JUNE 2019 M. Sc. Thesis in Civil Engineering MUSA BUDAK

REPUBLIC OF TURKEY
GAZİANTEP UNIVERSITY
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES

IN TUNNELING WORK ASSESSMENT OF RISKS TO BE ENCOUNTERED IN OCCUPATIONAL HEALTH AND SAFETY AND HAZARD ANALYSIS

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MUSA BUDAK
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In Tunneling Work Assessment of Risks to be Encountered in Occupational Health and Safety and Hazard Analysis

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Civil Engineering

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Supervisor

Prof. Dr. Hanifi ÇANAKCI

by

Musa BUDAK

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Musa BUDAK

ABSTRACT

IN TUNNELING WORK ASSESSMENT OF RISKS TO BE ENCOUNTERED IN OCCUPATIONAL HEALTH AND SAFETY AND HAZARD ANALYSIS

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Tunnel construction stages have been identified primarily in this study which is one of the heaviest and most dangerous part of the construction works. Then the hazards and risks that could be encountered in terms of occupational health and safety were then determined for each of these identified stages. A description of the planned preventive actions to remove the risks has been made. For this purpose a questionnaire was prepared for 35 different fields of activity involved in tunnel constructions stages. These questionnaires were send to 5 different occupational health and safety expert to identify risk preventive actions and hazards using binary comparison according to their importance level. This study is carried out in Bahçe-Nurdağı high speed train project that has 2 tunnels each is 10 kilometers in length. With the studies done in the project, it is aimed to determine the order of precedence according to the importance level of the hazards, risk preventive actions detected in tunnel construction stages. Throughout the result of this study awareness about the type and level of risks and hazards in tunnel works has increased. Therefore, risk of death and injury may be minimized and thus tunnel works can be completed at desired time and conditions.

Keywords: Occupational health and safety, Risk, Importance level, Binary comparison.

ÖZET

TÜNEL ÇALIŞMALARINDA İŞ SAĞLIĞI VE GÜVENLİĞİ YÖNÜNDEN KARŞILAŞILACAK RİSKLERİN DEĞERLENDİRİLMESİ VE TEHLİKE ANALİZİ

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İnşaat işlerinin en ağır ve en tehlikeli kısımlarından biri olan bu çalışmada, öncelikle tünel yapım aşamaları belirlenmiştir. Ardından belirlenen bu aşamaların her biri için iş sağlığı ve güvenliği açısından karşılaşılabilecek tehlike ve riskler tespit edilmiştir. Söz konusu bu riskleri ortadan kaldırmak için planlanan önleyici faaliyetlerin tanımlamaları yapılmıştır. Bu amaçla, tünel yapım aşamalarında yer alan 35 farklı faaliyet alanı için bir anket hazırlanmıştır. Bu anketler, önem seviyelerine göre ikili kıyaslama kullanarak risk önleyici faaliyetleri ve tehlikeleri tanımlamak için 5 farklı iş sağlığı ve güvenliği uzmanına gönderilmiştir. Bu çalışma, her biri 10 kilometre uzunluğunda 2 tünele sahip olan Bahçe-Nurdağı yüksek hızlı tren projesinde gerçekleştirilmiştir. Projede yapılan çalışmalar ile tünel yapım aşamalarında tespit edilen tehlikelerin ve risk önleyici faaliyetlerin önem derecesine göre öncelik sırasının belirlenmesi amaçlanmıştır. Bu çalışma sonucunda tünel çalışmalarındaki tehlike ve risklerin türü ve seviyesi konusunda farkındalık artmıştır. Bu nedenle, ölüm ve yaralanma riski en aza indirgenebilir ve böylece tünel çalışmaları istenen zamanda ve koşullarda tamamlanabilir.

Anahtar Kelimeler: İş sağlığı ve güvenliği, Risk, Önem derecesi, İkili kıyaslama.

“To My Family”

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I also would like to thank to my best friends Kenan POLAT and Merdan TOKDEMİR for their helps and valuable suggestion.

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ABBREVIATIONS

NATM	New Austrian Tunnel Method
TBM	Tunnel Boring Machine
ADECO-RS	The Analysis of Controlled Deformation in Rocks and Soils
OHS	Occupational Health and Safety
D	Dead
LL	Limb Loss
I	Injured
OD	Occupational Disease
PPE	Personal Protective Equipment
TS-EN	Turkish Standards-Europeane Norm
OHSU	Occupational Health and Safety Unit

CHAPTER I

INTRODUCTION

1.1 Background

The oldest tunnels present 3000 years ago, valuable metals to investigate the Babylonians and Aztecs by India, Egypt and Mesopotamia have been built [1]. The first tunnel on the earth is said to have been opened under the Euphrates River near the city of Babylon in 4000 BC. This tunnel was built approximately 3.5x4.5 meters in diameter and 1 kilometer long [1].

Tunneling is also used as a war technique in later periods. It is known that underground tunnels are opened by digging and shoving in order to overcome the city walls. Tunnels, firing in front of hard rocks until 19th century and after heating the rock, the hot surface was excavated on the basis of spraying water and vinegar [2].

The most important development in the tunnel between the years opened tunnel under the River Thames 1823-1843 [1]. The importance of this tunnel was a French engineer Brunel's patented shield method the first time where the application. This system is 4.20 metres and 4.80 meters in the twin tunnel is currently used [1] (Figure 1.1).

Observation of large tunnels increase occurred in parallel with the development of railways. The first railway tunnel in France St. Etienne-Terre Noire was founded in 1826 in the line [1].

Frejus railway tunnel, starting from Torino city of Italy, it is a 13.7 kilometer long tunnel going to Modane city of France and passing through the alpine mountains [1,2] (Figure 1.2).

Figure 1.1 Thames Tunnel (By Noisy Decent Graphics).

Figure 1.2 Frejus Railway Tunnel (By Martin Lloyd).

The tunnel, which was 12.8 kilometers long at first was approximately twice as long as the longest tunnel of its period [1,2]. The east end of the tunnel, 1857 in Italy began to excavate the city of Bardonecchia in 1857, the other end of the Modane city of France was excavated [1,2]. Posted on December 26, 1870 the French and Italian workers meet at the point they arrive [1,2]. Tunnel opened to transportation on September 17, 1871 [1,2]. 1881 is stretched a bit longer now that length in tunnel was reached [1,2]. At the same time strengthen the study was in France side output. Frejus Tunnel is one of the oldest alpine skiing tunnel today.

Germain Sommeiller-led tunnel construction work will last 25 years of the envisaged but compressors (pneumatic drills) with a number of technological advances such as the invention of the project was completed in 14 years earlier than expected [1,2]. Especially in the last years of the work, dynamite was found and construction processes gained momentum. Later on, Gotthard Tunnel (Figure 1.3) and Simplon Tunnel (Figure 1.4) were constructed with similar methods.

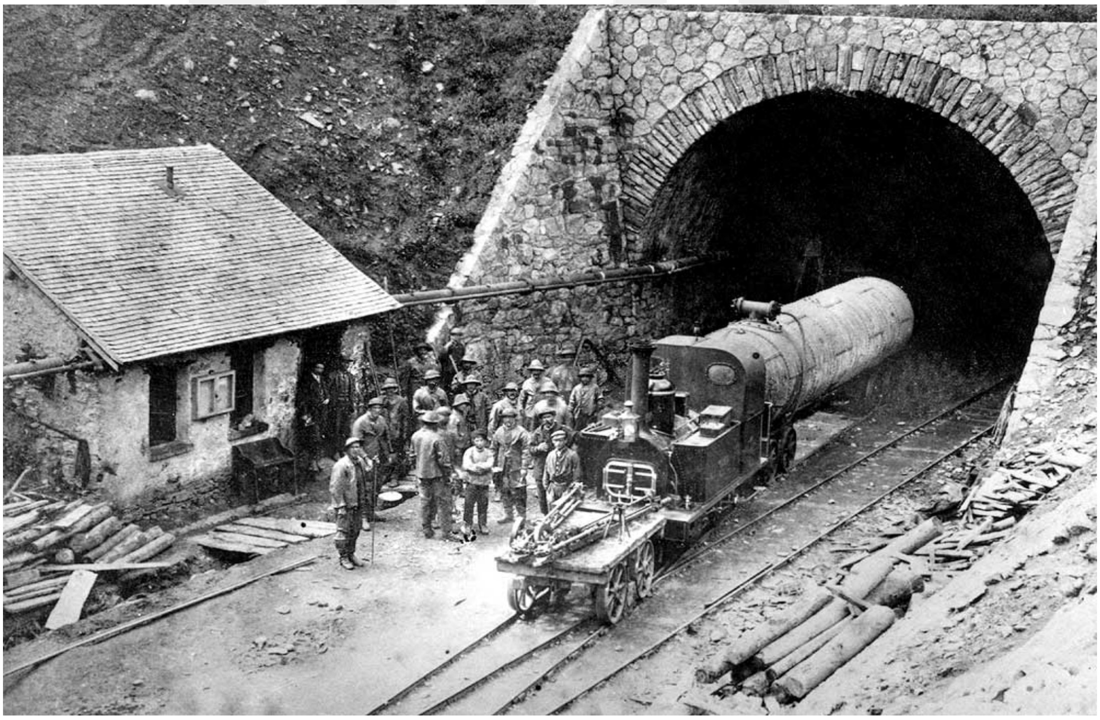


Figure 1.3 Gotthard Tunnel (By Iningenieursteckt).

Figure 1.4 Simplon Tunnel (By Eugenio Merzagora).

Between the years 1868 and 1871, there was already a railway line before the Frejus Tunnel and it was often used to transport England mail to India [1].

Frejus Tunnel today, it is one of the most important transportation lines connecting Rome and Paris. With the development of car and truck transportation, a road tunnel was constructed between 1974 and 1980 in the same direction [1].

In 1868, the New York subway was the first underground rail transport system of the American continent. Turkey is the first underground railway in 1874 in Galata–Pera was opened between [1].

One of Europe's great project carried out under the sea of English Channel tunnel system is completely impassable.

Channel tunnel (Figure 1.5), United Kingdom and France, which connects the sub-sea tunnel. The English channel are the chalk rock can be opened easily at the base of the tunnel occurring in a French engineer, 1802 offered the building of a tunnel connecting the two shores of the Strait of Dover [1,2]. Proposed by Napoleon was suspended because of the war. Such offers came up many times in the 19th century [1,2]. In the early 1880s, some private organizations began excavations to make a railway tunnel between the two shores [1,2]. Tunneling 1800 meters reaches the press, Britain's security of the project because of the dangerous campaign stopped making it [1,2].

Figure 1.5 Channel Tunnel (By Eurotunnel).

