4.57	2.05	2.32	1.85	1.82	1.83	2.90	2.05	4.17	2.23	1.94	1.99	2.45	2.16	39.04
Dev. Face	0.54	0.55	0.37	0.37	0.43	0.29	0.29	0.25	0.42	0.36	0.54	0.28	0.68	0.37	0.35	6.10
Gate Roads	0.02	0.01	0.00	0.00	0.02	0.01	0.03	0.04	0.06	0.13	0.13	0.04	0.08	0.16	0.02	0.73
Roadw, Gall.	0.17	0.21	0.88	0.12	0.12	0.13	0.23	0.23	0.42	2.11	3.52	2.45	1.58	1.42	1.13	14.33
Others	0.52	0.41	0.23	0.37	0.23	0.11	0.18	0.22	0.20	0.26	0.27	0.29	0.22	0.15	0.13	3.76
TOTAL	6.02	5.75	3.53	3.19	2.64	2.35	2.55	3.63	3.15	7.03	6.69	4.99	4.55	4.55	3.80	63.96

KOZLU

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. Face	1.27	0.86	0.28	0.33	0.31	0.20	0.44	0.52	0.34	0.95	0.82	0.64	0.67	0.49	0.45	8.58
Dev. Face	0.85	0.73	0.63	0.58	0.36	0.66	0.34	0.18	0.08	0.10	0.15	0.17	0.15	0.21	0.19	5.10
Gate Roads	0.24	0.28	0.23	0.36	0.21	0.05	0.05	0.15	0.15	0.51	0.33	0.21	0.27	0.15	0.12	3.34
Roadw, Gall.	0.97	1.28	0.68	0.21	0.30	0.22	0.17	0.16	0.07	0.19	0.23	0.20	0.11	0.14	0.09	4.68
Others	0.30	0.20	0.08	0.16	0.17	0.10	0.08	0.07	0.06	0.09	0.13	0.08	0.08	0.10	0.13	1.78
TOTAL	3.64	3.34	1.91	1.64	1.36	1.23	1.08	1.08	0.70	1.84	1.66	1.30	1.29	1.09	0.98	23.48

ÜZÜLMEZ

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. Face	2.13	2.46	1.13	1.30	0.93	0.86	0.58	0.55	0.84	1.28	1.08	1.40	1.23	1.04	1.29	18.12
Dev. Face	0.59	0.62	0.16	0.12	0.12	0.18	0.30	0.21	0.20	0.18	0.19	0.17	0.20	0.21	0.18	3.53
Gate Roads	0.10	0.16	0.03	0.02	0.05	0.06	0.06	0.04	0.04	0.06	0.07	0.11	0.08	0.10	0.03	1.02
Roadw, Gall.	0.25	0.25	0.18	0.13	0.19	0.12	0.14	0.09	0.07	0.15	0.16	0.11	0.12	0.13	0.13	2.23
Others	0.20	0.12	0.07	0.07	0.11	0.09	0.11	0.10	0.08	0.05	0.11	0.10	0.13	0.07	0.07	1.50
TOTAL	3.27	3.61	1.57	1.65	1.39	1.32	1.19	1.00	1.24	1.72	1.60	1.90	1.77	1.56	1.71	26.41

Table 133 NV(UP) Main duty of worker

TTK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. W.	12.28	12.28	7.05	6.23	5.01	4.12	4.18	5.11	4.13	10.10	9.27	7.77	6.81	6.46	5.37	105.37
Dev. W.	1.55	1.48	0.96	0.93	0.85	0.94	0.74	0.63	0.54	0.49	0.68	0.75	0.76	0.85	0.87	12.92
Trans. W.	0.58	0.58	0.36	0.31	0.32	0.40	0.40	0.43	0.50	0.57	0.66	0.51	0.62	0.65	0.62	7.55
Mech.,Elect.	0.47	0.45	0.30	0.31	0.26	0.28	0.25	0.31	0.37	0.33	0.36	0.29	0.34	0.31	0.25	4.89
Demont. W.	0.51	0.48	0.25	0.31	0.17	0.21	0.21	0.18	0.21	0.20	0.25	0.22	0.30	0.20	0.21	3.86
Others	0.55	0.54	0.45	0.35	0.27	0.21	0.17	0.17	0.19	0.30	0.28	0.22	0.25	0.22	0.30	4.41
Unknown	0.43	0.18	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53
TOTAL	16.36	15.98	9.36	8.45	6.88	6.16	5.94	6.83	5.94	11.99	11.50	9.76	9.08	8.69	7.61	139.53

AMASRA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
Prod. W.	1.66	1.67	1.26	0.88	0.54	0.50	0.37	0.24	0.20	0.47	0.63	0.52	0.35	0.42	0.21	9.36
Dev. W.	0.21	0.19	0.11	0.14	0.09	0.15	0.08	0.10	0.05	0.05	0.01	0.03	0.03	0.04	0.04	1.21
Trans. W.	0.06	0.08	0.09	0.05	0.06	0.06	0.07	0.06	0.03	0.04	0.02	0.02	0.02	0.00	0.01	0.63
Mech.,Elect.	0.07	0.07	0.03	0.04	0.02	0.01	0.02	0.04	0.08	0.05	0.01	0.02	0.01	0.05	0.04	0.58
Demont. W.	0.00	0.03	0.02	0.03	0.02	0.03	0.04	0.02	0.03	0.00	0.01	0.01	0.01	0.00	0.02	0.27
Others	0.10	0.07	0.07	0.06	0.04	0.03	0.02	0.05	0.01	0.04	0.04	0.03	0.03	0.01	0.02	0.60
Unknown	0.09	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
TOTAL	2.20	2.14	1.58	1.21	0.77	0.79	0.60	0.51	0.40	0.65	0.72	0.62	0.46	0.52	0.35	12.74

ARMUTÇUK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. W.	0.87	0.93	0.62	0.61	0.57	0.35	0.39	0.60	0.38	0.68	1.01	1.19	1.11	0.96	0.69	10.42
Dev. W.	0.07	0.06	0.08	0.07	0.09	0.08	0.05	0.05	0.04	0.03	0.06	0.12	0.08	0.15	0.14	1.11
Trans. W.	0.04	0.04	0.05	0.04	0.02	0.02	0.03	0.04	0.08	0.09	0.07	0.07	0.12	0.08	0.11	0.84
Mech.,Elect.	0.05	0.03	0.02	0.04	0.03	0.06	0.02	0.04	0.06	0.03	0.09	0.02	0.06	0.05	0.01	0.60
Demont. W.	0.04	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.08	0.11	0.09	0.03	0.06	0.55
Others	0.03	0.05	0.04	0.04	0.02	0.01	0.02	0.01	0.01	0.02	0.04	0.02	0.01	0.02	0.02	0.35
Unknown	0.06	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
TOTAL	1.16	1.15	0.83	0.81	0.75	0.52	0.52	0.76	0.58	0.90	1.36	1.53	1.47	1.28	1.03	13.95

KARADON

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**TOTAL**
Prod. W.	4.74	4.52	2.66	2.27	1.92	1.59	1.84	2.88	2.28	6.14	5.65	4.10	3.53	3.57	2.81	50.08
Dev. W.	0.55	0.54	0.35	0.38	0.32	0.34	0.30	0.25	0.18	0.16	0.15	0.26	0.23	0.24	0.28	4.53
Trans. W.	0.13	0.12	0.08	0.08	0.13	0.16	0.15	0.21	0.31	0.32	0.40	0.26	0.32	0.37	0.32	3.36
Mech.,Elect.	0.08	0.11	0.10	0.13	0.10	0.07	0.08	0.12	0.14	0.14	0.18	0.17	0.19	0.12	0.08	1.80
Demont. W.	0.23	0.24	0.14	0.20	0.10	0.12	0.12	0.10	0.12	0.13	0.15	0.10	0.16	0.14	0.13	2.17
Others	0.23	0.18	0.20	0.13	0.07	0.08	0.06	0.07	0.12	0.14	0.14	0.11	0.11	0.11	0.17	1.91
Unknown	0.07	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
TOTAL	6.02	5.75	3.53	3.19	2.64	2.35	2.55	3.63	3.15	7.03	6.69	4.99	4.55	4.55	3.80	63.96

Table 133 (continued)

KOZLU

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. W.	2.69	2.42	1.36	1.18	0.98	0.84	0.84	0.84	0.46	1.53	1.20	0.95	0.90	0.68	0.60	17.00
Dev. W.	0.38	0.39	0.26	0.23	0.20	0.19	0.10	0.11	0.11	0.12	0.26	0.17	0.20	0.23	0.23	3.11
Trans. W.	0.13	0.15	0.08	0.08	0.05	0.08	0.07	0.06	0.04	0.09	0.10	0.10	0.10	0.10	0.08	1.29
Mech.,Elect.	0.09	0.10	0.07	0.07	0.04	0.05	0.04	0.04	0.05	0.05	0.05	0.03	0.04	0.04	0.04	0.79
Demont. W.	0.11	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.00	0.36
Others	0.08	0.14	0.09	0.07	0.06	0.05	0.02	0.03	0.02	0.05	0.03	0.04	0.04	0.03	0.03	0.75
Unknown	0.16	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
TOTAL	3.64	3.34	1.91	1.64	1.36	1.23	1.08	1.08	0.70	1.84	1.66	1.30	1.29	1.09	0.98	23.48

ÜZÜLMEZ

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Prod. W.	2.27	2.74	1.20	1.33	1.00	0.87	0.72	0.69	0.94	1.42	1.24	1.49	1.29	1.08	1.25	19.51
Dev. W.	0.33	0.30	0.16	0.13	0.16	0.19	0.23	0.13	0.16	0.13	0.16	0.19	0.21	0.21	0.17	2.83
Trans. W.	0.22	0.19	0.05	0.06	0.06	0.09	0.09	0.06	0.06	0.05	0.10	0.09	0.09	0.14	0.13	1.49
Mech.,Elect.	0.18	0.15	0.08	0.03	0.07	0.08	0.10	0.07	0.04	0.06	0.05	0.07	0.05	0.04	0.05	1.12
Demont. W.	0.13	0.11	0.02	0.05	0.03	0.04	0.02	0.03	0.01	0.01	0.02	0.03	0.07	0.04	0.02	0.61
Others	0.11	0.09	0.06	0.05	0.07	0.04	0.04	0.01	0.03	0.05	0.03	0.03	0.05	0.05	0.07	0.80
Unknown	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
TOTAL	3.27	3.61	1.57	1.65	1.39	1.32	1.19	1.00	1.24	1.72	1.60	1.90	1.77	1.56	1.71	26.41

Table 134 NV(UP) Injured body part

TTK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Head	1.55	1.65	1.03	1.01	0.80	0.61	0.60	0.77	0.59	1.08	1.08	1.00	0.99	1.03	0.81	14.51
Hands	4.78	4.71	2.78	2.44	1.89	1.74	1.83	1.98	1.68	3.41	3.55	3.10	2.84	2.67	2.50	41.58
Feet	3.18	3.44	2.13	1.85	1.67	1.44	1.30	1.56	1.36	2.81	2.73	2.05	1.89	1.65	1.52	30.47
Arms	0.89	0.91	0.51	0.49	0.43	0.37	0.31	0.42	0.40	0.81	0.90	0.73	0.71	0.80	0.67	9.34
Legs	1.78	1.39	0.92	0.71	0.52	0.53	0.53	0.74	0.59	1.40	0.98	1.10	1.02	1.22	0.91	14.22
Main Body	3.83	3.59	1.82	1.74	1.40	1.33	1.15	1.19	1.08	1.97	1.82	1.44	1.35	1.09	1.03	25.45
Various	0.35	0.30	0.18	0.21	0.18	0.13	0.22	0.17	0.23	0.51	0.44	0.35	0.27	0.23	0.18	3.97
TOTAL	16.36	15.98	9.36	8.45	6.88	6.16	5.94	6.83	5.94	11.99	11.50	9.76	9.08	8.69	7.61	139.53

