OPTIMAL FLEXIBLE PAVEMENT CROSS-SECTION DESIGN USING QUANTITY-DISCOUNT COST MODEL

SUMMARY REPORT 123-28(S)

SUMMARY OF
RESEARCH REPORT 123-28

PROJECT 1-8-69-123

Cooperative Highway Research Program
with U. S. Department of Transportation
Federal Highway Administration

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY

June, 1975

Optimal Flexible Pavement Cross-Section Design Using Quantity-Discount Cost Model

by

Danny Y. Lu, Robert L. Lytton, and Chester H. Michalak

The principal purpose of the research summarized in this publication is to develop a fairly general pavement cross-section model and several typical quantity-discount cost models, and integrate these models into the Texas Flexible Pavement Design System (FPS). The report also explains the development of a separate master pavement cross-section model that is independent of FPS and is capable of calculating cross-section areas for any pavement cross-section.

FPS Pavement Cross-Section Model

A fairly general pavement cross-section model has been developed for FPS. Input data for this model are: (1) widths of pavement, shoulders and road side slopes; (2) thickness of pavement layers, shoulder layers, fill material, overlay material and upgrade material and (3) side slopes. The model calculates the volumes of each of the pavement, shoulder, fill, overlay and upgrade materials layers per unit length along the pavement centerline direction. This model has 36 versatile features.

FPS Quantity-Discount Cost Model

Construction material discounts are often offered for the purchase of larger quantities. Four discount models of unit construction material cost have been developed: constant cost, log-log relation of cost to layer thickness, log-arithmetic, and linear. Usage of the quantity-discount model can be divided into two stages. In the first stage, unit costs at maximum and minimum thickness are input to the model. These data are used to calculate two parameters representing the relation between cost and layer thickness. Once these two parameters have been calculated, a specific thickness can be used in the second stage to calculate the discounted unit cost at that thickness.

Modified FPS Cost Model

Cost models used in previous FPS programs have been extensively modified due to the inclusion of the full pavement cross-section model. Additions to calculations of the initial construction cost are shoulder costs and fill material costs. Costs of subbase extensions under shoulders are also included. Added to the overlay construction cost are costs of overlay extensions over the shoulders and the material costs of upgrading materials. Maintenance of the shoulder surface is included in the calculation of the routine maintenance cost. The rates of production of both overlay and upgrading materials are used to calculate the traffic delays during an overlay construction period during which excessive traffic delays result in higher user's cost. At the end of the analysis cycle, the salvage value of the pavement is estimated based on the residual worth of the pavement, shoulder, fill, overlay and upgrading materials.

Findings

Significant findings are: (1) the inclusion of shoulders, subbase extensions under shoulder and fill materials in the estimation of initial construction costs may alter the optimal design strategy that is selected; (2) the optimal design strategy selected for new construction may not be the same when costs are computed by the constant unit cost and by a quantity-discount unit material cost model; (3) neither overlay extensions over shoulders nor upgrading materials nor the use of the different quantity-discount unit cost models have any noticeable effects on the final selection of an optimal overlay design strategy and (4) the potential savings in construction cost from using the full-cross section and quantity-discount models in selecting pavement designs for new construction warrants its implementation in FPS.

Master Pavement Cross-Section Model

Separately from the FPS program, a master pavement cross-section model has been devised to calculate each specific area of any complicated pavement cross-section. Input data for this model are known slopes of lines, known coordinates of points, known thicknesses of layers and point numbers of bounded areas. This model is essentially a set of simultaneous linear algebraic equations. The model provides the minimum data requirement to precisely describe an in-service pavement cross-section for use in the pavement feedback data system.

Conclusions

The simple pavement cross-section model and the linear quantity-discount cost model, which have been integrated into the FPS computer program, are recommended for use by the State Department of Highways and Public Transportation. The master pavement cross-section model will assist the development of the pavement feedback data system in the description of pavement cross-sections, and should eventually be incorporated into FPS for determining the optimum strategy for reconstructed and widened pavements.

Implementation Statement

This report presents evidence to show that consideration of the quantity of materials in the full pavement cross-section and the decrease of construction material costs with increasing quantities will affect the selection and total cost of the optimal design strategy in the State Department of Highways and Public Transportation's Flexible Pavement Design System (FPS). A new version of the FPS computer program, FPS-13-TTI, has been developed in this study and is recommended for immediate implementation. Changes in FPS-13-TTI as compared to FPS-11 are additions of a fairly general pavement cross-section model and four quantity discount cost models.

In addition, a master pavement cross-section model (MPCS) has been developed in this study to calculate the area of any complicated cross-section whenever it becomes necessary to know the precise material requirements of the optimal design strategy resulting from the FPS-13-TTI. The MPCS program is ready for immediate implementation too. The MPCS model can also be utilized to determine the minimum data storage requirement of in-service pavement cross-sections for use in the pavement feedback data system.

The published version of the report may be obtained by addressing your request as follows:

Phillip L. Wilson, State Planning Engineer
Transportation Planning Division
State Department of Highways and
Public Transportation—File D-10R
P. O. Box 5051
Austin, Texas 78763
(Phone: (512) 475-7403 or TEX-AN 822-7403)