Revista Minelor – Mining Revue
ISSN-L 1220-2053 / ISSN 2247-8590
vol. 31, issue 3, pp. 1-8, selected paper from the First International EnviroMining Virtual Conference 2025

THE HISTORICAL DEVELOPMENT AND THE FORECASTING ON FUTURE STATE OF MECHANIZED EXCAVATION

Sertaç DÜNDAR[1], Niyazi BİLİM[2]*

[1]Konya Technical University, Konya, Turkiye, sdundar@ktun.edu.tr
[2]Konya Technical University, Konya, Turkiye, nbilim@ktun.edu.tr

DOI: 10.2478/minrv-2025-0024
received – 16.01.2025 / revised – 08.02.2025
accepted – 18.02.2025 / published – 22.09.2025

Abstract: *Humankind has been processing rocks and using them as tools since before the advent of settled life. Early hunting tools featured sharp rock edges, and humans have continued to work with rocks throughout history. Mechanized excavation refers to the process of excavation using mechanical tools and equipment. Throughout history, various power sources such as human labor, animal power, steam engines, and fossil fuel-powered motors have been employed in excavation processes. Many of these tools and machines have been updated and transformed into modern equipment through technological advancements. Many of these methods are still in use today. However, with the advancements in technology, automation systems have increasingly taken a prominent role in mechanized excavation.*
This study provides an overview of the historical development of mechanized excavation and offers insights into the modern mechanized excavation equipment used today. In light of this information, projections have been made concerning the potential mechanized excavation methods that may be utilized in the future.
Keywords: *Mechanized excavation, ancient excavation, tunneling, coal mining, future of excavation, TBM*

1. Introduction

Prior to adopting a sedentary lifestyle, early humans began utilizing and processing stones for practical purposes, including hunting. The tips of hunting tools were crafted from sharp-edged rocks, marking the beginning of humanity's enduring relationship with stone processing. Over the course of history, humans continued to refine techniques for working with rocks, adapting these methods to meet evolving needs.

In contemporary society, excavation processes hold critical importance, particularly within the mining and construction industries. The role of excavation has expanded significantly, driven by technological advancements and the growing demands of modern society. This evolution witnessed a marked acceleration following the conclusion of World War II, as innovations in engineering and machinery became increasingly accessible.

Mechanized excavation refers to the use of mechanical equipment in the excavation of rocks and soils. Throughout history, various energy sources, including human labor, animal power, steam engines, and fossil fuel-driven machinery, have been employed to perform excavation tasks. With technological progress, these tools have undergone continuous transformation, evolving into sophisticated modern equipment. In recent years, automation systems have emerged as a significant development in mechanized excavation, gradually replacing traditional methods. One notable example of advanced technology in this field is the full-face tunnel boring machine (TBM), which has revolutionized large-scale excavation projects.

Given society's ever-expanding infrastructure and resource demands, the continued development of mechanized excavation is both necessary and inevitable. This study explores the historical evolution of mechanized excavation and provides insights into its prospective advancements in the coming years.

2. First Excavations

Humankind has engaged in mining activities since ancient times. The first known mine in history was manually excavated by Neanderthals around 40,000 BCE at Bomvu Hill in Swaziland. Subsequently, the manual digging method was improved with the application of the fire-setting technique. This technique

* Corresponding author: Konya Technical University, Konya, Turkiye, sdundar@ktun.edu.tr

involved lighting a fire near the rock surface and then extinguishing it quickly, causing the rock mass to crack due to the strong thermal gradient [1]. For excavation purposes, the horns and bones of animals were initially used (Figure 1).

Fig. 1. Primitive excavation tools made from deer antler and bone residues [2]

After stone working began, rocks such as obsidian were used. (Figure 2). Obsidian was also used as a war tool.

Fig. 2. Digging equipment made of obsidian used in ancient times [3]

3. History of Mechanized Excavation

With the industrial revolution in the 18th century, diggers and other equipment used in the mining sector began to use this technology. With the discovery of steam power, it was first used in pumps to remove water from the underground environment (Figure 3). Later, with the help of steam power, it began to be used to transport excavated materials and personnel.

