Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(7) (2021) 613-616
DOI: 10.22060/ceej.2020.17506.6585

Introducing a New Method for the Pavements' Maintenance and Rehabilitation Planning

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ABSTRACT: Roads are considered as one of the most extensive civil infrastructures and national capitals of each country. Pavement maintenance and rehabilitation (M&R) management is one of the most important problems, which can help to reduce further costs. Two issues are important in the field of road maintenance and rehabilitation management; the first type of M&R option and then time its application. In this paper, it was attempted to combine prioritization, artificial intelligence, and optimization methods to select the optimal option for the maintenance and rehabilitation of pavement sections at any time interval. For this purpose, the analytical hierarchy process was used to prioritize the branches in the pavement network. In the next step, using a linear programming model, the probability of selecting maintenance and rehabilitation options for pavement sections was maximized considering several specific constraints. A fuzzy inference system was used to determine the probability of selecting each maintenance and rehabilitation option in pavement sections. A case study in Mahan (Kerman) was used to run the proposed model. Based on the results, it can be concluded that the proposed algorithm can consider different parameters and indices for pavement branches and sections. In addition, it offers different scenarios for the selection of M&R options in a year. The model helps to compare various scenarios based on different budgets for each year. In all, the proposed algorithm facilitates the process of selecting M&R options in the different sections of a road network and provides a scientific approach to manage maintenance roads.

Review History:
Received: Dec. 10, 2019
Revised: Feb. 15, 2020
Accepted: Feb. 24, 2020
Available Online: Mar. 10, 2020

Keywords:
Pavement management
Fuzzy
Optimization
Maintenance and rehabilitation

1. INTRODUCTION

Road pavement maintenance and rehabilitation (M&R) is an important and traditional task among highway engineers. Various M&R strategies and procedures have been employed by related organizations to preserve pavement and postpone its deterioration. The type and strategy of choosing M&R options had been the subject of much research over the years [1]. Lack of proper maintenance for a road can cause premature failure. Road crashes also might increase. Road maintenance costs vary from 3% to 10% of the value of roads in Iran. It is essential to be started from the beginning of the operation and continued throughout the life of the road [2].

A detailed systematic and scientific approach is needed to manage pavement rehabilitation and maintenance and simple models cannot be used in this regard. This paper intends to discuss M&R management using several scientific tools including hierarchical analysis process (AHP), linear programming (LP), and fuzzy inference system (FIS) simultaneously. The main innovation of this paper will be to present a new framework based on mathematical decision-making tools to determine the optimal choice for pavement M&R.

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2. METHODOLOGY

The main purpose of this paper is to present a framework with mathematical modeling and planning to determine the optimal M&R options for asphalt concrete pavement sections at any time interval. In this regard, first by using the AHP model, the branches in the pavement network are prioritized. In the next step, using FIS, the possibility of choosing any M&R option in each pavement section is achieved. Finally, using linear programming, it is tried to determine optimum options with the objective function of maximizing the probabilities and at the same time considering several constraints.

The first step is to prioritize the branches with the AHP model, taking into account the four parameters of functional classification, traffic, access, functional classification, and the tourism-commercial importance of the branch. For this purpose, paired comparisons would be conducted using experts' viewpoints and then the model is run by Expert Choice 11 software.

The output of the FIS is the probability of selecting each M&R option given in the linear programming objective function. Fuzzy means lack of clarity, and this concept is similar to human inference. FIS is used to systematically describe human knowledge and make appropriate inferences

Table 1. An example of a table

Variable	Change interval
PCI	0-100
SN	0-10
IRI	0-16
DV	0-100
DPCI	0-6
BPN	0-100

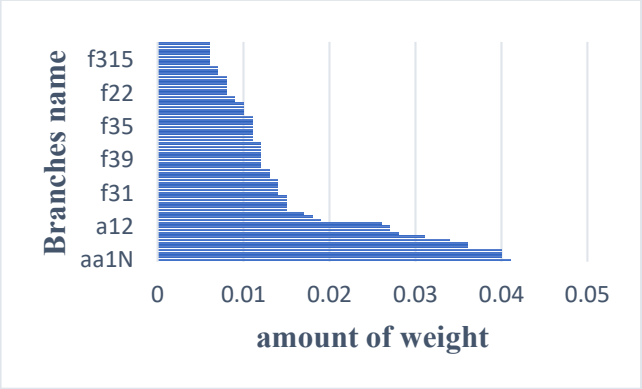

Fig. 1. Weights diagram of pavement network branches

and decisions. The purpose of fuzzy logic is to map from the input space to the output space. An elementary mechanism in this regard is the use of a set of if-then commands called fuzzy rules [3].

By reviewing the research literature on factors and parameters affecting the selection of M&R option, the fuzzy input variables were selected, and using experts' opinions, 6 variables from the total of variables considered for our FIS model. After the selection of input variables (Table 1), their membership functions have been determined as Gaussian.

In this paper, for each M&R option including crack filling, fog seal, slurry seal, chip seal, micro-surfacing, recycling, overlay, and reconstruction FIS rules have been provided. The output of each FIS is the probability of selecting that option based on different combinations of input variables

Finally, linear programming was used to maximize the probability of selecting M&R options in pavement sections. The decision variable in this model is a binary, which indicates the implementation of an option or not. The objective function of the model is to maximize the probabilities relating to performing a specific option. Several constraints relating to the total budget, ability of the organization in each year, proportionality between functional classification and type of M&R option and among others.

