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# Methodology for Load-Zoning Pavements

Texas has approximately 17,500 miles of load-zoned pavements, comprising more than 20 percent of the number of centerline miles on the state-maintained system. These pavements are primarily low-volume farm-to-market roads constructed in the 1950s, at a time when legal load limits were lower than they are now. Like most governments, Texas does not have the money to upgrade all existing load-zoned pavements to accommodate present truck traffic, nor is this justifiable for many of these pavements because of the continuing low traffic volumes. To do so would divert funds from higher-priority highway and bridge improvement projects.

Most load-zoned roads in Texas are still posted with a gross vehicle weight (GVW) limit of 58,420 lb, corresponding to the legal load limit at the time these roads were designed and built. Since the load from a vehicle is transmitted to the pavement through its axles, establishing load limits based on axle weight and axle configuration is a more rational approach than the one presently used. Recognizing the need for a better methodology of load-zoning pavements, the Texas Department of Transportation (TxDOT) funded a project to develop a procedure for evaluating load restrictions on the basis of axle load and axle configuration. Research efforts conducted at the Texas Transportation Institute (TTI) led to the development of the Program for Load-Zoning Analysis (PLZA) that pavement engineers may use to evaluate the need for load restrictions and to determine, as appropriate, the single and tandem axle load limits based on a user-prescribed reliability level.

## What We Did...

A load-zoning analysis will generally address the following questions:

- Is there a need for posting load limits on a given route?

- If load restrictions are necessary, what axle load limits should be used?

Consequently, the framework researchers used to develop PLZA incorporates these two steps in the load-zoning analysis. This approach was adopted as most load-zoning evaluations in recent years pertained to the removal of existing load limits on roads that have been upgraded through rehabilitation or reconstruction. This situation has come about since the districts make every effort to rehabilitate an existing load-zoned road to a higher standard to accommodate truck traffic at the legal load limits. Thus, it is expected that most applications will relate to the applicability of removing existing load limits, rather than to posting new load limits.

The methodology developed for evaluating load restrictions is based on predicting the effects of load limits on pavement performance. Figure 1 illustrates the framework used to develop the load-zoning analysis program. In this framework, axle weight restrictions are established based on the minimum service life or time to next resurfacing required by the pavement engineer. The evaluation of performance uses data from characterization of the route and from the determination of the expected number of truck loadings for the user-specified analysis period.

To predict the induced pavement response under surface wheel loads, PLZA uses a layered elastic pavement model that permits users to characterize pavement materials as linear or nonlinear. The predicted horizontal strain at the bottom of the asphalt layer and the vertical strain at the top of the subgrade are used with the Asphalt Institute performance equations to predict the number of allowable load repetitions for given axle loads

and configurations. Due to variability in materials and layer thicknesses, predictions of pavement life will vary accordingly along the route. To consider this variability, PLZA uses the service life predictions to compute the probability that the service life will be less than the required life specified by the engineer. The reliability is, thus, determined and used in PLZA to establish the need for load restrictions and to determine single and tandem axle load limits, as appropriate.

## What We Found...

**Sensitivity Analysis of Predicted Performance**

Researchers conducted a sensitivity analysis of predicted pavement life to:

- evaluate the effects of pavement design factors on predicted performance;

- identify design variables that are important in the load-zoning analysis; and

- verify whether the effects of design variables are consistent with engineering experience and practice.

The findings from the sensitivity analysis are summarized as follows:

- Overall, the results showed that pavement life (based on the Asphalt Institute fatigue equation) is influenced the most by surface thickness and base modulus, and, to a lesser degree, by the base thickness and surface modulus. The subgrade modulus exhibited an appreciable effect only for the thin pavement.

