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Application of Artificial Intelligence in Underground Tunnelling System in Metro Rail Transport

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***Abstract*- the construction and maintenance of underground tunnels for metro rail transport systems are critical to ensure safe, efficient, and reliable transportation for passengers. Artificial Intelligence (AI) is a promising technology that can be used to improve the construction and maintenance of underground tunnels. In this paper, we review the current state of AI applications in tunnelling and explore the potential for AI to improve the construction and maintenance of underground tunnels in metro rail transport systems. We examine the various AI techniques that can be applied to tunnel construction and maintenance, including machine learning, deep learning, and computer vision. We also discuss the challenges associated with implementing AI in tunnelling and propose potential solutions. Finally, we provide case studies that illustrate the successful application of AI in tunnelling projects around the world. Our review suggests that AI has the potential to significantly improve the efficiency, safety, and cost effectiveness of underground tunnelling projects in metro rail transport systems.**

Keywords: Artificial Intelligence, Tunnelling, Metro Rail Transport, Machine Learning, Deep Learning, Neural Networks, Predictive Maintenance, Construction, Safety, Efficiency.

I. INTRODUCTION

Tunnels play a crucial role in the transportation engineering systems worldwide, and they are particularly significant in metro systems. Tunnels are utilized in various ways in the metro transport system to facilitate the movement of people and goods.

In recent years, artificial intelligence has become a booming technology in the fields of geotechnical engineering, tunnelling, and engineering geology. One potential area of application for AI is the use of machine learning methods, which is a branch of artificial intelligence, in tunnelling. By leveraging these methods, engineers can enhance their understanding of geological conditions and predict how the tunneling process will be affected by factors such as soil composition, rock structure, and water flow. This can help them to design tunnels that are safer, more efficient, and less prone to unexpected delays or costly construction errors. Overall, the use of artificial intelligence in tunnelling holds tremendous promise for advancing transportation engineering and improving the way we move people and goods around the world.

II. APPLICATION AND METHODS

Planning of a tunnel is a complex process that involves several critical factors to be considered to ensure a successful and safe construction. Here are some of the essential conditions that need to be taken into account during the planning of a tunnel:

1. Geological and Topographical Conditions: These conditions include the soil and rock composition, structure, and stability, as well as the topography of the surrounding area. The geological and topographical conditions are significant as they can significantly impact the tunnel's design, construction, and operation.
2. Cross-Section and Length of Continuous Tunnel: The cross-section and length of the continuous tunnel are determined based on several factors such as the anticipated traffic volume, ventilation requirements, and construction limitations. The cross-section of the tunnel also affects its stability and resistance to water pressure.
3. Time and Cost Considerations: The time and cost required for constructing a tunnel are significant factors that influence the tunnel's planning. The estimated construction time and cost are based on factors such as the geological and topographical conditions, tunnel length, and construction method.
4. Limits of Surface Disturbance: The limits of surface disturbance include the potential impact of construction activities on the surrounding environment, such as noise pollution, vibration, and dust. These factors need to be managed to minimize the impact on the environment and surrounding communities.
5. Building Conditions over Tunnel Alignment: The building conditions over the tunnel alignment include the presence of buildings or structures above or adjacent to the tunnel, which can affect the tunnel's stability and integrity. The presence of these structures may require additional reinforcement and support for the tunnel.

Overall, planning a tunnel requires a comprehensive analysis of several critical factors, including geological and topographical conditions, time and cost considerations, limits of surface disturbance, building conditions over the tunnel alignment, and many other important factors. By considering all these factors, engineers can ensure the construction of a safe and efficient tunnel that meets the needs of the community.

There are several methods available for constructing tunnels, and the selection of the appropriate method depends on several factors such as geological conditions, tunnel length, the potential impact on the population and traffic, and cost.

1. Classical Methods: This method involves manually excavating the tunnel using hand tools. Although it is

an old method, it is still used in specific cases where modern machinery is not suitable or where the excavation work is minor.