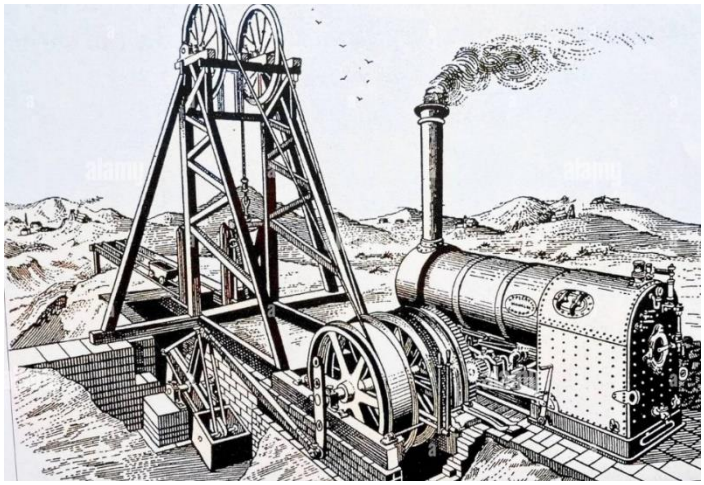

Fig. 3. Use of steam power in mining [4]

With the discovery of dynamite by Alfred Nobel in 1867, it began to be used for excavation operations in mining. It made excavation operations, especially in hard rocks, easier. One of the most important factors in the development of mechanized excavation is the increase in the need for energy with the industrial revolution and the resulting increase in the production need in coal mining. In this process, pressurized air-powered pick hammers began to be used. Pick hammers were used in the production and preparation stages in underground mines.

In coal production, kirving machines were first used in Scotland in the 1850s, with cast iron and compressed air as a cutting tip (Figure 4). In the early 1950s, plough and drum cutting machines began to be used in production, thus an increase in production was observed [5, 6]. The working principle of kirving machines is to cut the coal seam horizontally along the foot, create a free surface and ensure excavation by allowing the coal to fall under the effect of gravity.

Fig.4. Use of kirving cutting machine [7]

Mechanized excavation systems owe their development to coal mining. Mechanized excavation systems began with their use in coal production in the 19th century. In the mid-1930s, attempts were made to load the excavated coal with a pot-a-brick machine. Instead of pulling a pot-a-brick along the excavation face and then digging, the idea of digging along the face led to the invention of the coal plow. The coal plow was developed with the idea of digging by pulling a machine with cutting tips along the face [6].

Coal plows were known as a very economical technology in the production of thin coal seams in Europe in the 1990s. However, with the transition to thick-seamed coal production mining, this technology lost its importance. Today, with the idea of economical production of thin coal seams coming back to the agenda, the use of plow technology has started again [8]. Plows were used very frequently in coal mines in Germany between 1950 and 1980 [6,9].

Different types of coal plows have been developed and used. An example of the sliding type of plough is shown in Figure 5.

