

Time Efficiency and Quality of Section 8 ECRL Project Based on New Austrian Tunneling Method (NATM)

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Abstract

The East Coast Rail Link (ECRL) is a major infrastructure initiative aimed at improving connectivity between the east and west coasts of Peninsular Malaysia through modern railway technology. One of the tunneling methods used in the project is the New Austrian Tunneling Method (NATM). However, there is limited research analyzing the relationship between time efficiency and quality in NATM applications. This study focuses on identifying factors that influence time efficiency in NATM within the ECRL project, determining time efficiency based on NATM implementation, and exploring the correlation between time efficiency and construction quality. The research relies on secondary data from ECRL documentation, including the Detailed Implementation Program (DIP), actual tunneling progress records, Non-Conformance Reports (NCR), and quality inspection reports. These data sources are used to evaluate time efficiency and analyze tunnel construction quality. Data were processed using Microsoft Excel to compare planned and actual excavation progress, calculate productivity rates, and generate time efficiency ratios and graphs. Quality measures were assessed by analyzing the number of NCRs and results from quality inspections. The study revealed a correlation between time efficiency and tunnel quality, as variations in time efficiency corresponded with the frequency of NCRs issued. Overall, the research provides a detailed assessment of how time efficiency in NATM tunnel construction impacts construction quality. The findings offer valuable insights that can support future project planning, enhance productivity, and improve overall quality control in similar tunneling projects across Malaysia and beyond.

1. Introduction

The East Coast Rail Link (ECRL) is one of Malaysia's most significant infrastructure undertakings, designed to enhance connectivity between the east and west coasts of Peninsular Malaysia. A pivotal aspect of the ECRL involves tunneling through diverse geological conditions, especially in Section 8, which spans from Gombak to Serendah and includes three major tunnels: Gombak Tunnel (0.959 km), Serendah Tunnel 1 (3.595 km), and Serendah Tunnel 2 (9.882 km). Given the complexity of this section, the New Austrian Tunneling Method (NATM)

has been chosen for its adaptability and cost-effectiveness in varying ground conditions. Tunnel construction using NATM emphasizes real-time ground condition monitoring and flexible support systems. In large-scale projects like the ECRL, maintaining time efficiency and construction quality are essential. Time efficiency refers to executing activities within the planned timeline, minimizing delays, while quality refers to meeting technical, safety, and durability standards. A balanced execution of both is critical yet challenging, especially when unpredictable ground behavior or planning inefficiencies arise.

Although NATM has been widely implemented globally, there remains a lack of localized research specifically assessing how NATM affects time efficiency and construction quality in Malaysia, particularly for the ECRL. This gap impedes the development of optimized practices for tunnel construction under Malaysian geological conditions. Understanding the factors that influence the effectiveness of NATM is critical to achieving timely project delivery and maintaining structural quality. Moreover, the core principles of the New Austrian Tunneling Method (NATM) demand a careful correlation between time efficiency and construction quality. This dual objective presents a notable challenge, as efforts to accelerate progress may compromise the tunnel's structural integrity, while prioritizing quality could potentially slow down the construction timeline. If these gaps are not addressed, similar future infrastructure projects may face delays, cost overruns, or compromised tunnel safety. Conversely, closing this gap enables the establishment of best practices and contributes valuable insights to national tunneling guidelines.

The objectives of this research are structured to address the challenges and knowledge gaps associated with the application of the New Austrian Tunneling Method (NATM) in the East Coast Rail Link (ECRL) project, specifically in Section 8. Firstly, the study aims to identify potential factors influencing time efficiency during New Austrian Tunneling Method (NATM) in the ECRL project. These factors may include geological conditions, construction planning, equipment reliability, and workforce productivity. Secondly, this research seeks to determine the time efficiency based on the application of New Austrian Tunneling Method (NATM) of the ECRL project. Through this analysis, the study intends to assess how efficiently NATM is executed under real site conditions. Finally, the research aims to develop the relationship between time efficiency and quality regarding tunneling construction of NATM in the ECRL project. As NATM relies on flexible ground response and adaptive support techniques, this study will explore how efforts to maintain or improve time efficiency impact the overall quality and safety of the tunnel structures. Collectively, these objectives are designed to provide practical insights and recommendations for optimizing tunnel construction using NATM in future infrastructure projects.

