SIGNIFICANCE OF REMOTE SENSING AND GIS IN NEW AUSTRIAN TUNNELING METHOD (NATM)-RELATED TUNNEL CONSTRUCTION

Shubham Kanojiya[1*], Dr Gopal Krishna Mehta[2]

Article History: **Received:** 20/04/2023 **Revised:** 10/05/2023 **Accepted:** 17/06/2023

Abstract

Tunnels are essential substructures that are deeply influenced by the soil that surrounds them, particularly when employing the New Austrian Tunneling Method (NATM), in which the soil that surrounds the tunnel disperses under part of the load applied and the leftover load is borne by the tunnel's initial lining. Tunnels are influenced strongly by the soil that surrounds them. NATM is a tunneling construction technique that prioritizes security, safety, and economics. In this paper author review based on the Significance of Remote Sensing and Geographic information system (GIS) in the NATM-related to Tunnel Construction. Although the suggested architecture shows promise, there are currently significant limitations that might be addressed by integrating a NATM-based tunneling platform, an Application Programming Interface (API) for remotely detecting phenomena, and cutting-edge data gathering and processing technologies. From the comparative study, the author can deduce that the suggested approach, Intelligent Neural Network (INN), provides the greatest value of (95%) for accuracy, which is much higher than any of the other techniques considered.

Keywords: New Austrian Tunneling (NATM), Geographic information system (GIS), satellite data, Machine learning, Computer vision, Underground construction

[1*]Research Scholar, Department of Civil Engineering, Shri Venkateshwara University, Amroha, Uttar Pradesh, kanojiyashubham878@gmail.com
[2]Research Scholar, Department of Civil Engineering, Shri Venkateshwara University, Amroha, Uttar Pradesh, gkmehta1970@gmail.com

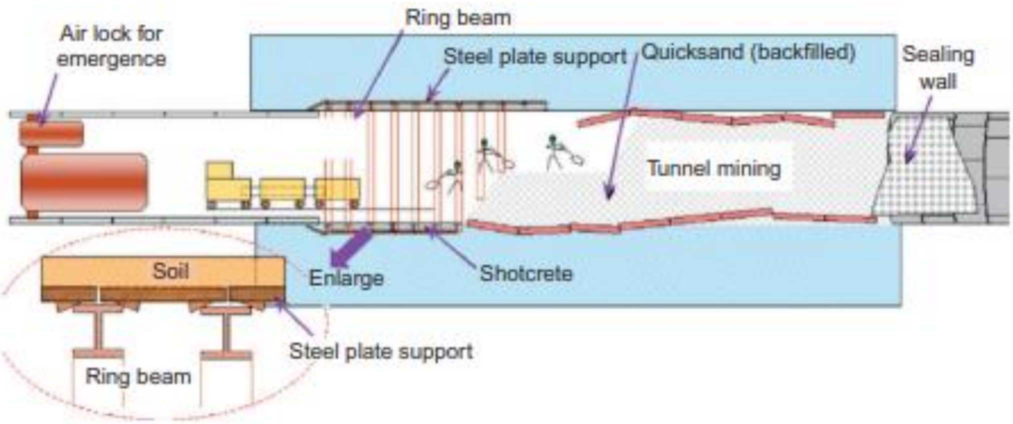
***Corresponding Author:** Shubham Kanojiya
*Research Scholar, Department of Civil Engineering, Shri Venkateshwara University, Amroha, Uttar Pradesh, kanojiyashubham878@gmail.com

DOI: 10.53555/ecb/2023.12.si10.00565

1. Introduction

Tunnels are a practical option for getting around obstacles like water or land. Underground space usage is becoming more crucial as the globe develops, not only in cities but also in rural regions and even underwater. These underground digs take place in a wide variety of ground conditions, from those conducive to excavation to those that are very challenging. Several techniques, such as tunnel boring machine (TBM) tunneling, the new Austrian tunneling method (NATM), cut and cover excavation, the immersed method, jacked box tunneling, etc. are employed for tunnel building because of the complexity of ground conditions. Among them, the NATM method, which employs the drill-and-blast method of excavation, is the most popular since it allows for a large range of geometric freedom and could be utilized for tunnels of almost any size in rock [1].

