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Method for computation of priority order for Romanian bridge management system

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Abstract

Development of a bridge management system needs an algorithm for the computation of the order of priority. The order is generally based on a composite index. Such an index is necessary and no bridge management system can really perform its tasks without one.

Management of bridges implies a special attention in allocation of the funds to where the technical and economical needs impose and where the benefits are maximal. To establish a correct priority order the index taken into account must have a multi-criterial base.

Administrators, together with research organizations and universities, have created procedures to compute the urgency of intervention using multiple parameters. Selection of these parameters was made starting from the goals observed and the specific conditions concerning the administrator and the roads and bridges network.

This proposal is part of Romanian National Administration of Roads to develop a decision tool for the management of bridges.

The algorithm proposed in the article is very simple and straightforward. It is based on the present regulations and it is not necessary to modify the present way of inspection of the bridges. The equations are very clear, simple and easy to use. Their form is logical and easy to explain.

A unique overall priority index was defined which makes the creation of a list of priority very handy. This priority index includes both degradation and functional influences. Based of simulation, their maximal values were selected in such a way that the final result to be balanced and meaningful. Levels of action were determined and introduced.

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1. INTRODUCTION

The work in bridge management implies a special attention in fund allocation to where the technical and economical needs impose and where the benefits are maximal. To establish the priority order on a multi-criterial base, the administrators, together with research organizations and universities, have created procedures to compute the urgency of intervention using multiple parameters. Selection of these parameters was made starting from the goals observed and the specific conditions concerning the administrator and the roads and bridges network.

The methods developed in different countries are not similar due to the subjectivity involved in each one. Specific conditions, different ways to perceive the things, different mentalities lead to different interpretations of the concept of necessity / urgency. Also, the concept of benefit is treated differently or only implicit included in the mechanism of prioritization. Such an example of different vision is the consideration of the influence of the road transportation infrastructure on the environment. While in many countries they don't appear at all among management problems in the Scandinavian countries the environment issues are of a special importance and they surpass many other criteria.

2. ELEMENTS USED IN PRIORITIZATION

In order to set the order in which the bridges (and in general terms any structures or systems) are treated their technical condition is fundamental. Hence, the condition is the main issue treated and used in all bridge assessment and management systems in the world. Obviously, the concept of technical condition has different meanings and different numerical form expressions for different countries but the principle is the same.

Beside indicators describing the technical condition indicators describing the importance of the structure within the road may be included. Also indices for the importance of the road within the entire road network may be considered. Another important element to bear in mind is the position of the road within the community it serves.

The volume of traffic is an element frequently present in the decision process. The importance of a bridge is higher when the traffic on and under the bridge is higher. Based on this, indices describing the traffic are defined and used in priority definition. Some management systems include among other priority criteria the cost for works. Others include also the results of the benefit / cost analysis. The

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costs included are both administration costs and user costs. The values for the costs are either explicit expressed or implicit by the use of other parameters that involves differential costs (i.e. detour length). The costs or the benefit / cost analysis results are more and more used as they are required by international financial institutions.

3. FUNCTIONALITY OF THE BRIDGE

The bridges are structures constructed to establish the continuity of the way where the roads intersects an obstacle. The obstacle might be a deep valley, a river, a railway, or other human creations including another road. The bridge have to be regarded within the network together with the road sector which it is part of, with the obstacle it meets and the community it serves.

In the general context, from different points of view, the bridge might be seen having a certain importance for: the persons involved in traffic, for the inhabitants of the adjacent area, for the industry, and for local trade. The points of view are multiple and are relevant for a category or another.

Based on the importance awarded in different situations one can imagine a computation of the global importance the bridge might have. Assessment of the importance refers to conceiving a numerical computation procedure where the selected functional factor to be quantified. General equation might have different forms, including probabilistic. However, further in this paper we will try to select a minimal number of essential factors and to retain a formula as simple as possible.

3.1 Selected functional factors

Regarded from different points of view, by different persons with different aims and scopes, the bridge may be classified as having certain functionality in correlation with the goal observed. Functional parameters are numerous but in this paper we tried to retain only those considered to be significant from the point of view of the road and bridge administrator.