2. Literature Review

The East Coast Rail Link (ECRL) project is one of the largest railway infrastructure developments in Malaysia, spanning a total length of 665 kilometers. It serves as a critical transportation corridor linking the east and west coasts of Peninsular Malaysia, enhancing connectivity and promoting economic growth. Based on figure 1, the alignment comprises a 404-kilometer subgrade route, 138 kilometers of bridges, and 53 kilometers of tunnels (Malaysia Rail Link Sdn Bhd, 2024). Section 8 of the project, located between Gombak and Serendah, plays a vital role due to its complex topographical features, including mountainous terrain that necessitates advanced tunneling techniques. This section includes 13 subgrades, 11 bridges, and 3 tunnels namely the Gombak Tunnel, Serendah Tunnel 1, and Serendah Tunnel 2 with cumulative tunnel lengths exceeding 14 kilometers (China Communications Construction Company ECRL, 2024). Construction activities in this section are guided by method statements provided by the main contractor, China Communications Construction Company Ltd. (CCCC), and overseen by Malaysia Rail Link (MRL) to ensure compliance with engineering, safety, environmental, and quality standards.

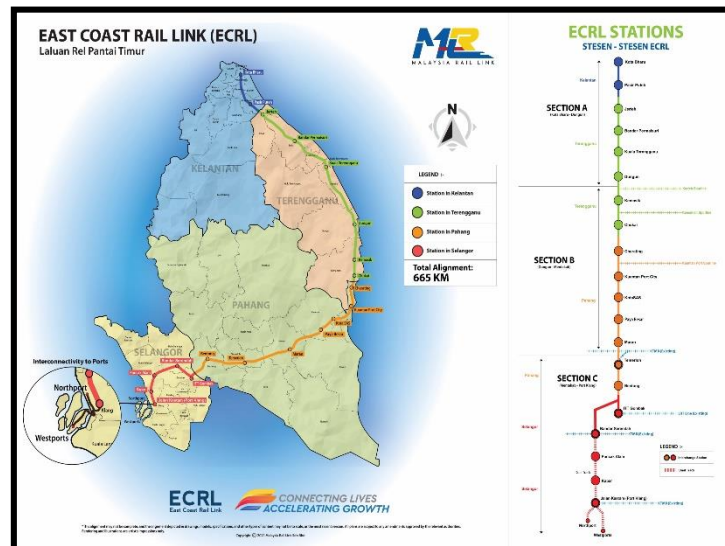


Fig. 1 ECRL Project Alignment

The New Austrian Tunneling Method (NATM) is a widely adopted tunneling technique introduced in the 1960s by Ladislaus von Rabcewicz. NATM leverages the self-supporting capacity of the surrounding rock or soil by allowing controlled deformation, which reduces stress on the tunnel lining (Aygar, 2020). This approach incorporates a combination of shotcrete, steel ribs, rock bolts, and flexible excavation sequences that are continually adjusted based on real-time site conditions. One of the method's distinguishing features is the use of the Observational Method (OM), which involves continuous monitoring and adaptation during construction to ensure safety and stability (Spross & Larsson, 2014). The Austrian standard ONORM B2203 categorizes rock behavior into specific classes to determine appropriate support systems, ranging from stable to squeezing rock types, ensuring a systematic approach to support installation (Aygar, 2020). NATM has demonstrated success in multiple projects worldwide, including the Bolu Tunnel in Turkey and the Lau Gunung Hydropower Plant in Indonesia. These projects highlight NATM's flexibility in adapting to various geological conditions, from soft soils to hard rock, while maintaining structural integrity and cost efficiency (Khoir & Putri, 2017; Saha & Mukherjee, 2022).

Time efficiency in tunnel construction is critical for managing costs and meeting project deadlines. It is defined as the optimal use of available time to complete construction activities without unnecessary delays or resource wastage. Špačková, Sejnoha, and Straub (2012) argue that conventional deterministic methods for scheduling are often inadequate in tunneling projects due to the high level of uncertainty inherent in geological conditions. As an alternative, probabilistic modeling offers more realistic and adaptive planning approaches, accounting for geological variability and equipment performance. Various factors influence time efficiency in tunnel construction, including ground and hydrological conditions, tunnel length and cross-section, construction method, equipment reliability, and site management (Špačková et al., 2012; Mohammadi et al., 2023). Risk management also plays a key role in maintaining construction timelines, especially when dealing with unpredictable events such as groundwater ingress, equipment failure, or adverse weather conditions (Mauretta et al., 2020). According to Memon, Roslan, and Zainun (2014), effective strategies to improve time performance include thorough pre-planning, contractor qualification vetting, shift-based work scheduling, and frequent coordination meetings among project stakeholders.

