

Extended Abstract Template for Amirkabir Journal of Science and Research

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ABSTRACT

Maintenance and rehabilitation scheduling optimization is one of the most critical parts of the pavement management system. Pavement agencies usually face large-scale pavement networks. The complexity of network management is exponentially increased in the circumstances that the dimension of the network is extended. Hence, meta-heuristic algorithms and decomposition techniques are usually applied to solve these problems. In this investigation, energy consumption optimization is taken into account as an essential environmental criterion. Furthermore, a recently developed meta-heuristic algorithm called Soccer league competition algorithm is utilized to solve the problem. This robust algorithm is inspired by the competitions of players and teams in soccer leagues. A real network containing 84 segments is the case study of this investigation. According to the results, the Soccer league competition algorithm is competent to solve a large-scale network problem in a short time. Moreover, the comparison of different strategies outcomes indicates that considering energy consumption as the second objective function reduces the energy consumption and total cost 13% and 10%, respectively, and increases the average international roughness index by 9%.

KEYWORDS

Pavement management system (PMS), Maintenance and rehabilitation planning, Soccer league competition algorithm (SLC), Energy consumption.

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1. Introduction

Due to the importance of sustainable development, environmental issues have become an immense concern for travel agencies. To this end, energy consumption, as one of the most critical environmental criteria ought to be scrutinized in pavements maintenance and rehabilitation planning [1].

Robinette et al. [2] declared that the environmental effects of pavements maintenance strategies should be considered in life cycle cost analysis. Faghieh-Imani et al. [3] expressed that the condition of roads, the financial issues, and the environmental parameters such as energy consumption should be taken into account in pavements maintenance simultaneously. Accordingly, in this investigation, the energy consumption is taken into consideration in the optimization problem, and the outcomes of this problem are compared with a performance-based model.

2. Methodology

In this section, the pavement performance indicator selection and the performance model is described. Afterward, the problem modeling of two strategies is explained. Ultimately, the algorithm applied to solve the optimization problem is introduced.

2.1. Performance indicator selection

Performance indicators pave the way for detecting the optimal maintenance and rehabilitation treatments applied to enhance the condition of the pavement network. In this study, the International Roughness Index (IRI) is utilized to make the model. Because increasing the value of IRI leads to increasing the travel time, used cost, and driver's complaint [4]. Meanwhile, the performance model introduced by Tsunokawa and Schofer [5] is considered to estimate the pavement's deterioration rate. The mentioned model is presented in Eq. (1).

$$IR_{it}^* = IR_{it^0} \exp(\beta(t^* - t^0)) \quad (1)$$

2.2. Problem modeling

Two models are considered in this study, including single-objective and two objective optimization models. In single-objective modeling, the condition of pavements is the objective function of the model. In the two-objective problem, the energy consumption and condition of pavements are set as the objective function simultaneously. The objective function of single-objective optimization is presented in Eq. (2). The two-objective optimization model considers Eq. (2) and (3)

simultaneously as the objective functions. The constraints of these two optimization problems are equally, and they indicate in Eq. (4) to (11).

$$\text{Minimize } \sum_{i=1}^I (|IR_{iT} - IR_i^*|) \quad (2)$$

$$\text{Minimize } \sum_{i=1}^I \sum_{k=1}^K \sum_{t=1}^T A_i E N_{ikt} x_{ikt} \quad (3)$$

$$\sum_{i=1}^I \sum_{k=1}^K A_i C_{ikt} x_{ikt} \leq B_t \quad \forall t \in T \quad (4)$$

$$IR_{it} = IR_{i0} \exp(\beta t) + \sum_{j=1}^{t-1} \sum_{k=1}^{K-1} x_{ikt} e_{ik} \exp(\beta(t-j)) \quad \forall i \in I \quad (5)$$

$$IR_{it} \geq IR_{min} \quad \forall t \in T \quad (6)$$

$$IR_{it} \leq IR_{max} \quad \forall t \in T \quad (7)$$

$$\overline{IR}_t = \frac{\sum_{i=1}^I IR_{it} A_i}{\sum_{i=1}^I A_i} \quad \forall t \in T \quad (8)$$