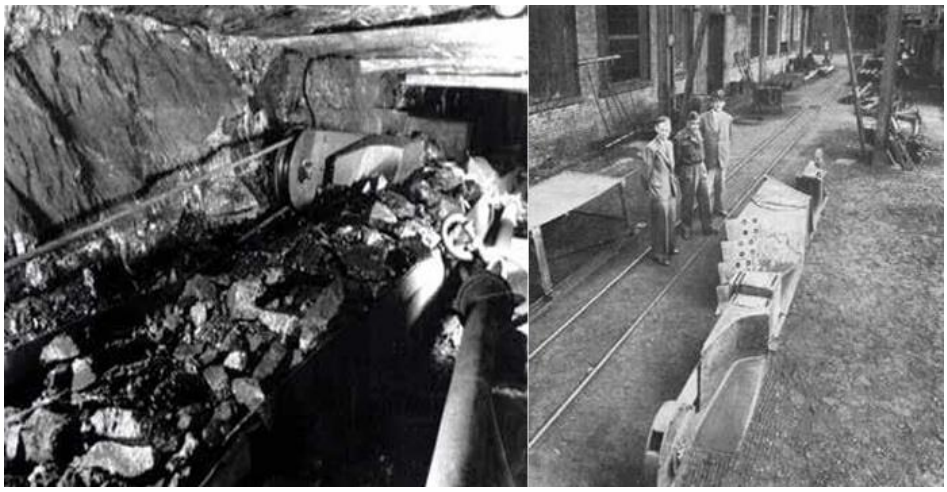

Fig.5. First coal plow in use [10]

Towards the end of the 1950s, the coal plow was developed in Germany and the drum shearer in England, and hydraulic poles were replaced by frame and shield type hydraulic walking supports [10]. In longwall coal mining, drum shearer machines and coal plows are frequently preferred machines today. Chain conveyors are used to transport the ore produced by both machines and mechanical supports are used to ensure the stability of the roof [6]. Figure 6 shows a drum shearer and coal plow, which are still used for production in coal mines today.

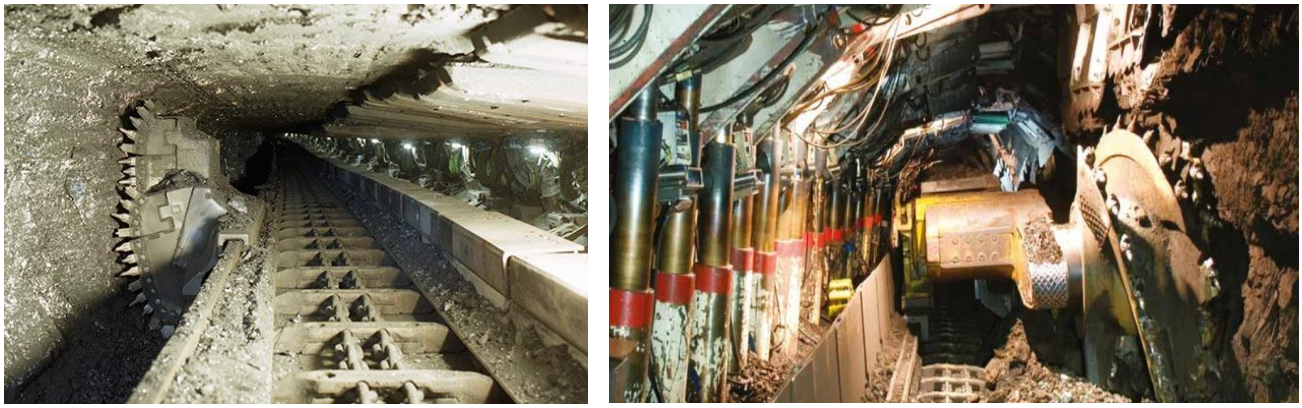

Fig.6. Coal plow and Drum Cutter loader in use [11, 12]

Along with drum shearer, continuous miners and roadheaders have been developed for underground excavations and tunneling activities. Both machines provide excavation with cutting tips placed on a rotating drum. With continuous miners and roadheaders, the entire excavation area cannot be excavated in one go.

Continuous miners are used for production purposes in coal mines in the USA. They are also used in tunneling projects. A continuous miner is presented in Figure 7. Selective mining activities can be carried out with continuous miners. While continuous miners had an operator cabin when they were first developed, today they can be operated with a remote control without the operator being on the machine.