During the years 1957–1965, the NATM was created. Rabcewicz classified seven different kinds of rock masses (ranging from clay to hard rock) and three different forms of deformation (loosening, compressing, and swelling) in 1944. Furthermore, the state of the rock was categorized as either loosening, squeezing, or swelling. This categorization has informed the subsequent development of various forms of assistance. There was a link established in 1957 between rock mass behavior, rock mass characteristics, failure duration, and tunnel supports. Because of its adaptability and low-price tag, the NATM has found widespread use in tunneling operations with limited distances. The budget for a NATM project, like that of any construction endeavor, is especially vulnerable to delays. Many uncertainties in geotechnical/ geological conditions, variance in human resources, and varying reliabilities of construction machines usually cause the actual tunnel building process to diverge from its original design. Project management challenges at a higher level, such as cost overruns and delays, are generally the result of work that deviates from the original plan. The plan-work divergence on NATM projects is often found via the use of the project monitoring record, which details the actual construction phase in detail. Project managers boost output by identifying bottlenecks and eliminating them via analysis and planning acceptable.



[2]. **Figure 1** describe the tunnel construction using NATM method.

1.1 General Sequence for the Construction Using NATM

- **Marking of Drill Holes**

Drill sites are marked on the tunnel face according to the blasting pattern. Both wedge and burn cuts are

- **Drilling of Holes**

While working with mild soil or rock, manual excavators are utilized, whereas when working with hard rock, boomer machines are used.

- **Charging with Explosives**

Explosives are loaded into the holes and linked to detonators in this technique. At last, a central link has been made between all the detonators [3].

- **Charging and Blasting**

An explosion at the primary connection, to which all the detonators are linked, sets off the subsequent explosions of the explosives placed in the drilled holes at predetermined intervals (often at a rate of 1 ms).

- **Scaling and Mucking**

When the dust and toxic fumes produced by the blasting operation have been eliminated, this step could begin. The procedure involves the elimination of facial loose wounds that have not yet healed.

- **Installation of Primary Support**

Given the significance of the setup time on the ground, this is a very crucial and challenging aspect. The period that follows blasting or manual excavation during which the earth might stand without external support is called the standup time. Primary support uses shotcrete or rock bolts. Shotcrete thickness, grade, rock bolt length, type, and diameter depend on the design. Heading, benching, and inverting makeup tunnel construction.

- **Provision to Avoid Ingress of Water**

The main issue is the possibility of the tunnel collapsing due to water getting inside. When the main support system has been set up, a water-proofing membrane is installed, often in the structure of a Dimplex or Nyllex strip, to inhibit this from happening.

- **The Supplementary Structural Support**

Lattice girders, steel ribs, a second layer of shotcrete, and other supports might be added if the strata need them for further structural stability [4].

1.2 Geographic Information Systems (GIS)

Information that is expressed spatially or geographically could be stored, retrieved, analyzed, and displayed using several different types of geographic information systems, each of which has its own set of definitions. It utilizes a wide definition that encompasses any information system optimized for the storage, retrieval, analysis, and display of geographically referenced spatial and temporal information. The word geography could be thought of as a synonym for the more general term geographic, which refers to the scientific study of Earth's regions, features, inhabitants, and processes. GIS refers to systems and technologies in this article, whereas GI Science is a broader discipline that encompasses more theoretical study. Hence, the primary aims of GIS have been data collection (geo-information), analysis (geo-objects and their interactions), and exploration (advanced geographic laws that influence spatiotemporal behavior). Basic GIS capabilities, such as computer mapping and associated technologies, have extended users' access to 2D/3D visual and digital pictures of the physical world to 4D mostly along the time dimension. As a result of the incorporation of geographical statistics and spatial analysis, GIS has advanced well beyond its humble mapping application roots and now offers its users meaningful insights into spatial and temporal distributions and connections. Along with other forms of geographic inquiry, GIS has recently been used to probe the physical and social dynamics of geographical phenomena throughout the globe.

2. Literature of Review

This strategy has been employed by a wide range of authors, who then presented their findings after doing a literature review.