AMASRA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Head	0.23	0.21	0.19	0.19	0.11	0.08	0.04	0.05	0.05	0.10	0.10	0.08	0.08	0.07	0.03	1.53
Hands	0.67	0.60	0.41	0.26	0.17	0.21	0.21	0.20	0.12	0.18	0.22	0.18	0.10	0.12	0.15	3.60
Feet	0.47	0.43	0.32	0.21	0.22	0.18	0.16	0.10	0.09	0.13	0.13	0.09	0.07	0.10	0.06	2.59
Arms	0.11	0.17	0.07	0.04	0.03	0.05	0.02	0.02	0.01	0.04	0.07	0.04	0.04	0.05	0.02	0.76
Legs	0.19	0.25	0.16	0.11	0.07	0.09	0.09	0.04	0.04	0.08	0.11	0.13	0.08	0.09	0.05	1.57
Main Body	0.52	0.44	0.42	0.39	0.16	0.13	0.04	0.10	0.08	0.11	0.10	0.09	0.08	0.08	0.03	2.50
Various	0.01	0.03	0.00	0.01	0.02	0.04	0.04	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.18
TOTAL	2.20	2.14	1.58	1.21	0.77	0.79	0.60	0.51	0.40	0.65	0.72	0.62	0.46	0.52	0.35	12.74

Table 134 (continued)

ARMUTÇUK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Head	0.09	0.11	0.08	0.07	0.10	0.04	0.05	0.10	0.07	0.12	0.12	0.14	0.18	0.10	0.08	1.40
Hands	0.40	0.36	0.21	0.25	0.23	0.14	0.15	0.20	0.17	0.22	0.38	0.47	0.42	0.39	0.30	4.07
Feet	0.32	0.30	0.29	0.20	0.21	0.14	0.11	0.21	0.13	0.25	0.38	0.39	0.38	0.32	0.24	3.71
Arms	0.05	0.05	0.04	0.05	0.05	0.04	0.06	0.05	0.07	0.07	0.12	0.16	0.14	0.16	0.11	1.15
Legs	0.06	0.06	0.04	0.04	0.04	0.03	0.04	0.07	0.03	0.08	0.11	0.11	0.12	0.13	0.16	1.03
Main Body	0.21	0.23	0.13	0.14	0.11	0.10	0.11	0.11	0.09	0.15	0.23	0.24	0.23	0.18	0.15	2.30
Various	0.03	0.04	0.04	0.06	0.02	0.02	0.00	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.29
TOTAL	1.16	1.15	0.83	0.81	0.75	0.52	0.52	0.76	0.58	0.90	1.36	1.53	1.47	1.28	1.03	13.95

KARADON

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Head	0.55	0.63	0.36	0.35	0.22	0.13	0.24	0.39	0.24	0.47	0.50	0.44	0.32	0.47	0.40	5.65
Hands	1.65	1.49	1.05	0.95	0.74	0.67	0.70	0.96	0.79	1.92	1.97	1.47	1.53	1.38	1.14	18.26
Feet	1.23	1.32	0.75	0.66	0.60	0.57	0.56	0.82	0.71	1.55	1.56	1.11	0.92	0.77	0.76	13.82
Arms	0.30	0.26	0.17	0.17	0.16	0.12	0.11	0.23	0.18	0.46	0.45	0.31	0.27	0.36	0.30	3.83
Legs	0.64	0.51	0.39	0.30	0.20	0.20	0.19	0.45	0.36	0.89	0.56	0.52	0.55	0.74	0.46	6.90
Main Body	1.43	1.44	0.76	0.71	0.62	0.65	0.63	0.71	0.67	1.27	1.20	0.78	0.66	0.60	0.58	12.66
Various	0.22	0.10	0.05	0.03	0.09	0.01	0.12	0.07	0.20	0.48	0.45	0.36	0.29	0.24	0.17	2.85
TOTAL	6.02	5.75	3.53	3.19	2.64	2.35	2.55	3.63	3.15	7.03	6.69	4.99	4.55	4.55	3.80	63.96

KOZLU

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Head	0.36	0.29	0.22	0.19	0.17	0.18	0.11	0.12	0.11	0.17	0.17	0.16	0.18	0.14	0.12	2.63
Hands	1.01	0.97	0.58	0.47	0.34	0.33	0.34	0.35	0.22	0.65	0.56	0.48	0.41	0.38	0.38	7.32
Feet	0.43	0.64	0.42	0.37	0.31	0.22	0.23	0.22	0.13	0.44	0.39	0.24	0.29	0.22	0.18	4.68
Arms	0.20	0.12	0.09	0.09	0.06	0.07	0.05	0.06	0.05	0.11	0.14	0.06	0.10	0.09	0.08	1.32
Legs	0.66	0.30	0.20	0.12	0.10	0.11	0.08	0.10	0.07	0.17	0.13	0.11	0.10	0.11	0.09	2.33
Main Body	0.90	0.92	0.34	0.31	0.35	0.28	0.23	0.17	0.11	0.28	0.24	0.24	0.21	0.14	0.12	4.58
Various	0.08	0.10	0.06	0.10	0.03	0.05	0.04	0.07	0.02	0.03	0.03	0.02	0.01	0.00	0.01	0.62
TOTAL	3.64	3.34	1.91	1.64	1.36	1.23	1.08	1.08	0.70	1.84	1.66	1.30	1.29	1.09	0.98	23.48

ÜZÜLMEZ

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Head	0.32	0.40	0.18	0.22	0.19	0.18	0.16	0.13	0.13	0.24	0.21	0.21	0.23	0.25	0.20	3.28
Hands	1.03	1.31	0.54	0.51	0.42	0.40	0.42	0.28	0.41	0.46	0.54	0.66	0.54	0.50	0.57	8.55
Feet	0.74	0.75	0.35	0.41	0.33	0.33	0.23	0.24	0.34	0.47	0.42	0.39	0.35	0.31	0.34	5.98
Arms	0.21	0.32	0.14	0.14	0.13	0.09	0.08	0.08	0.09	0.15	0.15	0.21	0.20	0.18	0.18	2.37
Legs	0.20	0.27	0.14	0.14	0.12	0.10	0.12	0.11	0.11	0.21	0.10	0.24	0.22	0.19	0.20	2.48
Main Body	0.74	0.54	0.20	0.22	0.18	0.19	0.16	0.15	0.16	0.19	0.19	0.18	0.22	0.14	0.21	3.58
Various	0.02	0.03	0.02	0.00	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.16
TOTAL	3.27	3.61	1.57	1.65	1.39	1.32	1.19	1.00	1.24	1.72	1.60	1.90	1.77	1.56	1.71	26.41

Table 135 NV(UP) Education level of casualties

TTK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Primary Sch.	12.11	11.89	7.05	6.30	5.24	4.62	4.13	4.33	3.48	6.30	6.18	5.25	4.78	4.53	3.94	89.01
Secondary Sch.	2.08	2.01	1.17	1.17	0.79	0.77	0.90	1.09	1.13	2.11	1.90	1.72	1.54	1.50	1.32	21.17
High Sch.	1.75	1.86	1.08	0.93	0.82	0.75	0.87	1.30	1.25	3.41	3.23	2.61	2.65	2.53	2.23	27.45
University	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.02	0.02	0.02	0.00	0.03	0.01	0.01	0.01	0.14
Unknown	0.42	0.22	0.06	0.04	0.03	0.02	0.03	0.09	0.06	0.16	0.18	0.15	0.11	0.13	0.11	1.76
TOTAL	16.36	15.98	9.36	8.45	6.88	6.16	5.94	6.83	5.94	11.99	11.50	9.76	9.08	8.69	7.61	139.53

AMASRA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Primary Sch.	1.65	1.59	1.25	0.91	0.62	0.63	0.44	0.35	0.30	0.44	0.51	0.44	0.32	0.31	0.19	9.27
Secondary Sch.	0.25	0.24	0.17	0.17	0.07	0.07	0.08	0.06	0.04	0.05	0.05	0.02	0.05	0.03	0.02	1.22
High Sch.	0.21	0.29	0.16	0.13	0.07	0.09	0.08	0.09	0.06	0.15	0.16	0.14	0.09	0.17	0.13	2.06
University	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown	0.09	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.01	0.01	0.18
TOTAL	2.20	2.14	1.58	1.21	0.77	0.79	0.60	0.51	0.40	0.65	0.72	0.62	0.46	0.52	0.35	12.74

ARMUTÇUK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Primary Sch.	0.85	0.85	0.57	0.65	0.58	0.39	0.35	0.55	0.37	0.57	0.76	0.90	0.84	0.76	0.57	9.25
Secondary Sch.	0.10	0.13	0.11	0.07	0.06	0.04	0.04	0.06	0.09	0.04	0.16	0.17	0.15	0.14	0.13	1.41
High Sch.	0.16	0.14	0.14	0.10	0.10	0.08	0.12	0.14	0.12	0.27	0.42	0.45	0.47	0.38	0.30	3.10
University	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Unknown	0.05	0.03	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.02	0.00	0.02	0.01	0.03	0.19
TOTAL	1.16	1.15	0.83	0.81	0.75	0.52	0.52	0.76	0.58	0.90	1.36	1.53	1.47	1.28	1.03	13.95

KARADON

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Primary Sch.	4.48	4.30	2.58	2.30	1.98	1.75	1.73	2.07	1.66	3.41	3.27	2.53	2.26	2.27	1.98	38.34
Secondary Sch.	0.82	0.78	0.52	0.45	0.35	0.32	0.44	0.68	0.66	1.29	1.19	0.90	0.73	0.82	0.63	10.53
High Sch.	0.65	0.62	0.41	0.40	0.30	0.28	0.35	0.80	0.77	2.22	2.09	1.45	1.47	1.37	1.13	14.15
University	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.08
Unknown	0.06	0.06	0.02	0.03	0.00	0.01	0.03	0.07	0.05	0.10	0.14	0.10	0.08	0.09	0.06	0.87
TOTAL	6.02	5.75	3.53	3.19	2.64	2.35	2.55	3.63	3.15	7.03	6.69	4.99	4.55	4.55	3.80	63.96

Table 135 (continued)

KOZLU

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Primary Sch.	2.80	2.60	1.57	1.32	1.10	0.98	0.85	0.80	0.51	1.01	0.94	0.67	0.67	0.58	0.49	16.24
Secondary Sch.	0.35	0.34	0.19	0.18	0.13	0.15	0.12	0.13	0.08	0.37	0.27	0.31	0.28	0.24	0.23	3.36
High Sch.	0.31	0.32	0.14	0.13	0.12	0.10	0.10	0.13	0.10	0.43	0.42	0.29	0.32	0.26	0.26	3.48
University	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.03
Unknown	0.18	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02	0.02	0.01	0.01	0.00	0.37
TOTAL	3.64	3.34	1.91	1.64	1.36	1.23	1.08	1.08	0.70	1.84	1.66	1.30	1.29	1.09	0.98	23.48

ÜZÜLMEZ

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Primary Sch.	2.25	2.55	1.13	1.16	0.98	0.90	0.71	0.60	0.67	0.92	0.89	0.96	0.90	0.77	0.85	16.05
Secondary Sch.	0.57	0.53	0.21	0.30	0.19	0.22	0.24	0.21	0.32	0.38	0.34	0.41	0.37	0.34	0.35	4.99
High Sch.	0.43	0.51	0.23	0.19	0.22	0.20	0.24	0.19	0.23	0.40	0.36	0.50	0.49	0.45	0.48	5.20
University	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.03
Unknown	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.15
TOTAL	3.27	3.61	1.57	1.65	1.39	1.32	1.19	1.00	1.24	1.72	1.60	1.90	1.77	1.56	1.71	26.41

