Implementation of the Decision-Making Algorithm in the Bridge Management System

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Abstract. Traditionally, for the full functioning of bridge management systems, they contain: a block for collecting information about structures, a block for making decisions, and a block for implementing decisions. However, in most of these systems, the decision-making block does not take into account the significance of the structure, and the priority of restoration work is determined only based on data about their technical conditions. In conditions of a large number of bridges and limited funding, the task of taking into account the significance of structures when forming a strategy for their restoration becomes relevant. The authors propose a decision-making algorithm that takes considers this feature and has been implemented using the example of Apastovsky and Pestrechinsky municipal districts of the Republic of Tatarstan, the Russian Federation. Firstly, the technical condition of the structures under consideration was taken into account. Then their significance was assessed, considering the traffic intensity of these objects and the functional classification of the highways on which they are located. Next, an approximate estimate of the cost of restoring these objects was made, and the necessary costs were distributed over several years. As a result of the work done, an optimal strategy for bringing 48 bridges to standard was formed.

Keywords: Strategy · Bridge · Management systems · Algorithm · Location

1 Introduction

Bridges are an important component of any developed transport infrastructure. The uninterrupted operation, comfort and safety of traffic depend on the technical condition of bridge structures. Based on these reasons, the task of ensuring the safety of bridge structures is always relevant.

A bridge management system is a means of managing bridges throughout their life cycle (design, construction, operation, and maintenance). Bridge management systems help road authorities perform tasks such as bridge inventory (database), systematic planning of maintenance, repair and restoration activities, optimizing the allocation of financial resources, and improving the safety of bridge users.

Many scientific papers [1–9] are devoted to bridge control systems. Some of them summarize the world experience of using such systems [1–3], some talk about the experience of using them in specific regions [4–10]. Scientific research in the field of development of bridge management systems is developing in several directions. The authors

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Hanley, Lee, Wang, Shim, Wattan, and Jeong monitor and collect information to form databases or create models [11–16]. Other researchers, on the contrary, use the information obtained as a forecast or assessment of the technical condition of bridges. [17–24]. For example, Valenzuela proposes to introduce an indicator of the technical condition of the bridge [17], and Gao and Zambon scientists predict the condition and operation of concrete bridges [20, 23]. The most interesting are the works of the authors Fang, Sun, Inkoom, which offer a probabilistic approach to the functioning of a system of elements or bridge structures [25, 26]. There are other works in this area of research [27–31].

Having considered approaches to the development and use of bridge management systems, we have come to the conclusion that in most systems, when determining the priority of repair work at the decision-making stage, the significance of the structure is not taken into account. However, the task of accounting for the significance of structures becomes especially relevant in the conditions of their large number and limited financial resources. It is especially important to take into account the uncertainty in the development of the operating conditions and the importance of construction in the road network when forming strategies for the restoration of bridges located on roads of regional significance in the Russian Federation. Therefore, the purpose of this study is to build an adapted algorithm for the functioning of regional bridge management systems.

2 Materials and Methods

Earlier, in [29], the authors proposed a decision-making algorithm, which was refined and presented in Fig. 1 with changes.

The algorithm consists of the following main stages:

- Estimation of Technical Condition;
- Assessment of the Importance;
- Assessment of the Cost.

In this paper, in order to demonstrate the principles of the algorithm, bridges located on regional highways in Apastovsky and Pestrechinsky districts of the Republic of Tatarstan are considered.

For the algorithm to work effectively the following initial information about bridge structures was needed:

- name of the structure;
- technical condition of the structure (emergency, pre-accident, unsatisfactory, satisfactory, good, design);
- year of the last diagnosis or inspection of the structure;
- category of road where the structure is located;
- traffic intensity on the road where the structure is located;
- potential number of users of the bridge structure;
- the possibility and the length of the bypass;
- type of work required to bring the structure into a standard condition (construction to replace the existing one), reconstruction, major repairs, repairs, maintenance);
- bridge surface area.