The fundamental goal of the bridge is to guarantee the continuity and the smoothness of the traffic on a road. The road has certain geometric and traffic characteristics. Also the road has a certain classification within the national network. In the same time the bridge intersects an obstacle which, at its turn, generates an importance. Moreover, the surrounding area can influence the way the bridge importance is perceived. The selected factors are presented in the following table.

Table 1. Factors selected in the evaluation of the functional importance

Index	**Significance**
UF1	Category of the road the bridge is situated on
UF2	Type of the obstacle
UF3	Index of traffic
UF4	Index of bridge length
UF5	Index of detour length
UF6	Position
UF7	Activity / habitation / circulation under and around the bridge

In our paper we used the preview factors to define the "functional importance index" or "functional priority factor". This index will be further used as an element to establish the priority and the order the bridges will be treated.

Following, we will present the quantification and motivation for the factors.

Category of the road the bridge is carrying

According to present regulations and codes, roads are divided in more categories. For administrators, a road with a higher assigned importance indicates the necessity of a more vigorous intervention on all the adjacent elements, sub-systems and structures.

Road category is not necessarily related to traffic. As an example, the international treaties Romania is party at assign a number of European road corridors. The roads on these corridors have precedence before roads with equal or even higher traffic that are not specified in the treaties.

Starting from these considerations we proposed an order of importance for the bridges on different road categories.

Table 2. Quantifying the road category

UF1	**Category of the carried road**
	Motorway; European road
	Main national road
	Secondary national road; main county road; main streets in municipalities
	Secondary county roads; main streets in towns
	County roads; secondary municipal and town streets
	Streets in communes; others

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These values don't vary too much in time and can be determined based on data already available in office as the inspector may find them on the inspection form and he/she only do corrections, where necessary.

Category of the obstacle which the bridge is intersecting

Analogue to the prevue judgment, it is important to consider the type of the obstacle the bridge intersects, whether it is a watercourse, a railway, or another road.

When the bridge is over a road we shall use similar values with the preview factor starting from the idea that the road has similar importance and the damages for traffic interruption are similar whether it is on the bridge or under the bridge. In the same time the cases when the bridge is a passage over the railway were considered.

When the bridge is over a river differences were considered according with of the water stream width. This is assessed by the inspector in the field and is measured at the level of the minor scour. If the water flow is divided in more branches the distance on the bridge axe between the exterior banks of the exterior branches is considered.

The cases where the river is navigable, or there are known seasonal torrents are included.

Table 3. Quantifying the obstacle intersected by the bridge

UF2	Category of intersected obstacle
	Highway; European road; navigable watercourse
	Main national road; railway; water stream larger than 50 meters
	Secondary national roads; main county roads; main streets in municipalities; water stream between 25 and 50 meters width
	Secondary national roads; main streets in towns; water stream between 5 and 25 meters width; valley with abundant seasonal torrents
	Communal roads; secondary streets in towns; water stream narrower than 5 m
	Streets in communes; valleys with no water

If the bridge intersects simultaneously more obstacle the higher note will be taken into consideration.

Traffic influence

Constructed to ensure the continuity of the traffic, the bridge has a higher importance as the traffic on it is higher. For the purpose of this paper the value

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taken into consideration is the physical traffic, including the vehicle without engine.

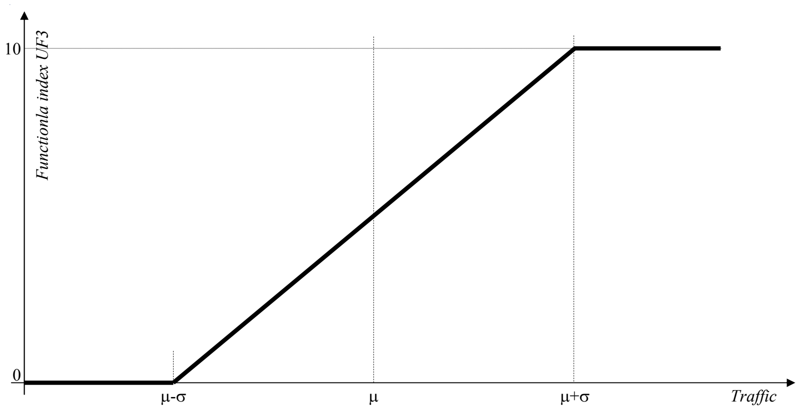

Fig. 1 Function for definition of UF3

For parallel bridges, the concerning part of the traffic will be considered for each one. The average and the standard deviation are considered, at national level or for the part of the network we analyze. Based on them one may define a function for the index UF3. In the preview picture a linear function is presented but other convenient functions are often used.