Quality in tunneling refers to the extent to which construction processes and outcomes meet design specifications, safety standards, and operational performance expectations. It encompasses both Quality Control (QC) and Quality Assurance (QA) practices aimed at ensuring structural reliability, material durability, and occupational safety. Ma (2011) notes that quality measures serve as benchmarks that guide the evaluation of construction effectiveness. The Observational Method (OM), integral to NATM, facilitates continuous real-time monitoring, enabling timely interventions and adaptive support implementation in response to changing site conditions. However, maintaining high construction quality is challenging due to multiple influencing factors. Workforce skill level, effective communication among stakeholders, quality of equipment and materials, and proper scheduling are among the critical elements that affect project quality (Oke, Aigbavboa & Dlamini, 2017; Farooqui, Ahmed & Lodi, 2008). A lack of coordination and improper supervision can result in rework, safety hazards, or even structural failures. For instance, the 2021 Ikoyi building collapse in Lagos exemplifies the dire consequences of ignoring quality standards, resulting in significant loss of life and financial setbacks (Okonta et al., 2024). The literature emphasizes the need for integrated QA/QC systems, skilled labor, and well-structured planning to ensure successful tunneling projects.

3. Methodology

Figure 2 shows the project follows a structured methodology, including literature review, data collection, data interpretation and data analysis, as outlined in the detailed flowchart.

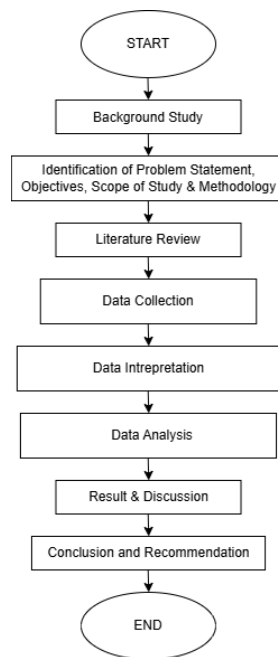


Fig. 2 Research Flowchart

This study investigated the relationship between time efficiency and construction quality in the application of the New Austrian Tunneling Method (NATM) within Section 8 of the East Coast Rail Link (ECRL) project. The methodology was designed to rely solely on secondary data derived from project documentation, which included construction progress records, quality inspection reports, and non-conformance reports sourced from Malaysia Rail Link (MRL) and China Communications Construction Company Ltd. (CCCC). The research process began with preliminary consultations involving the academic supervisor, industrial supervisor, and tunnel site engineers to refine the problem statement, objectives, scope, and research approach. A detailed literature review was conducted to establish a theoretical foundation on NATM principles, time efficiency variables, and tunneling quality benchmarks.

3.1 Data Collection from ECRL Project Documentation

Data collection for this study focused exclusively on secondary sources obtained from the ECRL project's official documentation, particularly those maintained by Malaysia Rail Link (MRL) and China Communications Construction Company (CCCC). The decision to rely on secondary data was based on the research scope, which did not require new data gathering but rather the interpretation of existing project information. This included documents such as tunnel excavation schedules, construction progress logs, quality control assessments, and engineering reports. These materials provided essential insights into tunneling progress, resource allocation, work procedures, and compliance with design specifications.

The secondary data covered both technical and managerial aspects of the NATM application, offering a comprehensive view of how time and quality were managed during construction. This method ensured that the study remained grounded in real-world conditions and operational practices, enhancing its relevance and practical value. The collected documentation included internal reports on planned versus actual construction progress, NCR (Non-Conformance Reports), and Quality Inspection Reports that helped in drawing correlations between performance metrics and construction quality.