- On the basis of rutting, the analysis showed that predicted pavement life is influenced significantly by the layer moduli and thicknesses. In particular, the surface thickness, base thickness, and subgrade modulus are observed to have the most impact on the predicted life, which varied in the same direction as the change in each design variable.
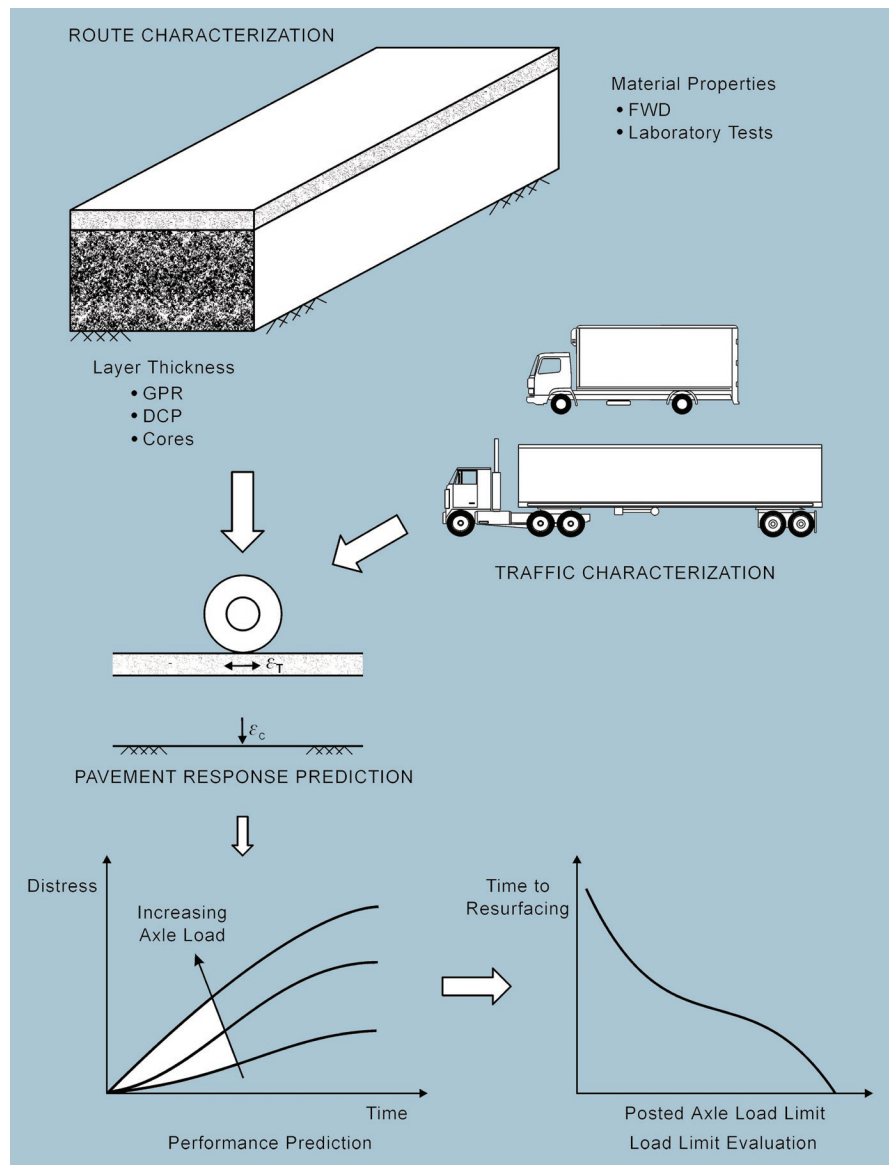


Figure 1. Methodology for Load-Zoning Pavements

- The rut depth criterion was observed to govern the predicted pavement life for the thin and medium pavements, while the fatigue criterion governs the service life for the thick pavement. Since most roads that undergo a load-zoning analysis fall under the thin and medium categories, this observation implies that, for roads comparable to the pavements analyzed, rutting will likely control the load restrictions, based on the Asphalt Institute performance equations.

- In terms of options to rehabilitate existing load-zoned roads to carry legal load limits, the results from the sensitivity analysis imply that

increasing the surface thickness and/or improving the base material are primary options an engineer should consider to improve the expected fatigue life of the pavement. The effect of these changes on predicted pavement response is to reduce the bending effect under load, and the tensile strain at the bottom of the surface mix. Theoretically, this reduction in tensile strain translates to a higher number of load repetitions prior to crack initiation. In addition, the increase in surface thickness adds to the number of load repetitions for crack propagation. On the basis of the rut depth criterion, the primary options

an engineer should consider are to increase the surface thickness and/or base thickness, and to improve the subgrade through stabilization or replacement with a better material. The effect of these changes is to reduce the compressive strain at the top of the subgrade, resulting in a predicted increase in pavement life.

