Improved Imputation of Missing Pavement Performance Data Using Auxiliary Variables

J. Farhan[1] and T. F. Fwa, M.ASCE[2]

Abstract: Missing data in pavement condition and performance records of pavement management systems (PMS) are commonly encountered in practice. Imputation of missing data is often required in the analysis of pavement performance and decision making for maintenance and management of pavement networks. The traditional methods of handling missing data by pavement engineering professionals include deletion of affected records, and imputation of missing data by means of interpolation substitution, mean substitution, or regression substitution. Today, the advancement of computer technology has permitted the use of computationally complex stochastic methods of multiple imputation to improve the accuracy of imputed data. This study proposes an improved multiple imputation approach using a joint multivariate model on the understanding that, besides pavement performance data, a typical PMS database also collects data of related pavement properties and nonpavement variables such as traffic and weather conditions. The proposed approach develops an imputation strategy that uses selected pavement properties and nonpavement data as auxiliary variables in the multiple imputation analysis for missing pavement performance data. The theoretical basis and imputation procedure of the proposed approach are first presented, followed by a case study using the Long-Term Pavement Performance (LTPP) database to illustrate the choice of auxiliary variables and the steps involved in imputing missing rutting and roughness data respectively. The merits of the proposed approach are demonstrated by comparing the imputed results with actual measured data and by comparing the results with those obtained using the multiple imputation method without the inclusion of auxiliary variables. **DOI: 10.1061/(ASCE)TE.1943-5436.0000725.**

Author keywords: Pavement management system; Pavement performance; Missing data impuation; Multiple imputation; Aauxiliary variables; Pavement roughness; Pavement rut depth.

Development of an Electrophoretic Display Technology for Selectively Retroreflective Signs and Pavement Markers

Christopher Y. Brown[1]; Thomas A. Brubaker[2]; Andrew M. Churchill[3]; Gregory M. Crosswhite[4]; David Fried[5]; Leslie Kirsch[6]; Daniel A. Zelman[7]; and David J. Lovell, A.M.ASCE[8]

Abstract: This paper describes an enabling technology that could be used to develop electronic roadway signs and markers whose display content can be changed and that are selectively retroreflective. This would give them the good visibility of retroreflective signs at night, coupled with invisibility under circumstances where they are not meant to be seen, thereby reducing both confusion and light pollution. This paper describes how the half-silvered and blackened glass beads that constitute the visible components of the display were fabricated in the lab and derives their geometric optics, demonstrating their retroreflective capabilities. The paper also describes the construction of a transparent top electrode necessary to establish the electric field for changing the displays and derives some of the electric properties of the electrode and the resulting capacitorlike display. The work is in an early developmental stage, and the paper concludes with an outline of some of the remaining issues that need to be solved before a working device could be constructed. **DOI: 10.1061/(ASCE)TE.1943-5436.0000717.**

Public Transport Travel-Time Variability Definitions and Monitoring

Le-Minh Kieu[1]; Ashish Bhaskar[2]; and Edward Chung[3]

Abstract: Public transport travel-time variability (PTTV) is essential for understanding the deteriorations in the reliability of travel time, optimizing transit schedules, and route choices. This paper establishes the key definitions of PTTV which firstly include all buses, and secondly include only a single service from a bus route. The paper then analyzes the day-to-day distribution of public transport travel time by using transit signal priority data. A comprehensive approach, using both parametric bootstrapping Kolmogorov-Smirnov test and Bayesian information criterion technique is developed, recommends lognormal distribution as the best descriptor of bus travel time on urban corridors. The probability density function of lognormal distribution is finally used for calculating probability indicators of PTTV. The findings of this study are useful for both traffic managers and statisticians for planning and analyzing the transit systems. **DOI: 10.1061/(ASCE)TE.1943-5436.0000724.**

Author keywords: Public transport; Travel time variability; Reliability; Travel time distribution; Probability; Indicators.

Soil Resilient Modulus Regressed from Physical Properties and Influence of Seasonal Variation on Asphalt Pavement Performance

Changjun Zhou, Ph.D.[1]; Baoshan Huang, Ph.D., P.E., M.ASCE[2]; Eric Drumm, Ph.D., M.ASCE[3]; Xiang Shu, Ph.D., A.M.ASCE[4]; Qiao Dong, Ph.D., A.M.ASCE[5]; and Sampson Udeh[6]

