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An Expert System as Applied to Bridges - Testing Phase

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Abstract

This project concludes a four part study regarding the development of an expert system called DOBES, to form conclusions as to the disposition of older bridges. The options include replacement, rehabilitation, improvement, abandonment and routine maintenance. The final phase tested and refined the program, producing excellent results, useful for general bridge management.

FINAL REPORT

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ABSTRACT

This report concludes a four-part study dealing with the use of an expert system called DOBES (Disposition of Old Bridges Expert System) to assist in VDOT's bridge management system. The program makes recommendations as to whether a bridge should be replaced, rehabilitated, improved, abandoned, or just routinely maintained. After some adjustment in the original software, field testing of DOBES yielded quite good results: its recommendations agreed rather well with those of experienced bridge engineers. The operational use of DOBES should not only save time and effort but should also provide a rational and consistent basis for decision making.

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INTRODUCTION

This report describes the last phase of a four-part study dealing with expert systems in relation to managing bridges and pavements.[1–3] In this final phase, the computer program developed called DOBES (Disposition of Old Bridges Expert System) was field tested by a number of Virginia Department of Transportation (VDOT) bridge engineers. The purpose of DOBES is to give bridge engineers a relatively easy and consistent way to determine the proper course of action regarding old bridges.

Specifically, five action options exist:

1. *Rehabilitate*. To rehabilitate a bridge is to restore it to its original condition.
2. *Improve*. To improve a bridge is to improve on its original characteristics. This is usually done by strengthening, widening, or both.
3. *Replace*. To replace a bridge is to remove or bypass the bridge and replace it with a new one on the same or a new alignment.
4. *Abandon*. To abandon a bridge is to take it out of service. An abandoned bridge may be destroyed or put to a new use, possibly at another site.
5. *Maintain*. To maintain a bridge is to keep it functioning essentially in its current condition.

Such determinations in a statewide bridge management program must be made yearly, and with thousands of such bridges involved, the overall task is quite large. It is expected that the use of DOBES will reduce the amount of time and effort needed to accomplish this task. Additional management efficiency could be gained if the recommendations generated by DOBES were incorporated into VDOT's Structure Inventory Form (B-79) as a guide for bridge engineers.

FIELD TESTING

Copies of the expert system program as developed in phase 3 of this study,[3] along with user manuals, were distributed to bridge engineers at VDOT's nine construction districts, as well as to the Structure and Bridge Division in Richmond. Because DOBES employed the computer language LISP, a special licensing fee had to be paid to Gold Hill Computers. Permission to distribute the software was also obtained from VDOT's Information Systems Division on a research basis.

On-site field visits were made as needed in order to ensure that the operation of DOBES was understood and that it was working properly. The associate author, working cooperatively with the local bridge engineers, collected data on 97 bridges. Of special interest were the data comparing the recommendation of DOBES with that of the bridge engineer for each bridge.

ANALYSIS

In the basic DOBES program, there are 15 free parameters that may be altered to improved the accuracy of the system. In order to make the system as accurate as possible, the following method was used to determine the best value for each parameter.

The parameters correspond to the weights of each of the possible primary recommendations of the system (replace, improve, maintain, rehabilitate, abandon) for each of the possible rule strengths (primary, mixed, and secondary). Initial weights for these parameters were set for the initial testing of the program.[3] Data collected from this phase yielded a considerable data base with which program accuracy could be rated.

The accuracy of the program was calculated as a percentage of agreement between the recommendation made by DOBES and that of the bridge engineer for each bridge in the DOBES data base. With regard to the initial values for the 15 parameters, the recommendations were in agreement 80 percent of the time.

A function was written into DOBES to cause it to calculate recommendations for all bridges in its data base, compare them to the recommendations of the bridge engineers, and report on the percentage of agreement. A program on a Sun workstation then took this information and altered the weights of the parameters to test the effect on the accuracy. The final weights were found to be the most accurate within the range of the original weights.

The procedure for changing the weights of the parameters begins with a calculation of the current accuracy (A0). Then, one parameter is increased by 1 to become (A+), and the accuracy recomputed. Then, the parameter is decreased to (A–), and the accuracy recomputed. If A+ > A0 > A–, then the increased value becomes the new parameter weight. If A– > A0 > A+, then the current weight of the parame-

ter is kept and the next parameter is altered. The current parameter is altered until the following is the case: A– < A0 > A+.

After all 15 parameters have been altered in this way, the procedure is repeated with the new parameter weights used as the initial weights. If, after the entire procedure, no parameter weight was changed, then the weights are considered stable and the accuracy is maximized. If any weights do change, further optimization may be possible. Since the weight of a parameter is changed only if it would increase the accuracy of the program, the optimization procedure will effectively lead to local optimization.

DISCUSSION

The agreement between the recommendations of DOBES and experienced bridge engineers at the 87 percent level (which was reached after optimization) is considered very good, as even human experts would probably differ to a similar degree in view of the "fuzziness" of the variables of the problem. Generally, the disagreements, when they do occur, are between replacing a bridge versus rehabilitating it. In principle, it would be desirable to replace rather than rehabilitate old bridges (with the exception of historical bridges). However, financial considerations may prohibit such a course of action, leading to the "balancing act" of weighing the merits of a new bridge and cost. To a lesser extent, there is some disagreement between rehabilitating a bridge or simply maintaining it. Again, the issue is one of cost.

Not only do the various rational procedures of DOBES yield quite good results, they also establish a consistent basis for evaluating all highway bridges in Virginia, regardless of district. However, DOBES is proposed for use as a resource, providing only recommendations.

The updated version of DOBES was sent to VDOT's Structure and Bridge Division and to VDOT's Information Systems Division for their review with regard to implementation in VDOT's bridge management system. The best use of DOBES is believed to be in the incorporation of its recommendation on VDOT's Structure Inventory Form (B-79) as a guide for the bridge engineer.

RECOMMENDATIONS

Given the successful performance of DOBES in field testing, it is recommended that the expert system be adopted as an integral part of VDOT's bridge management system. Specifically, it is recommended that the results of applying DOBES be incorporated into VDOT's Structure Inventory Form (B-79) as a guide for the bridge engineer with regard to maintaining, replacing, rehabilitating, improving, or abandoning an old bridge.

Because of the proprietary nature of DOBES, its public distribution outside VDOT is not possible at this time.

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