## Application of Load-Zoning Analysis Procedure

Researchers also used the load-zoning procedure to evaluate the need for load restrictions on four in-service pavements located in the Waco and Tyler Districts. This evaluation was conducted by using pavement evaluation techniques already implemented within TxDOT [specifically, the ground penetrating radar (GPR), falling weight deflectometer (FWD), dynamic cone penetrometer (DCP), COLORMAP, and MODULUS] and by using standard traffic information employed in pavement design. The experience with the initial applications of the load-zoning program demonstrated that it can be readily implemented within the department, in the researchers' opinion. Service life predictions from PLZA were also assessed against corresponding predictions from the MODULUS program. The results of this comparison showed that, in terms of the need for load restrictions, both programs produce the same ranking of the pavement sections tested and analyzed.

## The Researchers Recommend...

Based on results from the pilot demonstration of the PLZA program, researchers recommend posting of load limits on the basis of axle load and axle configuration. The evaluation of axle load limits indicated that single and tandem axle configurations have different damaging effects on pavements, and that posting load limits in terms of axle weight may

actually help TxDOT preserve the highway network in a way that will maintain or have the least negative impact on trucking productivity.

Researchers recommend that the load-zoning procedure be initially implemented through the Materials and Pavements Section of the Construction Division, which is staffed with engineers trained to operate GPR, FWD and DCP equipment, and to analyze GPR and FWD data using COLORMAP and MODULUS, respectively. As the need arises, implementation of the analysis program may be phased into the districts, particularly those with significant mileage of load-zoned pavements. The implementation of the program within the districts may be realized through training sessions conducted in-house or through an interagency agreement.

In actual applications, users must first characterize the route to be analyzed. This will require characterizing the truck traffic on the route, determining pavement layer thicknesses, and evaluating material properties. Truck traffic data may be requested from the Transportation Planning and Programming (TP&P) Division of TxDOT. The standard information reported by TP&P in the "Traffic Analysis for Highway Design" tables are used in PLZA to evaluate the need for load restrictions and to determine, as appropriate, the applicable single and tandem axle weight limits on a given route.

Researchers strongly suggest a GPR survey on the route to establish the variations in layer thicknesses. This survey should be conducted at the beginning of the evaluation. FWD data should be collected following the protocol established by TxDOT. For load-zoned pavements with surface thicknesses greater than 3 inches, pavement temperature measurements should be made to correct backcalculated asphalt concrete moduli to a standard

temperature. Alternatively, infrared surface temperatures may be measured during the survey for the purpose of predicting pavement temperatures at the time of test using the Texas-LTPP equation implemented in the Modulus Temperature Correction Program. Use of this equation requires the previous day's maximum and minimum air temperatures, which are readily obtained from the local weather service.

The researchers recommend that the FWD data be stored in a separate file for each segment of the route surveyed. Each file is then analyzed with the MODULUS program to estimate the stiffness of each pavement layer. The output file of the backcalculated moduli for each segment is directly input to the PLZA program for the load-zoning analysis.

In view of the possible variations in layer thickness and materials along the route, different results may be obtained for the different segments delineated from the GPR data. In practice, it will be difficult to implement numerous postings on a given route. Thus, the pavement engineer must still use his or her judgment in taking the results of the load-zoning analysis to establish how a given route should be posted. For example, the engineer may make the decision to post the route based on the weakest segment. This decision should also consider the current truck use of the particular route, alternative roadways that may be taken, the presence of load-zoned bridges, and the need to upgrade the route to carry truck traffic at the legal load limits.

## For More Details . . .

The research is documented in Report 2123-2, *Development of an Analysis Procedure for Load-Zoning Pavements*. In addition, detailed instructions on using the PLZA analysis software are found in Report 2123-1, *Program for Load-Zoning Analysis (PLZA): User's Guide*.

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## TxDOT Implementation Status
## October 2003

The methodology for Load-Zoning Analysis has been implemented at the Pavement & Materials Systems branch of the Materials and Pavements Section of the Construction Division.  This methodology and design software will be made available to the Districts in the future through a web-based training site.  The web-based training is being developed under IPR 5-1869.  TxDOT employees will have access to this training through a link in the Intranet that will also allow the down loading of the programs.

For more information, please contact: Dr. German Claros, P.E., Research and Technology Implementation Office (512) 467-3881 or gclaros@dot.state.tx.us.

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