

Development of Hungarian Bridge Management System

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The funds available for bridge maintenance, rehabilitation, and reconstruction are far below the realistic needs in Hungary. That is why the Ministry of Transport, Communication and Water Management has initiated countrywide coordinated efforts to establish the Hungarian bridge management system (BMS). The elements already existing are used, and new relevant research work is in progress. The main elements of the future Hungarian BMS, which are already more or less available, are as follows: computerized bridge data bank, uniform procedure for bridge inspection, countrywide bridge maintenance and construction programs until 2000, methods for the calculation of the gross and net values of bridges, cost-benefit calculation method for bridge rehabilitation and reconstruction, simplified BMS for the ranking of interventions, and a computer program for the selection of appropriate routes for oversized and overweight vehicles. A long-term bridge maintenance strategy has recently been developed.

By the early 1980s several new circumstances that had arisen worldwide required that formerly applied highway operation and maintenance methods be changed. The intensive growth of traffic and, in particular, axle loads increased the demand for roads

and bridges. At the same time, as a consequence of significant network development activities and the corrosion defects during the 1960s, the actual maintenance needs of existing bridges increased sharply. Throughout the world there now are insufficient financial resources for bridge maintenance and operation. The negative effect of postponing or delaying necessary bridge maintenance activities can be observed more often.

The current practice of concentrating financial resources on the construction of new bridges has caused problems in Hungary that are similar to those in west European countries, but on a smaller scale. Even though insufficient funds are available, there is an increased need for funds. This contradiction can be solved only by a well-based prioritization of projects in which their efficiencies are calculated and compared. These kinds of systems require decision arrangement and management activities, and registration and administration elements are worked out gradually in several areas of the Hungarian transport engineering system. After the compilation of the first version of our network-level pavement management system (for highway pavements) the bridge management system (BMS) began to be developed.

Bridge management means that all activities should be concentrated in a uniform system, which is necessary

for the long-term and efficient preservation of the serviceability and longevity of highway bridges. The following activities (intervention types) are included here: bridge operation, bridge protection, bridge inspection, sufficiency rating of bridges, bridge maintenance and rehabilitation, substitution of bridges because of deterioration, and new construction for increasing the serviceability of an insufficient bridge. The main elements of BMS are as follows: bridge condition evaluation, deterioration forecasting, design of improvement in various variants, and optimization. A schematic flow chart of the elements of BMS is provided in Figure 1.

Currently, several countries have already achieved considerable results from the development of their systems, although they are rather different. Because of the different conditions in Hungary, the adaptation of any system in an unchanged form cannot be considered realistic. However, Hungarian experts have carefully studied the major foreign BMSs (1-10).

The Ministry of Transport, Communication and Water Management recently decided that a concentrated effort must be made to develop a working BMS. The accomplishment of this huge task, which requires multiyear, coordinated activities of several Hungarian institutions, should be started by gathering and assessing the results already attained in this field, as well as determining future requirements. The following sections describe the more or less completed elements of the Hungarian BMS.

BRIDGE DATA REGISTRATION

Since 1965 data for some 5,800 Hungarian highway bridges have been registered and computerized; before that data were registered manually. This computerized registry consisted of the main data for bridges updated annually by using specialized forms. It was a totally centralized system, and costly programs were required for the eventual modification of the data content. The need for modern bridge management mainly justified the development of this system (E. Tóth, unpublished data).

Since 1989 the regional (highway directorate) level rather than the central level of data input and processing have been used. As a part of the Regional Highway Data Bank (TKA) new bridge data were included, for example, the following: sufficiency rating conforming to roadway width and loading capacity, foundation, waterproofing layer joint, bearing, barrier, traffic restriction data, improvement type and time, condition evaluation notes of five aspects (see next section), and data for the connecting road. The system uses International Business Machines-compatible personal computers. The data stored in TKA could be obtained only in the form of fixed tables until 1990. Later a so-called general data inquiry program was developed. Another program was developed. That program made possible the description of data for each bridge on a separate sheet.