Channel Tunnel is one of the engineering wonders of our century. In this project, which employs 14.000 workers, highly advanced excavation machines have been used for disposal of millions of metric tons of stone, soil and mud [1,2]. One of them is a huge worm-like two huge backhoe, began digging the channel end. Each of them with the help of a laser light orientation. Stores in memory the computer three-dimensional map of the channel, the angle of laser light are always checked. In addition, this tunnel system is a co-production of France and the UK.

France and UK reunited to build tunnel in the middle 1960s but the UK cited high costs and stopped construction in the 1970s [1]. During this time, 2.4 kilometers of the tunnel were excavated on both sides [1]. Channel tunnel in 1986 came up again [1]. The project was funded by a large number of banks borrowing and issuing shares from a consortium of French and British firms. The tunnel connecting Dover and Calais started in 1987 and completed in 1993 [1]. 50.5 kilometers long tunnel, 100 meters of the surface of the sea is 40 meters beneath the seabed [1]. Length of underwater tunnel section is 38 kilometers [1].

The date of tunnel construction in Turkey is based on the 1950 [3]. The first tunnels were constructed in order to prevent natural disasters (landslides, avalanches, fire, etc.) rather than shortening the distance and facilitating transportation. In Turkey, in the late 1980s in conjunction with the construction of highway speed, the tunnel in the construction of new equipment and the new Austria Tunneling Method (NATM) was used as construction technologies [3,4]. In early 1990, double tube tunnel systems were used in highways [3]. When we get to 2000 years is longer than 5 km tunnel systems built, after the year 2010, 10 kilometers to 15 kilometers long tunnel systems TBM (Tunnel Boring Machine) or drilling blasting is being built with methods such as [2,3]. Turkey in the past 20 years, more than 10 kilometers long tunnels with the introduction of attempted, tunnel safety has increased the importance of the work more.

Tunnelling includes a variety of risks, depending on the floor conditions. Tunneling construction before you begin the geological surveying for the whole tunnel in no time even if it was on the ground is not possible to determine the conditions. Therefore, accidents caused by sudden changes in ground conditions in tunnel construction have a significant share in the construction sector.
In recent years, the underground rail and road tunnels have witnessed a striking way job security issue. The most important reasons; implementation of high-risk construction methods, design, and construction work is made in the same company, keeping the short construction time, limited budget and construction sector is competition. More than 600 million US dollars lost in 19 accidents in the world since 2000 [5]. Of these, the financial loss of the accident in the Shanghai subway construction was $ 80 million (Figure 1.6) and the financial loss of the Singapore subway construction was $ 50 million (Figure 1.7) [5]. Dozens of employees lost their lives in both accidents.

Turkey is quite above the EU average in deadly business accidents. In Europe, an average of 2.2 million business accidents occurred in the year, 3709 people lost their lives in 2015 [6]. Turkey compared to the EU average per 100 thousand people employed fatal occupational accident rate has been identified as 14.4% (Figure 1.8). After the Occupational Health and Safety Law No. 6331 [7], which was published in the official newspaper on 30 June 2012 and entered into force on 1 January 2013, there has been an increase in the number of occupational accidents [8] (Figure 1.9).

Figure 1.6 Shanghai subway construction. [5]

Figure 1.7 Singapore subway construction [5].

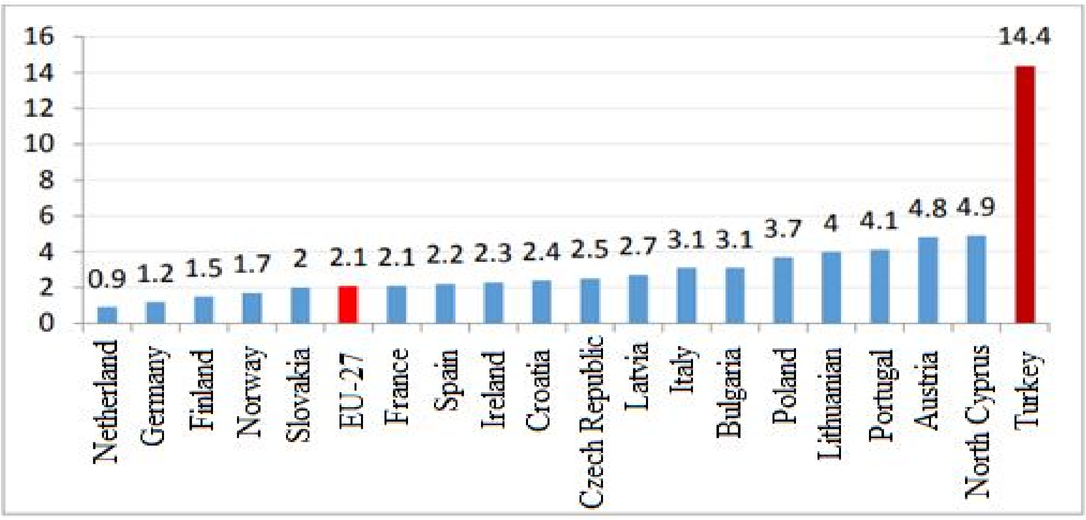


Figure 1.8 EU-Turkey rates of fatal occupational accidents (Eurostat, SGK 2010 statistics yearbook).

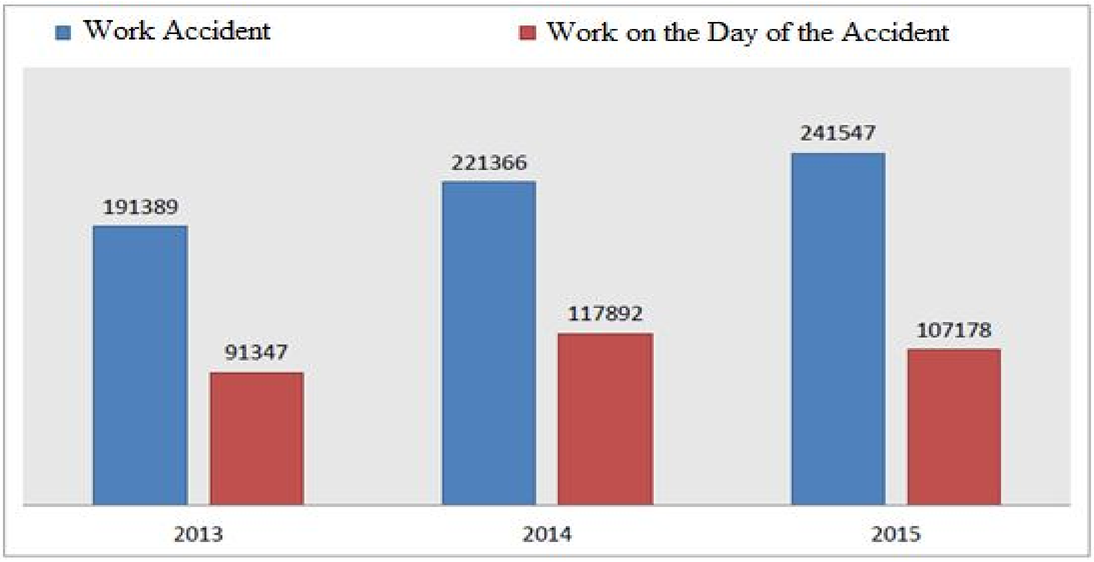


Figure 1.9 The numbers of occupational accidents by year [8].

1.2 Research Objectives and Scopes

The main objectives and scopes of this study are given as follows:

1) To prevent the hazards encountered in occupational health and safety as the methods and technologies used in tunnel construction stages develop and to ensure that work accidents are minimized.

2) Determining the applicability of the specified binary comparison method in tunnel works.

3) Will be met in the work hazards analysis of the tunnel in a healthy manner and so the tunnel systems to contribute to the further development of the method used.

4) As a result, it is aimed to contribute to the development and economy of the country by reducing the possible work accidents in every period and condition.

In Chapter 2, general definitions of tunnels, their development since, tunnel types according to the intended use and construction technique, on the world tunnel samples and occupational health and safety issues in the tunnels has been clarified.

In Chapter 3, the selected Microsoft Office program (Excel) for the specified method and with this program focuses on the characteristics and purpose of the developed binary comparison method.

In Chapter 4, the results of the determined method were presented and discussed.

In Chapter 5, the conclusions of the research were presented.

CHAPTER II

LITERATURE REVIEW

2.1 Tunnels

2.1.1. Definition

The tunnels can be defined as structures that have a defined cross-section, underground passage, which are planned in the project, in order to provide transportation or transmission. Tunnels are used to overcome natural obstacles such as mountainous terrain, rivers and seas, where the roads are not technically or economically feasible in a way that is not affected by climatic conditions with a safe and convenient transportation system. The tunnels were excavated to remove mines in history with modernization were introduced as the waterways, entry-exit routes. In the past, the tunnels were also used for military purposes to break down the fortress walls and to enter the fortress inside. The main uses of the tunnels are special structures such as motor vehicle transportation (Figure 2.1), subway, rail transportation and water transportation (Figure 2.2).

Figure 2.1 Bahçe-Nurdağı tunnel overview (By Musa BUDAK).

Figure 2.2 Artvin - Çoruh hydroelectric power plant transmission tunnel (By haldizinsaat.com.tr).

With the increase of industry and trade, many tunnels have been built, such as both highway and railway crossings, in order to shorten the roads to the mountains, rivers and even to the throat sea bottom. As the population of the city grew, the difficulties caused by the transport of passengers and goods led to the excavation of tunnels under the cities called metro (Figure 2.3).

Figure 2.3 Portugal Porto city subway (By gezilecek.org).

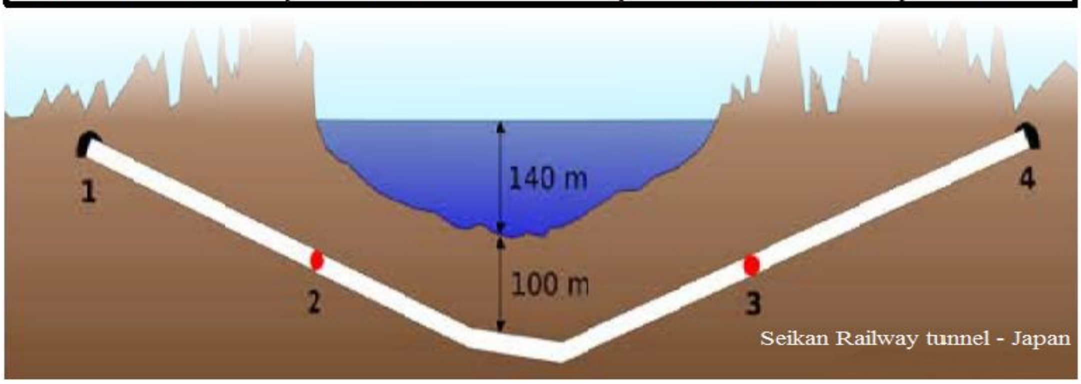
With modernizing, the requirements for the installation of hydroelectric power plants, sewage infrastructure of cities, water pipes and electrical power cables have also increased the need for tunnel construction. It is also a fact that tunnel-shaped passages eliminate the damage of traffic problems, air pollution, noise, animals and plants in cities and are a good refuge.