3.2 Data Interpretation using Microsoft Excel

The data analysis was carried out using Microsoft Excel as the primary analytical tool due to its suitability for handling construction performance data. The planned excavation progress and actual excavation progress were

extracted from project reports and tabulated for each of the three tunnel sites within Section 8. The planned data represented the originally scheduled progress as established during the design phase, while the actual data reflected the on-site execution and excavation timelines as recorded by project engineers.

Productivity rates were calculated by dividing the total excavation length (in meters) by the number of working days recorded for each tunnel section. Time efficiency was then quantified as the ratio of actual productivity rate to planned productivity rate, expressed as a percentage. This enabled a clear evaluation of whether the tunneling works progressed faster, slower, or on par with the original schedule. Any inconsistencies or deviations were further interpreted to identify possible causes, such as delays due to geological complications or equipment issues. This approach enabled a data-driven assessment of how NATM performed under real construction conditions in terms of time management.

3.3 Tunnel Construction Quality Measures Analysis

In parallel with time efficiency analysis, the study examined the quality of tunnel construction by reviewing quality inspection reports and Non-Conformance Reports (NCRs) issued during and after construction activities. These documents were sourced from the ECRL project quality assurance team and were verified through official project records. The quality inspection reports offered data on compliance with design standards, tunnel lining integrity, material specifications, and support system implementation. The NCRs detailed specific deviations from standards, outlining the type of non-conformance, root causes, and corrective actions taken.

By analyzing the frequency, type, and severity of quality issues documented in the NCRs, the study evaluated how often and to what extent the project encountered construction flaws. The QIRs provided a benchmark for expected performance levels, and comparing these against the NCR data allowed for the identification of quality-related challenges encountered during the NATM process. This dual analysis facilitated the exploration of how time-driven decisions might have impacted construction quality — for instance, whether accelerated timelines contributed to an increase in quality issues. Ultimately, the quality data supported the objective of establishing a clear relationship between time efficiency and tunnel construction quality within the NATM framework used in the ECRL Section 8 project.

4. Result and Discussion

Table 1 presents the analyzed excavation progress data for the Gombak Tunnel under the East Coast Rail Link (ECRL) project. The analysis aimed to assess time efficiency associated with the implementation of the New Austrian Tunneling Method (NATM) by comparing planned and actual excavation productivity rates and progress. The dataset comprised ten distinct excavation locations, each defined by specific chainage boundaries, excavation durations and calculated productivity rates. The planned duration and corresponding excavation lengths (in meters) for each location were obtained from the Detailed Implementation Program (DIP) for Section 8 of the ECRL project. In contrast, the actual excavation progress (in meters) was documented and recorded by the ECRL project team during on-site construction activities. This comparison enabled the identification of deviations between planned and actual performance, thereby providing insight into the time efficiency achieved during tunneling using the NATM approach.

Table 1 Planned and Actual Data for Gombak Tunnel

Activity Name (Segment)	Planned Duration (days)	Planned Progress (m)	Actual Progress (m)	Planned Productivity Rate (m/day)	Actual Productivity Rate (m/day)
Excavation 1 (CH517+540 - CH517+590)	26	50.00	107.20	1.92	4.12
Excavation 2 (CH517+320 - CH517+540)	90	220.00	269.80	2.44	3.00
Excavation 3 (CH517+270 - CH517+320)	60	50.00	175.00	0.83	2.92
Excavation 4 (CH517+240 - CH517+270)	21	30.00	36.00	1.43	1.71

Excavation 5 (CH517+170 - CH517+240)	45	70.00	60.60	1.56	1.35
Excavation 6 (CH517+150 - CH517+170)	21	20.00	44.60	0.95	2.12
Excavation 7 (CH517+050 - CH517+150)	45	100.00	53.00	2.22	1.18
Excavation 8 (CH517+020 - CH517+050)	22	30.00	85.73	1.36	3.90
Excavation 9 (CH517+000 - CH517+020)	22	20.00	99.34	0.91	4.52
Excavation 10 (CH516+961 - CH517+000)	28	39.00	16.99	1.39	0.61