The National Highway Data Bank (OKA) is now being developed. It has the following features:

- Wider data stock,
- Faster data processing,
- Up-to-date data inquiry, and
- Drawing programs.

Data storage on the basis of spatial information will be used when it becomes possible.

BRIDGE INSPECTION

Exact knowledge of the present condition of bridges constitutes a decisive element of bridge management.

Classification of the loading capacities and widths of bridges is of major importance, although the necessary improvements to a bridge can be identified only on the basis of significant knowledge of the present condition of a bridge.

In the 1980s the Institute for Transport Sciences (KTI) in Budapest developed and tested a 12-point evaluation method in which the bridge was classified by using a single condition note (11). The most important

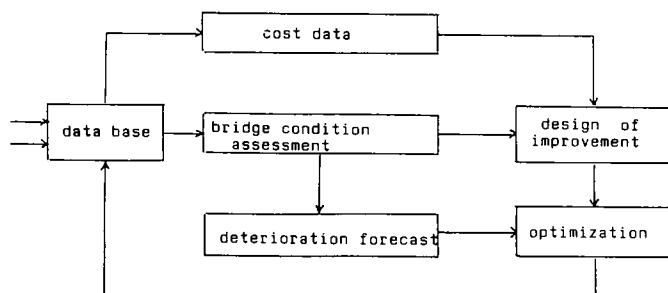


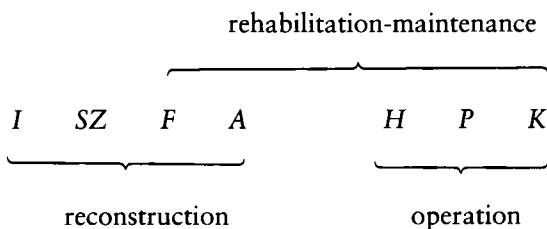
FIGURE 1 Flowchart of Hungarian BMS.

feature of the method was its weighing by geometrical means.

This procedure was developed further, taking into consideration the experiences gained (11–13) by the Ministry of Transport, Communication and Water Management.

The major element of the modification was the use of five main aspects (superstructure, foundation, bridge accessories, deck, and environment) for the final evaluation instead of the former single one. The five main aspects can be determined by using 19 subelements of the bridge elements. Therefore, it can directly reveal the element(s) that needs to be repaired. Another new feature is the application of ratings 1 to 5, as in the case of roads, instead of ratings 0 to 5, which were used previously. According to the final guideline published in 1989 the meanings of the extremes of the ratings are as follows: 1 is perfect condition and 5 indicates severe deficiencies.

The reconstruction needs, as well as maintenance-rehabilitation needs, can be determined on the basis of the load-carrying capacity (T) and the roadway width (SZ) as well as the five main indicators of the sufficiency rating (superstructure, F ; foundation, A ; bridge accessories, H ; deck, P ; environment, K):



Recently, guidelines have been completed for acquiring the condition and defect size, the *Yearly Bridge Inspection Report* (14). The main objectives of yearly bridge inspections are to update the data for the bridge, which may have changed, and assessment of the urgency for eventual improvement.

MEDIUM-TERM BRIDGE PROGRAM

On behalf of the Ministry of Transport, Communication and Water Management, the Bridge Department at the Széchenyi István Technical College, Győr, together with the bridge engineers of the highway directorates, completed the report *Bridge Program until 2000* (15). Assessment and a summary of the necessary bridge improvements and priority ranking of bridge projects as the contribution to the creation of a domestic BMS constituted the main goals of the program.

