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Optimizing the life cycle cost of bridges by considering the reliability of bridges (Case study of bridges from Sari to Mahmudabad)

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ABSTRACT: Maintenances are necessary to ensure the safety and serviceability of existing bridges. With the increasing number of existing bridges, maintenance cost a large proportion of financial fund and have a significant impact on the environment. Bridges like any other structure and perhaps more than most of them are affected by the environment. Because they belong to sensitive and high costly structures, failure to maintain them will have devastating effects. Bridges are needed continuous maintenance in order to service properly during their life cycle. Therefore, in this study, the issue of maintenance and repair of urban bridges in Mazandaran province has been studied with regard to the life cycle cost and reliability of bridges. To do this end, a mathematical programming model which includes minimizing maintenance and user costs as well as maximizing system reliability. In order to solve the proposed model, a multi-objective particle swarm optimization algorithm is developed. Also, a sensitive analysis is done on the failure rate. Results show that increases in this parameter cause increasing cost and decreasing reliability. This indicates that the proposed algorithm is working properly and the results of this research can be trusted.

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1- Introduction

Bridges are a key element of any country's highways and are more expensive to build than other road components. Damage to the bridge, along with increased traffic loads and adverse environmental conditions and the location of the bridges, and as a result, the rapid deterioration of the structural components of the bridge requires immediate maintenance operations. Bridges, like any other structure and perhaps more than many of them, are affected by the environment and even assuming proper design and precise execution, many factors affect their durability and health, and since they are considered expensive and sensitive structures failure to maintain them will have devastating effects. Thus, regular inspections are essential to compensate for these breakdowns to avoid excessive costs. Unfortunately, many policymakers and bridge managers around the world, including Iran, acknowledge the need for regular inspection and maintenance of bridges over their useful lives, but the need for early planning in the decision-making and design stages. They do not understand the basic principles that ensure the durability and stability of the stairs in the long run. In most cases, officials abandoned bridge maintenance during operation and turned to treatment strategy rather than prevention [1]. Bridges could not last forever, sooner or later, any form of structure used and any materials used to build them will show signs of wear. There are many factors such as the shape of the structure, building materials, quality of construction, design, execution, weather conditions, scour, heat, fatigue, earthquake, flood, air, and density of incoming loads that affect how and the amount of erosion in the deterioration of the bridge. Prior to the 1970s, bridges often chose the cheapest materials when building bridges, regardless of the annual maintenance costs involved. Early wooden bridges were completely destroyed after a while. -they went. But many types remained, made of materials such as cast iron, ordinary iron, steel, concrete and steel, reinforced concrete, and prestressed concrete. The number of bridges that need special maintenance in different countries is increasing day by day, and because the direct cost of the required engineering work is very high, so there is a need to use more logical methods in the allocation of existing budgets to ensure they are economical. Given that bridges are constantly under load and on the other hand are exposed to external factors such as weather and natural disasters, the issue of their maintenance is extremely important. Today,

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the maintenance of bridges is addressed systematically using maintenance systems. In general, maintenance programs can be divided into two groups: 1) Preventive maintenance and repair 2) Necessary maintenance and repair. On the other hand, preventive activities are carried out to maintain the condition of the structure and its components in the current state and to prevent the inefficiency of structures, which are divided into 2 groups: a) planned and b) reactive [2]. The maintenance process includes various measures such as inspection, maintenance and preventive maintenance, and necessary maintenance, etc. These measures are performed by the relevant consultants and contractors at appropriate times [3]. In this research, the planning and scheduling of bridge maintenance will be examined with the aim of minimizing life cycle costs and user costs to maintain the reliability of the bridge structures under maximum conditions. In this study, the bridges from Sari to Mahmudabad have been studied. For this purpose, a mathematical model has been developed and solved using a multi-objective particle swarm optimization algorithm.

