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Life cycle cost analysis (LCCA) of railway tracks maintenance decisions using the Markov forecast model based on the track recording machine data

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ABSTRACT: Rail transportation system plays an important role in the development of the economies of the countries. This system will be worn over time by operation and weather conditions and will require maintenance. One of the goals of this operation is to keep the tracks in an acceptable condition and prevent their excessive deviation from the optimal situation. Railways maintenance and repair management system has been studied and implemented to optimize activities and reduce related costs. Such systems have used various techniques to predict the future state of failure. Choosing the best maintenance policy is the goal of these systems. For policymaking, the best and most cost-effective option, life-cycle cost analysis is required. In the following, with help of the Markov prediction model, the life cycle cost (LCC) model is suggested for rail and ballast. In the end, it was found that the main costs in the ballast part are renewal costs and the track unavailability costs. The effect of renewal tonnage on these two costs is far higher than other costs. As you can see, the lowest ballast life cycle cost in the range of 100 to 150 million gross tons. In this study, assuming annual tonnage (16 million gross tonnages) as previously mentioned, it results in a renewal life of about 6 to 10 years. This value for the rails is from 500 to 540 million gross tons, which is equivalent to 30 to 35 years.

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1- INTRODUCTION

After the construction of the railway tracks, a set of operations is carried out to maintain their quality and keep efficiency at the optimal level which is referred to as maintenance operations. In general, a proper track maintenance decision system should be able to answer the question of when and how to maintain the track to get the most profit by spending the least cost. [1]. Using the Markov chain is one way to achieve degradation models and predict future conditions [2-4]. Ayyub et al. [5] and Hakhamaneshi and Shafahi [1] have presented the Markov model by optimizing and creating the transition matrix and Prescott has proposed the Markov chain by statistical analysis on the relative rate of rail wear [6].

The issue raised in this study is the implementation of a process for making optimal maintenance decisions for railways, taking into account long-term costs. The main focus of the work is on the implementation of the overall framework of the decision-making system based on life cycle cost. In this study, we have tried to compile a comprehensive database with the least error. After that, the degradation model is formed using comprehensive information. In the end, efforts have been made to process maintenance costs for the life cycle cost analysis.

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2- METHODOLOGY

Many studies have used approaches in the form of extrapolation or nonlinear fitting to produce track prediction models having railway track conditions in different sections according to their age. Extrapolation models have the essence of a definitive model. Also, the form of a specific function has been often used in fitting models, usually exponential or polynomial models.[1]

In this study, the TTQI described in the previous section has been used. This index changes from 0 (zero) which represents the state of best track condition to 470 which is the threshold of complete failure (very bad condition). As discussed in the preceding section, the tolerance range of this index is presented fuzzily. Being fuzzy means that there is no clear boundary between track quality states. Also, Table 1 presents the track state classification for use in the Markov model. The presentation of the fuzzy Markov model can be one of the proposed future works.

In this study, a block is considered the smallest maintenance unit. Thus, for each class, a transition matrix has been computed that it's main diagonal shown in Table 4. It should be noted that, based on the information available in some classes, there is insufficient information to recommend the Markov model, so not all of the classes in Table 2 are present.

Since most maintenance activities focus on rail and ballast

Table 1. The track state classification corresponding to TTQI index

Track State	Track Quality	TTQI
1	Excellent	0 – 75
2	Good	75 – 177.5
3	Medium	177.5 – 345
4	Bad	345 – 390
5	Bad and Very Bad Gap	390 – 470
6	Very Bad	More than 470

Table 2. Diagonal elements of transition matrices for the classes of tracks

Class	P_{11}	P_{22}	P_{33}	P_{44}	P_{55}
K=1	0.8216	0.7111	0.5827	0.3271	0.2107
K=2	0.8442	0.7007	0.6137	0.4174	0.1124
K=3	0.8972	0.7552	0.5624	0.3410	0.1439
K=4	0.8342	0.6921	0.6023	0.3746	0.2752
K=5	0.7824	0.6885	0.5364	0.3488	0.2400
K=7	0.8320	0.7376	0.5435	0.3669	0.1754
K=8	0.8373	0.6829	0.5967	0.3820	0.1457
K=13	0.7923	0.6931	0.5627	0.4237	0.1913
K=14	0.8142	0.7329	0.6037	0.3913	0.1395
K=15	0.8636	0.7271	0.5723	0.3843	0.1993
K=16	0.8122	0.7084	0.6277	0.3955	0.2321
K=17	0.7444	0.6625	0.5291	0.3627	0.2557
K=18	0.7324	0.6271	0.4423	0.3725	0.1524

and also due to having reliable information on rail and ballast maintenance costs, this study presents only the rail and ballast maintenance, LCC model. It should be noted that the Rail and ballast LCC model are developed models available in the literature. Although both the Rail and Ballast LCC models have been discussed separately, an integrated approach should be developed. The result true comprehension of both models determines the best renewal time (in cumulative tonnage) for both.

3- CONCLUSION

In this study, the proposed new index MahmoudiFard [7] was used to improve the accuracy of the model. One advantage of using this indicator is the direct use of track recorder machine outputs. In the LCC Analysis section, considering the most important components of the railroad that are most likely to be repaired and maintained, their life cycle cost model and a way to find the optimal time for maintenance operations are presented. Applying the life cycle cost analysis to ballast maintenance decisions showed that in addition to incorporating cost and cost over time in the process of determining the rail and ballast renewal optimum time, this analysis results in near-realistic responses. For example, as you can see, the lowest ballast life cycle cost in the range of 100 to 150 million gross tons. In this study, assuming annual tonnage (16 million gross tonnages) as previously mentioned, it results in a renewal life of about 6 to 10 years. This value for the rails is from 500 to 540 million gross tons, which is equivalent to 30 to 35 years.

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