Enrico et al., (2022) [5] introduce the stability of the tunnel face is investigated using soft computing methods. Several widely used soft computing methods, such as linear regression and the artificial neural network, are trained using a database constructed from the literature. Parameters include tunnel diameter, cover depth, soil dry density, cohesion, friction angle, and cohesion. The stability of face support is declared, and the pressure on the face is predicted, using soft computing methods. As compared to other methods, the artificial neural network is superior. Artificial neural networks are used to estimate the facial support pressure for statistically distributed samples, and failure probabilities are calculated using Monte Carlo simulations. This allows for a precise assessment of tunnel face stability and an approximation of support pressure.

An et al., (2022) [6] illustrate a smart neural network model was constructed to provide a more accurate estimate, and experiments were run using simulated tunnel excavation on various terrains to evaluate the model's ability to accurately predict the amount of deformation that would occur. The experimental results show that this model has a much less margin of error in its predictions than a traditional neural network does. The prediction accuracy of this model is better than 95%, and its volatility rate is less than 11%, whereas the volatility rate of traditional prediction accuracy is larger than 365%. The neural network model allows for very accurate predictions of intelligent tunnel deformation.

Soranzo et al., (2022) [7] suggest using reinforcement learning rather than the human approach since it is a broad framework within the subject of AI that handles control difficulties. This is possible and has been shown in previous research, although with simplified methods. As a result of integrating the Finite Difference Method with a Python script, the output of the former was used to train the machine learning model that was subsequently deployed, which led to an improvement in the selection of the support classes. The benchmark tests conducted by the authors validated the efficacy of strategy in selecting the most appropriate support classes for a variety of datasets, and they also demonstrated a relationship between performance and the total number of training episodes.

Mirsepahi et al., (2021) [8] examine how various twin tunneling patterns using the NATM affect the internal pressures exerted by the earth during settlement. The three most typical tunneling patterns in NATM—top heading (TH), central diaphragm wall (CDW), and sidewall drift (SD)—are considered here. It also investigated how different tunneling patterns affected a single pile. When the findings are compared, The TH pattern is shown to have more surface settlements than the CDW pattern. Growth and decrease of pile bending moment in twin tunneling were significantly impacted by tunneling patterns. For any given tunneling arrangement, 2D is the effective zone of maximum axial force distribution along the pile (D is the diameter of the tunnel).

Kong et al., (2021) [9] looked at the possibility of employing a TBM to excavate a pilot tunnel while a NATM was used to blast out the tunnel's back extension at the same time, reaping benefits such as greater constructability, lower costs, and lessened vibration and noise. To reduce the likelihood of accidents caused by faulty equipment (a drawback of TBM), a shield was constructed. This shield, together with the separation distance between the shield and the NATM, was analyzed for their respective contributions to reducing the blast's impact. When comparing blasting without a protection shield to blasting with a protection shield, the vibration velocity drops by 36.02 percent at a distance of 2 meters, 49.29 percent at 4 meters, 58.86 percent at 8 meters, and 65.85 percent at 20 meters.

Balta et al., (2021) [10] developed a Bayesian Belief Network (BNN)-based technique for risk assessment of Tunnel Boring Machine (TBM) tunneling projects. BBN Tunnel is a decision-support tool built on the BBN model to assess the impact of different latency-reducing safeguards. In this study, the author utilized BBN Tunnel and a risk assessment method to simulate interactions between risk components, build a risk network, estimate delay, and provide guidance to decision-makers as they develop cost-effective risk mitigation solutions.

Aygar, (2020) [11] aimed to examine the circumstances under which the NATM practices might be successful by investigating the basic principles of the NATM and applying them to the tunneling practices in the Bolu tunnel. The NATM standards were used in the design of the Bolu tunnel project. The tunnel's procedures have a significant bearing on the NATM. Moreover, this demonstrates that the tunnel's problem-solving strategies are in line with NATM concepts. The research concludes by classifying the foundations on which NATM principles rest and recommending appropriate revisions. The analysis revealed that the clay fractions made about 80% of the substance. When the low-angle fault zone was overlapping, vertical deformations formed. Up to 63 centimeters of deformation were measured.