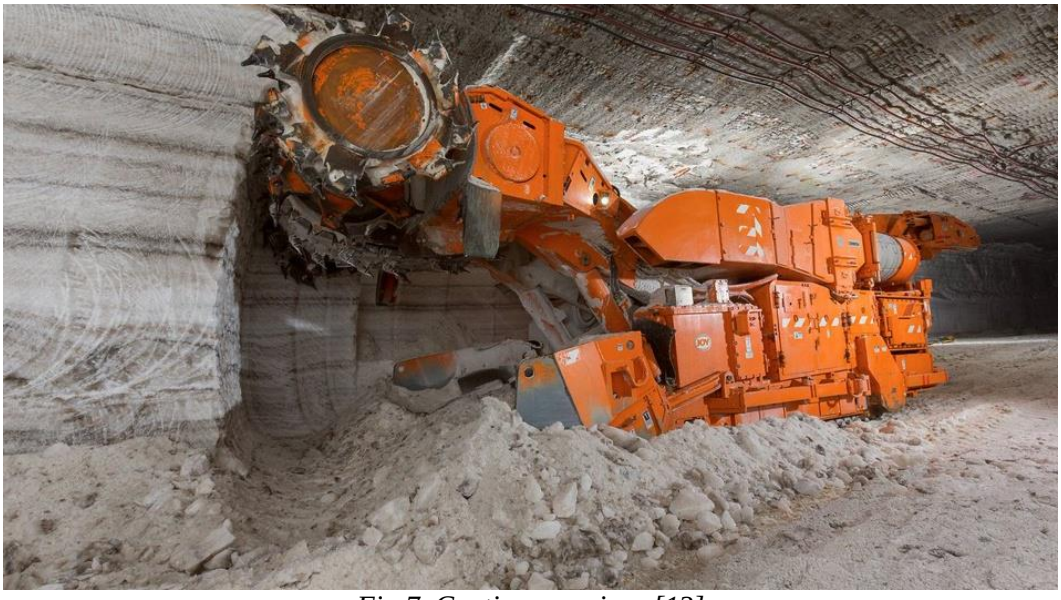

Fig.7. Continuous miner [13]

Another mechanized excavation machine that has the same working principle as continuous miners is the roadheaders. Both mining operations and excavation operations for ore production are carried out with these machines. Roadheaders are named according to the direction of rotation of the drum on their booms. If the drum with the cutting tips rotates parallel to the boom axis, it is called a parallel drum roadheader, and if the drum with the cutting tips rotates perpendicular to the boom axis, it is called a vertical drum roadheader. Although the drums have different rotation patterns, these two machines do not have any advantages or disadvantages over each other. Both vertical drum roadheader and parallel drum roadheader are presented in Figure 8.

Fig.8. Vertical drum roadheader and parallel drum roadheader [14, 15]

While these developments were taking place in underground mining, excavators were also used as excavation machines in open pit mining. Especially with the industrial revolution, as the need for coal mines increased, larger capacity excavators and different excavation equipment were developed. Rotary bucket excavators operating at higher capacities began to be used. A rotary bucket excavator is presented in Figure 9. Rotary bucket excavators are mechanized excavation machines that have digging buckets on a drum and work on the principle of loading the excavated material into it and transporting it. At the same time, there is a belt conveyor on it for the transportation of the excavated material and with the help of this belt, the excavated material is loaded directly to the stock area or to the transportation equipment and the transportation process is carried out. Rotary bucket excavators also work with the help of electric motors today.

Fig. 9. Rotary bucket excavators [16]

Another large capacity mechanized excavator used in open pit mining is the dragline. Draglines are large capacity excavator machines in which a large excavation bucket is controlled by ropes and the excavated material is transferred directly to the stockpile. Electrically operated draglines are used especially in open pit coal mines (Figure 10).

Fig. 10. Dragline in an open-pit coal mine [17]

This breakthrough, which began in the mid-1900s, continues today. Excavators, rotary bucket excavators, draglines, continuous miners, roadheaders, coal plows and drum shearer are used. All of these excavation equipment used are classified as partial face excavation machines. There are also full-face excavation machines. These are mechanized excavators called full face tunnel boring machines (TBM) that can excavate the entire excavation face in one go.