Table 136 NV(UP) Age of casualties

TTK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
≤ 25	4.90	4.34	1.79	0.80	0.20	0.00	0.40	1.03	0.71	3.53	2.64	1.33	0.61	0.27	0.07	21.80
26-30	5.73	6.43	3.92	3.68	2.95	2.26	2.00	2.71	1.99	5.43	5.32	4.21	3.64	3.15	2.10	55.25
31-35	1.35	1.26	1.26	1.68	1.98	2.29	2.22	1.91	1.95	1.79	2.04	2.82	3.24	3.68	3.67	33.66
36-40	2.75	2.21	1.27	1.13	0.75	0.49	0.48	0.61	0.80	0.89	1.22	1.09	1.19	1.17	1.34	17.08
41-45	1.18	1.38	0.90	0.92	0.85	0.97	0.69	0.48	0.33	0.20	0.13	0.20	0.32	0.35	0.36	9.16
46≤	0.15	0.25	0.22	0.23	0.14	0.15	0.15	0.09	0.16	0.15	0.16	0.12	0.09	0.06	0.05	2.17
Unknown	0.30	0.12	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
TOTAL	16.36	15.98	9.36	8.45	6.88	6.16	5.94	6.83	5.94	11.99	11.50	9.76	9.08	8.69	7.60	139.53

AMASRA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
≤ 25	0.69	0.63	0.34	0.17	0.04	0.00	0.00	0.00	0.00	0.14	0.16	0.05	0.01	0.02	0.02	1.97
26-30	0.67	0.80	0.71	0.53	0.34	0.34	0.23	0.14	0.07	0.19	0.29	0.24	0.13	0.19	0.07	4.60
31-35	0.25	0.15	0.18	0.21	0.23	0.28	0.25	0.24	0.20	0.20	0.16	0.20	0.20	0.24	0.15	3.24
36-40	0.38	0.33	0.19	0.16	0.07	0.03	0.04	0.08	0.10	0.08	0.11	0.10	0.08	0.04	0.07	1.78
41-45	0.10	0.15	0.13	0.11	0.08	0.13	0.06	0.05	0.03	0.02	0.00	0.02	0.02	0.03	0.03	0.87
46≤	0.01	0.05	0.03	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.19
Unknown	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
TOTAL	2.20	2.14	1.58	1.21	0.77	0.79	0.60	0.51	0.40	0.65	0.72	0.62	0.46	0.52	0.35	12.74

Table 136 (continued)

ARMUTÇUK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
≤ 25	0.32	0.35	0.18	0.09	0.06	0.00	0.06	0.16	0.09	0.25	0.29	0.23	0.12	0.09	0.00	2.17
26-30	0.41	0.42	0.34	0.35	0.32	0.24	0.24	0.33	0.22	0.38	0.54	0.62	0.58	0.48	0.31	5.55
31-35	0.10	0.12	0.09	0.18	0.24	0.20	0.15	0.18	0.19	0.19	0.34	0.48	0.55	0.56	0.50	3.80
36-40	0.17	0.16	0.14	0.11	0.06	0.03	0.02	0.05	0.06	0.08	0.15	0.16	0.17	0.12	0.18	1.55
41-45	0.11	0.08	0.07	0.07	0.04	0.04	0.04	0.04	0.01	0.00	0.02	0.03	0.04	0.02	0.04	0.67
46≤	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.03	0.00	0.01	0.01	0.00	0.13
Unknown	0.04	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
TOTAL	1.16	1.15	0.83	0.81	0.75	0.52	0.52	0.76	0.58	0.90	1.36	1.53	1.47	1.28	1.03	13.95

KARADON

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
≤ 25	1.80	1.35	0.62	0.24	0.04	0.00	0.21	0.69	0.48	2.29	1.70	0.81	0.36	0.14	0.01	10.61
26-30	2.30	2.55	1.43	1.28	1.07	0.76	0.83	1.59	1.15	3.44	3.36	2.35	2.03	1.79	1.15	26.86
31-35	0.36	0.35	0.52	0.73	0.76	0.84	0.91	0.78	0.85	0.74	0.91	1.26	1.51	1.96	1.89	14.29
36-40	1.10	0.90	0.52	0.43	0.29	0.20	0.18	0.29	0.36	0.34	0.56	0.39	0.45	0.50	0.55	6.96
41-45	0.38	0.50	0.34	0.38	0.41	0.49	0.35	0.23	0.21	0.12	0.08	0.10	0.14	0.14	0.17	4.11
46≤	0.07	0.09	0.10	0.11	0.06	0.06	0.07	0.05	0.10	0.09	0.09	0.08	0.05	0.03	0.02	1.09
Unknown	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
TOTAL	6.02	5.75	3.53	3.19	2.64	2.36	2.55	3.63	3.15	7.03	6.69	4.99	4.55	4.55	3.79	63.96

KOZLU

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
≤ 25	1.10	0.91	0.32	0.14	0.01	0.00	0.06	0.13	0.05	0.54	0.39	0.19	0.10	0.02	0.02	3.70
26-30	1.21	1.24	0.87	0.75	0.62	0.42	0.30	0.36	0.20	0.84	0.77	0.61	0.58	0.41	0.30	9.27
31-35	0.34	0.37	0.24	0.29	0.35	0.51	0.47	0.37	0.28	0.27	0.28	0.35	0.40	0.42	0.46	5.47
36-40	0.56	0.39	0.24	0.22	0.19	0.12	0.10	0.12	0.12	0.15	0.18	0.12	0.16	0.18	0.18	2.91
41-45	0.26	0.32	0.19	0.21	0.17	0.14	0.12	0.09	0.03	0.03	0.02	0.02	0.05	0.05	0.02	1.63
46≤	0.02	0.05	0.05	0.04	0.02	0.04	0.03	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.33
Unknown	0.15	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
TOTAL	3.64	3.34	1.91	1.64	1.36	1.23	1.08	1.08	0.70	1.84	1.66	1.30	1.29	1.09	0.98	23.48

ÜZÜLMEZ

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
≤ 25	0.96	1.11	0.34	0.17	0.04	0.00	0.07	0.10	0.11	0.37	0.24	0.17	0.07	0.02	0.00	3.54
26-30	1.12	1.42	0.60	0.78	0.61	0.52	0.40	0.37	0.42	0.67	0.65	0.67	0.52	0.42	0.39	9.52
31-35	0.27	0.27	0.24	0.29	0.39	0.46	0.43	0.34	0.44	0.38	0.41	0.67	0.73	0.63	0.83	7.04
36-40	0.53	0.42	0.19	0.22	0.15	0.12	0.14	0.08	0.18	0.24	0.24	0.33	0.35	0.36	0.37	3.92
41-45	0.34	0.33	0.16	0.15	0.17	0.18	0.13	0.07	0.06	0.02	0.02	0.04	0.07	0.11	0.10	1.91
46≤	0.04	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.04	0.04	0.03	0.02	0.02	0.01	0.02	0.46
Unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
TOTAL	3.27	3.61	1.57	1.65	1.39	1.32	1.19	1.00	1.24	1.72	1.60	1.90	1.77	1.56	1.71	26.41

Table 137 NV(UP) Experience of casualties

TTK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
0-1 Year	9.92	10.77	1.31	0.00	0.00	0.01	0.95	2.96	1.89	7.57	7.45	0.28	0.03	0.14	0.21	41.79
2-5 Years	0.67	0.68	5.43	6.05	4.77	4.25	0.70	0.00	0.76	1.75	1.57	7.29	6.52	5.51	4.58	51.43
6-10 Years	2.11	1.13	0.61	0.61	0.30	0.33	3.12	3.09	2.74	2.13	2.00	0.34	0.45	1.35	1.36	21.87
11-15 Years	2.49	1.84	1.10	1.11	0.87	0.84	0.54	0.34	0.21	0.12	0.15	1.62	1.91	1.58	1.36	15.78
16-20 Years	1.01	1.40	0.78	0.53	0.86	0.66	0.52	0.35	0.22	0.22	0.16	0.10	0.07	0.02	0.03	6.81
21≤	0.17	0.15	0.13	0.15	0.08	0.07	0.09	0.09	0.11	0.20	0.17	0.14	0.10	0.08	0.07	1.80
Unknown	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.04
TOTAL	16.36	15.98	9.36	8.45	6.88	6.16	5.94	6.83	5.94	11.99	11.50	9.76	9.08	8.69	7.61	139.53

AMASRA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
0-1 Year	1.41	1.49	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.47	0.01	0.01	0.05	0.05	3.45
2-5 Years	0.00	0.02	1.08	0.90	0.61	0.60	0.06	0.00	0.01	0.01	0.01	0.36	0.25	0.36	0.18	4.30
6-10 Years	0.35	0.22	0.12	0.11	0.00	0.01	0.45	0.42	0.36	0.29	0.24	0.03	0.00	0.01	0.01	2.59
11-15 Years	0.30	0.20	0.12	0.11	0.09	0.10	0.06	0.04	0.02	0.00	0.00	0.21	0.19	0.09	0.10	1.66
16-20 Years	0.12	0.18	0.11	0.08	0.07	0.07	0.03	0.04	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.62
21≤	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.12
Unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
TOTAL	2.20	2.14	1.58	1.21	0.77	0.79	0.60	0.51	0.40	0.65	0.72	0.62	0.46	0.52	0.35	12.74

ARMUTÇUK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
0-1 Year	0.71	0.80	0.08	0.00	0.00	0.00	0.17	0.42	0.21	0.46	0.69	0.01	0.00	0.00	0.01	3.45
2-5 Years	0.00	0.01	0.50	0.58	0.62	0.43	0.01	0.00	0.09	0.20	0.32	1.22	1.06	0.80	0.58	6.03
6-10 Years	0.17	0.14	0.10	0.08	0.00	0.01	0.28	0.28	0.25	0.23	0.27	0.04	0.13	0.27	0.27	2.43
11-15 Years	0.17	0.10	0.08	0.11	0.05	0.05	0.03	0.04	0.01	0.00	0.00	0.23	0.26	0.18	0.16	1.35
16-20 Years	0.11	0.10	0.06	0.03	0.07	0.03	0.03	0.01	0.01	0.00	0.06	0.01	0.02	0.01	0.00	0.56
21≤	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.02	0.01	0.00	0.02	0.01	0.13
Unknown	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
TOTAL	1.16	1.15	0.83	0.81	0.75	0.52	0.52	0.76	0.58	0.90	1.36	1.53	1.47	1.28	1.03	13.95

KARADON

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
0-1 Year	3.46	3.58	0.54	0.00	0.00	0.00	0.54	2.02	1.27	4.93	4.79	0.16	0.01	0.03	0.06	21.29
2-5 Years	0.62	0.53	1.96	2.23	1.58	1.34	0.27	0.00	0.47	1.04	0.87	4.01	3.53	3.08	2.48	23.63
6-10 Years	0.70	0.43	0.24	0.20	0.28	0.28	1.20	1.26	1.08	0.73	0.71	0.15	0.24	0.78	0.67	9.02
11-15 Years	0.88	0.66	0.42	0.48	0.36	0.42	0.26	0.17	0.13	0.12	0.16	0.54	0.68	0.61	0.52	6.32
16-20 Years	0.29	0.50	0.33	0.20	0.38	0.28	0.22	0.15	0.14	0.14	0.09	0.06	0.04	0.00	0.03	2.91
21≤	0.06	0.05	0.05	0.07	0.03	0.03	0.05	0.03	0.06	0.07	0.08	0.07	0.05	0.05	0.04	0.78
Unknown	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
TOTAL	6.02	5.75	3.53	3.19	2.64	2.35	2.55	3.63	3.15	7.03	6.69	4.99	4.55	4.55	3.80	63.96

Table 137 (continued)

KOZLU

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
0-1 Year	2.26	2.30	0.31	0.00	0.00	0.00	0.13	0.35	0.18	1.21	1.15	0.07	0.01	0.02	0.05	7.44
2-5 Years	0.04	0.06	1.04	1.15	0.94	0.90	0.21	0.00	0.06	0.22	0.17	0.99	0.98	0.73	0.65	8.28
6-10 Years	0.51	0.22	0.12	0.12	0.02	0.04	0.52	0.59	0.40	0.34	0.29	0.05	0.05	0.10	0.12	3.53
11-15 Years	0.48	0.40	0.25	0.20	0.23	0.14	0.08	0.06	0.02	0.00	0.00	0.16	0.25	0.23	0.16	2.56
16-20 Years	0.31	0.31	0.14	0.11	0.15	0.14	0.12	0.07	0.03	0.04	0.02	0.01	0.01	0.00	0.00	1.35
21≤	0.03	0.04	0.04	0.05	0.01	0.02	0.02	0.01	0.01	0.03	0.03	0.02	0.00	0.01	0.00	0.31
Unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	3.64	3.34	1.91	1.64	1.36	1.23	1.08	1.08	0.70	1.84	1.66	1.30	1.29	1.09	0.98	23.48