According to the program, a given number of bridges chosen from the viewpoint of their condition, size, or

traffic volume must be assessed through a detailed condition survey consisting of a 19-point condition evaluation and cost needs estimation. The following data are recorded on the bridge inspection report: former and present bridge condition determined visually, measured condition data, and photographs of typical defects. The program is based on the existing bridge data bank. The priority ranking is an open, flexible, multiparameter, and interactive process. The maintenance and development needs of highway bridges can be calculated. In the case of a given project, the cost needs of optimal improvements as well as the extra costs of delayed intervention can also be estimated.

This condition evaluation was carried out on the 1,272 bridges with deck surface areas of more than 70 m² [this is 60 percent of the total surface areas of Hungarian bridges; bridge improvements requiring more than 2 million Hungarian forints (HUF; US\$1 = about 120 HUF) were treated separately]. During the survey the actual condition of each structural element was assessed by using notes reflecting the severity of deficiencies, as well as the type, time, and extent of the optimum improvements for bridges with ratings of three to five in an 8-year time period.

It was found that repairs on 45 percent of the bridges on main roads and 60 percent of the bridges on secondary roads were urgent.

The average maintenance and reconstruction costs were taken into account on the basis of 1991 price levels, a forecasted inflation rate was considered, and the quantity of hidden (covered) defects was evaluated to be 10 percent of the visible defects. Five percent of the costs was used for the preparatory work for improvements. Approximate deterioration curves were applied. Table 1 presents the improvement needs for 8 years on the basis of 1991 prices.

A priority ranking of bridge improvements was made, taking into consideration the actual condition, the traffic volume, and the cost needs.

The maintenance priority ranking for 1992 was carried out, using the expert opinions of the regional bridge engineers, by averaging five variants.

BRIDGE VALUE CALCULATION

For the economic foundation of bridge management, knowledge of the actual net/gross (percent) value ratio is needed.

By 1981 calculation of the gross and net values of the Hungarian highway network had been completed. Approximate mean values for bridges were applied, and linear depreciation rates were considered. During later repeated value estimations, in 1986 and 1990, practically the same technique was used for bridges. Figure 2

TABLE 1 Bridge Funds Needed for Next 8 Years

	Funds (million HUF)	Unit needs (HUF/m ² /year)	Percentage of gross value
Maintenance funds needed	9882,21	1400	1,00
Development funds needed	7569,42	950	1,33

presents the values that were obtained. Since, among others, the maintenance-rehabilitation funds needed depend on the actual gross value and the net/gross (percent) value ratios, further development of the bridge value calculation procedure became necessary to obtain a more realistic result.

The main steps of this research work (11) are as follows:

- Collection of past available bridge cost data,
- Calculation of mean unit costs for each bridge type and every year,
- Control of these unit costs by using the official indexes of price changes available for main construction materials and activity groups,
- Calculation of a more reliable gross value for all bridges by using the data bank and the unit costs obtained,
- Establishment of typical deterioration curves to determine the net values by using both domestic experience and foreign data,
- Determination of the net value and the net/gross (percent) value ratio of our highway bridge stock by the new procedure, and
- Calculation of the maintenance-rehabilitation needs for various policies as a function of gross value and net/gross (percent) value ratio.

An important task of a realistic value calculation is determination of the necessary yearly maintenance needs. Research work by KTI on this topic (16) has revealed that the general condition preservation of bridges would need some 2.1 times more funds than the average of the funds available in recent years.

COST-BENEFIT ANALYSIS OF BRIDGE IMPROVEMENT

On the initiation of the World Bank, connected with the loan Transport II given to Hungary, KTI has completed an economic efficiency calculation scheme and its software for bridge improvements.

The cost-benefit analysis (efficiency calculation) covers various types of bridge rehabilitation and reconstruction. The calculation is carried out by using the incurred costs and the resulting economic benefits. The costs and benefits during the investigation period (30 years here) are discounted to the first year (17).

The main input groups of the program are as follows:

- Bridge location and geometric, statistical, value, and operational characteristics;
- Traffic parameters and traffic evolution factors for various vehicle types;
- Characteristics of detour routes;
- Features of bridge improvement;
- Forecasted bridge deterioration data; and
- Forecasted net value of bridge.