4.1 Gombak Tunnel Construction Progress Result

The excavation progress analysis of the Gombak Tunnel provides key insights into the time efficiency achieved through the New Austrian Tunneling Method (NATM). Planned versus actual excavation data from ten segments were compared to assess performance. Figure 3 illustrates the differences in progress for each segment. Segment 1 exceeded expectations, achieving 107.20 meters over a planned 50.00 meters in 26 days. Segment 2 also outperformed slightly, reaching 269.80 meters against a 220.00-meter plan over 90 days. Segment 3 saw a major gain, completing 175.00 meters versus a 50.00-meter plan in 60 days. Segment 4 also surpassed its goal with 36.00 meters against 30.00 meters planned. In contrast, Segment 5 underperformed with only 60.60 meters completed over a 70.00-meter target. Segment 6 doubled its output with 44.60 meters versus 20.00 meters planned in 21 days. Segment 7 showed notable underperformance, reaching just 53.00 meters of a 100.00-meter plan. Segment 8 nearly tripled its goal with 85.73 meters over 30.00 meters planned in 22 days. Segment 9 had the highest efficiency, completing 99.34 meters versus a planned 20.00 meters. However, Segment 10 recorded the lowest output with only 16.99 meters achieved out of a 39.00-meter plan, indicating significant delay.



Fig 3 Planned Progress vs Actual Progress Graph for Gombak Tunnel

4.1.1 Gombak Tunnel Productivity Rate

Productivity rate, expressed in meters per day, was adopted as the primary metric for gauging construction efficiency during tunnel excavation. This rate reflects how effectively excavation activities are completed over time and is typically expressed in meters per day (m/day), indicating the average linear progress achieved during each working day. Planned productivity rates were taken from the project schedule, while actual productivity rates were derived from on-site progress records. For this research, there will be 2 types of productivity rate

which are planned productivity rate and actual productivity rate. The productivity rate can be calculated by using the following formula:

$$\text{Productivity Rate} \left(\frac{m}{\text{day}} \right) = \frac{\text{Excavation Progress (m)}}{\text{Total duration (day)}} \quad (1)$$

Where:

- The planned productivity rate is calculated using the planned excavation length over the planned duration
- The actual productivity rate uses actual excavation progress, still referenced against the planned duration to maintain comparability.

Figure 4 illustrated the comparison between planned and actual productivity rates across all excavation segments. Segment 1 performed well, with an actual productivity rate of 4.12 m/day, surpassing the planned rate of 1.92 m/day. Segment 2 also showed improvement, increasing from 2.44 m/day to 3.00 m/day over its 90-day duration. Segment 3 recorded one of the largest gains, rising from 0.83 m/day to 2.92 m/day. Segment 4 maintained a steady output, with actual productivity slightly above the planned rate at 1.71 m/day versus 1.43 m/day. Segment 5 fell below expectations, achieving only 1.35 m/day compared to the planned 1.56 m/day. In contrast, Segment 6 improved significantly, reaching 2.12 m/day against a target of 0.95 m/day. Segment 7 underperformed, producing just 1.18 m/day instead of the expected 2.22 m/day, likely due to site challenges. Segment 8 demonstrated strong efficiency, increasing from a planned 1.36 m/day to 3.90 m/day. Segment 9 achieved the highest productivity rate at 4.52 m/day, far exceeding its planned rate of 0.91 m/day. Lastly, Segment 10 showed the weakest performance, recording only 0.61 m/day against a planned rate of 1.39 m/day, indicating possible operational setbacks.

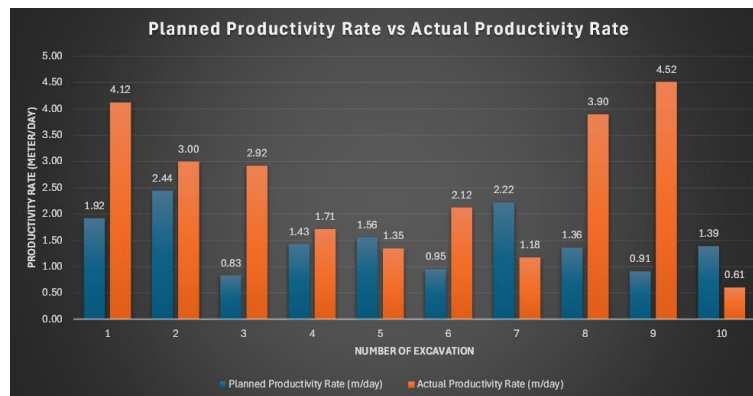


Fig 4 Planned Productivity vs Actual Productivity Graph for Gombak Tunnel

4.1.2 Gombak Tunnel Time Efficiency

To accurately assess time efficiency during tunnel excavation in Section 8 of the East Coast Rail Link (ECRL) project, efficiency percentages were calculated. This method provided a clear and quantifiable way to evaluate how actual field performance aligned with planned productivity targets. By comparing actual productivity rates to planned rates, the efficiency percentage (%) served as a reliable indicator of whether excavation activities were completed on time, ahead of schedule, or delayed. The formula used to calculate time efficiency was:

$$\text{Time Efficiency (\%)} = \frac{\text{Actual Productivity Rate} \left(\frac{m}{\text{day}} \right)}{\text{Planned Productivity Rate} \left(\frac{m}{\text{day}} \right)} \times 100 \quad (2)$$

The efficiency percentage is calculated by dividing the actual productivity rate by the planned rate, then multiplying by 100 to express the result as a percentage. This value is essential for interpreting time performance during excavation:

- Above 100%: Indicates the work progressed faster than expected, reflecting positive time efficiency and early completion.
- Exactly 100%: Shows that actual productivity perfectly matched the planned rate, meaning the schedule was precisely met.
- Below 100%: Suggests slower-than-expected progress, highlighting potential delays or inefficiencies that may warrant further analysis.

The time efficiency of tunneling operations in the Gombak Tunnel was evaluated using a standardized efficiency percentage formula. This method allowed for a measurable comparison between planned and actual productivity, providing clear insights into the effectiveness of the New Austrian Tunneling Method (NATM) implementation. Efficiency values were calculated for ten excavation segments, as illustrated in Figure 5. Segment 1 demonstrated strong performance with an efficiency of 214.40%, exceeding its planned schedule by 114.40%. Segment 2 also performed well, achieving 122.64% efficiency, with actual excavation exceeding the 220.00-meter target by nearly 50 meters. Segment 3 was a standout, recording 350.00% efficiency after completing 175.00 meters compared to the 50.00-meter plan. Segment 4 achieved 120.00% efficiency, with progress closely matching the expected output, reflecting accurate planning and favorable site conditions.

Segment 5 underperformed slightly, reaching only 86.57% efficiency after achieving 60.60 meters out of the planned 70.00 meters. This minor shortfall may have resulted from geological challenges or equipment-related delays. Segment 6 marked a significant recovery with 223.00% efficiency, completing more than double the planned progress. Conversely, Segment 7 showed the weakest performance aside from Segment 10, with only 53.00% efficiency after completing just over half of the planned excavation. Segment 8 delivered excellent results, achieving 285.77% efficiency with 85.73 meters completed instead of the planned 30.00 meters. Segment 9 recorded the highest efficiency at 496.70%, completing 99.34 meters—nearly five times the planned progress. In contrast, Segment 10 had the lowest efficiency at 43.56%, completing only 16.99 meters out of 39.00 meters. Overall, 7 out of 10 excavation segments achieved time efficiency above 100%, indicating that NATM was generally effective in meeting or exceeding excavation targets under suitable conditions.