ÜZÜLMEZ

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
0-1 Year	2.02	2.63	0.25	0.00	0.00	0.00	0.13	0.31	0.29	0.77	0.72	0.04	0.00	0.01	0.01	6.58
2-5 Years	0.03	0.04	0.90	1.22	1.02	0.99	0.15	0.00	0.16	0.33	0.34	1.26	1.07	0.73	0.90	9.68
6-10 Years	0.36	0.11	0.04	0.09	0.01	0.00	0.65	0.55	0.69	0.52	0.47	0.09	0.08	0.30	0.37	4.33
11-15 Years	0.66	0.49	0.22	0.21	0.16	0.14	0.11	0.03	0.02	0.01	0.00	0.46	0.55	0.49	0.40	3.95
16-20 Years	0.17	0.30	0.14	0.11	0.19	0.16	0.13	0.08	0.05	0.03	0.02	0.02	0.01	0.01	0.00	1.37
21≤	0.04	0.04	0.02	0.01	0.02	0.02	0.01	0.03	0.03	0.07	0.05	0.04	0.05	0.02	0.02	0.48
Unknown	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
TOTAL	3.27	3.61	1.57	1.65	1.39	1.32	1.19	1.00	1.24	1.72	1.60	1.90	1.76	1.56	1.71	26.41

Table 138 NV(UP) Days lost with respect to accident types

TTK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	93	103	68	51	58	60	50	52	51	74	63	62	61	49	29	924
Transport.	6	5	4	3	6	9	3	11	8	11	10	12	6	8	7	111
Mat. Hand.	46	39	22	27	27	38	31	19	21	40	33	27	28	28	26	452
Slip/Fall	19	23	13	19	25	20	18	26	14	25	24	19	16	23	19	305
Struck Obj.	10	16	11	16	12	7	13	21	17	42	46	22	17	19	24	299
Mech. Electr.	5	6	5	6	5	6	4	4	3	5	9	10	7	7	6	90
Others	20	19	10	12	15	23	15	15	7	5	5	5	2	3	2	158
TOTAL	199	212	133	133	149	164	135	147	121	201	191	156	137	137	114	2,339

AMASRA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	9.4	15.9	9.5	4.7	5.5	4.8	3.7	2.1	1.5	1.7	2.2	2.3	1.2	2.0	1.3	61.6
Transport.	0.5	1.7	0.8	0.5	0.4	1.5	1.0	0.0	0.4	0.6	0.5	1.6	0.1	0.1	0.4	10.1
Mat. Hand.	6.7	4.1	3.3	3.7	1.2	0.7	0.8	0.3	0.3	1.5	0.5	0.7	0.4	0.6	0.6	22.4
Slip/Fall	1.9	2.1	2.9	1.2	1.4	1.7	0.4	1.4	0.3	2.2	1.2	1.6	0.5	0.6	0.9	20.0
Struck Obj.	1.4	2.2	1.2	1.4	0.1	0.9	0.4	0.1	0.1	0.5	0.6	0.7	0.7	0.6	0.4	10.8
Mech. Electr.	1.0	1.3	1.3	0.0	0.8	0.7	0.2	0.1	0.1	0.3	0.3	0.2	0.1	0.1	0.4	6.5
Others	2.8	2.2	1.5	1.6	1.5	0.7	1.4	1.0	1.6	0.8	0.8	0.3	0.1	0.1	0.2	15.2
TOTAL	23.7	29.5	20.5	13.1	10.9	11.0	7.9	5.1	4.3	7.6	6.1	7.4	3.3	4.1	4.2	146.7

Table 138 (continued)

ARMUTÇUK

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	0.0	0.0	0.0	0.0	0.0	4.2	1.1	0.4	3.9	3.5	6.8	9.6	8.1	6.6	4.5	43.6
Transport.	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	1.9	1.5	1.7	1.1	1.6	0.9	0.9	8.9
Mat. Hand.	0.0	0.0	0.0	0.0	0.0	2.2	0.5	0.1	1.5	2.0	4.3	2.1	3.8	3.2	1.3	19.0
Slip/Fall	0.0	0.0	0.0	0.0	0.0	2.1	0.8	0.1	1.2	3.1	6.6	4.4	3.4	2.9	3.7	24.8
Struck Obj.	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.5	0.0	0.1	0.0	0.0	0.1	1.1
Mech. Electr.	0.0	0.0	0.0	0.0	0.0	1.3	0.2	0.0	0.3	0.2	1.3	0.7	1.5	1.8	0.4	6.7
Others	0.0	0.0	0.0	0.0	0.0	0.9	0.7	0.0	0.2	0.2	1.0	1.0	1.0	0.6	0.5	5.8
TOTAL	0.0	0.0	0.0	0.0	0.0	11.1	3.3	0.7	9.0	11.0	21.7	19.0	19.4	15.9	11.4	110.0

KARADON

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	59.1	51.1	41.0	25.4	32.2	29.5	24.6	33.8	32.8	50.5	41.9	35.2	38.4	26.4	9.0	531.7
Transport.	0.0	0.0	0.0	0.0	1.4	0.0	0.4	3.5	3.0	6.4	6.0	3.5	2.3	2.7	3.4	32.5
Mat. Hand.	24.8	29.5	18.2	19.7	19.9	27.3	24.6	14.7	16.5	25.9	26.2	21.0	14.4	16.9	12.6	313.4
Slip/Fall	10.5	8.9	6.2	7.9	12.9	6.8	5.0	17.3	5.2	6.8	7.9	6.2	6.0	13.3	9.3	130.4
Struck Obj.	0.0	0.0	0.4	0.0	0.3	1.2	2.0	0.3	0.3	11.3	10.9	4.5	5.7	12.2	16.7	63.8
Mech. Electr.	0.0	0.8	0.7	0.1	0.4	0.0	0.4	0.7	2.1	1.9	7.1	4.1	2.8	2.2	2.2	25.0
Others	17.7	16.3	8.8	9.5	14.5	20.0	11.1	14.3	4.6	1.6	1.0	4.8	0.5	2.0	0.8	129.7
TOTAL	112.1	106.7	75.3	62.6	81.5	84.8	68.1	84.6	64.5	104.4	101.0	79.3	70.1	75.6	53.9	1,226.5

KOZLU

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	0.0	0.0	0.0	1.8	5.9	8.2	7.7	6.1	1.0	1.6	2.4	6.6	5.6	4.9	5.4	59.8
Transport.	0.0	0.0	0.0	0.0	0.4	2.8	0.7	2.1	0.0	0.1	0.0	2.4	0.6	1.4	2.0	13.1
Mat. Hand.	0.0	0.0	0.0	2.3	3.5	4.5	4.6	1.9	0.9	2.6	2.1	3.6	5.3	6.1	6.7	45.7
Slip/Fall	0.0	0.0	0.0	2.8	4.6	3.4	7.5	5.1	4.1	6.4	4.4	2.6	2.0	1.3	1.0	47.9
Struck Obj.	0.0	0.0	0.0	2.8	5.7	0.3	2.0	9.6	9.0	20.3	22.2	4.6	2.8	1.3	1.1	88.5
Mech. Electr.	0.0	0.0	0.0	0.4	0.2	0.4	1.4	0.7	0.2	0.3	0.6	1.5	1.4	1.3	1.0	10.0
Others	0.0	0.0	0.0	0.7	0.4	0.4	0.9	0.4	0.5	1.6	1.3	0.2	0.3	0.8	0.3	7.9
TOTAL	0.0	0.0	0.0	10.8	20.5	20.0	24.8	25.9	15.7	32.9	32.9	21.5	18.0	17.1	17.6	272.8

ÜZÜLMEZ

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL
Roof Fall	27.5	37.1	20.4	20.6	16.7	13.9	15.4	12.3	14.9	19.6	15.2	13.3	12.9	11.8	9.0	258.4
Transport.	5.5	3.9	3.4	2.6	3.7	4.4	0.9	5.0	3.2	2.9	3.0	2.6	1.6	2.7	1.0	46.8
Mat. Hand.	15.5	5.6	1.4	2.3	3.7	4.4	2.1	3.1	2.8	8.8	3.7	2.4	5.4	2.5	5.3	68.1
Slip/Fall	7.0	12.7	3.9	7.3	6.5	6.2	4.1	3.4	2.6	5.7	5.3	4.5	5.1	6.1	4.9	85.4
Struck Obj.	8.8	15.3	9.6	11.4	5.8	5.0	9.4	9.7	6.9	7.2	8.9	10.7	7.9	5.5	7.2	129.8
Mech. Electr.	4.2	3.7	3.3	5.0	4.1	4.0	2.3	2.2	0.8	2.4	1.1	3.9	1.7	1.9	1.6	42.3
Others	0.5	0.1	0.1	0.2	0.0	2.3	1.0	0.9	0.1	0.5	0.4	0.1	0.1	0.2	0.0	6.2
TOTAL	69.0	78.3	42.2	49.4	40.4	40.1	35.2	36.4	31.3	47.2	37.6	37.5	34.6	30.6	29.0	637.0

APPENDIX C

CONTINGENCY TABLES

Table 139 Accident probabilities with respect to age and accident type

TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	Total
≤ 25	0.070	0.001	0.036	0.016	0.021	0.005	0.007	**0.156**
26-30	0.175	0.005	0.086	0.044	0.053	0.012	0.021	**0.396**
31-35	0.097	0.009	0.045	0.032	0.032	0.010	0.016	**0.241**
36-40	0.040	0.011	0.023	0.018	0.016	0.005	0.011	**0.122**
41-45	0.017	0.007	0.013	0.010	0.007	0.003	0.009	**0.066**
46≤	0.004	0.002	0.003	0.003	0.002	0.001	0.002	**0.016**
Unknown	0.001	0.000	0.001	0.000	0.000	0.000	0.000	**0.003**
Total	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

AMASRA

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	Total
≤ 25	0.072	0.001	0.031	0.015	0.013	0.006	0.016	**0.155**
26-30	0.174	0.003	0.056	0.040	0.032	0.016	0.041	**0.361**
31-35	0.104	0.008	0.034	0.040	0.020	0.009	0.039	**0.254**
36-40	0.044	0.014	0.027	0.018	0.012	0.006	0.017	**0.139**
41-45	0.012	0.012	0.013	0.010	0.006	0.004	0.011	**0.068**
46≤	0.002	0.004	0.002	0.002	0.001	0.001	0.002	**0.015**
Unknown	0.002	0.001	0.002	0.001	0.000	0.001	0.001	**0.008**
Total	**0.411**	**0.044**	**0.163**	**0.125**	**0.085**	**0.043**	**0.128**	**1.000**

ARMUTÇUK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	Total
≤ 25	0.074	0.000	0.030	0.035	0.001	0.004	0.012	**0.156**
26-30	0.199	0.004	0.068	0.078	0.003	0.017	0.030	**0.398**
31-35	0.126	0.014	0.042	0.052	0.002	0.013	0.023	**0.273**
36-40	0.035	0.015	0.019	0.024	0.003	0.005	0.011	**0.111**
41-45	0.013	0.006	0.009	0.012	0.001	0.002	0.005	**0.048**
46≤	0.003	0.001	0.001	0.003	0.000	0.001	0.002	**0.010**
Unknown	0.001	0.001	0.001	0.001	0.000	0.000	0.001	**0.005**
Total	**0.450**	**0.041**	**0.170**	**0.204**	**0.011**	**0.041**	**0.083**	**1.000**