$$\overline{IR}_t \leq IR_t^{network} \quad \forall t \in T \quad (9)$$

$$\sum_{k=1}^K X_{ikt} = 1 \quad \forall i \in I, \forall t \in T \quad (10)$$

$$X_{ikt} \in \{0, 1\}, IR_{it} \geq 0 \quad (11)$$

Where, IR_{i0} , IR_{it} , IR_{min} , IR_{max} , IR_i^* , \overline{IR}_t , $IR_t^{network}$, A_i , β , B_t , C_{ikt} , and e_{ik} are the IRI of section i at the initial year, the IRI of section i at the time of t , the lower bound of acceptable IRI, the maximum allowed value of IRI, the ideal level of IRI at the end of analysis period, the average value of sections IRI at the year of t , the required the average value of sections IRI at the year of t , the section area, the deterioration rate, available budget at the year of t , unit price of the treatment k for section i at the time of t , and the improvement of IRI of section i owing to implementing treatment k , respectively.

2.3. Optimization algorithm

In this investigation, the soccer league competition algorithm is applied to find the optimal solutions to the problem. This algorithm is a recently developed meta-heuristic algorithm, which is inspired by the professional soccer league competitions. This algorithm is coded based on the details provided by Moosavian and Kasaei Roodsari [6].

3. Case study

A network including 84 sections with a total length of 251 km is the case study of this study. The average length of sections is equal to 2.99 km. Furthermore, the annual budget is considered 17 billion Toman (Iran currency) based on the report of road maintenance and transportation organization. The analysis period is 5 years, and the deterioration rate is taken into account 0.05 according to the authentic international publications [7-9].

4. Results and discussions

The average value of the section's IRI is illustrated in Figure 1a. As can be seen from the results of this figure, the average value of IRI is reduced steadily in two models. However, the single-objective model outweighs the two-objective model, and the average of network IRI in the single-objective model is 9% lower than that of the two-objective model.

The required cost to implement the optimal solution of single-objective and two-objective models is demonstrated in Figure 1b. Drawing on the results, the total money that should be paid for the optimal solutions of single-objective and two-objective models is equal to 57.4 and 52 billion Tomans, in the order mentioned. Hence, it can be postulated that consideration of energy consumption in pavement maintenance and rehabilitation problem may lead to reducing the total required cost.

The energy consumption of single-objective and two-objective models during the 5 year analysis period is indicated in Figure 1c. As can be perceived from the results of this figure, the performance of the two-objective model in order to reduce the energy consumption is by far better than that of the single-objective model. The reduction of energy consumption in the two-objective model is owing to the consideration of energy consumption as one of the objective functions of the model. The total energy required to implement the optimal solutions of the two-objective model is 13% lower than that of the single-objective model.

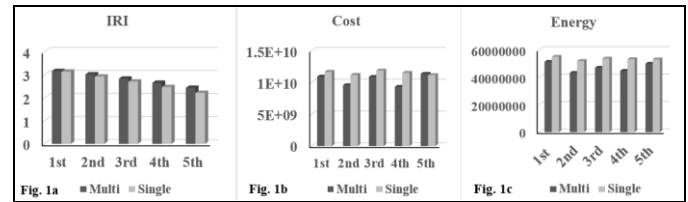


Figure 1. The results of single-objective and two-objective models

5. Conclusions

- Soccer league competition is highly qualified to solve large-scale maintenance and rehabilitation planning problems.
- Comparing the results of single-objective and two-objective models indicates that by consideration of energy consumption is model, the average value of IRI in the network is increased by 9%. Nonetheless, the total required cost and total energy consumption are reduced 9% and 13%, in the order mentioned, if two-objective model is replaced with single-objective model.
- By virtue of maintenance and rehabilitation planning, the average value of IRI is reduced steadily in both models.

6. References

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