The application area of the tunnels is the most railway, highways, dams, land and cities that carry water, sewer systems and metros. The world's longest railway tunnel is a 53.900 meter long Seikan tunnel, built in Japan in 1988 [2,9]. The longest road tunnel in the world is the St. Gotthard tunnel in the 16.910 meter long alpine mountains, which opened in Switzerland in 1980 [9]. The two other long tunnels that connect Italy to France in the Alpine Mountains are the 11.700 meter long Mont Blanc tunnels opened in the year 1978 and the 12.890 meter long Frejus tunnels opened in the year 1980 [2,9]. The longest tunnel in Turkey is the Ovit Tunnel, which is 14.2 kilometers long [10]. The longest tunnels in the world are listed in Table 1.1.

Table 1.1 The Longest Tunnels in the World [9].

WORLD'S LONGEST TUNNELS

HİGHWAY			
Name	**Location**	**Length**	**Completion Time**
Lærdal	Norway (Lærdal - Aurland)	24,51 km (15,2 mi)	2000
Zhongnanshan Tunnel	China (Shaanxi)	18,04 km (11,2 mi)	2007
Jinpingshan Tunnel	China (Sichuan)	17,54 km (10,9 mi)	2011
St. Gotthard	Swiss (Uri - Ticino)	16,91 km (10,5 mi)	1980
Arlberg	Austria (Vorarlberg - Tyrol)	13,97 km (8,7 mi)	1978
Xishan	China (Shanxi)	13,65 km (8,5 mi)	2012
Hongtiguan Tunnel	China (Shanxi)	13,12 km (8,2 mi)	2013
Hsuehshan	Taiwan	12,94 km (8,0)	2006
Fréjus	Franch - Italy	12,89 km (8,0)	1980
Maijishan Tunnel	China (Gansu)	12,29 km (7,6 mi)	2009
IRRIGATION TUNNELS			
Name	**Location**	**Length**	**Completion Time**
Delaware	ABD, New York	137 km (85 mi)	1945
Päijänne	Finland, South Finland	120,0 km (74,6 mi)	1982
Dahuofang	China, Liaoning	85,3 km (53,0 mi)	2009
Orange–Fish River	South Africa	82,8 km (51,4 mi)	1975
Bolmen Water Tunnel	Swedish, Kronoberg/Scania	82,0 km (51,0 mi)	1987
Želivka Water Tunnel	Czech Republic	51,08 km (31,7 mi)	1972
Arpa-Sevan Tunnel	Armenia	48,3 km (30,0 mi)	1981
#1 Tunnel	China, Shanxi	43,7 km (27,2 mi)	2011
#7 Tunnel	China, Shanxi	43,5 km (27,0 mi)	2002
Kárahnjúkar Hid. Satrl	Iceland, Austurland	39,7 km (24,7 mi)	2003-2007
RAİLWAY			
Name	**Location**	**Length**	**Completion Time**
Seikan Tunnel	Japan (Tsugaru Strait)	53,9 km	1988
Channel Tunnel	France/Britain	50,5 km	1994
Lötschberg Base Tunnel	Swiss (Alps)	34,5 km	2007
Guadarrama Tunnel	Spain (Sierra de Guadarrama)	28,4 km	2007
Taihang Tunnel	China (Shanxi)	27,85 km & 27,84 km, 2 tube	2007
Hakkōda Tunnel	Japan (Hakkōda Dağları)	26,5 km	2010
Iwate-Ichinohe Tunnel	Japan (Ōu Mountains)	25,8 km	2002
Lainzer/Wienerwaldtunnel	Austria (Viyana)	23,84 km	2012
Daishimizu Tunnel	Japan (Tanigawa Dağı)	22,2 km	1982
Qingyunshan Tunnel	China (Fujian)	22,16 km & 21,84 km, 2 tube	2013



2.1.2. Tunnel Types and Properties

2.1.2.1. Road Tunnels

Much more flexible in terms of route geometry than railway tunnels. Generally, road tunnel projects are projected according to an ± 2% slope [11]. If the traffic volume is low, the slope increases to ± 4% [11]. Higher slopes are not suitable for ventilation (CO, CO2, NO2, emissions etc.) and in terms of vision safety. The cross section of the highway is strictly dependent on daily traffic volume. In the long tunnels, "ventilation" and "fire safety" are the most important elements of the project.

2.1.2.2. Railway Tunnels

In railways, maximum slopes in terms of gravity parameter are 1.2% [11]. The maximum cross section of one or two track high speed train projects is 50 m², 80 m² and 100 m² respectively [11].

2.1.2.3. Metro Tunnels

Maximum capacity of trains to be operated on the tunnel line, train commercial speed, number of seats, comfort degree, number of vehicles, number of car doors and widths, station length etc. depends on the tracking intervals of train arrays, signaling and fee collection systems. A typical cross section for single and double track metro tunnels is 35 m² [11].

2.1.2.4. Hydraulic Power and Water Tunnels

Route geometry (path slope, curve radius) is more flexible than other tunnels. Usually opens in solid rock. Hydraulic power tunnel cross-sectional areas, depending on factors such as drop height, water flow and energy losses, vary between 10 m² and 30 m² [11].

2.1.2.5. Sewer Tunnels

The cross-sectional area of this tunnel system used in city infrastructure systems is 10 m² [11].

2.1.3. Tunnel Opening Methods

2.1.3.1. Classical Methods (18th - 19th Century)

German, American, Austrian, Belgian, British, Italian and Ottoman tunneling methods are in this group. They were widely used in mining until the last half of the 19th century [12]. Excavation is carried out by hand or by means of simple excavating tools, mostly thick, durable timber is used for reinforcement and rust is disposed with small transporters or steam transport vehicles. The excavations are mostly made of multistage, which are partly segmented and come down from top to bottom. Support is performed after the completion of each excavation phase. Although these methods have been abandoned nowadays, many of the known large tunnels were opened using these methods [12]. These methods are largely similar to each other, some of which are briefly described.

German Tunnelling Method (Core Removal): A serial box that opens up from the bottom to the top of each other and is a system that consists of supporting them (Figure 2.4). Opening galleries makes it easy to learn about the units that will be encountered during the excavation progress. In this method firstly after the foundation of the coating is formed, a wall-shaped coating is placed on the right-hand side and then the center is discharged, thus preventing overloads from the sidewalls [12].

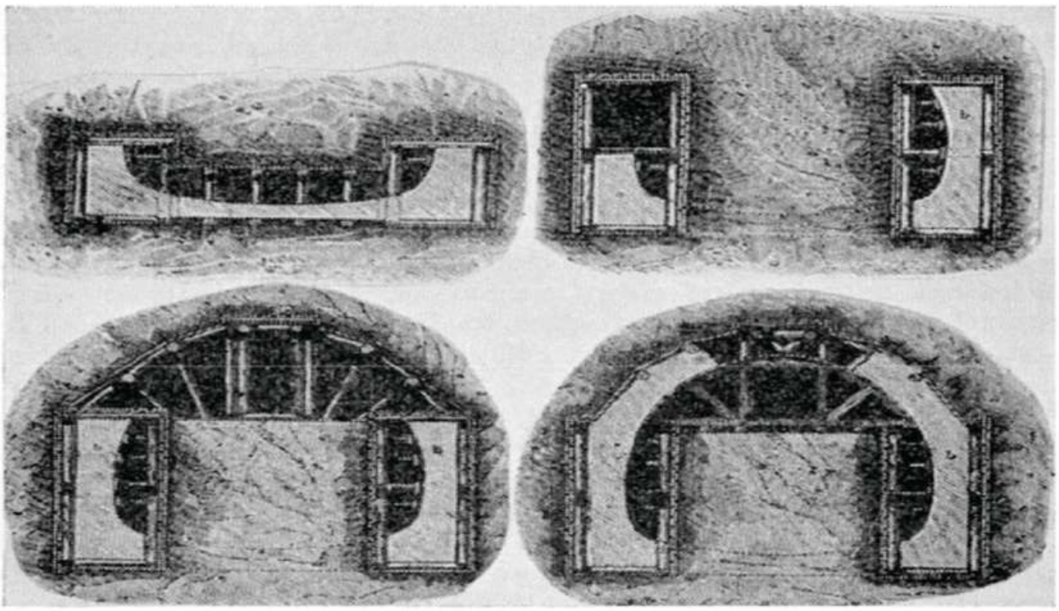


Figure 2.4 German Tunneling Method [12].

Austria Tunneling Method (Cross - Sliding): This method requires a sturdy structure that sits on the upper part of the upper half (crown) of the base center. Then timber support is made for full mirror excavation and with timber support positioned to cover the excavated area, it is placed between robust core support in the center. This method can withstand high ground pressures, but requires a high amount of timber with high strength [12].

English Tunneling Method (Crown-Sliding): In this method, which was excared from the middle part of the upper half, after the excavation of the middle section was completed timber supports were placed here, while the upper side of the timber supports was supporting the intratunnel coating, while the bottom part of the upper half excavation was suppressed (Figure 2.5). As the upper half excavation progresses, additional supports are erected along the excavation perimeter and ground excavation can be made as additional support is made. This system is economical due to the use of timber and allows for full mirror excavation. It can also be applied in many ground conditions. However, it is difficult to apply if there is no low matte load [12].