KARADON

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	Total
≤ 25	0.080	0.001	0.053	0.012	0.009	0.003	0.008	**0.166**
26-30	0.204	0.003	0.120	0.034	0.028	0.005	0.026	**0.420**
31-35	0.095	0.007	0.053	0.023	0.019	0.007	0.020	**0.223**
36-40	0.040	0.007	0.024	0.013	0.005	0.004	0.016	**0.109**
41-45	0.019	0.004	0.016	0.008	0.001	0.002	0.015	**0.064**
46≤	0.004	0.002	0.004	0.002	0.001	0.001	0.004	**0.017**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Total	**0.443**	**0.023**	**0.271**	**0.093**	**0.062**	**0.020**	**0.089**	**1.000**

Table 139 (continued)

KOZLU

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	Total
≤ 25	0.043	0.003	0.025	0.021	0.057	0.005	0.003	**0.157**
26-30	0.106	0.009	0.077	0.059	0.119	0.015	0.010	**0.395**
31-35	0.066	0.008	0.048	0.032	0.062	0.012	0.006	**0.233**
36-40	0.026	0.014	0.028	0.018	0.030	0.004	0.003	**0.124**
41-45	0.013	0.009	0.014	0.012	0.014	0.003	0.004	**0.070**
46≤	0.002	0.001	0.003	0.003	0.003	0.001	0.001	**0.014**
Unknown	0.001	0.001	0.001	0.001	0.002	0.000	0.000	**0.007**
Total	**0.256**	**0.046**	**0.197**	**0.147**	**0.288**	**0.040**	**0.026**	**1.000**

ÜZÜLMEZ

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	Total
≤ 25	0.069	0.003	0.015	0.011	0.028	0.009	0.001	**0.134**
26-30	0.166	0.008	0.044	0.038	0.080	0.023	0.002	**0.360**
31-35	0.116	0.011	0.030	0.035	0.055	0.016	0.002	**0.267**
36-40	0.054	0.011	0.016	0.024	0.033	0.009	0.002	**0.149**
41-45	0.022	0.009	0.006	0.013	0.016	0.004	0.001	**0.073**
46≤	0.005	0.003	0.001	0.003	0.003	0.001	0.001	**0.018**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Total	**0.432**	**0.046**	**0.112**	**0.124**	**0.216**	**0.062**	**0.008**	**1.000**

Table 140 Accident probabilities with respect to injury and accident type

TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Head	0.048	0.003	0.012	0.009	0.021	0.005	0.008	**0.104**
Hands	0.120	0.013	0.064	0.024	0.048	0.011	0.019	**0.298**
Feet	0.091	0.007	0.039	0.025	0.028	0.012	0.016	**0.218**
Arms	0.035	0.002	0.007	0.011	0.007	0.002	0.003	**0.067**
Legs	0.043	0.003	0.013	0.020	0.014	0.003	0.005	**0.102**
Main Body	0.056	0.007	0.067	0.029	0.009	0.002	0.012	**0.182**
Various	0.010	0.001	0.005	0.005	0.004	0.001	0.003	**0.028**
TOTAL	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

AMASRA

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Head	0.061	0.003	0.005	0.011	0.019	0.004	0.017	**0.120**
Hands	0.107	0.019	0.055	0.027	0.018	0.015	0.042	**0.283**
Feet	0.075	0.010	0.023	0.024	0.019	0.014	0.040	**0.203**
Arms	0.034	0.000	0.003	0.010	0.006	0.003	0.004	**0.060**
Legs	0.054	0.005	0.006	0.024	0.017	0.004	0.013	**0.124**
Main Body	0.073	0.006	0.071	0.026	0.006	0.002	0.012	**0.196**
Various	0.007	0.001	0.001	0.003	0.001	0.001	0.001	**0.014**
TOTAL	**0.411**	**0.044**	**0.163**	**0.125**	**0.085**	**0.043**	**0.128**	**1.000**

Table 140 (continued)

ARMUTÇUK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Head	0.057	0.003	0.010	0.011	0.003	0.006	0.009	**0.101**
Hands	0.133	0.016	0.062	0.039	0.002	0.010	0.031	**0.292**
Feet	0.099	0.008	0.059	0.052	0.003	0.019	0.026	**0.266**
Arms	0.042	0.005	0.006	0.020	0.001	0.003	0.005	**0.083**
Legs	0.026	0.002	0.010	0.028	0.001	0.002	0.005	**0.074**
Main Body	0.083	0.006	0.021	0.048	0.001	0.000	0.006	**0.165**
Various	0.011	0.001	0.002	0.005	0.000	0.000	0.002	**0.021**
TOTAL	**0.450**	**0.041**	**0.170**	**0.204**	**0.011**	**0.041**	**0.083**	**1.000**

KARADON

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Head	0.045	0.002	0.016	0.007	0.007	0.002	0.010	**0.088**
Hands	0.131	0.009	0.085	0.017	0.016	0.006	0.022	**0.285**
Feet	0.108	0.005	0.051	0.014	0.015	0.006	0.019	**0.216**
Arms	0.032	0.001	0.010	0.008	0.004	0.001	0.004	**0.060**
Legs	0.052	0.002	0.019	0.016	0.009	0.003	0.007	**0.108**
Main Body	0.059	0.004	0.082	0.024	0.004	0.002	0.024	**0.198**
Various	0.017	0.001	0.009	0.006	0.006	0.001	0.004	**0.045**
TOTAL	**0.443**	**0.023**	**0.271**	**0.093**	**0.062**	**0.020**	**0.089**	**1.000**

KOZLU

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Head	0.030	0.003	0.011	0.011	0.048	0.005	0.003	**0.112**
Hands	0.087	0.015	0.053	0.028	0.101	0.017	0.010	**0.312**
Feet	0.057	0.006	0.021	0.036	0.064	0.009	0.007	**0.199**
Arms	0.016	0.002	0.006	0.016	0.015	0.002	0.001	**0.056**
Legs	0.031	0.002	0.008	0.021	0.032	0.004	0.001	**0.099**
Main Body	0.030	0.017	0.094	0.028	0.021	0.003	0.002	**0.195**
Various	0.006	0.001	0.003	0.007	0.007	0.000	0.003	**0.026**
TOTAL	**0.256**	**0.046**	**0.197**	**0.147**	**0.288**	**0.040**	**0.026**	**1.000**

ÜZÜLMEZ

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Head	0.058	0.004	0.007	0.010	0.033	0.010	0.002	**0.124**
Hands	0.130	0.014	0.032	0.026	0.107	0.014	0.001	**0.324**
Feet	0.092	0.013	0.029	0.024	0.040	0.028	0.001	**0.227**
Arms	0.059	0.002	0.006	0.010	0.010	0.002	0.001	**0.090**
Legs	0.036	0.004	0.013	0.021	0.014	0.005	0.001	**0.094**
Main Body	0.055	0.008	0.025	0.032	0.012	0.003	0.001	**0.136**
Various	0.002	0.001	0.001	0.001	0.001	0.001	0.001	**0.006**
TOTAL	**0.432**	**0.046**	**0.112**	**0.124**	**0.216**	**0.062**	**0.008**	**1.000**

Table 141 Accident probabilities with respect to location and type of accident

TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.287	0.005	0.113	0.057	0.067	0.019	0.031	**0.578**
Dev. Face	0.056	0.004	0.027	0.019	0.017	0.005	0.011	**0.138**
Gate Roads	0.004	0.007	0.010	0.009	0.010	0.001	0.002	**0.043**
Roadw, Gall.	0.044	0.015	0.045	0.027	0.029	0.005	0.011	**0.177**
Others	0.012	0.005	0.012	0.011	0.008	0.005	0.010	**0.064**
TOTAL	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

AMASRA

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.238	0.006	0.081	0.049	0.059	0.021	0.055	**0.508**
Dev. Face	0.116	0.004	0.027	0.025	0.007	0.010	0.025	**0.214**
Gate Roads	0.001	0.006	0.003	0.002	0.001	0.000	0.001	**0.015**
Roadw, Gall.	0.048	0.023	0.041	0.036	0.015	0.006	0.030	**0.200**
Others	0.008	0.005	0.011	0.012	0.003	0.006	0.017	**0.062**
TOTAL	**0.411**	**0.044**	**0.163**	**0.125**	**0.085**	**0.043**	**0.128**	**1.000**

ARMUTÇUK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.374	0.002	0.127	0.131	0.006	0.031	0.053	**0.723**
Dev. Face	0.041	0.001	0.016	0.020	0.002	0.002	0.011	**0.093**
Gate Roads	0.007	0.003	0.006	0.008	0.000	0.000	0.001	**0.025**
Roadw, Gall.	0.016	0.019	0.010	0.028	0.001	0.003	0.006	**0.083**
Others	0.012	0.016	0.012	0.018	0.002	0.005	0.012	**0.076**
TOTAL	**0.450**	**0.041**	**0.170**	**0.204**	**0.011**	**0.041**	**0.083**	**1.000**

KARADON

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.335	0.003	0.154	0.045	0.023	0.006	0.043	**0.610**
Dev. Face	0.036	0.001	0.026	0.011	0.005	0.003	0.014	**0.095**
Gate Roads	0.002	0.005	0.001	0.001	0.000	0.000	0.001	**0.011**
Roadw, Gall.	0.059	0.012	0.076	0.025	0.033	0.005	0.015	**0.224**
Others	0.011	0.003	0.014	0.010	0.001	0.006	0.015	**0.059**
TOTAL	**0.443**	**0.023**	**0.271**	**0.093**	**0.062**	**0.020**	**0.089**	**1.000**

KOZLU

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.110	0.003	0.064	0.042	0.125	0.015	0.006	**0.365**
Dev. Face	0.072	0.007	0.049	0.028	0.047	0.008	0.006	**0.217**
Gate Roads	0.008	0.012	0.038	0.029	0.043	0.005	0.007	**0.142**
Roadw, Gall.	0.052	0.017	0.029	0.038	0.052	0.007	0.004	**0.199**
Others	0.014	0.006	0.018	0.009	0.021	0.005	0.002	**0.076**
TOTAL	**0.256**	**0.046**	**0.197**	**0.147**	**0.288**	**0.040**	**0.026**	**1.000**

Table 141 (continued)

ÜZÜLMEZ

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. Face	0.338	0.011	0.077	0.065	0.146	0.046	0.004	**0.686**
Dev. Face	0.061	0.007	0.013	0.021	0.025	0.004	0.002	**0.134**
Gate Roads	0.002	0.010	0.005	0.009	0.011	0.001	0.000	**0.039**
Roadw, Gall.	0.018	0.013	0.012	0.015	0.019	0.006	0.002	**0.085**
Others	0.014	0.005	0.005	0.013	0.015	0.004	0.001	**0.057**
TOTAL	**0.432**	**0.046**	**0.112**	**0.124**	**0.216**	**0.062**	**0.008**	**1.000**

Table 142 Accident probabilities with respect to experience and accident type

TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
0-1 Year	0.130	0.003	0.070	0.031	0.044	0.008	0.013	**0.300**
2-5 Years	0.163	0.006	0.077	0.044	0.045	0.013	0.020	**0.369**
6-10 Years	0.061	0.008	0.026	0.020	0.022	0.006	0.013	**0.157**
11-15 Years	0.033	0.012	0.022	0.018	0.013	0.005	0.011	**0.113**
16-20 Years	0.012	0.005	0.009	0.008	0.005	0.002	0.007	**0.049**
21≤	0.002	0.002	0.002	0.002	0.002	0.001	0.002	**0.013**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

AMASRA

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
0-1 Year	0.125	0.002	0.053	0.028	0.021	0.012	0.030	**0.271**
2-5 Years	0.160	0.004	0.052	0.042	0.034	0.012	0.033	**0.337**
6-10 Years	0.083	0.009	0.027	0.027	0.013	0.009	0.036	**0.203**
11-15 Years	0.031	0.018	0.021	0.022	0.013	0.007	0.018	**0.130**
16-20 Years	0.010	0.010	0.009	0.005	0.003	0.002	0.009	**0.049**
21≤	0.001	0.001	0.002	0.001	0.001	0.001	0.002	**0.009**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.411**	**0.044**	**0.163**	**0.125**	**0.085**	**0.043**	**0.128**	**1.000**