2. Mechanical Drilling or Cutting: This method involves the use of mechanical drills or cutting machines to excavate the tunnel. This method is faster than the classical method and is suitable for tunnels with hard rock.
3. Cut-and-Cover: This method involves excavating a trench, constructing a tunnel, and then covering the tunnel with soil. This method is suitable for short tunnels and is often used for metro stations and road tunnels.
4. Drill and Blast: This method involves drilling a hole in the rock, inserting explosives, and blasting the rock. This method is suitable for tunnels with hard rock and is often used in mines and hydroelectric projects.
5. Shields and Tunnel Boring Machines (TBM): This method involves using a shield or TBM to excavate the tunnel. The shield or TBM excavates the tunnel and installs a lining simultaneously. This method is faster and less disruptive than other methods.
6. New Austrian Tunnelling Method (NATM): This method involves excavating the tunnel in small sections and installing a temporary support system until the permanent lining is installed. This method is suitable for tunnels with variable ground conditions.
7. Immersed Tunnel Special Methods (Tunnel Jacking): This method involves constructing the tunnel on land, sinking it into a pre-dredged trench, and then backfilling around it. This method is suitable for tunnels beneath waterways.

In metro construction, the most common tunnelling methods used are cut-and-cover, TBM, and NATM. The selection of the appropriate method depends on the geological conditions, tunnel length, the potential impact on the population and traffic, and cost. Therefore, it is crucial to consider all the factors before selecting the appropriate tunnelling method for a specific project.

Tunnel Boring Machine (TBM)

Tunnel Boring Machine (TBM)

Tunnel Boring Machine (TBM) tunnelling is facing an increasing demand for minimizing soil and built-environment disturbance caused by tunnelling, while optimizing the efficiency of the tunnelling process with regards to delay, cost, safety, and environmental impact. This is particularly crucial in urban areas, where tunnelling operations are exposed to complex geological conditions, such as high heterogeneity, water inflow, rock bursting, and squeezing. The TBM has emerged as an efficient option for meeting these demands and has become a popular tunnelling method in urban areas due to its ability to comply with these requirements.

Application of Artificial Intelligence in TBM tunnel

1. The application of Artificial Intelligence (AI) in Tunnel Boring Machine (TBM) tunnelling has become increasingly popular due to its ability to improve efficiency, reduce costs, and enhance safety in tunnelling projects.
2. AI can be used in various stages of TBM tunnelling, including planning, design, construction, and maintenance. In the planning and design stage, AI can assist in predicting ground conditions and identifying potential risks, such as geological faults or water inflows. By analyzing data from geological surveys and historical tunnelling projects, AI algorithms can provide valuable insights to optimize the tunnel alignment, diameter, and length, as well as the selection of TBM type and parameters.
3. During construction, AI can improve the performance of TBM by optimizing the cutting parameters based on real-time data from sensors, such as torque, thrust, pressure, and temperature. By using machine learning algorithms, AI can also adapt to changing ground conditions and adjust the TBM operation accordingly to reduce the risk of downtime and damage.
4. In addition, AI can enhance safety by predicting and detecting potential hazards, such as rock bursts or collapses, and alerting the operators in real-time. By analyzing the data from sensors and cameras, AI can also provide insights into the health status of the TBM components and predict maintenance needs to prevent breakdowns and reduce downtime.
5. Overall, the application of AI in TBM tunneling can significantly improve the efficiency, safety, and cost effectiveness of tunnelling projects, especially in complex urban environments. However, the implementation of AI requires a comprehensive data collection and management system, as well as skilled professionals with knowledge in both tunnelling and AI.

III. RESULT AND DISCUSSION.

Effect of Artificial intelligence in Tunnel works. The traditional tunneling technology is dominantly based on experience analogy and limited amount of numerical analysis, which severely restricts the development of the tunneling technology. Need to be updating the tunneling

Technology with Artificial intelligence for faster and timely construction of an ideal transport system. In country like India this most advanced technologies will boost the future transport constructions in busy and congested cities also like Mumbai and Delhi in India.

