

## CHAPTER 5 : CONCLUSION AND SUGGESTION

### 5.1. CONCLUSION

This study presents a comprehensive safety engineering analysis of Multi Utility Tunnel (MUT) construction methods within the Ibu Kota Nusantara (IKN) development. By identifying hazards related to equipment, materials, workers, and environmental conditions, the research highlights critical risks such as trench collapse, formwork failure, lifting hazards, and geotechnical instability specific to the IKN site conditions.

The risk assessment and safety analysis show that the cast-in-place method carries a higher overall risk than the precast method (5.74 vs 5.25). This elevated risk stems from prolonged on-site exposure to excavation hazards, structural instability, and the challenges of working within weak claystone soil conditions. In contrast, the precast method significantly reduces on-site risks by relocating high-risk activities to controlled factory environments, though lifting and rigging operations remain a key safety concern. Overall, the findings support the adoption of the precast construction method as the safer alternative for MUT implementation in IKN. This research contributes practical, evidence-based recommendations to support risk-informed decision-making, and enhances the application of safety engineering principles in large-scale underground infrastructure projects.

To address these risks, the study proposes a mitigation framework consisting of targeted control strategies, including geotechnical safety measures (e.g., slope stabilization, trench protection), structural risk controls (e.g., proper formwork design, bracing), and lifting safety protocols (e.g., crane capacity verification). The function of this framework is to serve as a systematic guide for identifying, managing, and reducing high-risk activities throughout the MUT construction lifecycle. It provides a structured basis for engineers and project managers to proactively apply safety measures based on site-specific hazards. All proposed controls align with relevant international and national standards (ISO 45001, OSHA 1926, and Permen PUPR No. 10/2021), ensuring their applicability to infrastructure development projects across Indonesia.

## 5.2. SUGGESTIONS

Based on the results of this research, several suggestions are proposed for both practical implementation and academic advancement:

### 1. Enhance Safety Planning in Early Design Stages

Construction method selection should be supported by risk-based analysis during the planning phase. Designers and project managers should integrate safety engineering considerations into method statements, WBS development, and equipment logistics, particularly for high-risk segments of MUT projects.

### 2. Standardize Mitigation Measures

Authorities and contractors are encouraged to adopt standardized mitigation frameworks, especially for formwork systems, lifting plans, and trench safety protocols. These should refer to internationally recognized guidelines (e.g., ISO 45001, OSHA 1926) and be contextualized for tropical geotechnical conditions like IKN's.

### 3. Focus on Precast Safety Optimization

While precast methods offer a lower risk profile, lifting operations still carry severe hazard potential. It is suggested that future implementation incorporates digital tools (e.g., lifting simulations, 4D BIM sequencing) to predict, monitor, and control lifting-related risks with greater precision.

### 4. Strengthen Workforce Training and Supervision

To reduce risk exposure on-site, ongoing training in hazard recognition, safe lifting practices, and emergency response should be institutionalized. Supervision protocols must also be reinforced to ensure consistent application of safety procedures during MUT construction.

### 5. Encourage Future Research

Further studies are suggested to explore the integration of real-time monitoring systems (e.g., IoT sensors, BIM-based safety dashboards) for risk prediction. Comparative studies involving lifecycle safety, cost-performance trade-offs, and behavioral safety analysis would also enrich the knowledge base in underground infrastructure safety.