ARMUTÇUK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
0-1 Year	0.116	0.001	0.051	0.050	0.003	0.009	0.018	**0.247**
2-5 Years	0.222	0.004	0.069	0.084	0.003	0.017	0.034	**0.432**
6-10 Years	0.075	0.014	0.026	0.034	0.002	0.009	0.014	**0.174**
11-15 Years	0.025	0.014	0.018	0.023	0.002	0.004	0.011	**0.096**
16-20 Years	0.010	0.005	0.006	0.011	0.001	0.002	0.006	**0.040**
21≤	0.002	0.002	0.000	0.002	0.000	0.001	0.002	**0.009**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.001**
TOTAL	**0.450**	**0.041**	**0.170**	**0.204**	**0.011**	**0.041**	**0.083**	**1.000**

Table 142 (continued)

KARADON

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
0-1 Year	0.162	0.001	0.106	0.024	0.019	0.004	0.017	**0.333**
2-5 Years	0.172	0.004	0.097	0.034	0.031	0.006	0.026	**0.369**
6-10 Years	0.060	0.009	0.031	0.015	0.006	0.005	0.016	**0.141**
11-15 Years	0.033	0.006	0.023	0.013	0.005	0.003	0.016	**0.099**
16-20 Years	0.014	0.001	0.011	0.006	0.000	0.001	0.012	**0.045**
21≤	0.003	0.002	0.003	0.001	0.001	0.001	0.003	**0.012**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.443**	**0.023**	**0.271**	**0.093**	**0.062**	**0.020**	**0.089**	**1.000**

KOZLU

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
0-1 Year	0.076	0.008	0.045	0.048	0.129	0.007	0.005	**0.317**
2-5 Years	0.111	0.008	0.087	0.047	0.070	0.018	0.011	**0.353**
6-10 Years	0.034	0.005	0.025	0.022	0.056	0.005	0.003	**0.150**
11-15 Years	0.025	0.017	0.026	0.016	0.016	0.005	0.004	**0.109**
16-20 Years	0.009	0.007	0.011	0.010	0.013	0.004	0.003	**0.058**
21≤	0.001	0.001	0.002	0.003	0.003	0.001	0.001	**0.013**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.256**	**0.046**	**0.197**	**0.147**	**0.288**	**0.040**	**0.026**	**1.000**

ÜZÜLMEZ

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
0-1 Year	0.126	0.003	0.032	0.020	0.051	0.015	0.002	**0.249**
2-5 Years	0.165	0.011	0.041	0.046	0.078	0.025	0.002	**0.367**
6-10 Years	0.073	0.007	0.017	0.021	0.036	0.009	0.002	**0.164**
11-15 Years	0.050	0.014	0.017	0.024	0.035	0.008	0.001	**0.149**
16-20 Years	0.014	0.008	0.004	0.009	0.012	0.004	0.000	**0.052**
21≤	0.004	0.002	0.002	0.004	0.004	0.001	0.001	**0.018**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.432**	**0.046**	**0.112**	**0.124**	**0.216**	**0.062**	**0.008**	**1.000**

Table 143 Accident probabilities with respect to main duty and accident type

TTK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. W.	0.344	0.008	0.161	0.083	0.101	0.023	0.036	**0.755**
Dev. W.	0.033	0.003	0.019	0.014	0.012	0.003	0.009	**0.093**
Trans. W.	0.004	0.017	0.008	0.008	0.007	0.002	0.008	**0.054**
Mech.,Elect.	0.004	0.002	0.007	0.006	0.005	0.006	0.005	**0.035**
Demont. W.	0.010	0.002	0.006	0.004	0.003	0.001	0.003	**0.028**
Others	0.007	0.003	0.005	0.008	0.003	0.001	0.005	**0.032**
Unknown	0.001	0.000	0.001	0.001	0.000	0.000	0.000	**0.004**
TOTAL	**0.403**	**0.035**	**0.206**	**0.123**	**0.131**	**0.036**	**0.065**	**1.000**

Table 143 (continued)

AMASRA

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. W.	**0.345**	0.009	0.125	0.084	0.066	0.025	0.081	**0.735**
Dev. W.	0.040	0.003	0.014	0.014	0.004	0.006	0.013	**0.095**
Trans. W.	0.002	**0.019**	0.004	0.007	0.003	0.001	0.013	**0.049**
Mech.,Elect.	0.007	0.003	0.007	0.008	0.006	0.006	0.009	**0.045**
Demont. W.	0.004	0.000	0.005	0.003	0.002	0.003	0.004	**0.021**
Others	0.012	0.009	0.008	0.007	0.004	0.001	0.006	**0.047**
Unknown	0.002	0.001	0.002	0.001	0.000	0.000	0.001	**0.008**
TOTAL	**0.411**	**0.044**	**0.163**	**0.125**	**0.085**	**0.043**	**0.128**	**1.000**

ARMUTÇUK

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. W.	0.388	0.002	0.128	0.141	0.005	0.031	0.052	**0.747**
Dev. W.	0.033	0.001	0.013	0.019	0.001	0.002	0.011	**0.079**
Trans. W.	0.005	0.027	0.008	0.012	0.003	0.000	0.005	**0.060**
Mech.,Elect.	0.005	0.004	0.009	0.010	0.001	0.007	0.007	**0.043**
Demont. W.	0.015	0.002	0.007	0.010	0.001	0.001	0.003	**0.040**
Others	0.003	0.003	0.003	0.011	0.000	0.001	0.005	**0.025**
Unknown	0.002	0.001	0.002	0.001	0.000	0.000	0.001	**0.006**
TOTAL	**0.450**	**0.041**	**0.170**	**0.204**	**0.011**	**0.041**	**0.083**	**1.000**

KARADON

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. W.	0.383	0.002	0.224	0.065	0.055	0.009	0.045	**0.783**
Dev. W.	0.030	0.001	0.017	0.008	0.002	0.001	0.012	**0.071**
Trans. W.	0.005	0.017	0.009	0.006	0.003	0.002	0.012	**0.053**
Mech.,Elect.	0.003	0.001	0.007	0.004	0.000	0.005	0.007	**0.028**
Demont. W.	0.014	0.001	0.009	0.004	0.001	0.001	0.005	**0.034**
Others	0.007	0.001	0.004	0.006	0.002	0.002	0.008	**0.030**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.001**
TOTAL	**0.443**	**0.023**	**0.271**	**0.093**	**0.062**	**0.020**	**0.089**	**1.000**

KOZLU

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. W.	0.214	0.018	0.128	0.100	0.222	0.026	0.017	**0.724**
Dev. W.	0.030	0.006	0.037	0.019	0.032	0.005	0.003	**0.132**
Trans. W.	0.003	0.013	0.011	0.007	0.013	0.003	0.004	**0.055**
Mech.,Elect.	0.001	0.003	0.009	0.008	0.008	0.004	0.001	**0.034**
Demont. W.	0.003	0.002	0.004	0.002	0.004	0.000	0.000	**0.015**
Others	0.004	0.003	0.007	0.009	0.006	0.001	0.001	**0.032**
Unknown	0.001	0.001	0.001	0.001	0.002	0.000	0.000	**0.008**
TOTAL	**0.256**	**0.046**	**0.197**	**0.147**	**0.288**	**0.040**	**0.026**	**1.000**

Table 143 (continued)

ÜZÜLMEZ

	RF	Trans.	Mat. Hand.	Slip/Fall	Struck Obj.	Mech. Electr.	Others	TOTAL
Prod. W.	0.365	0.013	0.086	0.076	0.151	0.045	0.002	**0.739**
Dev. W.	0.039	0.008	0.009	0.021	0.023	0.004	0.003	**0.107**
Trans. W.	0.003	0.016	0.006	0.010	0.016	0.003	0.002	**0.056**
Mech.,Elect.	0.008	0.002	0.005	0.006	0.013	0.007	0.000	**0.042**
Demont. W.	0.007	0.003	0.003	0.003	0.007	0.001	0.001	**0.023**
Others	0.009	0.004	0.003	0.008	0.005	0.001	0.000	**0.030**
Unknown	0.001	0.000	0.000	0.001	0.000	0.000	0.000	**0.002**
TOTAL	**0.432**	**0.046**	**0.112**	**0.124**	**0.216**	**0.062**	**0.008**	**1.000**

Table 144 Accident probabilities with respect to age and injury

TTK

	Head	Hands	Feet	Arms	Legs	Main Body	Various	Total
≤ 25	0.014	0.047	0.035	0.011	0.018	0.028	0.004	**0.156**
26-30	0.039	0.116	0.090	0.027	0.042	0.070	0.012	**0.396**
31-35	0.028	0.073	0.050	0.017	0.025	0.041	0.007	**0.241**
36-40	0.014	0.037	0.026	0.007	0.010	0.025	0.003	**0.122**
41-45	0.007	0.019	0.014	0.003	0.005	0.015	0.002	**0.066**
46≤	0.002	0.005	0.003	0.001	0.001	0.003	0.001	**0.016**
Unknown	0.000	0.001	0.001	0.000	0.000	0.001	0.000	**0.003**
Total	**0.104**	**0.298**	**0.218**	**0.067**	**0.102**	**0.182**	**0.028**	**1.000**

AMASRA

	Head	Hands	Feet	Arms	Legs	Main Body	Various	Total
≤ 25	0.016	0.045	0.030	0.012	0.020	0.030	0.001	**0.155**
26-30	0.041	0.104	0.079	0.023	0.045	0.066	0.004	**0.361**
31-35	0.037	0.072	0.047	0.014	0.034	0.045	0.006	**0.254**
36-40	0.015	0.037	0.030	0.008	0.015	0.032	0.002	**0.139**
41-45	0.009	0.018	0.013	0.002	0.006	0.018	0.001	**0.068**
46≤	0.001	0.006	0.003	0.000	0.002	0.002	0.000	**0.015**
Unknown	0.001	0.002	0.002	0.000	0.001	0.002	0.000	**0.008**
Total	**0.120**	**0.283**	**0.203**	**0.060**	**0.124**	**0.196**	**0.014**	**1.000**

ARMUTÇUK

	Head	Hands	Feet	Arms	Legs	Main Body	Various	Total
≤ 25	0.013	0.043	0.044	0.011	0.014	0.027	0.003	**0.156**
26-30	0.044	0.113	0.105	0.031	0.030	0.067	0.008	**0.398**
31-35	0.026	0.077	0.072	0.029	0.019	0.046	0.005	**0.273**
36-40	0.011	0.038	0.030	0.007	0.006	0.016	0.003	**0.111**
41-45	0.003	0.017	0.012	0.004	0.004	0.007	0.001	**0.048**
46≤	0.001	0.004	0.002	0.001	0.000	0.001	0.000	**0.010**
Unknown	0.002	0.001	0.001	0.000	0.000	0.001	0.000	**0.005**
Total	**0.101**	**0.292**	**0.266**	**0.083**	**0.074**	**0.165**	**0.021**	**1.000**

Table 144 (continued)

KARADON

	Head	Hands	Feet	Arms	Legs	Main Body	Various	Total
≤ 25	0.012	0.047	0.037	0.011	0.020	0.031	0.007	**0.166**
26-30	0.036	0.118	0.094	0.027	0.047	0.080	0.019	**0.420**
31-35	0.021	0.067	0.046	0.013	0.025	0.042	0.011	**0.223**
36-40	0.011	0.030	0.022	0.006	0.010	0.025	0.005	**0.109**
41-45	0.006	0.018	0.014	0.003	0.005	0.016	0.002	**0.064**
46≤	0.002	0.005	0.003	0.001	0.002	0.004	0.001	**0.017**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Total	**0.088**	**0.285**	**0.216**	**0.060**	**0.108**	**0.198**	**0.045**	**1.000**

