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USING A DISCRETE-EVENT SIMULATION MODEL FOR EFFICIENT OPERATION OF TUNNEL BORING MACHINES

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ABSTRACT

A tunnel boring machine (TBM) is the primary resource in a tunnel construction project and generally its advance rate is equal to the performance rate of the whole project. Regarding previous studies, the utilization factor of TBMs is approximately 50% most of the time. The process of repair and maintenance of various parts of the machine and the logistic equipment takes 50% of the time. The model presented here, tries to simulate the whole process of tunneling in Ahwaz Urban Railway project, in Iran, that contains two 23Km long tunnels and find out how impairment of different parts of the TBMs can delay the project. The results of the model show that changing the policy of repair and maintenance of the TBMs in the project can improve the utilization factor of them. This model can be implemented in other tunneling projects to test different policies of TBMs' repair and maintenance.

1 INTRODUCTION

Advance rate of tunnel boring machines (TBMs) mostly depends on three factors, as follows: 1) soil (or rock) characteristics, 2) repair and maintenance of different parts of the machine, and 3) logistics and supporting facilities. To prediction of performance of a TBM, two parameters consisting of penetration rate (ROP) and advance rate (AR) of TBM must be estimated. ROP is defined as the distance excavated divided by the operating time during a continuous excavation phase, while AR is the actual excavated and supported distance divided by the total time (Frough et al., 2012). The ROP mostly depends on the characteristics of the soil (or rock), but AR is dependent of the whole process of TBM tunneling and the three factors mentioned above. Although ROP is an important parameter, but the total performance of the TBM is calculated on the basis of AR. AR and ROP are related to each other based on the following equation:

$$AR=ROP\times U$$

Where, U (utilization factor)= the working hours of the TBM divided by the total duration which it is working or being repaired, maintained or is idle waiting for logistics and supporting facilities.

Based on previous studies, the utilization factor of TBMs is mostly about 50% or even less. The utilization factor in Turin metro line 1 was 26% at the beginning of the project and increased to 51% after the first 150 excavated rings (Avitabile et al., 2010). In Tarabya tunnel in Istanbul, the utilization factor of the TBM is 53% in 7700 meters of the tunnel (Bilgin et al., 2005). The utilization factor of the TBM in Karaj-Tehran water conveyance tunnel was about 21% (Frough et al., 2012) and this parameter in Qomroud water conveyance tunnel was about 23% (ShariatAlavi et al., 2010).

Ahwaz Urban Railway project, that is the case in this presentation, is located in Ahwaz, south west of Iran. The project contains two parallel tunnels, each 23Km long that are being excavated using two TBMs (the outer diameter of the TBMs is 6.8m). For the first and the second TBM in this project, the utilization factor were 51% and 47%, respectively.

This case study aims to simulate the whole process of TBM tunneling in Ahwas subway project and find out how different scenarios of repair and maintenance can affect the utilization factor of the TBM. The model is developed using discrete-event simulation (DES) method.

2 MODEL DESCRIPTION

The simulation model is developed in Anylogic using DES modeling method. The model simulates all processes in the cycle of TBM tunneling, including: 1) logistic supports of the TBM using locomotives and rolling stocks and their movement inside the tunnel, 2) loading tunnel segments and unloading muck from rolling stocks in the tunnel portal, 3) excavation of tunnel by the TBM, 4) mounting segments to support the tunnel against earth collapse, 5) impairment of different parts of the machine and the process of repair and maintenance of the TBM.

In Ahwaz Urban Railway project, the impairments are grouped and recorded in 5 preliminary groups and 62 secondary groups. The 5 preliminary groups are: 1) mechanical, 2) electrical, 3) execution, 4) logistics, and 5) miscellaneous. At the time of this study, each one of the two TBMs have excavated nearly 6,000 meters and their actual data have recorded in a database system. The model presented here, uses this statistical data to simulate the remained part of the tunnels that is about 12,000 meters long for each tunnel.

Based on the results of the model, changing the policy of repair and maintenance can save time and improve the utilization factor of the TBMs. From the beginning of the project, repairs made after an impairment had happened. The results of the presented model show that assigning a duration to maintenance, can improve the utilization factor of the two TBMs.

3 CONCLUSIONS

The results of the implementation of the developed DES model show that the model can improve the utilization factor of TBMs and reduce the duration of the project. Resources are allocated to the project with respect to TBM working hours, in consequent the utilization factor of other resources is improved too. The proposed model can be implemented in other TBM tunneling projects to forecast projects duration and cost.

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