2- Problem definition

In this study, the maintenance planning problem will be investigated with the aim of minimizing the life cycle cost, including maintenance and user costs, and maximizing the reliability of the Sari-Mahmoudabad axis staircase. These two goals completely conflict with each other. Naturally, more money must be spent to maximize the reliability of the bridge, and on the other hand, reducing the cost leads to a decrease in the reliability of the bridge. Therefore, a balance must be struck between these two goals and a solution or solutions must be found to optimize maintenance strategies. In order to solve the proposed problem, a multi-objective particle mass optimization algorithm has been developed. The bridges used in this study include ten bridges that form a bridge network. The location of the bridges is on the road from Sari to Mahmudabad, which includes the origin (Sari) and the destination (Mahmudabad) which is connected on both sides. Due to the fact that the route is busy, there are many problems if any of the network stairs breaks down. The importance of a bridge or group depends on the performance of the entire bridge network. By reviewing and selecting the maintenance method of each bridge, the reliability of each bridge is increased to improve network connectivity. Therefore, information related to technical identification, general inspection and main inspection of stairs, field surveys have been collected. Also, it is assumed that highway bridges are the only vulnerable elements of the transportation network. The roads that connect the two bridges never fail. In this case, the performance of the network lifetime is examined in terms of the reliability of the connection of the source to the destination.

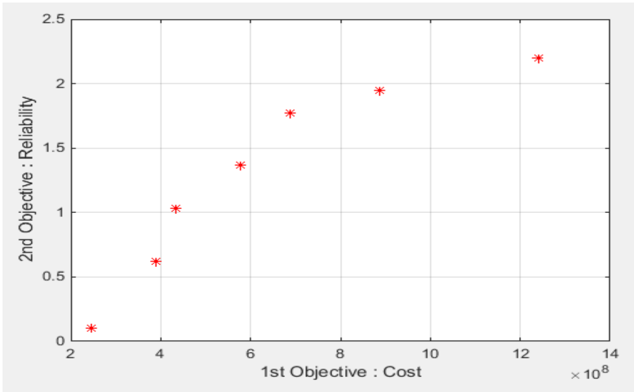

Fig. 1. Pareto solution gained

3- Results

Due to the high complexity and impossibility of an accurate solution to this problem, an algorithm that can give a close answer to the exact answer is needed, so the best option is to use meta-heuristic algorithms inspired by behaviors in nature, and creates an answer close to the optimal answer. There are several methods for meta-heuristic algorithms, among which the multi-objective particle swarm optimization algorithm has been used for this research. After coding based on the mathematical model defined in MATLAB software and using the desired algorithm, desirable outputs have been received. Seven Pareto solutions are obtained that have a total of different maintenance and repair costs and use and reliability (Figure 1). It can be seen that the cost of the life cycle has also increased with increasing reliability. Thus, the decision maker will choose one of these answers with reliability and cost of life cycle according to his desired priority. In the following, the sensitivity of the failure rate is analyzed. Thus, the value of this parameter has been changed from 0.1 to 0.9 and its effect on the two objective functions of life cycle cost and reliability has been analyzed. The results of this study show that with increasing failure rate, cost increases and reliability decreases.

4- Conclusion

In this research, a mixed integer programming model has been developed for the two-objective optimization of bridge maintenance and repairs, including the two objectives of minimizing life cycle costs and maximizing the reliability of bridges. The objective function of life cycle cost is obtained from the sum of maintenance costs and user costs. For this purpose, parameters, variables, objective functions and problem constraints were presented. In order to solve the proposed problem, a multi-objective particle mass optimization (MOPSO) algorithm was developed. To evaluate the proposed model, a case study including 10 intercity bridges located between Sari and Mahmoudabad has been considered and the types of failures along with their failure rates have been obtained. Since the proposed model had two objectives, a set of answers has been reported as a Pareto solution set. In order to further analyze the proposed model, sensitivity analysis was performed on the parameter of the failure rate of the bridges. The computational results show that as the failure rate increases, the life cycle costs increase and the reliability of the bridges decreases. Also according to the study, the following results have been obtained.

The minimum life cycle cost of the Sari - Fereydoonkanaar route bridges, including maintenance costs and user costs, was obtained using the proposed model.

Simultaneously with the use of this model, the maximum reliability of the bridge was achieved.

Types of failures in this route were identified and their values were calculated.

The probability of connection and subsequent failure of each group of bridges was calculated.

A set of Pareto solutions was obtained by solving the problem using the proposed MOPSO algorithm.

The solution with the lowest cost (245,193,000) and the solution with the highest reliability (2.2) were provided.

With the increase in the failure rate of bridges, the amount of costs has increased and the reliability has decreased. The highest cost is related to the failure rate of 0.9 with the amount of 1.351.145.000 and the highest amount of reliability is related to the failure rate of 0.1 with the amount of 2.7.

High failure rate leads to many and consecutive failures and will have a direct and great impact on reliability

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