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Superior Modeling of Hard Rock TBM Performance Using Novel Predictive Analytics Methodologies

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Abstract

In the past decades, TBM performance analysis takes paramount importance among several project management and underground space technology problems on account of its impact on cost estimation, time planning, efficiency improvement and other relative issues. The main aim of this paper is to propose new superior equations for TBM performance prediction in hard rock conditions. The Gene Expression Programming (GEP), and models through the Imperialistic Competitive Algorithm (ICA), are developed in this study, as novel predictive analytics methodologies. The proposed models of this study improve the accuracy of predictive equations developed through a database of TBM performance in one of the most complex tunneling projects in the world.

Keywords: Performance prediction, Tunnel boring machine (TBM), Predictive modeling, Gene expression programming (GEP), Imperialist competitive algorithm (ICA).

1. INTRODUCTION

TBM performance prediction in the past forty years has become one of the most sophisticated problems in geotechnical engineering. This challenge is directly related to the cost estimation, time planning, efficiency improvement, and other associated issues of the project management. A number of attempts have been conducted to estimate TBM performance in the difficult grounds since the 1970s (e.g., [1, 2]). These efforts, which has no specific conclusion nor a comprehensive formulation, can be categorized into the theoretical and the empirical models. The theoretical studies are usually based on laboratory testing results, probe in operation of TBM and influence of cutter disk on a rock sample, and other related issues [3]. However, due to some difficulties encountered in providing field rock conditions in the laboratory and lack of available equipped laboratories, the theoretical models have not been developed progressively. On the other hand, the empirical studies are conducted based on both field data of the rock mass properties (including the Uniaxial Compressive Strength (UCS), the Joint Spacing (JS), the Distance between Planes of Weaknesses (DPW), the Brittleness Index (BI), the Brazilian Tensile Strength (BTS), angle between planes of weakness, and TBM driven direction (α), etc.) and the machine recorded parameters (e.g., Thrust Force, Torque, cutter load, Power, and number of cutters, etc.) [4, 5, 6, 7]. The empirical methods can be classified into four groups including simple models [8], multiple parameters models [4, 6], probabilistic models [9], and computer-aided models [10, 11, 12]. The computer-aided models, which have been developed considering various rock and machine parameters, have a better correlation with actual measurements in comparison to the other mentioned types of models. In recent years, different types of linear and non-linear regression analyses have been combined with computer algorithms to improve the results for manufacturer companies and site managers of tunneling projects usage [13].

The literature review shows that there is no consensus on the quantitative or qualitative influence of various variables on TBM penetration rate, but it has been improved through introducing advanced models [14]. Therefore, in this study, two new superior equations are introduced through new predictive analytics approaches including the Imperialist Competitive Algorithm (ICA) and the Gene-Expression Programming (GEP) which are two powerful and popular techniques in data mining.