3. RESULTS AND DISCUSSION

The model was run for a road network as the case study in Mahan (Kerman). The weight of the pavement branches (ωj) obtained by AHP with Expert Choice 11 software can be seen in Fig. 1. In this Figure, the numbers written on the horizontal axis indicate the amount of weight and the names written on the vertical axis are the names of the pavement network branches.

The probability of selecting the M&R options for pavement sections was calculated by the FIS model. Membership functions for input indices are Gaussian. As an example, the membership function for the PCI input variable is shown in Fig. 2.

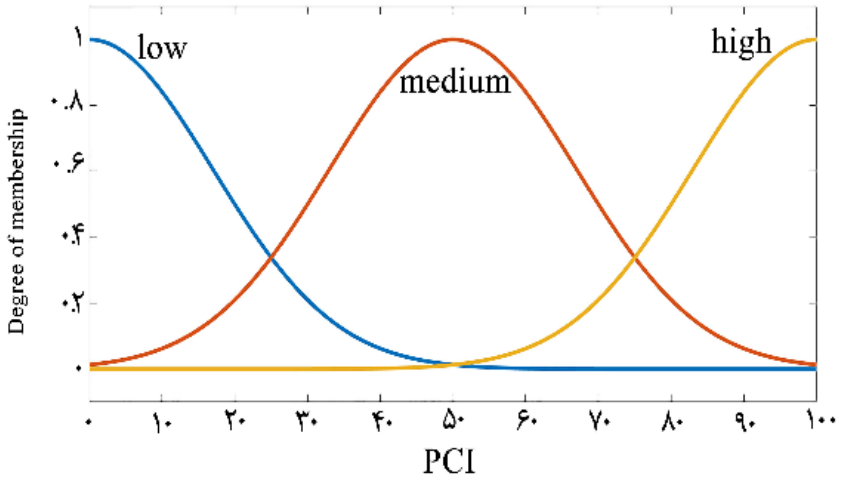

Fig. 2. Input membership function for modeling using fuzzy inference system

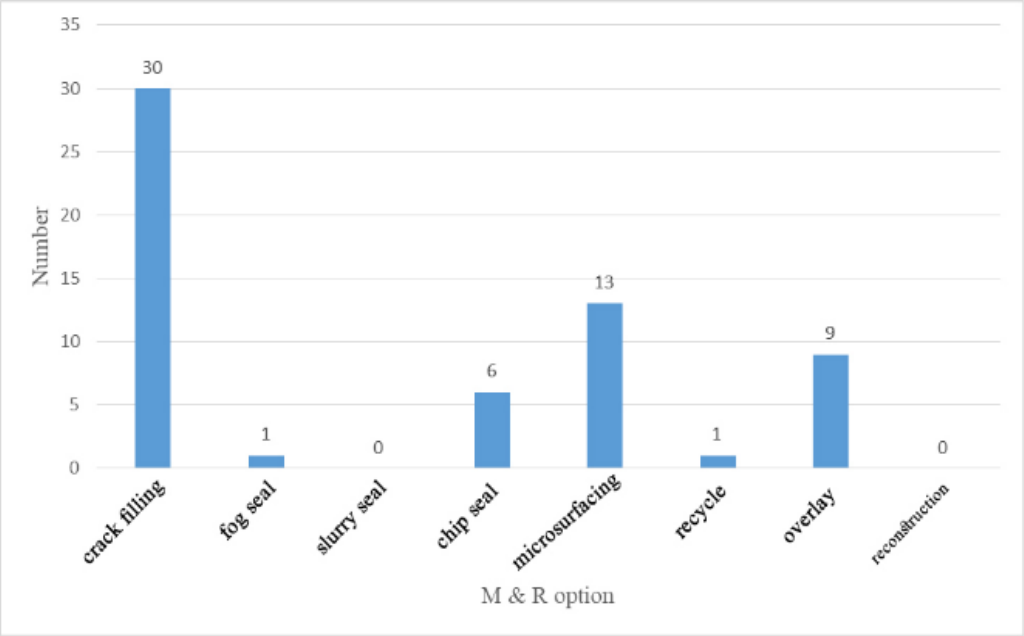

Fig. 3. The number of options selected for each method in the first scenario

Finally, with the help of MATLAB and executing the linear programming model, the results are obtained (Fig. 3). Here, for two different scenarios with an unlimited budget (allocation of 660 billion rials) and with a limited budget allocation (allocation of 300 billion rials), the results have been presented.

Proposed sections in the first scenario for preventive maintenance are mostly micro-surfacing and are in high importance branches. In the second scenario, assuming a budget of 300 billion rials, results indicated that the model uses the maximum ability of the M&R organization but offers less costly options (such as fog seal and chip seal).

4. CONCLUSION

The results of this paper revealed that the functional classification had the greatest effect on the prioritization of the branches as expected and freeways with the weight of 0.04 are the most important roads.

The current model in both budget scenarios proposes options for filling the cracks that are expected to have a high PCI index.

In the first scenario, assuming an unlimited budget, the results indicated that the model, while using the total ability, uses more micro-surfacing from preventive options. However, in the second scenario for the high-priority branches, the model leads to less costly options. In both budget scenarios, the model proposes options for major repairs for the sections that do not have the appropriate structural condition.

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HOW TO CITE THIS ARTICLE

H. Behbahani, N. Nadimi, M. Khaleghi, Introducing a New Method for the Pavements' Maintenance and Rehabilitation Planning, Amirkabir J. Civil Eng., 53(7) (2021) 613-616.

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