The following bridge improvement types can be investigated:

- Load-bearing capacity increase,
- Widening,

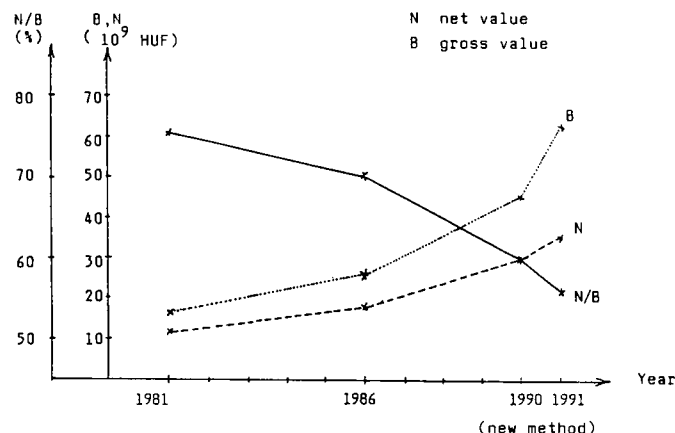


FIGURE 2 Asset values of Hungarian bridge stock between 1981 and 1991.

- Substance preservation (e.g., replacement of bridge pavement with eventual repair of waterproofing layer),
- Total in situ reconstruction,
- Replacement of a pontoon bridge or a ferry by permanent bridges, and
- Reconstruction together with correction of the connecting road.

The following economic benefit types are considered:

- Lower vehicle operating costs because of better bridge geometry,
- Fewer time costs because of the elimination of the detour route,
- Lower time costs because of the end of narrowing of the bridge pavement to a single lane of traffic,
- Lower accident costs because of improvements to the geometric features of the bridge,
- Higher net value as a consequence of pavement condition improvement,
- Lower vehicle operating costs because of better pavement condition,
- Lower time costs because of better pavement condition,
- Lower vehicle operating costs because of the more favorable geometric features of the road leading to the bridge, and
- Lower vehicle operating costs because of the elimination of the detour of a motorway's total traffic volume to one of the carriageways.

The outputs of the variants investigated are as follows: internal rate of return, first year's return.

FIRST PHASE OF SIMPLIFIED HUNGARIAN BMS

The first phase of the simplified Hungarian BMS (HGR) was established by 1991 (18).

The algorithms of four improvement subsystems (maintenance, reconstruction, rehabilitation, and operation) as well as the program for the operational subsystem have been completed. The latter collects estimates in quantity and sums the operational improvement types for each bridge in pieces, in length (in meters), deck surface area (in square meters) and value (in thousands of HUF).

Algorithms for priority ranking and estimation of economic efficiency are also available.

In a given priority class, the ranking of necessary improvements is carried out as a function of their efficiency levels by a yearly schedule.

The urgency priority is as follows:

- Improvement types that cannot be delayed,
- Improvement types that can be delayed for the short term and that can be financed, and

- Improvement types that can definitely be delayed and that can be financed.

The software is also applicable for managing a rather deteriorated bridge stock.

The data base and the improvement module of HGR were developed further in 1992 so that the following features have been attained: the necessary data for the double—former and present—reference system; more technical bridge data; 22 condition elements instead of the former 19; 60 typical improvement types instead of the earlier 22; and an extended cost module that considers the new requirements of the Road Fund.

Optimum criteria were suggested for the management of a bridge stock in a crisis situation (19). The main questions to be answered by the bridge operator are as follows:

- What technically necessary improvements are needed?
- Which improvements can be considered urgent?
- Which improvements can increase most significantly the service offered by the bridges?
- What is the yearly improvement schedule permitted by the available funds?
- Is the quantity of bridge improvement projects increased or decreased by a given funds/cost ratio?