Abstract: Subgrade soil, as the critical underlying support for other pavement layers and traffic loads, should be stiff enough to maintain the integrity of pavement structures and the smoothness of pavement surface. The resilient modulus, as an indicator of subgrade stiffness, is an essential input in the AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG). At input level 1 of MEPDG, the MEPDG generalized model is required to describe resilient modulus of subgrade soil, and the coefficients of this model are used for pavement design. The change of the resilient modulus model has raised the interest of many state highway agencies and made it necessary to convert old resilient modulus test data into new ones required for the MEPDG model. In this study, the coefficients of the generalized and the universal models for soil resilient modulus were obtained through regression of the results of 13 soils in Tennessee. The coefficients of the two models were also compared. There is a potential risk that the coefficients from the universal model may be mistakenly used in the MEPDG instead of those coefficients from the generalized model. The consequence of this improper use was demonstrated in the comparison between the miscalculated and the real resilient moduli. The coefficients of the generalized model were correlated to soil physical properties, which provided an alternate time-saving and economical method to obtain soil resilient modulus as level 2 inputs. The coefficients were obtained at different post-compaction water contents, to allow the estimation of pavement response under seasonal moisture variation of subgrade. Rutting and roughness of two typical pavement sections were analyzed to investigate the influence of the seasonal variation of soil resilient modulus on pavement performance. The results showed that moisture variation had a significant effect on subgrade resilient modulus and, subsequently, on pavement performance. It is recommended that seasonal change in soil resilient modulus be considered in the analysis on pavement performance. **DOI: 10.1061/(ASCE)TE.1943-5436.0000727.**

Author keywords: Subgrade; Resilient modulus; Mechanistic-Empirical Pavement Design Guide (MEPDG); Generalized model; Coefficients; Seasonal moisture variation.

Selection of Preoverlay Repair Methods for Asphalt Overlay on Asphaltic and Composite Pavements in Wisconsin Based on Cost Effectiveness

Haifang Wen, Ph.D., P.E., M.ASCE[1]; and Xiaojun Li, Ph.D.[2]

Abstract: Asphalt concrete (AC) overlay is a commonly used rehabilitation technology for existing distressed pavements. Current practice regarding the selection of preoverlay repair is based on the experience of designers and field engineers. Therefore, the performance of asphalt overlays vary significantly. There is a need to develop a guideline to select the most cost-effective preoverlay repair methods. In this study, a database that includes 338 historic asphalt overlay projects is developed. The service lives of the asphalt overlays, based on each preoverlay repair method, are determined. The agency and user costs over the service lives are analyzed. The results indicate that the pavement distress index (PDI) development method based on the regression can be used to predict the service lives of overlays on AC and composite (COMP) pavements (concrete pavement that has been overlaid at least once). For existing AC pavements, milling is recommended when alligator cracking is extensive and no preoverlay repair is needed for other major preoverlay distresses. For existing COMP pavements, milling is recommended regardless of the preoverlay distresses' extent and severity. **DOI: 10.1061/(ASCE)TE.1943-5436.0000710.**

Author keywords: Preoverlay; Distress; Repair method; Performance; Asphalt concrete overlay; Service life; Cost analysis.

Estimating "True" Variability of Traffic Speed Deflectometer Deflection Slope Measurements

Samer Wehbe Katicha, A.M.ASCE[1]; James Bryce, S.M.ASCE[2]; Gerardo Flintsch, M.ASCE[3]; and Brian Ferne[4]

Abstract: In this paper, the difference sequence method is used to decompose traffic speed deflectometer (TSD) deflection slope measurements variability into "true" spatial variability that is due to pavement structural changes and noise variability. A robust method to evaluate the noise standard deviation is presented and the difference sequence method is validated using simulated examples. The difference sequence method is then used to calculate the noise standard deviation and "true" spatial variability of TSD deflection slope measurements. The evaluated noise standard deviation is also used to determine the optimal smoothing of TSD deflection slope measurements using an unbiased measure of the risk. This method is compared with the generalized cross validation (GCV) criterion to determine the optimal smoothing. Results suggest the unbiased risk criterion performs better than the GCV criterion. This gives an objective method, which is currently lacking, to average TSD measurements, and more generally any continuous deflection device measurements. Finally, the results in this paper are presented under the reproducible research paradigm; a *MATLAB* implementation is made available that can be downloaded and used to reproduce all figures and tables presented in this paper. **DOI: 10.1061/(ASCE)TE.1943-5436.0000711.**

Assessing the Transferability of the Highway Safety Manual Predictive Method for Urban Roads in Fortaleza City, Brazil

Flávio Cunto[1]; Lucas Sobreira[2]; and Sara Ferreira[3]