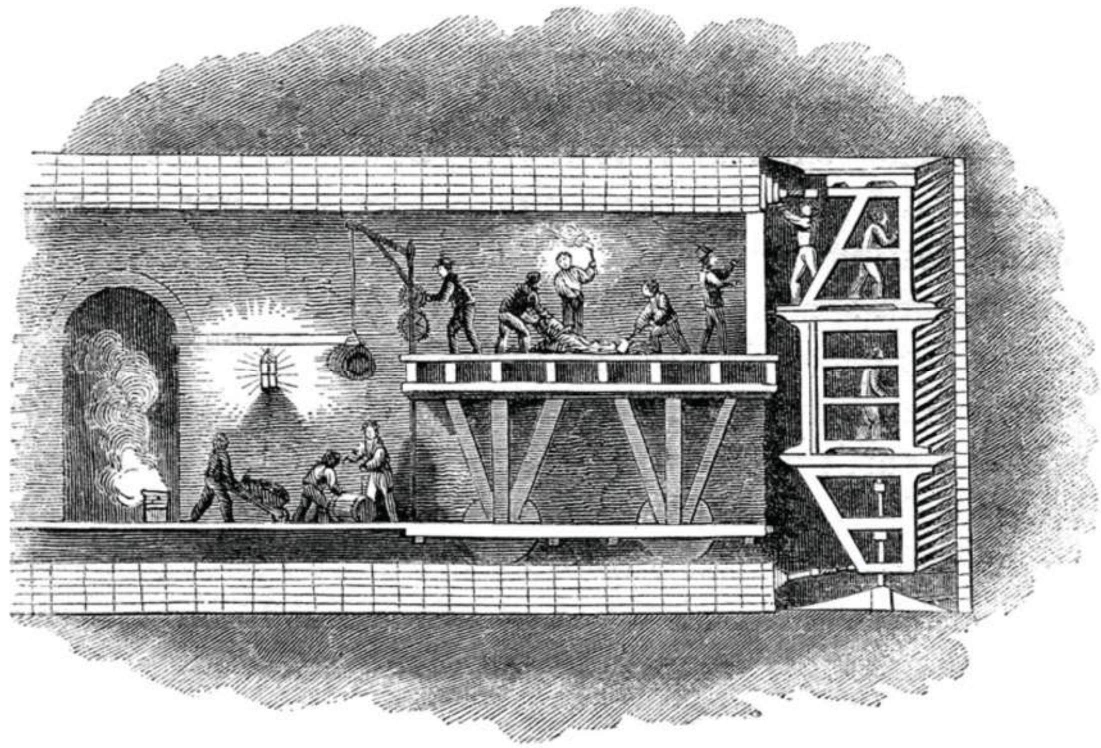


Figure 2.5 English Tunneling Method [12].

American and Italian Tunneling Methods: According to the recent history of the tunnel studies, the methods of American and Italian (Figure 2.6), contrary to the above mentioned methods, have made progress by digging the large section close to the full mirror excavation, so that the excavation cavity is immediately (brick or stone) and thus provide tunnel stability [12].

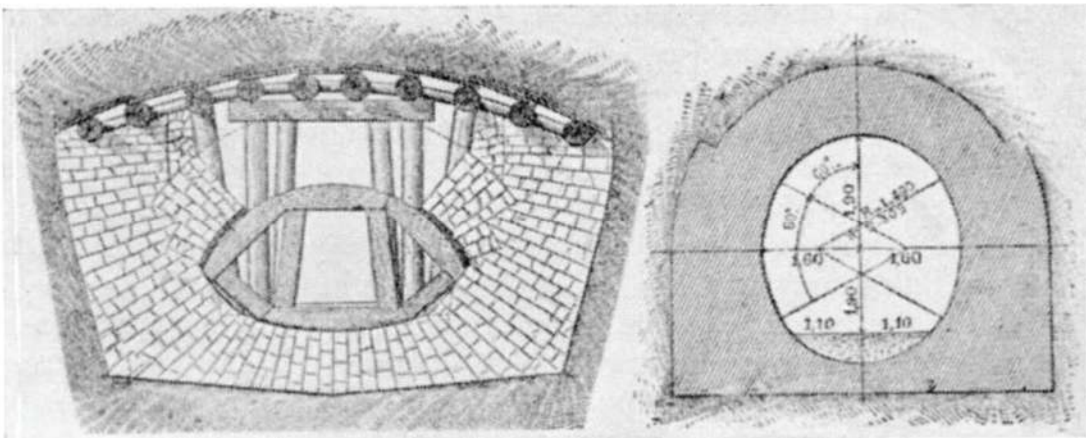


Figure 2.6 Italian Tunneling Method [12].

The two commonly used tunneling methods are NATM and ADECO-RS. Furthermore other than these, it can be called more excavation methods; there are also methods such as drill-explode, open-close, mechanical excavation, tunnel opening machine, excavation, etc. the two methods (NATM and ADECO-RS), which are almost similar but have a different philosophy, have been briefly mentioned.

2.1.3.2. NATM (New Austrian Tunneling Method)

This method was first revealed by Rabcewicz in 1962, but became widespread in 1964 [12]. In particular the first implementation of the method, which emerged from the experience in the Austrian alps, was built in the Frankfurt Metro construction in 1969 [12]. The main philosophy of the method consists of two main elements. The first of these; to support the rock in the underground excavation instead of supporting the rock. In this way, allowing the environment rock to relax, instead of carrying high pressures after the first excavation, it is to provide self-transportation by strengthening the environmental rock with the strengthening elements applied [4]. The easiest way to achieve this is to allow a certain amount of deformations by a flexible coating after the excavation (shotcrete) and then to reinforce it with rock bolts. Other important philosophy is; especially in weak rock conditions, dividing the excavation into different small sections [4,12]. Rabcewicz's philosophy is based on a dynamic project, which includes the basis of action development against deformation characteristics by following the excavation of the surrounding rock behavior. This method classifies the rock or excavation classes in various sources with letters expressed in A, B, and C [12]. However, since this classification is rather subjective, it has heard the need to create a numerical subsection.

2.1.3.3. ADECO-RS

Another method used to open tunnels today is the ADECO-RS, known as "controlled deformation analysis on rocks and floors". This method is raised on the Lunardi side; it is stated that the progressive excavation is not a proper method for tunneling but rather a full mirror excavation should be made. Thus, 3 different rock behaviour is defined after full mirror excavation. These; rupture or block drop is the shape of the mirror swelling or separation and the flowing ground. According to Lunardi, the mirror must be supported. Because it serves as the key to the behavior of the tunnel mirror. Especially in trapped ground conditions, understanding of excavation-mirror behavior is the secret of successful tunnel excavation. According to this method, it is recommended to support in-tunnel deformation without too much permission, since deformations cannot be stopped once started. [12].

2.1.4. Construction Works in Tunnels

Before proceeding to tunnel construction phases, we can explain the terms used in tunneling works;

Tunnel: They are underground structures with different dimensions and slopes of less than 30 °, which are connected to the earth with two sides.

Gallery: Unlike the tunnels, there is no condition for such gaps to be connected to the earth.

Well: They are underground structures, which are close to vertical or vertical.

Ground: The name given to the environment where the excavation was made.

Stirrup: The stirrup line is the level at which the belt is placed on the edge feet and the level at which it is determined is called the level of stirrup.

Stirrup Line: It is the cross section of the horizontal position that goes from the point to the right and left of the tunnel. This line is equal to the exact diameter in the horizontal state passing through the central tunnels and coincides with it.

Center Line: It is a plane intersection that divides the tunnel into two equal parts.

Kalot: Part of the cross sectional area above the stirrup level.

Stros veya Core: The middle part of the most cross section area is below the stirrup level.

Ano: In the implementation of any method, it is called a tunnel part in which a process is carried out at once. Ano length is 1.5 m-9.0 m depending on the type of soil and the method applied [11].

Raft: It is the base part of the tunnel which is usually given the opposite arch shape under the edge legs of the tunnel in order to spread the load to the tunnel.

Edge Feet: The side walls are from the base to the stirrup level.

Arch: It is the ceiling part which rests on the edge legs of the building.

Keystone: The highest part of the arch on the most cross-section axis is the structure woven from the edge of the feet, which closes with a stone called "keystone ". The general structure of the tunnel system is shown in Figure 2.7.

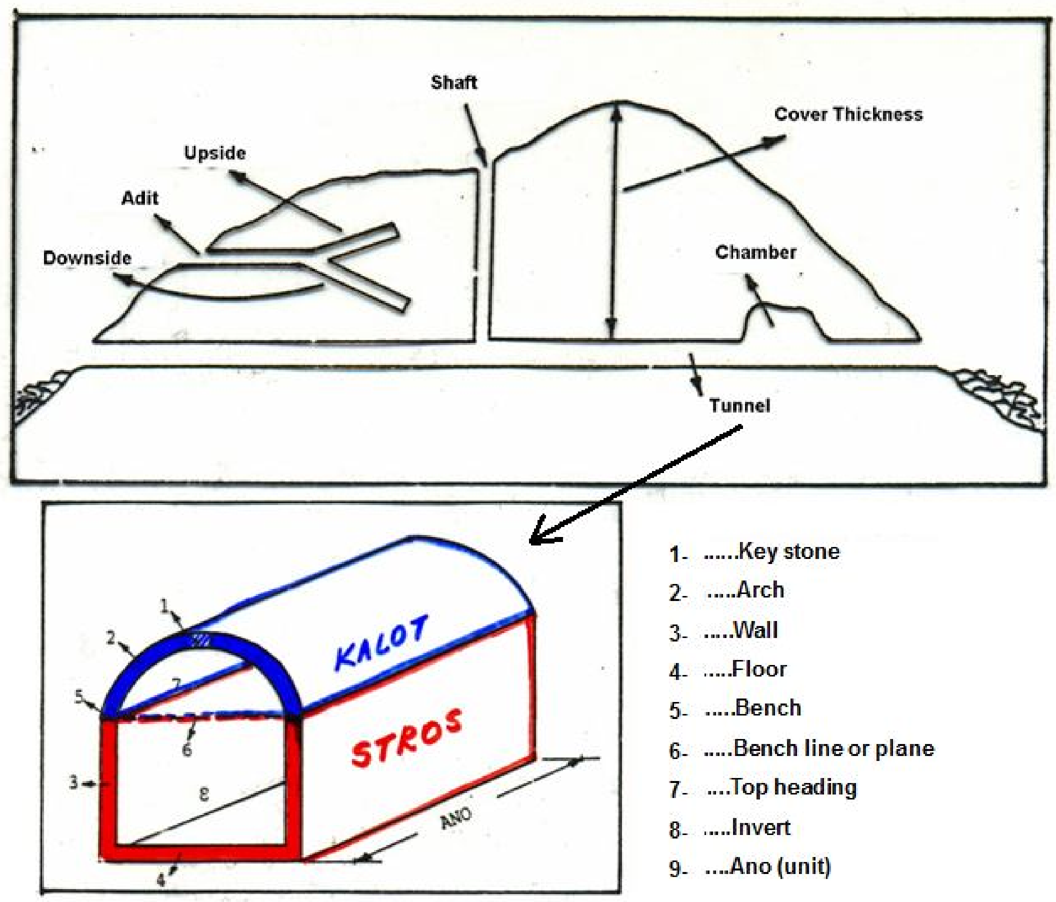


Figure 2.7 Two and Three Dimensional View of the Tunnel [13].

2.1.4.1. Preparation Steps

In the construction of tunnels, there are many works such as construction of site plant, blasting works, excavation and fortification works, shotcrete, tunnel mold works. (Figure 2.8, 2.9, 2.10, 2.11, 2.12).

Figure 2.8 Tunnel construction site [11].

Figure 2.9 Drilling holes for insertion of explosives [11].

Figure 2.10 In tunnel scotcrete process [11].

Figure 2.11 Installation of explosives in the tunnel mirror [11].

Figure 2.12 In tunnel mold Works [11].

2.1.4.2. Ventilation

The ventilation system in the tunnels is examined under two headings, which are temporary and continuous. The temporary ventilation system is divided into three as blower, absorbent and absorbent blower. (Figure 2.13, 2.14, 2.15).