Software and a data base have been developed for network-level bridge management purposes. The data base covers the bridge stock of a county highway department. Its further development is planned in order to deal with the national bridge stock.

The present system can analyze the bridge stock or any part of it by using a 26-parameter screening. It also possesses a statistical data processing module and a module that calculates the funds needed.

The software can process about 100 data items for the bridge from the data bank, as well as 300 other data items on bridge management (such as condition, sufficiency rating, intervention quantity, price, cost, funds, and form of financing).

The maintenance module of the system is capable of processing some 400 data items for the whole bridge stock of a highway department. It stores the time series of condition and sufficiency data.

Seventy-three different intervention types (9 operational, 50 maintenance, and 14 rehabilitation options) can be calculated by the system. Their parameters refer to bridge sections (expressed in pieces, meters, square meters, or thousands of HUF).

The statistical and management modules are able to solve 30 different engineering-management tasks.

The statistical screening module produces lists and tables, enabling the aggregation of bridge sections with different condition scores.

The intervention module can perform several network-level management tasks, such as the following:

- Calculation of intervention needs,
- Determination of the realistic threshold values of intervention strategies and tactics,
- Calculation of cost needs and funds split ratios,
- Network-level economic analysis for finding the optimum action,
- Technical-economic decision support, and
- Planning and documentation of the design.

The main role of the system is to help the bridge managers at the highway departments before the completion of the first Hungarian BMS.

FÖMTERV BRIDGE MANAGEMENT MODEL

The Hungarian design firm FÖMTERV recently initiated the elaboration of a system with the following features (A. Horváth, unpublished paper):

- The input data come from a detailed survey of sample bridges selected from the whole stock according to strict sampling rules and from visual inspection of the rest of the stock,
- The measured data are extended to each element of all bridges by using the mathematical similarity theory and Pólya heuristics,
- With the help of the mathematical similarity theory all of the bridges can be compared (their absolute order is given by their differences from the ideal bridge),
- Any structural elements of the bridges can be compared, and
- The eventual urgent improvement needs of any element of any bridge can be identified.

LONG-TERM BRIDGE MAINTENANCE STRATEGY

Recently, a long-term (10-year) maintenance strategy was compiled for the whole state highway network (20). An important part of this strategy was the bridge maintenance strategy covering nearly 5,900 structures. Based on the actual condition of the bridge asset, three strategy variants (optimum, condition preservation, minimum) were investigated.

The major results obtained by using this strategy were as follows:

- More funds are needed for bridge condition evaluation, cleaning of bridges and culverts, maintenance of bridge drainage systems, and removal of plants that are traffic safety hazards and that impair the capacities of

structures (to prevent severe deterioration, which would require major high-cost maintenance or rehabilitation);

- The average age of bridges of the state highway network is 41 years; nearly 400 bridges are older than 80 years;
- About 30 percent of the bridges have insufficient load-bearing capacities or deck widths;
- Twenty-seven percent of the asset is below the optimum, whereas 9 percent is below the critical level (these quality levels have been determined separately for the main bridge elements and major road types by using expert estimation);
- If the minimum strategy is used, the ratio of the bridge asset below this critical level will triple during the next 10 years;
- The following shares of the whole bridge stock should be improved for various structural elements in order to obtain the general optimum condition after 10 years: substructure, 20 percent; superstructure, 27 percent; bridge deck, 38 percent; and bridge accessories, 38 percent;
- The savings in road user costs are, on average, about 10 times higher than the additional bridge maintenance or rehabilitation costs, so these latter interventions are extremely cost-effective (it is especially true if the investigation is carried out for a longer period, e.g., 30 to 50 years);
- Efforts should be made to reach the overall optimum bridge condition as quickly as possible (e.g., in 10 years) since this is the best way of reducing the total costs; and
- The development of a working BMS that can be applied both on the network and the project level is an important and urgent task.

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