Ebu et al., (2020) [12] describe the causes of the tunnel's collapse at the portal and its continuation's midsection. As this is a case of relevance to the tunneling community and will impact future tunnel-building efforts, the authors also describe the planned tunnel support systems and numerical studies of them. The stability of tunnel excavation is discussed, as is its connection to portal excavation. Hence, tunnels dug through the brittle ground are taken into account, and the need of addressing tunnel face stability in tunneling studies is emphasized. According to the data, the tunnel's ceiling has a vertical distortion of 7.80 cm, the tunnel's shoulders, 8.45 cm, the tunnel's benches, 2.60 cm, and the tunnel's basement, 3.25 cm.

Wu et al., (2020) [13] introduce a comprehensible AI system for detecting NATM building projects with minimal cost photos from site monitoring. The approach uses Bayesian statistics to combine the existing NATM building knowledge with the evidence gathered by DL-based computer vision models. Site CCTV (closed-circuit television) surveillance videos from four different NATM tunneling projects are analyzed, and the results show that the system can (i) label NATM work cycles based on the work timeline, (ii) identify NATM work categories within each work cycle, and (iii) estimate the degree of plan-work deviation at the construction cycle level. For a real-world NATM tunneling project, the suggested framework shows promising outcomes.

Yun et al., (2020) [14] use a statistical machine learning technique called support vector machines (SVM) to create an expert system for designing tunnel support structures. SVM is a strong learning approach that has been extensively used for a broad range of pattern classification and regression issues. The authors will also demonstrate, using real-world data, that the proposed SVM-based expert systems can provide realistic and objective design recommendations for tunnel support patterns. As a result, it established the viability of using machine learning to assess rock masses via this study.

Comparison of Literature of Review

The results of the review of relevant literature were shown in Table 1.

Table 1: Comparison of the Literature of Review

Author	Technique	Outcome
Enrico et al., (2022) [5]	Linear Regression (LIR) and Artificial Neural Network (ANN)	According to the results, the artificial neural network performs best on the test data, as measured by the coefficient of determination ($R^2 = 0.795$).
An et al., (2022) [6]	INN	The model's prediction accuracy is above 95%, but its volatility rate is about 11%, which is up to 3.65 times lower than that of traditional approaches.
Soranzo et al., (2022) [7]	Deep Neural Network (DNN)	The model seems to be very sensitive to the total number of episodes, as shown by these findings. Insufficient data might cause the model to choose the incorrect course of action or fail to optimize rewards.
Mirsepahi et al., (2021) [8]	NATM	Settlements on the ground's surface were greatest for the TH pattern and smallest for the central diaphragm wall (CDW), with the CDW design reducing settlement by 22% in the first tunneling and 17% in the second (twin tunneling).
Kong et al., (2021) [9]	Tunnel Boring Machine (TBM) and NATM	There was hardly any ground surface vibration immediately above point A, and it dropped by 36.02 percent, 49.29 percent, 58.86 percent, and 65.85 percent when the distance between the blasting point and the protective shield grew from 2 meters to 4 meters, 8 meters, and 20 meters, respectively.
Balta et al., (2021) [10]	Bayesian Belief Network (BBN)	The results validated the viability of using BBN Tunnel and the risk assessment technique to model interdependencies between various risk factors, construct a risk network, calculate delay times, and provide guidance to decision-makers as they seek efficient means of reducing risk.
Aygar, (2020) [11]	NATM	The analysis revealed that the clay fractions made about 80% of the substance. When the low-angle fault zone was overlapping, vertical deformations formed. Up to 63 centimeters of deformation were measured.
Ebu et al., (2020) [12]	NATM	When the results are analyzed, it is shown that the tunnel is experiencing vertical deformations of 7.80 cm at its ceiling, 8.45 cm at its shoulders, 2.60 cm at its benches on both the left and right and 3.25 cm at its foundation.
Wu et al.,(2020) [13]	Artificial Intelligence (AI)	The results demonstrate that every Bayesian technique outperforms the standard one (Model for Identifying Categories in CNN's Work)
Yun et al., (2020) [14]	Support Vector Machine (SVM)	Tests on actual data demonstrate the suggested expert systems' ability to provide credible, data-driven recommendations for tunnel support pattern design using SVM.