KOZLU

	Head	Hands	Feet	Arms	Legs	Main Body	Various	Total
≤ 25	0.018	0.052	0.030	0.008	0.020	0.027	0.003	**0.157**
26-30	0.039	0.118	0.084	0.026	0.043	0.074	0.012	**0.395**
31-35	0.029	0.078	0.045	0.013	0.021	0.042	0.006	**0.233**
36-40	0.017	0.040	0.022	0.005	0.009	0.027	0.003	**0.124**
41-45	0.008	0.019	0.015	0.002	0.005	0.018	0.002	**0.070**
46≤	0.002	0.004	0.003	0.001	0.001	0.004	0.001	**0.014**
Unknown	0.001	0.002	0.001	0.001	0.001	0.002	0.000	**0.007**
Total	**0.112**	**0.312**	**0.199**	**0.056**	**0.099**	**0.195**	**0.026**	**1.000**

ÜZÜLMEZ

	Head	Hands	Feet	Arms	Legs	Main Body	Various	Total
≤ 25	0.014	0.043	0.031	0.013	0.012	0.020	0.001	**0.134**
26-30	0.041	0.117	0.088	0.030	0.035	0.047	0.002	**0.360**
31-35	0.036	0.082	0.055	0.027	0.030	0.034	0.002	**0.267**
36-40	0.020	0.052	0.032	0.013	0.010	0.021	0.001	**0.149**
41-45	0.010	0.023	0.016	0.005	0.006	0.011	0.001	**0.073**
46≤	0.003	0.006	0.005	0.001	0.001	0.002	0.000	**0.018**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Total	**0.124**	**0.324**	**0.227**	**0.090**	**0.094**	**0.136**	**0.006**	**1.000**

Table 145 Accident probabilities with respect to age and experience

TTK

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	Total
≤ 25	0.118	0.038	0.000	0.000	0.000	0.000	0.000	**0.156**
26-30	0.167	0.202	0.025	0.002	0.000	0.000	0.000	**0.396**
31-35	0.013	0.127	0.081	0.018	0.002	0.000	0.000	**0.241**
36-40	0.000	0.002	0.049	0.060	0.009	0.002	0.000	**0.122**
41-45	0.000	0.000	0.002	0.030	0.029	0.004	0.000	**0.066**
46≤	0.000	0.000	0.000	0.002	0.007	0.006	0.000	**0.016**
Unknown	0.000	0.000	0.000	0.000	0.002	0.000	0.000	**0.003**
Total	**0.300**	**0.369**	**0.157**	**0.113**	**0.049**	**0.013**	**0.000**	**1.000**

Table 145 (continued)

AMASRA

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	Total
≤ 25	0.117	0.038	0.000	0.000	0.000	0.000	0.000	**0.155**
26-30	0.137	0.189	0.034	0.001	0.000	0.000	0.000	**0.361**
31-35	0.016	0.109	0.096	0.031	0.002	0.000	0.000	**0.254**
36-40	0.001	0.001	0.071	0.056	0.010	0.000	0.000	**0.139**
41-45	0.000	0.000	0.002	0.037	0.025	0.003	0.000	**0.068**
46≤	0.000	0.000	0.000	0.003	0.008	0.004	0.000	**0.015**
Unknown	0.001	0.000	0.000	0.002	0.004	0.001	0.000	**0.008**
Total	**0.271**	**0.337**	**0.203**	**0.130**	**0.049**	**0.009**	**0.000**	**1.000**

ARMUTÇUK

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	Total
≤ 25	0.102	0.053	0.000	0.000	0.000	0.000	0.001	**0.156**
26-30	0.134	0.230	0.029	0.004	0.000	0.000	0.000	**0.398**
31-35	0.010	0.147	0.091	0.021	0.004	0.001	0.000	**0.273**
36-40	0.000	0.002	0.052	0.045	0.009	0.003	0.000	**0.111**
41-45	0.000	0.000	0.001	0.024	0.019	0.004	0.000	**0.048**
46≤	0.000	0.000	0.000	0.002	0.006	0.002	0.000	**0.010**
Unknown	0.001	0.000	0.001	0.001	0.002	0.001	0.000	**0.005**
Total	**0.247**	**0.432**	**0.174**	**0.096**	**0.040**	**0.009**	**0.001**	**1.000**

KARADON

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	Total
≤ 25	0.126	0.039	0.000	0.000	0.000	0.000	0.000	**0.166**
26-30	0.193	0.204	0.022	0.001	0.000	0.000	0.000	**0.420**
31-35	0.013	0.124	0.072	0.012	0.002	0.000	0.000	**0.223**
36-40	0.000	0.001	0.044	0.053	0.009	0.001	0.000	**0.109**
41-45	0.000	0.000	0.002	0.030	0.028	0.003	0.000	**0.064**
46≤	0.000	0.000	0.000	0.003	0.007	0.008	0.000	**0.017**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Total	**0.333**	**0.369**	**0.141**	**0.099**	**0.045**	**0.012**	**0.000**	**1.000**

KOZLU

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	Total
≤ 25	0.127	0.031	0.000	0.000	0.000	0.000	0.000	**0.157**
26-30	0.174	0.198	0.020	0.003	0.000	0.000	0.000	**0.395**
31-35	0.016	0.121	0.081	0.013	0.002	0.000	0.000	**0.233**
36-40	0.001	0.002	0.047	0.062	0.009	0.003	0.000	**0.124**
41-45	0.000	0.001	0.002	0.028	0.033	0.005	0.000	**0.070**
46≤	0.000	0.000	0.000	0.001	0.008	0.005	0.000	**0.014**
Unknown	0.000	0.000	0.000	0.001	0.005	0.001	0.000	**0.007**
Total	**0.317**	**0.353**	**0.150**	**0.109**	**0.058**	**0.013**	**0.000**	**1.000**

Table 145 (continued)

ÜZÜLMEZ

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	Total
≤ 25	0.101	0.033	0.000	0.000	0.000	0.000	0.000	**0.134**
26-30	0.136	0.193	0.027	0.004	0.000	0.000	0.000	**0.360**
31-35	0.012	0.138	0.085	0.027	0.004	0.000	0.000	**0.267**
36-40	0.000	0.002	0.048	0.082	0.009	0.006	0.000	**0.149**
41-45	0.000	0.000	0.002	0.033	0.030	0.007	0.000	**0.073**
46≤	0.000	0.000	0.001	0.003	0.008	0.006	0.000	**0.018**
Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Total	**0.249**	**0.367**	**0.164**	**0.149**	**0.052**	**0.018**	**0.000**	**1.000**

Table 146 Accident probabilities with respect to injury and location

TTK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
Head	0.060	0.015	0.004	0.017	0.008	**0.104**
Hands	0.173	0.040	0.014	0.050	0.020	**0.298**
Feet	0.131	0.029	0.010	0.036	0.013	**0.218**
Arms	0.041	0.009	0.002	0.011	0.004	**0.067**
Legs	0.062	0.012	0.003	0.020	0.005	**0.102**
Main Body	0.098	0.028	0.008	0.034	0.013	**0.182**
Various	0.013	0.004	0.001	0.009	0.002	**0.028**
TOTAL	**0.578**	**0.138**	**0.043**	**0.177**	**0.064**	**1.000**

AMASRA

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
Head	0.062	0.025	0.001	0.027	0.005	**0.120**
Hands	0.142	0.058	0.005	0.055	0.023	**0.283**
Feet	0.104	0.045	0.002	0.038	0.014	**0.203**
Arms	0.035	0.014	0.000	0.009	0.002	**0.060**
Legs	0.065	0.024	0.002	0.026	0.006	**0.124**
Main Body	0.097	0.044	0.003	0.042	0.011	**0.196**
Various	0.005	0.003	0.000	0.004	0.001	**0.014**
TOTAL	**0.508**	**0.214**	**0.015**	**0.200**	**0.062**	**1.000**

ARMUTÇUK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
Head	0.073	0.009	0.003	0.008	0.007	**0.101**
Hands	0.209	0.025	0.009	0.024	0.025	**0.292**
Feet	0.197	0.025	0.005	0.023	0.016	**0.266**
Arms	0.056	0.010	0.003	0.005	0.009	**0.083**
Legs	0.052	0.007	0.002	0.008	0.005	**0.074**
Main Body	0.120	0.016	0.004	0.012	0.012	**0.165**
Various	0.016	0.001	0.000	0.002	0.002	**0.021**
TOTAL	**0.723**	**0.093**	**0.025**	**0.083**	**0.076**	**1.000**

Table 146 (continued)

KARADON

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
Head	0.055	0.008	0.001	0.017	0.006	**0.088**
Hands	0.175	0.027	0.004	0.063	0.017	**0.285**
Feet	0.135	0.021	0.003	0.046	0.010	**0.216**
Arms	0.036	0.005	0.000	0.015	0.003	**0.060**
Legs	0.069	0.009	0.001	0.025	0.005	**0.108**
Main Body	0.119	0.020	0.002	0.042	0.015	**0.198**
Various	0.020	0.005	0.000	0.016	0.002	**0.045**
TOTAL	**0.610**	**0.095**	**0.011**	**0.224**	**0.059**	**1.000**

KOZLU

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
Head	0.039	0.026	0.014	0.021	0.012	**0.112**
Hands	0.122	0.067	0.046	0.056	0.022	**0.312**
Feet	0.076	0.039	0.033	0.036	0.016	**0.199**
Arms	0.022	0.011	0.008	0.013	0.003	**0.056**
Legs	0.044	0.017	0.010	0.024	0.004	**0.099**
Main Body	0.056	0.051	0.029	0.042	0.017	**0.195**
Various	0.007	0.007	0.003	0.007	0.003	**0.026**
TOTAL	**0.365**	**0.217**	**0.142**	**0.199**	**0.076**	**1.000**

ÜZÜLMEZ

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
Head	0.085	0.018	0.003	0.010	0.008	**0.124**
Hands	0.221	0.042	0.015	0.026	0.019	**0.324**
Feet	0.159	0.030	0.008	0.018	0.012	**0.227**
Arms	0.069	0.010	0.002	0.005	0.003	**0.090**
Legs	0.065	0.011	0.005	0.009	0.004	**0.094**
Main Body	0.084	0.021	0.006	0.014	0.009	**0.136**
Various	0.003	0.001	0.000	0.002	0.000	**0.006**
TOTAL	**0.686**	**0.134**	**0.039**	**0.085**	**0.057**	**1.000**

Table 147 Accident probabilities with respect to age and location

TTK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	Total
≤ 25	0.108	0.013	0.004	0.028	0.003	**0.156**
26-30	0.261	0.044	0.012	0.069	0.011	**0.396**
31-35	0.138	0.038	0.011	0.041	0.014	**0.241**
36-40	0.048	0.025	0.009	0.022	0.019	**0.122**
41-45	0.019	0.014	0.005	0.013	0.013	**0.066**
46≤	0.004	0.003	0.002	0.004	0.004	**0.016**
Unknown	0.001	0.001	0.000	0.001	0.001	**0.003**
Total	**0.578**	**0.138**	**0.043**	**0.177**	**0.064**	**1.000**

Table 147 (continued)

AMASRA

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	Total
≤ 25	0.096	0.027	0.001	0.029	0.003	**0.155**
26-30	0.215	0.075	0.001	0.062	0.008	**0.361**
31-35	0.121	0.066	0.003	0.046	0.019	**0.254**
36-40	0.055	0.028	0.006	0.035	0.016	**0.139**
41-45	0.016	0.012	0.003	0.024	0.012	**0.068**
46≤	0.002	0.004	0.000	0.004	0.004	**0.015**
Unknown	0.003	0.002	0.000	0.002	0.001	**0.008**
Total	**0.508**	**0.214**	**0.015**	**0.200**	**0.062**	**1.000**

ARMUTÇUK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	Total
≤ 25	0.137	0.008	0.003	0.005	0.003	**0.156**
26-30	0.330	0.029	0.007	0.019	0.012	**0.398**
31-35	0.179	0.035	0.008	0.029	0.021	**0.273**
36-40	0.055	0.014	0.003	0.019	0.021	**0.111**
41-45	0.017	0.005	0.003	0.010	0.013	**0.048**
46≤	0.002	0.002	0.001	0.002	0.004	**0.010**
Unknown	0.002	0.001	0.001	0.000	0.002	**0.005**
Total	**0.723**	**0.093**	**0.025**	**0.083**	**0.076**	**1.000**