Length of the bridge

A bridge is considered with much attention when it is longer. A culvert imposes less technical problems while a one kilometer bridge needs a permanent surveillance. Therefore, we set different categories of bridge lengths and an index (UF4) is quantified.

Detour length

A bridge is more important when few possibilities for detour are available. Several kilometers are not very important but when several one must go for more than 10 kilometers when the bridge is closed the bridge must be regarded with permanent care and must be considered important. Some scale for the detour length was proposed so that index UF5 to be quantified.

Position

In the same line of judgment, position of the bridge toward the communities is important. The next table considers different positions:

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Table 4. Bridge position

UF6	Category / Position
	Highly industrialized area Historical or special interest bridge
	Urban area
	Mountainous area
	Semi-urban area
	Commune / village
	Rural area

Activities / habitation / circulation

This factor is related to activities in immediate proximity of the bridge or immediately downstream on lower levels. In this category we consider different activities (industrial, agricultural, commercial etc.) or habitations that are located under or immediately downstream of the bridge. Circulation of pedestrians, goods and services are also assessed here. UF7 index is set.

3.2. Functional priority index

Because the factors that influence the importance of a bridge may not be measured with instruments and they are subjective in character we might conclude that there is no absolute criterion for comparison. However, the global importance is higher as it influences and concerns directly or indirectly a higher number of persons, institutions, and businesses. Hence, one may consider that the function describing the importance is cumulative. Each factor presented earlier refers to a class of affected elements. It this way we include the majority of the relevant group of interest.

Subsequently we define the functional priority index as a sum of the preview presented factors:

$$IP_F = \sum_i \left(UF_i \times P_{UFi} \right) \tag{4}$$

Where:

IP_F Functional priority index;

UF_i Functional index i;

P_{UFi} Weight factor for the functional index i.

In the preview equation the weight factor were set the unitary value ($P_{UFi} = 1$) as the value of the functional indices are already differentiated.

The values of IP_F vary between 0 and 40.

4. PRIORITY ORDER. THE PROPOSED METHOD.

Any methodology to set a priority order for action at bridges must consider the technical condition (degradation status) and functionality. Beside this, costs, technology, available resources items may be included.

A bridge may be positioned in a “space of urgency” (see the next picture):

The position in this space indicates simultaneous the two important directions: functional priority and priority due to degradation.

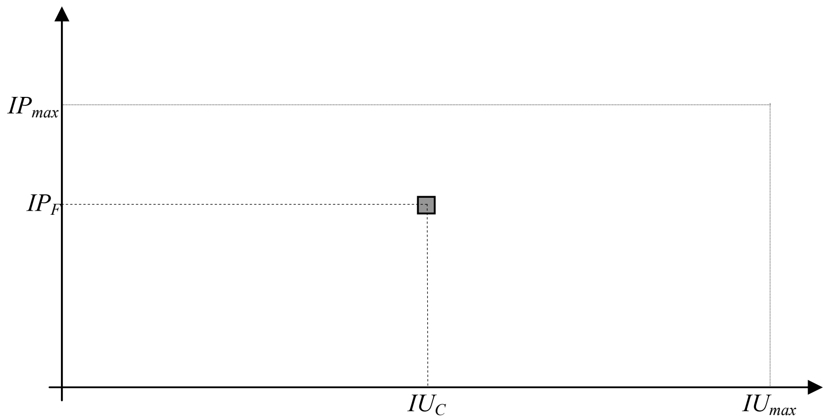

Fig. 2 The space of urgency: Functional / degradation

4.1. Computation of the order index

We have seen that the priority in treating a bridge is given by both quality and functional considerations. The two elements are not cumulative. At extreme values of degradation, the functionality plays no determinant role except for similar values. To combine the two values we consider the distance, in the “space of urgency”, from the origin to the position of the bridge.

Mathematically this is expressed by:

$$IO = \sqrt{IU_C{}^2 + IP_F{}^2} \tag{4}$$

where:

IO Order index (overall priority);

IU_C Quality urgency index (degradation index);

IP_F Functional priority index.