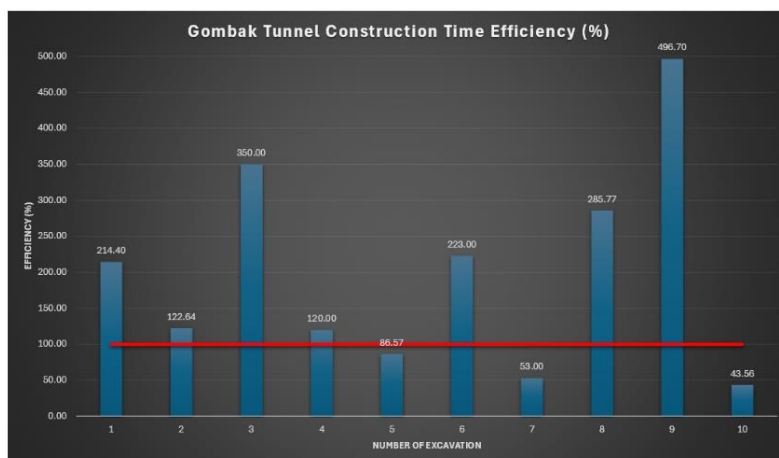


Fig 5 Gombak Tunnel Construction Time Efficiency

4.2 Tunnel Construction Quality Measures

During the Gombak Tunnel construction for Section 8 of the ECRL project, regular construction quality inspections were conducted to ensure compliance with NATM standards. These inspections assessed critical tunnel components such as shotcrete, wire mesh, rock bolts, and secondary linings, focusing on structural areas like the crown, bench, and invert. Environmental factors, including seepage and ground deformation, were also evaluated to maintain long-term tunnel integrity. Several quality issues were identified through these inspections, including a recorded Q-value of 0.33, indicating extremely poor rock mass conditions. This segment experienced over-excavation due to weak geotechnical data and communication lapses. In another case, inadequate bar anchorage in the inverted arch resulted from space constraints near the excavation face, compromising structural continuity.

A total of 15 Non-Conformance Reports (NCRs) were issued between May 2023 and May 2024. Common issues included poor shotcrete application, missing components, over-excavation, and improper installation of anchoring systems. Specific NCRs such as NCR-0008, NCR-0067, and NCR-0100 reflected recurring failures in support system implementation, requiring rework and causing construction delays. These quality deviations significantly impacted time efficiency. Rework triggered by NCRs often halted progress in affected areas, leading to timeline extensions. In particular, NCR-0071 involved both over-excavation and missing rock bolts, requiring dual corrective actions. Additionally, delayed drawing approvals (e.g., NCR-0009) and waterstop issues (NCR-0116) disrupted construction flow and affected adjacent tunnel activities.

4.3 The Relationship Between Time Efficiency and Quality Measures

Table 2 illustrate excavation segments by time efficiency which are segments above 100% (ahead) and below 100% (delayed). Segments with higher efficiency had an average of 1.43 NCRs per segment, while delayed segments recorded 1.67 NCRs per segment. This suggests the relationship between time efficiency and construction quality, where slower progress often correlated with more quality issues.

Table 2 Average NCR issued per segment for Gombak Tunnel

Time Efficiency Range	No. of Segment	No. of NCRs	Average NCR per Segment
Above 100%	7	10	1.43
Below 100%	3	5	1.67

Figure 6 supported this finding, showing that delayed segments experienced a higher frequency of NCRs. Although the average difference of 0.24 may appear small, it holds significance when accumulated across long tunnel sections. These findings confirm that compromised quality control, often due to schedule pressure or reactive management, can negatively impact both structural performance and project timelines in NATM tunneling.

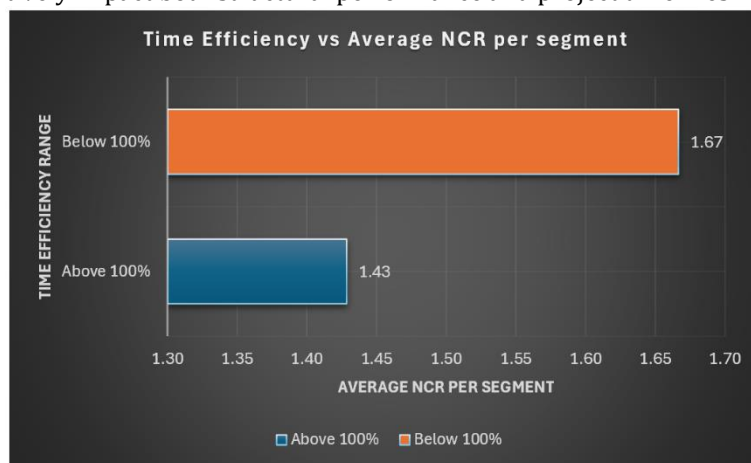


Fig 6 Gombak Tunnel Non-Conformance Report Data

5. Conclusion

This study successfully evaluated the relationship between time efficiency and construction quality in the application of the New Austrian Tunneling Method (NATM) for the Gombak Tunnel, Section 8 of the ECRL project. Through secondary data analysis and literature review, three research objectives were achieved. First, several key factors influencing time efficiency such as geological conditions, planning, equipment availability, and workforce management were identified. Second, by comparing planned and actual productivity rates across ten tunnel segments, the study found that 7 out of 10 segments exceeded 100% efficiency, highlighting effective NATM implementation. The third objective examined the correlation between time efficiency and quality through analysis of Non-Conformance Reports (NCRs). Segments with lower time efficiency recorded more NCRs, confirming that delays were often associated with increased quality issues. This demonstrated that time efficiency directly influenced the construction quality. Overall, the findings confirmed the correlation of time efficiency and quality performance in NATM tunneling. The study emphasized the importance of integrated planning and quality monitoring to ensure both timely delivery and structural reliability in future tunnel projects.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

