Abridgment

Further Refinement of Louisiana's Maintenance Cost Formulas

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This paper deals with the development of a procedure for reliably predicting highway maintenance requirements. Such a procedure would materially aid highway maintenance management in planning maintenance activities. The least squares analysis technique applied to a data base derived from the historical records maintained by the Louisiana Department of Highways yielded a series of models that adequately estimated maintenance requirements for planning purposes.

Since 1930, the Transportation Research Board (formerly the Highway Research Board) has spent a considerable amount of time and money in analyzing maintenance costs and relating the costs to causal factors. Large-scale research projects have been undertaken in which considerable amounts of historical and field data were collected and subsequently analyzed. The federal government, most state governments, and numerous local agencies have been continually working to find better methods of estimating maintenance costs. Those efforts made by the states of Louisiana, Arizona, Ohio, Idaho, and Virginia are noteworthy. Although a considerable amount of subjective and analytical study at federal, state, and local levels has been done in this area, little effort to date has been made to model different categories by grouping maintenance costs with respect to estimating their future requirements. In 1956, the Louisiana Department of Highways attempted to analyze maintenance costs by a quantitative method. A prediction method was developed that considered the age and later the roadway surface condition, traffic volume, subgrade classification, width of roadway surface, and right-of-way width.

Radzikowski (1, 2, 3, 4, 5, 6) wrote several reports on maintenance costs. Initial reports discussed the analysis of various maintenance cost data and suggested measures to be taken to reduce maintenance costs. In 1956, Radzikowski published a report describing a technique almost identical to the Louisiana Department of Highway's method, but he considered different variables in defining the base mile.

Sutarwala and Mann (7, p. 20) were the first to develop a conceptual mathematical model in the form of an equation that could predict the yearly maintenance cost of a given mile of roadway section. The equation developed was applicable only to the concrete pavements within the state of Louisiana. Two important conclusions were derived from this research effort. First, not only were the maintenance costs found to be independently related to the influencing variables themselves but also the interrelationship among the variables made an important contribution toward the estimation of maintenance requirements. Second, an assumption of only linear relationships between the maintenance costs and related variables was proved wrong, and cross product and nonlinear terms were found to be necessary to explain more fully the variation in maintenance requirements.

Mann (8) continued to work in this area. The initial model was modified in a way so that the adequacy of maintenance could be ensured. This was achieved by first evaluating the competence of the involved maintenance engineers in predicting maintenance costs first by using hypothetical sections for estimating maintenance expenditures and then by asking the maintenance engineers to estimate adequate maintenance expenditures on some selected physical sections in their jurisdictions. Adjustments that were necessary to correct deviations from uniform adequacy standards were made on these estimates. Thus reliance on what was spent as a measure of adequate maintenance was eliminated.

Betz (9), in a 1965 publication, reviewed all the research done in this field and pointed out the importance of such research work to developing countries. He concluded that the interractions and relationships among the influencing variables and maintenance requirements were complex in nature and any forced attempt to simplify them by trying to relate them independently would distort the validity of the models.

DATA PREPARATION

The data collected for this investigation were derived from different maintenance data files of the Louisiana

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Department of Highways. Some of the design data were taken from research reports published by the Research and Development Section of the Louisiana Department of Highways. Field observations were found to be unnecessary.

A preliminary investigation was made to ensure that all the data required to develop the models would be available. In certain cases, information could not be taken directly from the existing files and had to be mathematically derived from the raw data. Apart from the maintenance cost data by different categories, most of the other data were easily available and reliable. Certain assumptions were made concerning the available data.

1. Since the institution of recommendations made by a consultant's study, uniformity in adequate maintenance work has been achieved.
2. As a result of item 1, most of the maintenance cost data and performance data recorded during the previous 15 years are adequate and, to a great extent, reliable.
3. As a consequence of the initial assumption, it is assumed that control sections on which maintenance costs have assumed a regular pattern during the previous 5 years were adequately maintained. This assumption is justified because this research is primarily concerned with preventive maintenance.
4. Whenever the necessary data based on control section were not available (as was the case for all categories except surface maintenance and shoulder and approach maintenance data), the average of parishwide data for each of the highway functional classes was used.
5. Where conflict arose between data independently collected by the Maintenance Section and other sections of the Louisiana Department of Highways, the data recorded by the Maintenance Section were used.

DEVELOPMENT OF MAINTENANCE MODELS

Seven statistical models were developed by use of the least squares method. These models estimate maintenance costs requirements in dollars for the various categories as will be explained. The first five models are applicable to any control section; the models for (a) river-crossing operations and (b) maintenance overhead and administration are applicable at the parish and district levels respectively. The specific form of each model is given in the following sections. (These models are designed for U.S. customary units only; therefore, values are not given in SI units.)

Surface Maintenance

Surface maintenance cost per centerline mile = 19.6 + 177.9 (percentage of asphalt pavement) + 0.06 (percentage of concrete pavement) (average daily traffic) + 4.3 $(ADT)^{1/2}$ - 0.01 (ADT) (structural number). Coefficient of determination (r^2) = 0.86.

Shoulder and Approach Maintenance

Shoulder and approach maintenance cost per centerline mile = 17.5 + 284.7 (percentage of paved shoulder) + 13.8 (percentage of nonpaved shoulder) (soil support value) - 15.6 (percentage of paved shoulder) (soil support value) + 7.2 (age) - 55.3 (soil support value) + 1.9 $(ADT)^{1/2}$. $r^2 = 0.81$.

Roadside and Drainage Maintenance

Roadside and drainage maintenance cost per centerline mile = 50.8 + 909.5 (Interstate) + 151.0 (primary) + 3.9 (annual rainfall) + 22.5 (acres mowed). $r^2 = 0.70$.

Structure Maintenance

Structure maintenance cost per centerline mile = 42.9 + 2257.5 (number of steel structures) + 9.3 (length of steel structures) - 0.3 (deck area concrete and steel structures) + 0.3 (deck area of other structures). $r^2 = 0.50$.

Traffic Surface Maintenance

Traffic surface maintenance cost per centerline mile = 81.2 + 572.7 (Interstate) + 90.5 (primary) + 0.03 (urban traffic factor) + 0.04 (rural traffic factor). $r^2 = 0.86$.

River-Crossing Operations Maintenance

River-crossing operations maintenance cost per parish = 3608.9 + 5155.6 (number of bridge tenders) (salary increment factor) + 4516.4 (number of ferry tenders) (salary increment factor) + 8.1 (annual bridge openings) + 2957.5 (total ferry capacity). $r^2 = 0.98$.

Maintenance Overhead and Administration

Maintenance overhead and administration cost per district = 149 566.6 + 846.4 (total number of employees in district) (salary increment factor) + 84 251.4 (district centerline mileage per nonadministrative employee). $r^2 = 0.71$.

CONCLUSION

The development of adequate mathematical models for predicting various categories of maintenance cost requirements creates an extremely useful tool because intuitive and subjective estimates of needs by individual maintenance engineers may be verified. Although use of such models will not eliminate the problems of overmaintenance and undermaintenance, estimated maintenance requirements should be more consistent by being correlated to the causal factors that generate maintenance activities, which in turn will require more accountability in maintenance expenditures. It is important to note that generally these models were developed from parishwide or districtwide data and their application to any single short section must be done with caution. The effect of yearly inflation, although included as a salary increment factor in two of the models, must be considered in applying the models presented over time.

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