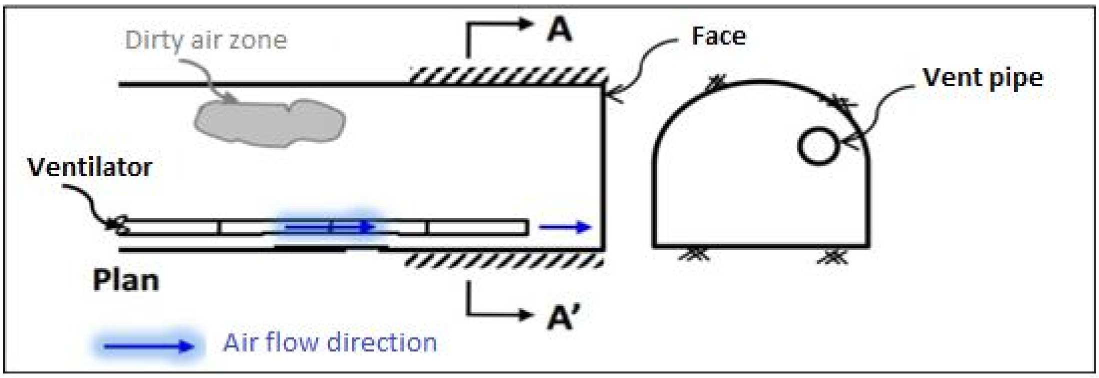


Figure 2.13 Blower ventilation [11].

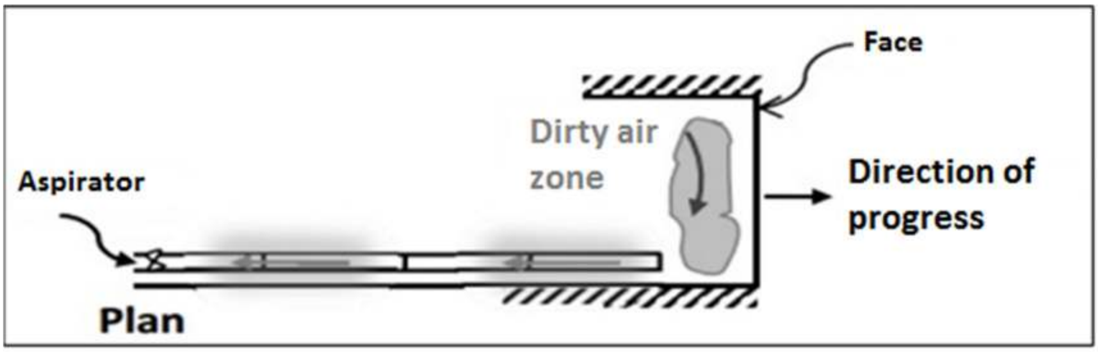


Figure 2.14 Absorbent ventilation [11].

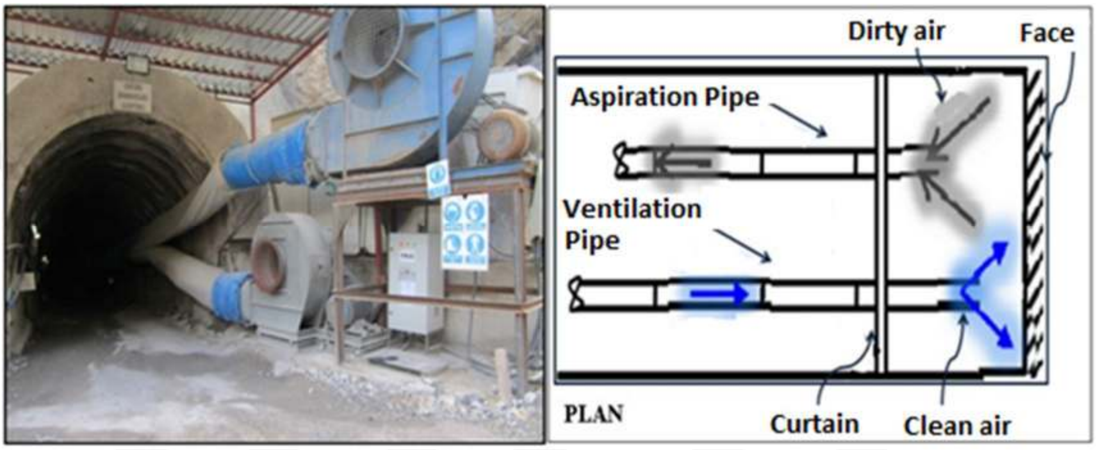


Figure 2.15 Absorbent blower system [11].

2.1.4.3. Electrical and Lighting Works

Together with the tunnel excavation works, the electrical panels are installed inside and outside of the tunnel to provide illumination within the tunnel. Generators are installed outside the tunnel. The electricity from the main panel installed outside the tunnel is transmitted to the secondary panels in the tunnel together with extension cables. In the tunnel, electricity is taken from the secondary panels if working with electrical work equipment. As there is water output in the tunnel, the cables transmitted into the tunnel must be withheld to prevent electricity from contacting the water. The illumination in the tunnel must be exposed to be protected from the external mechanical effects. In addition, according to the type and amount of gas output in the tunnel, explosion proof lighting or work equipment should be made of exproof material.

2.1.4.4. Water Drainage

One of the main problems of tunnel construction is the water that emerges from the ground. In order not to affect the work environment and the work being done, it should be ensured that the water leaking out from the excavated ground is evacuated. Water from the excavated ground should be drained out of the tunnel with the help of water pumps. Placing water pumps in the tunnel is an ongoing study with tunnel excavation.

2.1.5. Advantages and Disadvantages of Tunnelling

2.1.5.1. Advantages of Tunnelling

The tunneling method gain certain advantages compared with other methods, which are mentioned below:

1. The tunneling procedure is more economical in nature, compared to open cut trench method when the depth is beyond a limit.
2. The surface life or ground activities like transportation are not disturbed when tunneling is undergone.
3. The method ensures high-speed construction with low power consumption.
4. Reduces noise pollution.
5. These methods have freedom from snow and iceberg hazards, in areas of high altitudes.
6. Surface and air interference is restricted for tunnels.
7. Provision of tunnels with easy gradients, help in reducing the cost of hauling.
8. For the transportation of public utilities, tunneling method has a remarkable advantage compared to the bridge.
9. The dangerous open cut to a nearby structure, when it is needed, is solved by the tunneling method.
10. The tunneling grant greater protection in aerial warfare and bombing conditions.
11. Tunnels carry water to generate power.

2.1.5.2. Disadvantages of Tunnelling

The tunneling method gains certain disadvantages, which is due to its complexity and difficulty. Some of them are:

1. The initial investment cost for commencing the tunnel is high compared to the open cut method.
2. Highly skilled and experienced designers and engineer team only will work best for this operation.
3. Higher and constant supervision from the start to the end of the tunneling project is necessary without any compromise.
4. Highly sophisticated and specialized equipment are necessary to perform the tunneling operations.
5. Specialized equipment and methods are required for execution of the work
6. It is necesary to have skilled labors and technical supervision of high order for construction of the tunnels.
7. Construction of tunnels requires long time in completing as compared to open cut.

2.2. OHS (Occupational Health and Safety) in Tunnel Constructions

2.2.1. Danger and Risks in Tunnel Construction Works

2.2.1.1. General Hazards and Risks in Tunnel Excavations

The impact of moving vehicles on employees and objects, the failure of vehicles and work machines to work with reverse warning alerts, pedestrian or employees entering the working area, work machine during excavation work without traffic control, the emergency plan has not been prepared, such as jams and crushes during the change of TBM (Tunnel Boring Machine) heads can occur during the tunnel excavation stages of many hazards and risks [14,15].

Possible hazards and risks in tunnel construction are given in Table 1.2.

Table 1.2 The risks and possible consequences of tunnel work [5].

Danger	Source of Danger and Risk	Risk	Result
Explosive gases (Methane - Natural Gas)	-Methane - Natural Gas discharge -Explosion of gas due to leakage and insufficient ventilation	- Explosion - Combustion - Poisoning (CO)	D - LL - I
Suffocating gases (Carbon Dioxide, Nitrogen Oxides)	- Carbon Dioxide discharge - Suffocating gas is concentrated	- Suffocation	D - LL - I
Toxic gases (CO, hydrogen sulfur, nitrogen oxides etc.)	- Hydrogen sulfur etc. Toxic gase discharce - Toxic gas is concentrated in certain regions (CO, Nox, H_2S etc.)	- Poisoning	D - LL - I
Flooding	Karstic spaces filled with water, Floods from shafts and tunnel	- Drowning	D - LL - I
Dent	Dent, clearance dent block drop, scale drop	- Scale fall on - Impact - Pressure	D - LL - I
Closed and restricted work environment	Fire, flash, explosion, flooding, dent etc. absence of escape and shelter in cases	- Suffocation - Poisoning	D - LL - I
Heavy objects in motion	Work machines, forklift, cranes, trucks and carriers	- Fall over - Impact - Pressure	D - LL - I
Inflammable explosive substances	Explosive substances, Gas leakage from welding equipment	- Taking fire - Explosion	Multiple D - LL - I
Height	Fortification, drilling, scale control etc. work at high work	- Fall	D - LL - I
Moving machine assemb	All work equipments and work machines	- Machine jam	D - LL - I
High-voltage electricity (>65 Volt)	Electrical system, electrical equipment	- Electric shock	D - LL - I
Gases under pressure	Compressor, pneumatic equipment	- Explosion shock pulse - Shrapnel effect	D - LL - I
Liquids under pressure	Work machine, hydraulic equipment	- Splash	D - LL - I
Flammable substances	Liquid fuel, engine hydraulic oil, cable, plastic pipe parts	- Fire - Exposure to toxic gas	D - LL - I
Unsafe floor	Muddy, greasy ground	- Fall - Slipping	D - LL - I
Harmful dusts	Harmful dusts from formation during drilling or loading operations	- Exposure	D - LL - I - OD
Noise - vibration	All work equipment, piercing - breaker machines	- Prolonged exposure	OD
NOTE D: Dead, LL: Limb Loss, I: Injured, OD: Occupational Disease			

2.2.1.2. Dangers and Risks in Working Inside Tunnel

Power failure, gas and explosion, insufficient ambient illumination; employee shift, drop, etc. conditions such as harmful environmental conditions (gases, dust, smoke and steam), loss of consciousness due to insufficient ventilation or fainting, harmful gas poisoning, insufficient support and collapse due to wicker flooring, asbestos exposure, electric shocks, floods occur.