*The author confirm contribution to the paper as follows: **Time Efficiency And Quality Of Section 8 ECRL Project Based On New Austrian Tunneling Method (NATM): Muhammad Nazif Aiman Bin Mohamed Izamshah, Supervisor: Prof. Madya Ts. Dr. Joewono Prasetyo and Azrul Nizam Bin Ahmad. All authors reviewed the results and approved the final version of the manuscript.***

References

- [1] Aygar, E. B. (2020). Evaluation of new Austrian tunnelling method applied to Bolu tunnel's weak rocks. *Journal of Rock Mechanics and Geotechnical Engineering*, 12(3), 541–556. <https://doi.org/10.1016/j.jrmge.2019.12.011>
- [2] China Communications Construction Company ECRL. (2024). *CCC ECRL Section 8 Gombak Tunnel Drawing*.
- [3] Farooqui, R., Ahmed, S., & Lodi, S. (2008). Assessment of Pakistani Construction Industry – Current Performance and the Way Forward. *Journal for the Advancement of Performance Information and Value*, 1(1), 51. <https://doi.org/10.37265/japiv.v1i1.122>
- [4] Khoir, R. A., & Putri, A. D. (2017). The effectiveness of new austrian tunnelling method (NATM) for hydro power plant construction: lau gunung power plant, north sumatera, indonesia. *MATEC Web of Conferences*, 138, 04012. <https://doi.org/10.1051/mateconf/201713804012>
- [5] Ma, J. (2011). Quality control in tunnel construction with special reference to the application of the observational method. In Chang'an University, *Chang'an University*.
- [6] Malaysia Rail Link Sdn Bhd. (2024). East Coast Rail Link (ECRL): Value-adding Disruptor for National Logistics. In *Introduction to ECRL* (p. 2). <https://www.mrl.com.my>
- [7] Mauretta, S., Purba, H., & Purba, A. (2020). Risk identification in tunnel construction project: A literature review. *Facta Universitatis - Series Architecture and Civil Engineering*, 18(3), 261–286. <https://doi.org/10.2298/fuace200704019m>
- [8] Memon, A. H., Roslan, N., & Zainun, N. Y. (2014). Improving Time Performance in Construction Projects: Perspective of Contractor. *Journal of American Science*, 46–50. <http://www.jofamericanscience.org>
- [9] Mohammadi, M., Spross, J., & Stille, H. (2023). Models to Analyze Risk in Time and Cost Estimation of Tunneling Projects. *Geotechnical and Geological Engineering*, 42(2), 1445–1457. <https://doi.org/10.1007/s10706-023-02627-x>
- [10] Oke, A., Aigbavboa, C., & Dlamini, E. (2017). Factors Affecting Quality of Construction Projects in Swaziland. In University of Johannesburg, *University of Johannesburg*.
- [11] Okonta, E. D., Okeke, F. O., Ojelabi, E. T., & Akinola, A. V. (2024). Exploring the Role of quality management practices (QMS) in mitigating Construction Failures and building collapse. *Deleted Journal*, 1(1). <https://doi.org/10.1007/s44290-024-00115-6>
- [12] Špačková, O., Šejnoha, J., Straub, D., Engineering Risk Analysis Group, Technische Universität München, Dep. of Mechanics, Fac. of Civil Engineering, & Czech Technical University in Prague. (2012). Tunnel construction time and cost estimates: from deterministic to probabilistic approaches. *Engineering Risk Analysis Group, Technische Universität München, Germany*.
- [13] Spross, J., & Larsson, S. (2014). On the observational method for groundwater control in the Northern Link tunnel project, Stockholm, Sweden. *Bulletin of Engineering Geology and the Environment*, 73(2), 401–408. <https://doi.org/10.1007/s10064-013-0501-8>