The overall priority IO takes values between 0 and 107,70329614269(≈108). The value 0 corresponds to minimal urgency and the maximal value correspond to maximal priority in intervention. For eventual esthetical reporting consideration one may force to 100 values of IO larger than 100, but the probability for such situations is very low.

The order index IO helps us to find out where a bridge must be treated faster or it is possible to delay the intervention works. Periodically this index must be reevaluated and new actions are to be selected at the moment.

If no other decision support instrument is used, the actions result from the value of IO. Hence, thresholds may be defined.

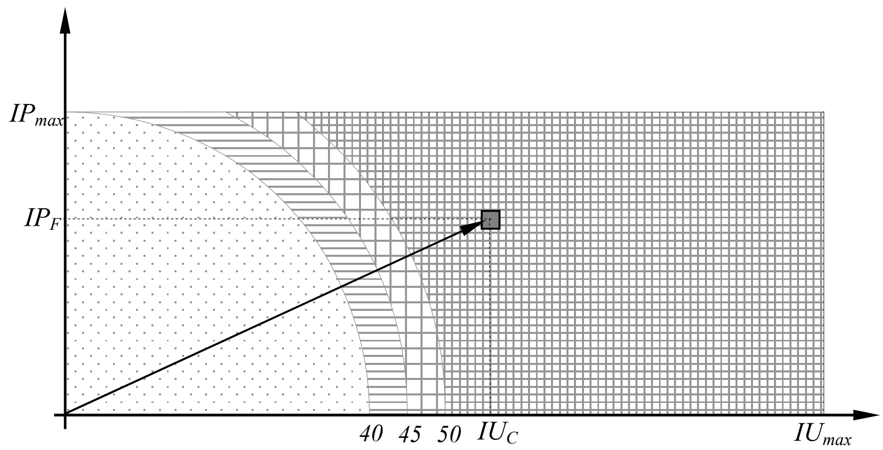

Fig. 3 Level of thresholds

According to the value of overall priority index one may infer and enforce some levels of action. Hereby, such levels are proposed in Table 5.

Table 5. Level of action

IO level	**Action**
0≤IO<40	Normal maintenance
40≤IO<45	Attention level! periodic follow-up
45≤IO<50	Alert level! Intense survey; intense maintenance
50≤IO	Immediate intervention

These levels impose some degrees in bridge treatment without interdiction for repairing or rehabilitation, as considered appropriate, when the IO index is lower then 50. Decision may be taken according to recommendation of a bridge management system using order index as a priority indicator, based on the available funds and on the benefit / cost analysis.

4.2. Observations to the introduction of order index

Functional priority index induces alone a maximum of 40 when IU_C is 0. Inclusion of a bridge with no physical degradation on the attention level might appear a little bit unnatural. However, let us not forget that, according to the system proposed in this paper, for a bridge to have IP_F at a value of 40 it must simultaneously cumulate the following conditions:

- To be situated in an industrial area or to be an historical bridge;
- To be more than 300m length;
- To be on a motorway or European road;
- To pass over a motorway or European road or a navigation channel;
- To have among the highest traffics in the country;
- Detour length to be more than 50km; and
- Under the bridge or downstream must exist an intense industrial activity.

These conditions are sufficiently restrictive that cannot be met. Such a bridge, if exists, has its own administration and maintenance system.

Because the two indices are asymmetric the functional priority index has the effect of a correction factor. Its influence is higher when the degradation factor is lower. However, considering that extreme values of IU_C are exceptions, when IU_C is in its median zone the influence of the IP_F may not be, in any case, ignored.

4. CONCLUSIONS

The algorithm proposed in the article is very simple and straightforward. It is based on the present regulations and it is not necessary to modify the present way of inspection of the bridges.

The equations are very clear, simple and easy to use. Their form is logical and easy to explain.

A unique overall priority index was defined which makes the creation of a list of priority very handy.

The overall priority index includes both degradation and functional influences. Based of simulation, their maximal values were selected in such a way that the final result to be balanced and meaningful. Levels of action were determined and introduced.

Development of such an index is necessary and no bridge management system can really perform its tasks without one. This proposal is part of Romanian National Administration of Roads to develop a decision tool for the management of bridges.

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