TBM machines are excavator machines that can perform excavating, loading, transportation and support works on their own. The tunnel boring machine developed by Charles Wilson, an American engineer, in 1851 was the first tunnel boring machine that could perform full face cutting and had a rotating cutting head [18]. Subsequently, the compressed air tunnel boring machine was developed by Colonel Beaumont in 1881. This tunnel boring machine is a machine that has cutting bits that break the rock into dust on a fixed cutting head (Figure 11). This machine was used for exploration in the English Channel and excavated more than 1.8 km [19, 20].

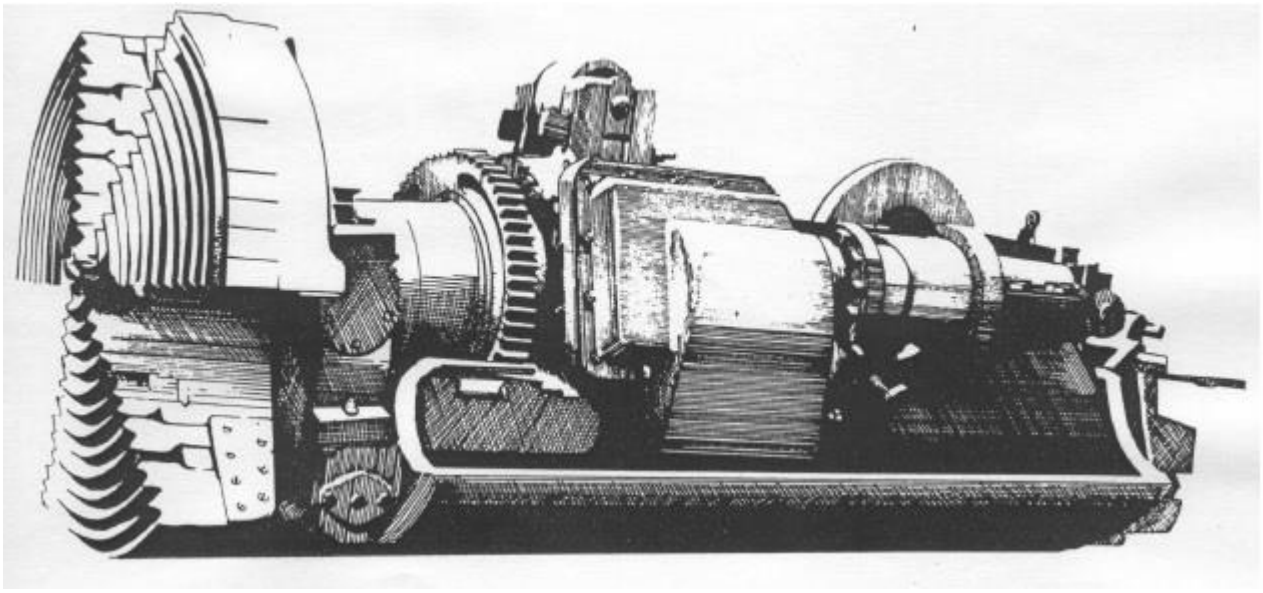

Fig. 11. Compressed air tunnel boring machine developed in 1881 [19]

Today, TBM machines are used very frequently in tunneling projects. TBM machines are also used in hard rocks and soft rock excavations. There are different types for this. The classification of TBMs is presented in Table 1.

Table 1. TBM Classification [21]

TBM Classification	
Open TBM's	Main Beam TBM
	Open Gripper TBM
	Kelly Beam TBM
Shielded TBM's	One Shielded TBM
	Telescopic TBM
	Gripper Shielded TBM
	Slurry Pressure Balance TBM
	Earth Pressure Balance TBM
	Compressed Air Balance TBM
	Mix-shield TBM
	Special TBMs

Shielded TBMs are generally used in soft and non-massive rock excavations, while open TBMs are used in massive and hard rock excavations.

Today, TBMs are used in many different sizes, from the construction of infrastructure systems in cities to the opening of tunnels with a diameter of 20 m. Figure 12 shows a micro TBM used in urban infrastructure works and the world's largest TBM used to date.