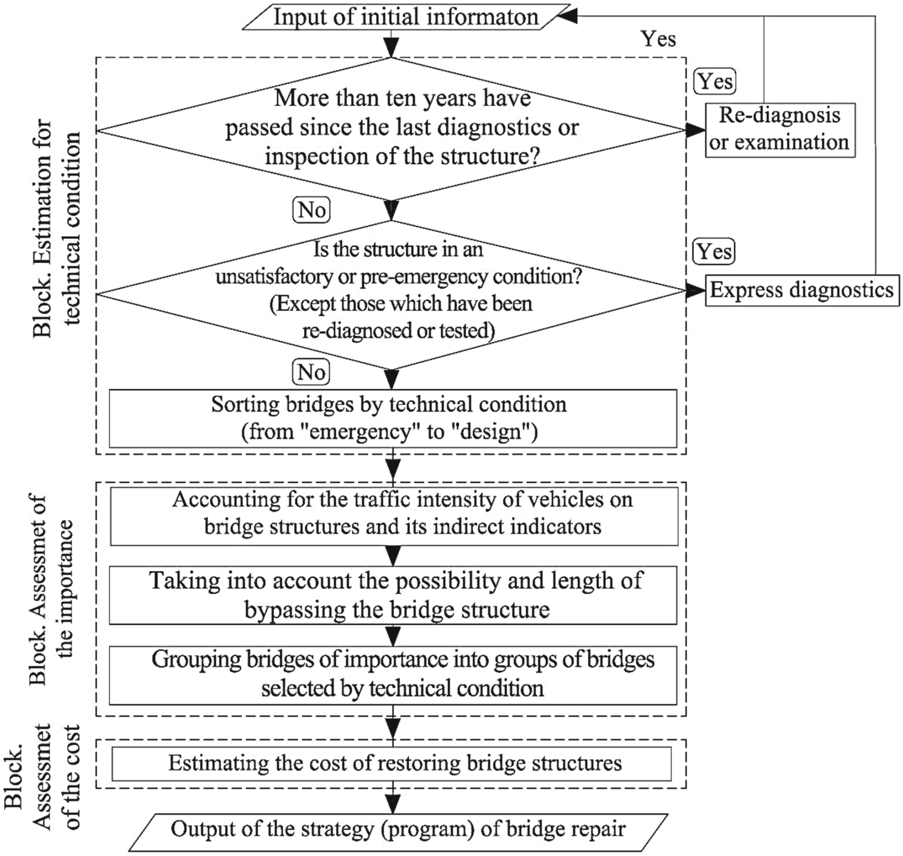

Fig. 1. Decision-making algorithm.

3 Results and Discussion

3.1 Estimation of Technical Condition

In the Apastovsky district of the Republic of Tatarstan, there are 29 bridges on regional roads. Of these, 7 are in unsatisfactory condition, 18 are in satisfactory condition and 5 are in good technical condition. There are 19 bridges on regional roads in Pestrechinsky district of the Republic of Tatarstan. Of these, 1 is in emergency condition, 4 in unsatisfactory condition, 10 in satisfactory condition and 4 in good technical condition.

This estimation of the technical condition of bridges is based on the data of their diagnostics, which was carried out in accordance with current Russian regulatory documents. For further operation of the algorithm bridges are sorted from the emergency state to the design state.

3.2 Assessment of the Importance

An objective numerical indicator of the significance of the bridge is the traffic intensity. However, this characteristic is not always known, so there is a need to use its indirect indicators. An indirect indicator of the traffic intensity on the bridge can be a functional classification of the highway on which it is located.

Based on the above, the relationship between the significance of the bridge and the classification of the road is formed according to Table 1. Then, within the technical condition of the set of bridges, objects with higher significance are selected.

Table 1. Degrees of significance depending on other parameters.

Significance of the bridge	Traffic intensity of vehicles per day	Functional class of a automobile road
High I	>14000	Main trunk automobile roads
High II	6000–14000	Secondary trunk automobile roads
High III	2000–6000	Main trunk automobile roads of inter-district significance
Medium I	1500–2000	Main distribution automobile roads Entrances to rural localities (the bridge provides access to more than 10 localities)
Medium II	1000–1500	Secondary distribution automobile roads Entrances to rural localities (the bridge provides access to 6–9 localities)
Medium III	200–1000	Entrances to rural localities (the bridge provides access to 4–5 localities)
Low I	100–200	Entrances to rural localities (the bridge provides access to 2–3 localities)
Low II	50–100	Entrances to rural localities (the bridge provides access to 1 locality)
Low III	<50	Distribution automobile roads of inter-district significance Entrances to rural localities (the bridge is located behind all or most of localities and access to them is not provided)

3.3 Assessment of the Cost

Estimating the cost of restoring bridges is a time-consuming task and, in order to optimize it, the cost of work is determined in Russian rubles, based on the cost of restoring similar objects on the territory of the Republic of Tatarstan in 2016–2019.

Based on the results of the algorithm, the priority of work on the restoration of bridges in the Apastovsky and Pestrechinsky districts of the Republic of Tatarstan was determined.

The total amount of funding required for these works was about 12.35 billion rubles. This amount of necessary funding is distributed over several years (Table 2).

Table 2. Strategy for restoring bridges in Apastovsky and Pestrechinsky districts.

Year of the strategy implementation	Number of objects	Necessary expenses, thousand rubles
1	11	308592.28
2	14	305265.26
3	6	309859.36
4	9	311440.16

This example shows that it is possible to take simultaneously into account the technical condition, significance and cost of bridges at the stage of determining the priority of their restoration in accordance with the decision-making algorithm proposed by the authors.

The proposed approach with the necessary adjustments can be integrated not only into existing road bridge management systems, but also into newly created ones.

4 Conclusions

In both domestic and foreign bridge management systems, when determining the priority of repair work at the decision-making stage, the significance of the structure is not taken into account.

The authors propose a decision-making algorithm that allows forming an effective repair strategy that determines the priority of work in the conditions of a large number of bridges and a limited amount of funding.

The proposed algorithm was tested in the Apastovsky and Pestrechinsky districts of the Republic of Tatarstan. Based on the results of modeling, a strategy was formed for bringing the bridge structures in operation to a standard state.

In order to optimize the algorithm and increase its efficiency, there is a need for further study and optimization of methods for evaluating the technical condition, significance and cost of bridge structures.

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