Blasting work in the tunnel; insufficient control result of suspended material falling on employees, inexperienced, non-authorized personnel to steer the blasting work, the employees during the blasting to avoid the safe distance, after blasting in the tunnel is insufficient ventilation, entering the working area after a certain period of time without detonation, lack of communication during blasting, noise during blasting, ground collapse, explosive filling of the mirror part of the tunnel during explosion and fire, during blasting material explosion, high heat and fire hazard after blowing, conditions such as the exposure of harmful gases after the explosion occurs.

Studies during the transport of material after blasting; material drop due to the lack of necessary controls in the tunnel, equipment accidents due to heavy loading of trucks, the presence of hazardous gas and dust in tunnels without adequate ventilation after the explosion, work equipment accidents due to the limitation of the maneuvering area of the work equipment, as there are no reverse warning lights on the work equipments, as the employees are crushed and conditions such as the collapse of supported areas during material transportation.

Ken removal in tunnel; dropping material during ken removal, jam of the employee during the ken removal in the work equipment basket, there are situations such as the fall of the worker who goes out and dismantles the ken in the ladle emerges.

Work done with hand tools in tunnel; improper use of tools, in places with inadequate lighting in the tunnel as a result of the random disposal of hand tools cut and injuries, electric shock in electrical hand tools, short circuit in hand tools such as occur.

Welding and cutting works in the tunnel; fire and explosion resulting from the source, employees do not use appropriate PPE, employees exposed to arc rays from the source, employees from the welding machine to electricity, equipment failure, because of the gas from the source to work respiratory danger, welding tubes used for the delivery, tubes used for welding (oxygen, propane, etc.) combustion and explosion, such as the risk of explosion of fatty hand-woven oxygen tubes are emerging.

Panels installed in tunnel; the doors of the panels are not locked, the cables used in the panels are worn out, the boards are not leakage current relay, such as the boards are in contact with water on the floor.

Communication and emergency warning systems; emergency warning hooter system to warn employees in emergency situations, outside the tunnel employees have no telephone line for communication, hazardous gas evacuation warning system is not like such conditions.

Tunnel ventilation system; lack of ventilation system as a result of respiratory distress, the ventilation system is far from the working area, ventilation pipes due to cracks and tearing of the air is not fully transmitted, despite the clean air in the tunnel is dirty air is not ejected, as a result of the failure of the power supply system does not activate the ventilation system stops.

Supporting works in tunnel; when spraying the concrete, the employee is exposed to the harmful materials of the concrete, crushing in the workings of the sealants, etc. in the case of mold work, crushing and compressing, falling from high to high in the mold work, material drop in the mold work, mold collapse occurs in the mold work.

No personal protective equipment (PPE); respiratory diseases due to the lack of mask in the tunnel, falling from high due to not wearing seat belts, not using a barrier against material fall, not using protective mask and glasses in welding work, not carrying oxygen mask for emergency situations, not using suitable work shoes, not using suitable gloves and contact with concrete as a result of skin injuries occur.

2.2.1.3. Dangers and Risks in Working Outside Tunnel

Storage and transportation of explosives; in case of fire and explosion in the explosive material store, the explosive is carried in an inappropriate way, the capsules and suppositories are carried in the same place, and the explosives are carried by unauthorized persons.

Landslide; landslide as a result of the worker to remain under the ground, not enough slope as a result of landslide, as a result of soil shift tunnel entrance exit closure, office and accommodation places such as the establishment without consideration of the possibility of landslide.

Energy systems; combustion and burns as a result of contact with the generator, electrical shock as a result of contact with the generator, fire of the generator, explosion of the generator and the emergence of harmful gases as a result of the operation of the generator can be listed as.

In concrete plants; absence of emergency stop wire on conveyor belt, loss of employee limb during cleaning of conveyor belts, accidents during cleaning of concrete mixers, employees falling into the collapse pools established in concrete plants, concrete silos high drop, electric shock in the control center and a fire hazard in the transformer center can be listed as.

Work in the vehicle maintenance and repair workshop; maintenance situations such as jams and squashes during repair, fire and explosions during welding work and fire and explosions during oil exchange.

2.2.2 Work Accidents and Other Issues in Tunnel Construction

2.2.2.1. OHS Problems in Tunnel Constructions

Ventilation; because there is no connection in the tunnels too long, only fan ventilation prevents adequate ventilationIf the work is done by the conventional drilling-blasting method, the gases formed after the blasting and the exhaust gases generated by the work machines cause quite problems in the working environment. Lack of redundant fantubes and redundant energy sources, as well as leakage and tear in fantube pipes, significantly increase the risk of working.

Evasive-Approach; the tunnels which are opened from a few kilometers to 10-15 kilometers are often operated simultaneously from two ends and there is no shafts, guide tunnel, approach tunnel or escape [11]. This is a factor that prevents recovery efforts in the event of a possible negative situation.

Control Drilling; geological survey and control drilling are not carried out adequately in the tunnel project route area. This situation reveals problems such as karstic space, dent, gas discharge and flooding during construction.

Tunnel Portals; tunnel inlet and outlet mouths often contain hazards and risks such as slope stability, landslide, slippage, water and flood flooding, etc. In addition, civilian (hunter, shepherd, traveler, inquisitive, etc.) people should be prevented from falling, material etc. during their wandering around the tunnel entrance. There is no precaution in the project for the protection of many tunnel constructions with barriers to wire mesh etc.

Danger of Dent; most of the time, a surprise dent can occur in well researched tunnel projects. These are caused by pressures over the computed fortification and tunnel coating values from time to time [15].

Flood; geologically, it is possible that a sudden flood of water will occur as a result of not investigating the karst cavities that are likely to have groundwater. It can occur as a result of the sudden break of karst cavities in the form of underground lakes [15].

Hazardous Gas Discharge; on the tunnel project route, possible to explode gas (methane, natural gas, etc.) and other suffocating (carbon dioxide, etc.) and toxic (hydrogen sulfide, etc.) from formations containing gas, a sudden gas discharge or leakage into the tunnel is likely to occur is one of the dangers. There is a risk of choking and poisoning if the equipment used in the tunnel is not suitable and employees are not adequately equipped with rescue equipment.

Working Time; 37,5 hours of work per week in underground mines is not applied in tunnel construction [11]. In addition, many dams and tunnel construction daily 11-12 hours and 7 days a week work is done, week holidays are known to be done at the end of the month or every 2 months [11].

Ex-Proof Equipment; as there is not enough research about the possible explosive gases in the tunnel, all machinery and equipment used in the tunnel and not selected according to the standards create a danger in the future [15].

Rescue Team; in the event of a very long tunnel construction failure, the rescue team and the necessary equipment are very important in terms of starting the rescue as soon as possible.

Oxygen Individual Rescue; in tunnel constructions, which are especially gas-hazard, and in tunnel constructions which are likely to cause vehicle and installation fire, spare-oxygen individual rescuers equipment should be used in replacement stations as much as the number of workers working in tunnel.

Remote Monitoring System; the use of remote monitoring and control systems in tunnel construction has become quite widespread due to the development of electronic systems. The use of these systems has become a legal necessity in most developed countries. In our country, the use of such systems is a necessity in terms of safety.

Power Cutting Equipment; in case of emergency and explosion gas etc. the system must be automatically cut.

Mining-Geological Engineer Commissioning; explosion, detection, ventilation, control of dangerous and harmful gases in closed areas, etc. mining engineers are experts in business. The geological situation of the route tunnel, control, drilling, etc. subjects fall into the field of Geology Engineering. For this reason, mining and geological engineer must be employed in tunnel construction.

Shotcrete application in Tunnels; shotcrete is applied before drilling a new hole in the tunnel mirror and before the fortification on the tunnel wall. Shotcrete is thought to be solid as concrete by looking at the appearance of the places applied but the concrete coating, tunnel mirror or cracks in the ceiling can be caused by the risk of falling ken masks and continue to work without taking any other measures. Most of the time, even after this operation in the tunnel mirror, the ceiling or the tunnel side wall of the migration, ruptures or rashes may occur.

2.2.3 Tunnel Construction Work Necessary Precautions

2.2.3.1. Precautions in Working Inside Tunnel

Suitable pedestrian routes must be made and marked for transportation of employees in the tunnel. Should be ensured to stay away from moving vehicles, if walking into the tunnel, continuous oxygen measurement should be done in the road route, if the measured value is less than the limit value of employees evacuation should be provided. If there is an inclined region, stairs should be made in order to prevent employees from falling by sliding, and if shaft well is opened to reach the tunnel, the seafarer type stairs (railing stairs) should be made in order for the employees to descend from the shaft. Workers should be given safety belts, workers should be registered in the tunnel entrance, workers should be provided oxygen masks which they can use in case of emergency against sudden oxygen drop in the working areas. Employees should be given dust masks and gas masks. If there is a different gas outlet or if the specific working result is measured in a different gas environment, the employees should be given masks accordingly. Most importantly, employees should be given training and information before they start to work. Vehicles and work machines should be reversing the signal and the flag should be provided traffic control. Only authorized person should intervene in power failure and lighting. Emergency lights should be installed against power failure, an authorized supervisor should constantly check the lighting inside the tunnel, appropriate stacking of the materials used in the tunnel should be done to prevent the employees from falling where the lighting is insufficient. Gas values in the tunnel against gas explosions must be measured continuously with gas measuring devices, measured gas values must be recorded. Ventilation systems must be in continuous working condition, if the elevator will be used to descend from the shaft, the system should be installed in accordance with TS-EN 12159: 2013 standard, and the shaft's mouth area should be surrounded with scarecrow to prevent workers from falling.

Explosion studies in tunnel; blasting must be done and controlled by authorized persons, explosives should be placed in accordance with the tunnel mirror area. Do not approach the electric components when drilling with jumbo, the jumbo is to be rinsing at a safe distance from the stone ejections while punching, the ear protector should be given to the employees due to the noise caused by the jumbo drill. As little as possible during the insertion of explosives should be kept in the tunnel, the generator must be active when placing explosives, appropriate warning signs should be set, ventilation system should be interrupted during blasting. Employees should be informed in advance about what needs to be done otherwise, necessary precautions should be taken against the risk of fire, ensuring that no one is in the tunnel before blasting. Blasting should be done after ensuring that everyone is at a safe distance, if the blasting zone is close to the residential areas within the city, the warning beacon must be set against vibration. After blasting, ventilation systems should be activated and if appropriate conditions are met, the authorized person should enter the blasting area under control. Gas detectors must be activated after blasting, check if support elements are damaged after blastin. The possibility of flow in the mirror section of the tunnel should be checked, energy and lighting systems of the working area after blasting should be checked. Appropriate ear protectors should be given to employees to be protected from noise.