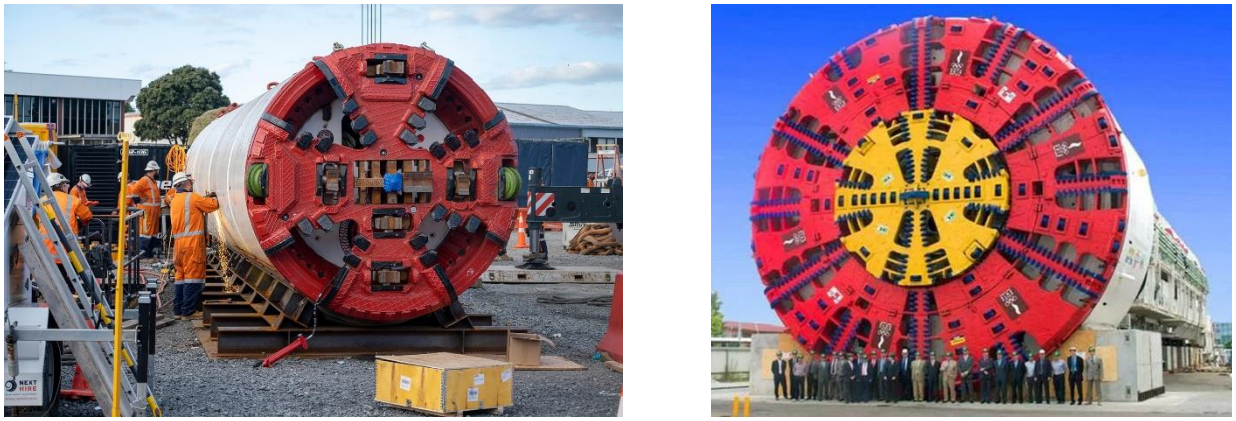

Fig.12. Micro TBM and Big TBM [22, 23]

4. Conclusions

When we examine from ancient times to the present, excavation operations have always been very important for humanity. Many excavation operations have been carried out for shelter, raw material supply, irrigation and transportation purposes. The process of digging with bare hands began and today, artificial intelligence-supported automation systems are used, excavation operations are carried out without even the need for an operator.

The biggest breakthrough started after the industrial revolution and accelerated in the second half of the 1900s. During this period, the use of steam power, the use of hydraulic systems and the integration of electrical systems into excavation mechanization have led to today's mechanized excavation systems.

Mechanized excavation systems, which make great contributions especially in terms of occupational health and safety, have also played a very important role in shortening project periods. Thanks to mechanized excavation systems, the negative environmental effects resulting from underground excavations have been reduced to minimum levels.

Considering the advancement of technology, it is inevitable that there will be some innovations in mechanized excavation systems. The development of artificial intelligence and its ability to solve some problems means that in the future, problems encountered during excavations underground or aboveground can be solved by artificial intelligence. Therefore, it is very likely that there will be mining sites completely controlled by robots in the near future. As a result of the information fed to artificial intelligence applications as a result of the drilling, it should be expected that they will take part in very important decision mechanisms such as how to extract the ore deposit in the most efficient way, what kind of production method will be chosen, and which equipment will be chosen. Therefore, the planning process of a mine and the mechanized excavator to be used during the operation will be able to produce and implement instant solutions to the problems encountered underground with the support of artificial intelligence. It is necessary to accept the fact that in the not-too-distant future, mining activities will also be completely dependent on the automation system and this system will be managed by artificial intelligence

References

[1] *** * ***, 2025
https://tunnel.ita-aites.org/en/cases-histories/history/ancient-period

[2] **Clark G., Piggott S.**, 1933
The Age of British Flint Mines. Antiquity, 7, 26, 166-183

[3] *** * ***, 2025
https://as2.ftcdn.net/v2/jpg/03/16/47/87/1000_F_316478713_Vq3vixRPhqIH5IFgyTIRD9OefurCvNQG.jpg

[4] *** * ***, 2025
https://c8.alamy.com/comp/2KNH0G5/steam-powered-engine-at-a-british-coal-mine-about-1840-2KNH0G5.jpg

[5] **Altındağ R., Güney A.**, 1994
Dünya'da ve Türkiye'de Uzun Ayak Kömür Madenciliğinde Mekanizasyonun Rolü', Çukurova Üniversitesi Mühendislik- Mimarlık Fakültesi 15. Yıl Sempozyumu, 391-397.