3. Comparative Analysis

Here, results from several Machines Learning (ML) techniques, such as Support Vector Machine (SVM), Artificial Intelligence (AI), Bayesian Belief Networks (BBN), Tunnel Boring Machine (TBM), Deep Neural Networks (DNN), ANN, are presented concerning New Austrian Tunneling Method (NATM)-related Tunnel Construction. To measure the performance of different algorithms, the authors use a broad variety of approaches. These algorithms have an average accuracy of 95% (Intelligent Neural Network). SVM (78.1% accuracy) maintained high quality when compared to DNN (51.8%), NATM (75% accuracy), and AI (81% accuracy).

Table 2 presents a comparison and contrast of several approaches to the literature review process.

Table 2: Comparative Analysis of Literature of Review Methods

Author	Technique	Accuracy
An et al., (2022) [6]	INN	95%
Soranzo et al., (2022) [7]	DNN	51.8%
Mirsepahi et al., (2021) [8]	NATM	75%
Wu et al., (2020) [13]	AI	81%
Yun et al., (2020) [14]	SVM	78.1%

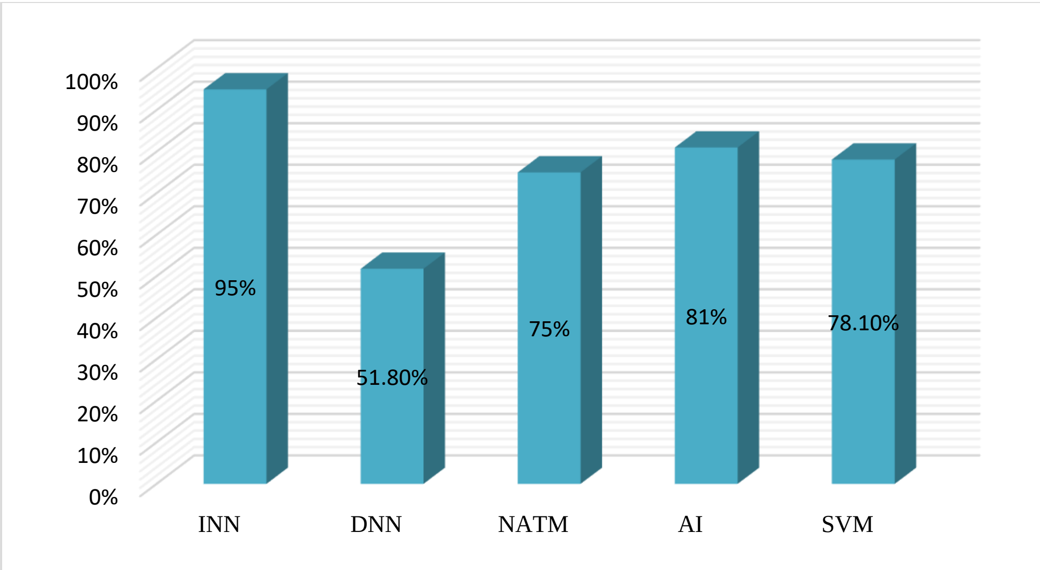


Figure 1: Comparative Analysis of Literature of Review methods

Figure 2 represents the accuracy of the techniques used in this inquiry is compared to the accuracy of other approaches that had been offered in the past for use in NATM-related tunnel construction in the following graph.

4. Conclusion And Future Scope

New Austrian Tunneling Method (NATM)-related Remote Sensing and Geographic Information System (GIS) Tunnel During the drill-and-blast tunneling process, construction has the potential to greatly improve management, risk assessment, and decision-making at every stage from planning to building. It has the potential to enhance teamwork, data sharing, communication between different branches of engineering, and physical coordination. The effectiveness of the system's design and potential improvements have been the subject of previous studies. The finding demonstrates that the INN module technique has a 95% higher rate of accuracy than other techniques, as demonstrated by the previous year's research and analysis. Despite its potential, the proposed framework has some restrictions that could be alleviated by combining a NATM-based tunneling platform with a remote sensing phenomenon API and the most recent data collection and processing technologies. Based on the preceding comparison analysis, it could be concluded that the proposed technique, namely INN, outperforms all other methods by providing the highest values of (95 %) for accuracy. This indicates that the value is absolute for accuracy value, which must be the highest to show their highest reliability.