KARADON

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	Total
≤ 25	0.117	0.008	0.001	0.039	0.002	**0.166**
26-30	0.285	0.028	0.002	0.098	0.007	**0.420**
31-35	0.133	0.025	0.003	0.052	0.012	**0.223**
36-40	0.047	0.019	0.003	0.020	0.019	**0.109**
41-45	0.024	0.012	0.002	0.011	0.015	**0.064**
46≤	0.005	0.003	0.001	0.004	0.004	**0.017**
Unknown	0.000	0.000	0.000	0.000	0.000	**0.000**
Total	**0.610**	**0.095**	**0.011**	**0.224**	**0.059**	**1.000**

KOZLU

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	Total
≤ 25	0.074	0.026	0.017	0.035	0.005	**0.157**
26-30	0.166	0.083	0.048	0.075	0.023	**0.395**
31-35	0.088	0.058	0.034	0.038	0.015	**0.233**
36-40	0.025	0.030	0.026	0.026	0.018	**0.124**
41-45	0.009	0.017	0.014	0.018	0.011	**0.070**
46≤	0.002	0.003	0.003	0.004	0.003	**0.014**
Unknown	0.001	0.001	0.001	0.003	0.002	**0.007**
Total	**0.365**	**0.217**	**0.142**	**0.199**	**0.076**	**1.000**

Table 147 (continued)

ÜZÜLMEZ

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	Total
≤ 25	0.113	0.007	0.003	0.009	0.002	**0.134**
26-30	0.291	0.029	0.007	0.025	0.008	**0.360**
31-35	0.189	0.034	0.009	0.022	0.013	**0.267**
36-40	0.067	0.036	0.010	0.017	0.019	**0.149**
41-45	0.022	0.023	0.007	0.009	0.012	**0.073**
46≤	0.005	0.005	0.002	0.003	0.003	**0.018**
Unknown	0.000	0.000	0.000	0.000	0.000	**0.000**
Total	**0.686**	**0.134**	**0.039**	**0.085**	**0.057**	**1.000**

Table 148 Accident probabilities with respect to experience and location

TTK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
0-1 Year	0.205	0.026	0.009	0.055	0.005	**0.300**
2-5 Years	0.239	0.043	0.012	0.065	0.010	**0.369**
6-10 Years	0.081	0.030	0.009	0.023	0.014	**0.157**
11-15 Years	0.039	0.025	0.009	0.021	0.019	**0.113**
16-20 Years	0.013	0.011	0.004	0.010	0.012	**0.049**
21≤	0.002	0.002	0.001	0.003	0.004	**0.013**
Unknown	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.578**	**0.138**	**0.043**	**0.177**	**0.064**	**1.000**

AMASRA

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
0-1 Year	0.165	0.046	0.001	0.054	0.005	**0.271**
2-5 Years	0.215	0.062	0.002	0.053	0.006	**0.337**
6-10 Years	0.071	0.066	0.004	0.041	0.022	**0.203**
11-15 Years	0.042	0.029	0.005	0.037	0.017	**0.130**
16-20 Years	0.014	0.009	0.003	0.014	0.009	**0.049**
21≤	0.001	0.003	0.000	0.002	0.003	**0.009**
Unknown	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.508**	**0.214**	**0.015**	**0.200**	**0.062**	**1.000**

ARMUTÇUK

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
0-1 Year	0.221	0.011	0.005	0.006	0.004	**0.247**
2-5 Years	0.347	0.042	0.008	0.022	0.013	**0.432**
6-10 Years	0.105	0.022	0.005	0.025	0.017	**0.174**
11-15 Years	0.034	0.013	0.004	0.020	0.025	**0.096**
16-20 Years	0.013	0.005	0.002	0.008	0.012	**0.040**
21≤	0.001	0.000	0.001	0.002	0.005	**0.009**
Unknown	0.001	0.000	0.000	0.000	0.000	**0.001**
TOTAL	**0.723**	**0.093**	**0.025**	**0.083**	**0.076**	**1.000**

Table 148 (continued)

KARADON

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
0-1 Year	0.235	0.016	0.001	0.077	0.003	**0.333**
2-5 Years	0.237	0.028	0.002	0.095	0.007	**0.369**
6-10 Years	0.083	0.021	0.004	0.022	0.011	**0.141**
11-15 Years	0.038	0.019	0.003	0.019	0.019	**0.099**
16-20 Years	0.014	0.010	0.001	0.007	0.014	**0.045**
21≤	0.003	0.002	0.000	0.003	0.004	**0.012**
Unknown	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.610**	**0.095**	**0.011**	**0.224**	**0.059**	**1.000**

KOZLU

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
0-1 Year	0.152	0.049	0.036	0.070	0.011	**0.317**
2-5 Years	0.134	0.093	0.042	0.062	0.022	**0.353**
6-10 Years	0.051	0.033	0.028	0.022	0.017	**0.150**
11-15 Years	0.019	0.028	0.024	0.024	0.014	**0.109**
16-20 Years	0.008	0.013	0.011	0.016	0.010	**0.058**
21≤	0.001	0.002	0.003	0.004	0.003	**0.013**
Unknown	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.365**	**0.217**	**0.142**	**0.199**	**0.076**	**1.000**

ÜZÜLMEZ

	Prod. Face	Dev. Face	Gate Roads	Roadw, Gall.	Others	TOTAL
0-1 Year	0.204	0.022	0.004	0.017	0.004	**0.249**
2-5 Years	0.305	0.020	0.009	0.025	0.008	**0.367**
6-10 Years	0.101	0.032	0.006	0.015	0.011	**0.164**
11-15 Years	0.061	0.040	0.012	0.016	0.020	**0.149**
16-20 Years	0.013	0.016	0.006	0.008	0.010	**0.052**
21≤	0.003	0.004	0.002	0.004	0.005	**0.018**
Unknown	0.000	0.000	0.000	0.000	0.000	**0.000**
TOTAL	**0.686**	**0.134**	**0.039**	**0.085**	**0.057**	**1.000**

Table 149 Accident probabilities with respect to injury and experience

TTK

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	TOTAL
Head	0.026	0.041	0.018	0.013	0.006	0.001	0.000	**0.104**
Hands	0.089	0.108	0.048	0.035	0.014	0.004	0.000	**0.298**
Feet	0.067	0.081	0.034	0.024	0.010	0.003	0.000	**0.218**
Arms	0.021	0.027	0.010	0.007	0.002	0.001	0.000	**0.067**
Legs	0.034	0.039	0.015	0.010	0.004	0.001	0.000	**0.102**
Main Body	0.055	0.062	0.028	0.023	0.012	0.002	0.000	**0.182**
Various	0.009	0.010	0.005	0.002	0.001	0.001	0.000	**0.028**
TOTAL	**0.300**	**0.369**	**0.157**	**0.113**	**0.049**	**0.013**	**0.000**	**1.000**

Table 149 (continued)

AMASRA

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	TOTAL
Head	0.027	0.048	0.024	0.016	0.005	0.000	0.000	**0.120**
Hands	0.082	0.085	0.062	0.036	0.015	0.002	0.000	**0.283**
Feet	0.053	0.068	0.044	0.025	0.011	0.002	0.000	**0.203**
Arms	0.022	0.019	0.011	0.006	0.001	0.000	0.000	**0.060**
Legs	0.035	0.043	0.021	0.018	0.005	0.002	0.000	**0.124**
Main Body	0.048	0.070	0.037	0.027	0.012	0.003	0.000	**0.196**
Various	0.003	0.004	0.004	0.003	0.000	0.000	0.000	**0.014**
TOTAL	**0.271**	**0.337**	**0.203**	**0.130**	**0.049**	**0.009**	**0.000**	**1.000**

ARMUTÇUK

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	TOTAL
Head	0.021	0.049	0.017	0.007	0.005	0.001	0.000	**0.101**
Hands	0.070	0.120	0.053	0.031	0.015	0.002	0.000	**0.292**
Feet	0.071	0.113	0.045	0.027	0.008	0.002	0.000	**0.266**
Arms	0.016	0.039	0.015	0.008	0.002	0.002	0.000	**0.083**
Legs	0.020	0.032	0.012	0.007	0.003	0.001	0.000	**0.074**
Main Body	0.044	0.071	0.028	0.014	0.005	0.002	0.000	**0.165**
Various	0.005	0.009	0.004	0.002	0.001	0.000	0.000	**0.021**
TOTAL	**0.247**	**0.432**	**0.174**	**0.096**	**0.040**	**0.009**	**0.001**	**1.000**

KARADON

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	TOTAL
Head	0.026	0.032	0.014	0.010	0.004	0.001	0.000	**0.088**
Hands	0.092	0.109	0.040	0.029	0.011	0.004	0.000	**0.285**
Feet	0.075	0.079	0.030	0.020	0.010	0.002	0.000	**0.216**
Arms	0.021	0.025	0.006	0.005	0.002	0.000	0.000	**0.060**
Legs	0.038	0.043	0.014	0.007	0.004	0.001	0.000	**0.108**
Main Body	0.065	0.066	0.029	0.023	0.013	0.002	0.000	**0.198**
Various	0.015	0.016	0.007	0.004	0.002	0.001	0.000	**0.045**
TOTAL	**0.333**	**0.369**	**0.141**	**0.099**	**0.045**	**0.012**	**0.000**	**1.000**

KOZLU

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	TOTAL
Head	0.027	0.045	0.019	0.014	0.006	0.001	0.000	**0.112**
Hands	0.100	0.109	0.051	0.032	0.015	0.004	0.000	**0.312**
Feet	0.062	0.073	0.029	0.021	0.012	0.003	0.000	**0.199**
Arms	0.021	0.021	0.007	0.004	0.003	0.001	0.000	**0.056**
Legs	0.041	0.031	0.013	0.009	0.004	0.001	0.000	**0.099**
Main Body	0.059	0.063	0.027	0.027	0.017	0.003	0.000	**0.195**
Various	0.008	0.009	0.004	0.002	0.002	0.001	0.000	**0.026**
TOTAL	**0.317**	**0.353**	**0.150**	**0.109**	**0.058**	**0.013**	**0.000**	**1.000**

ÜZÜLMEZ

	0-1 Year	2-5 Years	6-10 Years	11-15 Years	16-20 Years	21≤	Unknown	TOTAL
Head	0.026	0.047	0.023	0.018	0.008	0.002	0.000	**0.124**
Hands	0.083	0.113	0.053	0.051	0.017	0.006	0.000	**0.324**
Feet	0.058	0.084	0.035	0.032	0.012	0.005	0.000	**0.227**
Arms	0.022	0.037	0.015	0.012	0.003	0.001	0.000	**0.090**
Legs	0.022	0.038	0.016	0.013	0.003	0.001	0.000	**0.094**
Main Body	0.036	0.045	0.022	0.022	0.008	0.003	0.000	**0.136**
Various	0.002	0.002	0.001	0.001	0.001	0.000	0.000	**0.006**
TOTAL	**0.249**	**0.367**	**0.164**	**0.149**	**0.052**	**0.018**	**0.000**	**1.000**

CURRICULUM VITAE

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BS	METU Mining Engineering	1991
High School	Yenimahalle Industrial Vocational High School	1986

WORK EXPERIENCE

Year	Institution	Enrollment
2012-Present	MENR-PSD	Head of Department
2007-2012	MENR-GDEA	Chief of Division
2000 – 2007	MENR-GDEA	Engineer
1996 –2000	TKİ-OAL	Production Engineer
1995 –1996	Military Service	Soldier
1991 –1995	TKİ-OAL	Development Engineer

FOREIGN LANGUAGES

Advanced English,

PUBLICATIONS

"Performance Evaluation of Face Equipment Transporting Systems by Discrete Event Simulation"