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Prediction of Subsidence during TBM Operation in Mixed-Face Ground Conditions from Realtime Monitoring Data

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Abstract: The prediction of settlement during tunneling presents multiple challenges, as such settlement is governed by not only the local geology but also construction methods and practices, such as tunnel boring machine (TBM). To avoid undesirable settlement, engineers must predict the settlement under given conditions. The widely used methods are analytical solutions, empirical solutions, and numerical solutions. Analytical or empirical solutions, however, have limitations, which cannot incorporate the major causes of subsidence, such as unexpected geological conditions and TBM operational issues, among which cutterhead pressure and thrust force-related factors are the most influential. In settlement prediction, to utilize the machine data of TBM, two phases of long short-term memory (LSTM) models are devised. The first LSTM model is designed to capture the features affecting surface settlement. The second model is for the prediction of subsidence against the extracted features. One thing to note is that predicted subsidence is the evolution of settlement along TBM drive rather than its maximum value. The proposed deep-learning models are capable of predicting the subsidence of training and test sets with excellent accuracy, anticipating that it could be an effective tool for real-world tunneling and other underground construction projects.

Keywords: tunnel boring machine (TBM) operation; TBM induced ground settlement; deep learning; long short-term memory (LSTM); machine data

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1. Introduction

Underground construction using Tunnel Boring Machines (TBMs) is rapidly increasing to meet demands for new roads, railways, and electrical and telecommunication infrastructure associated with rapid urbanization. The TBM method offers several advantages, such as closed-mode operations, over other traditional approaches in terms of the safety measures involved in applying face-support pressures and the instant support provided by concrete linings, which mitigate the risks posed by the high groundwater pressure under water table.

Mixed-face ground conditions during TBM driving pose the most challenging risks. The soft soil at the top of the face and the hard rock at the bottom makes it difficult to maintain a proper face-support pressure and face stability, and increases the risk of excessive cutter wear, face collapse, sinkholes, or damage to surrounding structures [1]. To avoid undesirable settlement and provide appropriate safety measures, engineers must reliably predict the amount of settlement under given ground conditions. The most widely accepted analytic solution, proposed by Peck [2], is based on measurements from various projects and has been modified to apply to TBM excavations in geologically mixed-face conditions for metropolitan projects in the congested urban area [3].

However, an analytic solution has its own limitations, as it may not be able to incorporate the important causes of subsidence, such as unexpected geological conditions and subsequent ground deformation, over-excavation, untreated tail voids, curvature with a short radius, and TBM operational issues, including chamber pressure, penetration or