References

1. Rehman, Hafeezur, Abdul Muntaqim Naji, Wahid Ali, Muhammad Junaid, Rini Asnida

Abdullah, and Han-kyu Yoo. "Numerical evaluation of new Austrian tunneling method excavation sequences: A case study." *International Journal of Mining Science and Technology* 30, no. 3 (2020): 381-386.

2. Wu, Renjie, Yuji Fujita, and Kenichi Soga. "Integrating domain knowledge with deep learning models: An interpretable AI system for automatic work progress identification of NATM tunnels." *Tunnelling and Underground Space Technology* 105 (2020): 103558.
3. Phadke, Vaibhav, and Nikhil Titirmare. "Construction of tunnels, by new Austrian tunneling method (NATM) and by tunnel boring machine (TBM)." International Journal of Civil Engineering (IJCE) 6, no. 6 (2017): 25-36. DOI: https://doi.org/10.22214/ijraset.2021.36463. Available at www.ijraset.com.
4. Phadke, Vaibhav, and Nikhil Titirmare. "Construction of tunnels, by new Austrian tunneling method (NATM) and by tunnel boring machine (TBM)." *International Journal of Civil Engineering (IJCE)* 6, no. 6 (2017): 25-36.
5. Soranzo, Enrico, Carlotta Guardiani, and Wei Wu. "A soft computing approach to tunnel face stability in a probabilistic framework." *Acta Geotechnica* 17, no. 4 (2022): 1219-1238.
6. A Puzhen, Baoxin Jia, Fanli Meng, Zhixin Wang, Hailiang Wei, and Yinghui Zhang. "Forecast of Ground Deformation Caused by Tunnel Excavation Based on Intelligent Neural Network Model." Mobile Information Systems 2022 (2022).
7. Soranzo, Enrico, Carlotta Guardiani, and Wei Wu. "The application of reinforcement learning to NATM tunnel design." Underground *Space* 7, no. 6 (2022): 990-1002.
8. Mirsepahi, M., A. Nayeri, S. M. Mirhosseini, and S. H. Lajevardi. "Investigation of the effects of twin tunneling on ground surface settlement and internal forces of a single pile in 3D analysis." *Soil Mechanics and Foundation Engineering* 58 (2021): 63-70.
9. Kong, Suk-Min, Sang-Il Choi, Seung-Bo Shim, Hana Lee, Dong-Wook Oh, and Seong-Won Lee. "Stability evaluation of TBM pilot tunnels to rear blasting using the protective shield." *Applied Sciences* 11, no. 4 (2021): 1759.
10. *Balta, GC Koseoglu, I. Dikmen, and M. T. Birgonul. "Bayesian network-based decision support for predicting and mitigating delay risk in TBM tunnel projects." Automation in Construction 129 (2021): 103819.*
11. Aygar, Ebu Bekir. "Evaluation of new Austrian tunneling method applied to Bolu tunnel's weak rocks." *Journal of Rock Mechanics and Geotechnical Engineering* 12, no. 3 (2020): 541-556.
12. Aygar,Ebu Bekir, and Candan Gokceoglu. “Problems encountered during a railway tunnel excavation in squeezing and swelling materials and possible engineering measures: a case study from Turkey.” Sustainability 12, no.3 (2020): 1166.
13. Wu, Renjie, Yuji Fujita, and Kenichi Soga. "Integrating domain knowledge with deep learning models: An interpretable AI system for automatic work progress identification of NATM tunnels." *Tunnelling and Underground Space Technology* 105 (2020): 103558.
14. Yun, Yeboon, Genki Kaneko, Harushige Kusumi, Akinobu Nishio, and Tsutomu Kurotani. "Design for Support Patterns of NATM Tunnel Using Machine Learning." In *Information Technology in Geo-Engineering: Proceedings of the 3rd International Conference (ICITG), Guimarães, Portugal 3*, pp. 376-382. Springer International Publishing, 2020.