Abstract: AASHTO's Highway Safety Manual (HSM) provides guidance to safety professionals and is becoming a standard of practice, particularly for regions that require urgent action because of persistently high crash frequencies that have resulted from an overall lack of safety investments. Differences in crash data systems, local enforcement, driving behavior, and other factors have prompted studies assessing the international transferability of the HSM predictive method. The recent increase in crash occurrences in Brazilian urban areas and the World Health Organization (WHO) Decade of Action for Road Safety initiative have motivated a nationwide joint safety research effort. One of the fundamental questions in this project is related to the applicability of HSM safety performance functions (SPFs) for the Brazilian urban environment. This paper presents the initial results regarding the transferability of the HSM SPFs for estimating the expected average crash frequency of urban intersections in Fortaleza City, Brazil. The procedure consists of two major steps: the first step investigates the estimation of the calibration factor according the procedure outlined in the HSM and is followed by a model validation effort using a different data sample; the second step is comprised of an analysis of the overdispersion parameter k, either using the original estimates from the HSM or recalibrated estimates using local conditions. The results suggest that for the Fortaleza case, the calibrated HSM baseline SPFs can be used with caution. It is, however, worthwhile to analyze the effect of the calibration sample size on the model stability, and efforts to produce SPFs using local data must be considered. **DOI: 10.1061/(ASCE)TE.1943-5436.0000734.**

Author keywords: Highway safety manual; Safety performance functions; Crash modification factors; Observational studies.

Time-Headway Distributions on an Expressway: Case of Bangkok

Sooksan Panichpapiboon[1]

Abstract: Traffic flow modeling is one of the fundamental keys to solving a traffic engineering problem. Among many parameters, time headway is frequently used to model traffic flow characteristics. A statistical analysis of time headways is immensely important to both theoretical traffic modeling and simulation-based traffic modeling. Basically, it allows researchers to describe an inherently random pattern of traffic flows. Past studies have mainly focused on the time headways of vehicles on highways, freeways, and arterials. However, studies of time headways on urban expressways are rather limited and still need further investigation. In this paper, the author investigates and characterizes the time-headway distributions of vehicles traveling on an urban expressway in Bangkok, Thailand. Particularly, the exponential distribution, the lognormal distribution, and the generalized extreme value (GEV) distribution are used to model the time headways. It is found that the GEV distribution is most effective in modeling time headways. In fact, the GEV distribution can describe more than 90% of the empirical distributions on most lanes and sections of the expressway. On the other hand, the exponential distribution is the least effective distribution. It can only describe the empirical distributions during the periods when the traffic is extremely light. **DOI: 10.1061/(ASCE)TE.1943-5436.0000731.**

Author keywords: Time-headway; Traffic flow analysis; Statistical modeling.

Recommendations for the Minimum Thickness of Concrete Pavements Supporting F-15 and C-17 Aircrafts

Alessandra Bianchini, Ph.D., P.E.[1]; Carlos R. Gonzalez, P.E.[2]; and Walter R. Barker, Ph.D., P.E.[3]

Abstract: The procedure for the design of military rigid airfield pavements contained in the Unified Facilities Criteria 3-260-02 gives the minimum thickness of airfield concrete pavements as 152 mm (6 in.). The introduction of the C-17 aircraft and the requirement of dowel bars as a joint load transfer mechanism bring into question the validity of the 152-mm (6-in.) minimum thickness. With the objective of updating such minimum thickness criteria, a full-scale test section was constructed and trafficked with loads simulating F-15, B-52, and C-17 aircraft landing gear. Evaluation of the test section performance and analysis of the strain data supported a U.S. Army Engineer Research and Development Center team recommendations that the minimum pavement thickness be increased to 203 mm (8 in.) for any doweled airfield pavement and that the minimum thickness of 279 mm (11 in.) should be required for those pavements supporting C-17 aircraft. **DOI: 10.1061/(ASCE)TE.1943-5436.0000732.**

Author keywords: Rigid pavements; Minimum thickness; Strain gauges; Full-scale pavement test section; Heavy aircraft pavement.

Introduction

The basis for the Department of Defense (DoD) rigid pavement design procedure is contained in the Unified Facilities Criteria (UFC) 3-260-02 (UFC 2004) for the design of airfield pavements. The UFC also provides instruction regarding the minimum thickness of 152-mm (6-in.) rigid pavements should have, although such instructions are not related to the type of load or traffic the pavement is designed to support.

For rigid pavements, a thorough literature review did not indicate that specific performance studies were used to determine the

Airfield rigid pavements commonly require the presence of dowels along construction joints and in specific areas such as between existing and newly placed rigid pavements. Therefore, the dowel diameter would influence the minimum slab thickness. Tables 12-8 (UFC 2004) specifies a dowel diameter in relation to slab thickness. Dowels are usually placed at the slab midthickness within a criteria-allowed tolerance of 13 mm (0.5 in.) and the American Concrete Institute (ACI) recommends a minimum concrete cover of 76 mm (3 in.). Based exclusively on the construction requirements for the joints and dowel placement, the conclusion is that the minimum thickness of rigid airfield pavements should be