During the transportation of material after blasting; in the tunnel, it is necessary to make walking paths for the employees to enter comfortably, ventilated against dust and harmful gases in the tunnel and gas measurement should be done. After blasting, the remaining ken in the tunnel should be checked and removed. When people pass through the tunnel, the machines should stop, people must move past the standing machine, then the machine should act. The removal ken should be hung into the tunnel. If the tunnel diameter is large, the ken removal should be done with the appropriate lifting cranes, the worker should be working by attaching the seat belt in the crane basket. The work machines used in the tunnel should not be used without operator certificate, the work equipment used for the transportation of the material should be checked and the defective ones should be corrected. Do not overload the trucks that carry the material, reduce the effect of smoke from the exhaust of the work machines, suitable respiratory masks should be given to employees. The worker rotation must be provided, there should be a pointer to the work machines in the tunnel, the appropriate maneuvering areas should be created in order for the work machines to manoeuvre.

In welding work in the tunnel; welding work should not be carried out without obtaining approval from the competent person that the air is suitable in the working area. The welding machine must be checked if there is any malfunction or electrical leakage should be corrected, the employee doing the welding work should use the appropriate personal protective equipment (masks, gloves, etc.). The necessary system must be installed to destroy harmful gases from the welding. The tubes used for welding should not be placed randomly, tubes should be held upright, tube should be brought up to be used in the tunnel, excess should be stored outside the tunnel.

The welding tubes should have recoil safety valves against fires and explosions. To avoid fire and explosion in the tunnel, the welding job should be given a break if the welding blower overheds. The water in the tunnel should be considered when welding is done, as dry as possible should be ensured.

Energy in the tunnel; the panels inside the tunnel must be locked and no one else should intervene by the authorised person. The authorized person who will interfere with the electrical panel should be given a insulated based shoe, electrical panels should not be placed in random tunnels and should be hanged in the tunnel to appropriate places. Electric panels must have leakage current relays against electrical leaks, electrical panels and electrical work equipment must be grounded appropriately. Electrical cables that extend into the tunnel should not be worn, cables that are worn should be replaced, cables should be routed through the wall, cables should be prevented from contact with water. If there is hazardous gas in the tunnel, the lighting used must be made from exproof material.

Communication and emergency warning systems; in case of emergency, communication systems (such as radios, telephone lines, etc.) that may inform the inside of the tunnel or outside the tunnel must be established. In the tunnel studies that may flood water, the system should be established to measure the water level at the point where water will come, the limit value of the water level should be determined and in cases where the water level exceeds the limit value, evacuation of the employees in the tunnel should be ensured. Fixed gas meter systems that transmit the amount of gas in the tunnel to the control center should be installed, in cases where the amount of gas exceeds the limit value, evacuation of the employees in the tunnel should be provided.

Supporting works in tunnel; shotcrete should be sprayed against falling parts or blocks on the remaining mirrors. When spraying shotcrete into the tunnel the operator should stop at sufficient distance while shotcrete should be given personal protective equipment suitable for employees to avoid the affected concrete workers (masks, glasses, etc.). Employees should stay away from the electric parts of the shotcrete machines, and they should be stacked regularly so that the shoring do not fall on the employees. The installation of the Iksa and steel mats should be done with the help of a basket crane, the personal protective equipment suitable for the employees should be provided during the installation (gloves, barret, shoes, etc.). Installation shoring assembly instructions should be hung inside the tunnel. The ear protector should be given to the employees who are protected from noise during intra tunnel buloning. Bulon assembly should not be made in bucket bucket, suitable platforms must be installed for installation. In order to prevent them from falling from high in the tunnel mold work, collective protection measures should be taken in places at risk of falling. Where collective protection measures cannot be taken, life line should be established and employees should be given safety belts. In the studies made in tunnel mold with TBM (Tunnel Boring Machine) [2,14,16,17], workers against compression should be removed from the area while placing segments of the branches of TBM (Tunnel Boring Machine) [2,14,16,17].

Preparation for emergency action plan; the emergency action plan must be prepared and submitted before work starts, emergency plans must be revised every 6 months by the occupational health and safety unit (OHSU). The emergency action plan must be renewed after the accident and the event and should be added to the plan if there are no accidents or incidents. In tunnel emergency escape locations and gathering places must be identified, trainings should be given to employees on emergency situations. Management or employer must publish a statement and inform the employees continuously, the competent staff should check all the activities. Emergency warning systems should be installed and checked periodically, communication lines should be checked continuously.

2.2.3.2. Precautions in Working Outside Tunnel

Explosive storage; explosion storage should be installed in a place away from the working area, and the explosive storage should be surrounded appropriately. Unauthorized persons must be prevented from entering, if there are metal and radiation emitting devices (mobile phone, lighter, etc.) against explosions on the person who enters the explosive storage. The lock of the blast storage must be sealed in a way that does not spark, and scissors that do not spark in the cutting business should be used. Suitable fire extinguishers should be kept in the explosive tank and the instructions for use should be hanged in a suitable location.

Landslides and material drop; non-tunnel floor movements must be monitored continuously, if a dangerous situation is observed, the operation should be stopped.

Necessary measures should be taken, appropriate work around the tunnel should be made of slopes. The ken on the slopes should be removed. If the hillside around the tunnel work is a solid ground, it is not necessary to hillside the slope against the fall of the material should be shotcrete or the security net should be laid.

Energy systems; only authorized persons should intervene, generators should be turned around to prevent unauthorized persons from entering. Static grounding should be done against electric shocks of generators and periodic controls should be done. Generators should not be operated by wet hand and should not be touched to moving parts. Fire extinguishers should be kept near the generator, the instructions for use should be hung in appropriate places. The fuel should not be filled while the generators are operating.

Concrete plants; conveyor belts should have emergency stop ropes. A sailor type ladder must be constructed to reach the concrete silos. To prevent concrete mixers from falling in the slope, vehicle stopper bumps must be made to the edges of the slope. In order to prevent electric shock from transformers in the concrete plant control center, there must be an insulating mat on the floor. Only authorized persons should enter the control center and emergency stop buttons should be located in the control center which can completely stop the system in case of emergency. The grill should be placed in the bunker mouth to prevent employees from falling.

CHAPTER III

PROGRAMME OF WORKING

3.1. Program

3.1.1. Microsoft Office Program (Excel)

Microsoft Office Excel program has been used in studies to determine the importance of potential hazards and risks by binary comparison according to a certain systematics.

3.2. Method

3.2.1. Binary Comparison Method

The binary comparison method used in this study; in order to describe the risks related to health and safety in the tunnel works, the hazards that could be encountered in the tunnel construction stages were determined. In the tunnel construction stages, the potential risks that could be encountered in terms of occupational health and safety were determined. Then the measures planned to eliminate these risks were determined as substances. The result of this data obtained by taking advantage of the resulting dangers and measures in itself according to the degree of importance rating of the binary compared to the approximately 5 experts were given a study rated by.

3.2.1.1. Risk Assessment Table

In the table prepared for the evaluation of possible risks posed by the hazards encountered in tunnel construction phases;

1. Definitions of activities carried out in tunnel construction phases,
2. The definitions of possible hazards arising during these activities,
3. Definitions of possible risks that these hazards may cause,
4. Measures that are planned to control or eliminate these risks,
5. The degree of importance of the planned measures and hazards to be used in the binary comparison is given.

Example of risk assessment table for some activities in the tunnel studies are given in Table 1.3.

Table 1.3 Example of risk assessment table (By Musa BUDAK).

ASSESSMENT OF RISK BASED ON BILATERAL COMPARISONS			WHO MADE THE ASSESSMENT	
EACH ITEM ACCORDING TO THE SEVERITY OF EACH OTHER	1 (EQUALLY IMPORTANT), 3 (MORE IMPORTANT), 5 (VERY IMPORTANT), 7 (VERY POWERFUL IMPORTANT), 9 (ABSOLUTE IMPORTANT)	1/3 (MORE UNIMPORTANT), 1/5 (VERY UNIMPORTANT), 1/7 (VERY POWERFUL UNIMPORTANT), 1/9 (ABSOLUTE UNIMPORTANT)	DATE OF ASSESSMENT	
	2, 4, 6, 8 DOUBLE NUMBERS INDICATE INTERMEDIATE VALUES	1/2, 1/4, 1/6, 1/8 NUMBERS INDICATE INTERMEDIATE VALUES	PERSONS UNDER RISK	Operators, Contractors and Visitors
DESCRIPTION OF THE ACTIVITY	HAZARD DESCRIPTION	RISK DESCRIPTION	MEASURES PLANNED TO CONTROL OR ELIMINATE RISK	

3.2.1.2. Binary Comparison Table

In the table where the measures and dangers planned to eliminate the possible risks encountered in the tunnel construction stages are subjected to a binary comparison among themselves;

1. Determining the degree of importance of the planned measures to prevent each potential risk by being subject to binary comparison,
2. The determination of the degree of importance of the identified hazards is subject to binary comparison.

Example of binary comparison table for some activities in tunnel studies are given in Table 1.4.

Table 1.4 Example of binary comparison table (By Musa BUDAK).

Note: Dangers and measures that have more than 1 item in the detected dangers are subject to comparison.																		
BINARY COMPARISON		EXPERT SCORE																
Radioactive leakage that may occur on the nuclear device used in the land tightness control																		
Which measure	Compared with which measure	1	2	3	4	5	6	7	8	9	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9
1	2																	
	3																	
2	3																	
The effect of gas occurring during the preparation of sulphur in concrete sample		EXPERT SCORE																
Which measure	Compared with which measure	1	2	3	4	5	6	7	8	9	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9
1	2																	

EACH ITEM ACCORDING TO THE SEVERITY OF EACH OTHER	
1 (EQUALLY IMPORTANT), 3 (MORE IMPORTANT), 5 (VERY IMPORTANT), 7 (VERY POWERFUL IMPORTANT), 9 (ABSOLUTE IMPORTANT)	1/3 (MORE UNIMPORTANT), 1/5 (VERY UNIMPORTANT), 1/7 (VERY POWERFUL UNIMPORTANT), 1/9 (ABSOLUTE UNIMPORTANT)
2, 4, 6, 8 DOUBLE NUMBERS INDICATE INTERMEDIATE VALUES	1/2, 1/4, 1/6, 1/8 NUMBERS INDICATE INTERMEDIATE VALUES

BINARY COMPARISON		EXPERT SCORE																
Which hazard	Compared with which hazard	1	2	3	4	5	6	7	8	9	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9

CHAPTER IV

RESULTS AND DISCUSSIONS

This study was inspired by Turkey' s longest railroad tunnel to be the Bahçe-Nurdağı rapid train project. This project has 2 tube passages, each of which is 10 kilometers long. In the study on a project with these features, the data about the dangers that may be encountered during the tunnel construction stages and the solutions to the risks that these dangers may cause are analyzed according to their importance by 5 experts by using the binary comparison method among themselves. All the data obtained as a result of these assessments have been added to work in the CD environment and the conditions mentioned below have been identified.