[6] **Bilim N.**, 2018
Kömür Madenlerinde Kullanilan Sabanlarin Önemi Ve Seçim Kriterleri, Selcuk Univ. J. Eng. Sci. Tech., v.6, n.3, pp. 490-503, 2018

[7] *** * ***, 2025
https://media-cdn.tripadvisor.com/media/photo-s/03/0c/ae/b3/kentucky-coal-mining.jpg

[8] **Gondek H., Frydrýšek K. Ševčík A.**, 2011
Mining Machines in Technical Practice (Short Introduction), VŠB– Technical University of Ostrava, Faculty of Mechanical Engineering, 102s.

[9] **Bilgin N., Copur H., Balci C.**, 2014
Mechanical Excavation in Mining and Civil Industries, CRC Pres, Taylor & Francis Group, London Newyork. ISBN: 13: 978-1-4665-8475-4, 355p.

[10] **Çetinkaya U.**, 2019
Yerli İmkanlarla Üretilen Kalkan Tipi Yürüyen Tahkimatin Üretimi Ve Uygulamasi, MS Thesis, Konya Technical University. p. 88.

[11] *** * ***, 2025
https://d2e1tbtdbinpro.cloudfront.net/media/content/zz/Cat-thin-seam-longwall-installed-in-German-mine.jpg

[12] *** * ***, 2025
https://www.ctinovasyon.com.tr/core/uploads/page/document/1147_070319926540422.pdf

[13] *** * ***, 2025
https://www.exms.co.za/wp-content/uploads/2021/04/CM1.jpg

[14] *** * ***, 2025
https://www.australianmining.com.au/milestone-roadheader-rolled-out-in-australia/

[15] *** * ***, 2025
https://www.sanyglobal.com/product/mining_&_tunneling/roadheader/

[16] *** * ***, 2025
https://upload.wikimedia.org/wikipedia/commons/thumb/6/6a/Bagger-garzweiler.jpg/1000px-Bagger-garzweiler.jpg/

[17] *** * ***, 2025
https://crmining.com/wp-content/uploads/2023/01/Blair-Athol-Dragline-1.jpg

[18] **Maidl B., Schmid L., Ritz W., Herrenknecht M.**, 2008
Hard Rock Tunnel Boring Machines, Ernst & Sohn, Berlin

[19] **Stack B.**, 1995
Encyclopaedia of tunnelling mining and drilling equipment, 1-2, Mining Hobart Muden Publishing Company, Hobart, Australia, pp. 1911.

[20] **Dündar S.**, 2024
Analysis and Evaluation of Excavation Performance of EPB-TBMs: Hadim-Afşar-Bağbaşı Water Supply Tunnel Example, PhD Thesis, Konya Technical University. p. 147

[21] **Balcı C., Bilgin N., Çopur H., Tumaç D.**, 2009
Tam Cepheli Tünel Açma Makineleri (TBM) Performans Tahmini Ve Optimizasyonu, TÜBİTAK Araştırma Projesi Nihai Raporu, Proje No: 106M298.

[22] *** * ***, 2025
https://images.squarespace-cdn.com/content/v1/58c503e81e5b6c367860f34d/1625012211478-8AAWPN2L7W84MRSHI3A6/Micro+Tunnel+Boring+Machine+Domenica+in+a+yard+with+workers+in+hi-vis+welding

[23] *** * ***, 2025
https://www.aykutozdemir.com.tr/insaat/wp-content/uploads/2012/04/tbm-tunel-acma-makinasi-tunnel-boring-machine-6.jpg