Artificial Neural Networks (ANN) is part of supervised machine learning where we will be having input as well as corresponding output present in our dataset. Our whole aim is to figure out a way of mapping this input to the respective output. ANN can be used for solving both regression and classification problems.

The use of ‘ANN’ can provide an easy and user-friendly modelling environment with enhanced capabilities for tunnelling also. Once trained, the ANN can become an efficient tool for the prediction of the TBM’s performance. It is a very flexible system and it’s feed with updated construction data could improve its accuracy and expand its applicability limitations. In terms of identification risk prone areas, the use of investigation data in the ANN model could facilitate in the planning phase of tunnels, in selecting tunnel alignment, to the selection of TBM characteristics or even in selecting the most appropriate ground improvement technique.

A. Effect of BIM

Tunnel boring machine (TBM) projects have successfully applied linked data models and multimodal concepts in BIM, but those technologies have yet to be adopted in drill and-blast tunnelling. Centralized BIM model can allow the different engineering disciplines can work together and update the model in a common place.

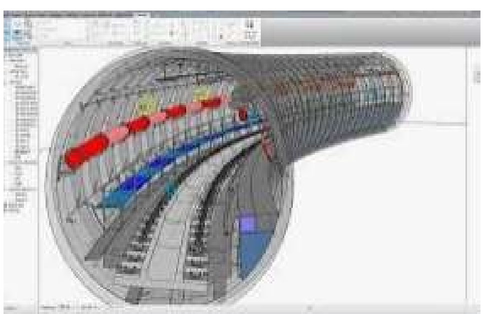

Figure 2: BIM modelling of Tunnel

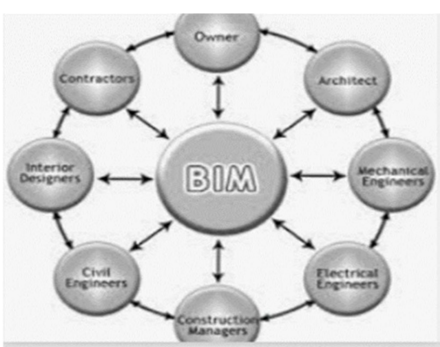

Figure 3: Centralized BIM

B. Advantages of BIM model

- Evaluation/Assessment.
- Preparation for the Transition / Project Pre-Planning.
- Execution of the Plan / Design and Construction.
- Operations and Maintenance through Experience and Expertise. Data exchange across the project lifecycle, Increased
- Efficiency, Better Information reduces errors and conflicts.
- Better communication improved results for the client.
- A responsive model.
- Keep up with the competition and future proof your business.

IV. CONCLUSIONS

The conclusion Tunnel boring machine (TBM) performance classifications, empirical models, statistical and artificial intelligent-based techniques which have been applied and introduced by the researchers in this field. Statistical and intelligent techniques which are applicable, powerful, and easy to implement, in estimating TBM performance parameters. The introduced models are accurate enough and they can be used for prediction of TBM performance in practice before designing TBMs.

Efficient planning, designing and managing of infrastructure using with Building Information Modelling (BIM) and other Finite Element modelling (FEM) methods to model the underground tunnels. The TBM allows the creation of the tunnel by digging directly into the rock/soil. While digging, the TBM also installs the precast segments in place, so that they form the coating of the tunnel. Inside the TBM, the segments are stored and then placed on the wall by an erector. All control of placing of tunnel segment and removing of muck deposit due to boring by control room inside the Tunnel operated with artificial intelligence. The traditional tunnelling technology is dominantly based on experience of analogy and limited amount of numerical analysis, which severely restricts the development of the tunnelling technology. Need to be updated the tunnelling Technology with Artificial intelligence for faster and timely construction of an ideal transport system. In country like India this most advanced technologies will boost the future transport constructions in busy and congested cities also like Mumbai and Delhi in India.

Figure 4: Tunnel with precast segments

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