4.1. Risk Assessment Results

As a result of the risk assessment work done;

1. Risk assessment of all activities performed in the tunnel construction works was carried out and the measures that could be taken were determined.
2. The preventive activities were mentioned in the form of substances and the sector employees were tried to be aware of the potential risks of tunnel work.
3. A sensitive rating system has been created to ensure that the measures to be taken for hazards and risks will be subjected to binary comparisons between them.
4. With the risk assessment study for tunnel studies, the risk assessment studies identified in previous studies were updated and then the risk assessment studies related to tunnels were aimed to contribute.

Risk assessment studies for some activities in the tunnel studies are given in Table 1.28, Table 1.35.

Table 1.28 Risk assessment study for the electrical work activities (By Musa BUDAK).

Table 1.28				
ELECTRICAL WORKS				
ASSESSMENT OF RISK BASED ON BINARY COMPARISONS			WHO MADE THE ASSESSMENT	
EACH ITEM ACCORDING TO THE SEVERITY OF EACH OTHER	1 (EQUALLY IMPORTANT), 3 (MORE IMPORTANT), 5 (VERY IMPORTANT), 7 (VERY POWERFUL IMPORTANT), 9 (ABSOLUTE IMPORTANT)	1/3 (MORE UNIMPORTANT), 1/5 (VERY UNIMPORTANT), 1/7 (VERY POWERFUL UNIMPORTANT), 1/9 (ABSOLUTE UNIMPORTANT)	DATE OF ASSESSMENT	
	2, 4, 6, 8 DOUBLE NUMBERS INDICATE INTERMEDIATE VALUES	1/2, 1/4, 1/6, 1/8 NUMBERS INDICATE INTERMEDIATE VALUES	PERSONS UNDER RISK	Operators, Contractors and Visitors
DESCRIPTION OF THE ACTIVITY	HAZARD DESCRIPTION	RISK DESCRIPTION	MEASURES PLANNED TO CONTROL OR ELIMINATE RISK	
ELECTRICAL WORKS	Electrically inappropriate operation	Electric shock	1. No maintenance of machines without electrical connection 2. Grounded plug etc. using	
	Transformer maintenance	Electric shock	1. Operation and locking of the electrical panels by authorized personnel only	
	Lack of illumination or failure	Impossible to work	1. Continuous control of the working environment by the electrical unit 2. Ensuring adequate lighting of the work environment	
	No landing and exit ladder	The worker falling down, The worker falling on other workers	1. Finding ladders on all scaffolds	
	Not using the appropriate PPE	Electric shock	1. Use of PPE suitable for electrical works	

Table 1.35 Risk assessment study for the laboratory activities (By Musa BUDAK).

Table 1.36				
LABORATORY				
ASSESSMENT OF RISK BASED ON BINARY COMPARISONS			WHO MADE THE ASSESSMENT	
EACH ITEM ACCORDING TO THE SEVERITY OF EACH OTHER	1 (EQUALLY IMPORTANT), 3 (MORE IMPORTANT), 5 (VERY IMPORTANT), 7 (VERY POWERFUL IMPORTANT), 9 (ABSOLUTE IMPORTANT)	1/3 (MORE UNIMPORTANT), 1/5 (VERY UNIMPORTANT), 1/7 (VERY POWERFUL UNIMPORTANT), 1/9 (ABSOLUTE UNIMPORTANT)	DATE OF ASSESSMENT	
	2, 4, 6, 8 DOUBLE NUMBERS INDICATE INTERMEDIATE VALUES	1/2, 1/4, 1/6, 1/8 NUMBERS INDICATE INTERMEDIATE VALUES	PERSONS UNDER RISK	Operators, Contractors and Visitors
DESCRIPTION OF THE ACTIVITY	HAZARD DESCRIPTION	RISK DESCRIPTION	MEASURES PLANNED TO CONTROL OR ELIMINATE RISK	
LABORATORY WORKS	Gas released during the extraction experiment in the laboratory	Poisoning	1. Use of protective materials (gas mask, work gloves, work shoes and respirator)	
	Improper removal of material from the sieve	Drop of material	1. Use of protective materials (gas mask, work gloves, work shoes and respirator)	
	Radioactive leakage that may occur on the nuclear device used in the land tightness control	Radioactive poisoning/serious illness	1. Staff will be given periodic training 2. Technological controls of the device will be made 3. Staff will be given dosimetry cards for control and will be checked in the relevant institutions	
	Effect of gas occurring during sulfur heading on concrete sample	Inhaling toxic gases	1. To ensure that the personnel are not affected by the harmful gases exposed by personal protective equipment 2. With the hood, the harmful gas will be removed from the environment	

4.2. Binary Comparison Results

As a result of the binary comparison method;

1. As a result of the activities carried out during the tunnel construction phases, the risks were subjected to binary comparisons by experts among themselves and the degree of importance was determined. Thus, it was determined which danger was more important than which danger and it was aimed to provide awareness for the work in the tunnel industry.

2. Measures are planned to control or eliminate the potential risks that may arise as a result of the activities carried out during the tunnel construction phases. Then, they were subjected to binary comparison by experts and their degree of importance were determined. Thus, it was determined which preventive activities were more important. Then it was decided which measures will be taken earlier. With these decisions, the accidents that will occur in the next tunnel work will be minimized so that the proper and effective implementation of occupational health and safety conditions will be ensured in the tunnel work.

Evaluation of certain measures and hazards as a result of the binary comparison by experts is given in Table 2.24 and Table 2.31.

Table 2.24 Binary comparison study for the electrical work activities (By Musa BUDAK).

Table 2.24																		
ELECTRICAL WORKS																		
Note: Dangers and measures that have more than 1 item in the detected dangers are subject to comparison.																		
BINARY COMPARISON		EXPERT SCORE																
Electrically inappropriate operation																		
Which measure	Compared with which measure	1	2	3	4	5	6	7	8	9	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9
1	2			X														
Lack of illumination or failure		EXPERT SCORE																
Which measure	Compared with which measure	1	2	3	4	5	6	7	8	9	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9
1	2		X															

EACH ITEM ACCORDING TO THE SEVERITY OF EACH OTHER	
1 (EQUALLY IMPORTANT), 3 (MORE IMPORTANT), 5 (VERY IMPORTANT), 7 (VERY POWERFUL IMPORTANT), 9 (ABSOLUTE IMPORTANT)	1/3 (MORE UNIMPORTANT), 1/5 (VERY UNIMPORTANT), 1/7 (VERY POWERFUL UNIMPORTANT), 1/9 (ABSOLUTE UNIMPORTANT)
2, 4, 6, 8 DOUBLE NUMBERS INDICATE INTERMEDIATE VALUES	1/2, 1/4, 1/6, 1/8 NUMBERS INDICATE INTERMEDIATE VALUES

BINARY COMPARISON		EXPERT SCORE																
Which hazard	Compared with which hazard	1	2	3	4	5	6	7	8	9	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9
Electrically inappropriate operation	Transformer Maintenance		X															
	Lack of illumination or failure			X														
	No landing and exit ladder				X													
	Improper use of PPE (Personal Protective Equipment)										X							
Transformer Maintenance	Lack of illumination or failure										X							
	No landing and exit ladder										X							
	Improper use of PPE (Personal Protective Equipment)										X							
Lack of illumination or failure	No landing and exit ladder			X														
	Improper use of PPE (Personal Protective Equipment)										X							
No landing and exit ladder	Improper use of PPE (Personal Protective Equipment)											X						

Table 2.31 Binary comparison study for the laboratory activities (By Musa BUDAK).

Table 2.31

LABORATORY WORKS

Note: Dangers and measures that have more than 1 item in the detected dangers are subject to comparison.

BINARY COMPARISON		EXPERT SCORE																
Radioactive leakage that may occur on the nuclear device used in the land tightness control																		
Which measure	Compared with which measure	1	2	3	4	5	6	7	8	9	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9
1	2			X														
	3		X															
2	3												X					

The effect of gas occurring during the preparation of sulphur in concrete sample		EXPERT SCORE																
Which measure	Compared with which measure	1	2	3	4	5	6	7	8	9	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9
1	2												X					

EACH ITEM ACCORDING TO THE SEVERITY OF EACH OTHER	
1 (EQUALLY IMPORTANT), 3 (MORE IMPORTANT), 5 (VERY IMPORTANT), 7 (VERY POWERFUL IMPORTANT), 9 (ABSOLUTE IMPORTANT)	1/3 (MORE UNIMPORTANT), 1/5 (VERY UNIMPORTANT), 1/7 (VERY POWERFUL UNIMPORTANT), 1/9 (ABSOLUTE UNIMPORTANT)
2, 4, 6, 8 DOUBLE NUMBERS INDICATE INTERMEDIATE VALUES	1/2, 1/4, 1/6, 1/8 NUMBERS INDICATE INTERMEDIATE VALUES

BINARY COMPARISON		EXPERT SCORE																
Which hazard	Compared with which hazard	1	2	3	4	5	6	7	8	9	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9
When conducting an extraction experiment in the laboratory, the exposed gas	Improper removal of the material from the elector			X														
	Radioactive leakage that may occur on the nuclear device used in the land tightness control															X		
	The effect of gas occurring during the preparation of sulphur in concrete sample	X																
Improper removal of the material from the elector	Radioactive leakage that may occur on the nuclear device used in the land tightness control																	X
	The effect of gas occurring during the preparation of sulphur in concrete sample										X							
Radioactive leakage that may occur on the nuclear device used in the land tightness control	The effect of gas occurring during the preparation of sulphur in concrete sample							X										

CHAPTER V

CONCLUSIONS

Growth and development in our country has led to rapid development of the tunnel sector. However, in parallel with the development of the sector, the desired level of occupational health and safety has not been achieved. In particular, the establishment and development of security culture in construction works is important for the implementation of new approaches in terms of occupational health and safety. Occupational accidents, occupational diseases and all kinds of related losses in the sector will be possible only to be informed about the occupational health and safety legislation and practices of the employees. In tunnel construction work, firstly identifying risks and taking preventive and protective measures more effectively will help prevent or reduce potential accidents.

This study is to determine the risks that may occur according to the hazards identified in the tunnel construction studies and propose the measures to be taken in order of priority. First of all, tunnel construction types, construction stages and the methods used are then the hazards that may occur in the construction phase, the possible risks caused by these hazards and the data contained in the necessary measures.

Finally, to identify the hazards, risk and risk measures that are determined in terms of occupational health and safety in the tunnel construction stages and to determine the order of importance based on the considered scoring principle of possible hazard and risk prevention activities. As a result of this, it is aimed to minimize the possible accidents that may occur by putting the activities of hazard and risk prevention into a certain systematic and to contribute to the economy of the country by carrying out the tunnel work in a healthy way.

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APPENDIX

1- Result of risk assessment method and results of binary comparison method made by 5 experts (1 unit CD)