PAVEMENT PERFORMANCE DATA ANALYSIS FORUM

Sponsored by the TRB Data Analysis Working Group
Michael I. Darter, Chairman
A. Robert Raab, TRB Senior Program Officer

August 18, 2002
Room 102, Radisson SAS Falconer Hotel, Falkoner Allé 9
Copenhagen, Denmark

0900-0930am	Call to Order Chairman's Welcome Staff Report
0930-1000am	**MODELING PAVEMENT ROUGHNESS BY COMBINING MULTIPLE DATA SOURCES** Jorge A. Prozzi, The University of Texas at Austin, USA
1000-1015am	Presenter's Questions
1015-1030am	Morning Break
1030-1100am	**USING GENETIC ALGORITHMS AND MULTI-CRITERIA ANALYSIS IN THE OPTIMIZATION OF A LOCAL AUTHORITIES HIGHWAYS MAINTENANCE SCHEDULE** Thomas Brownlee, The University of Birmingham, United Kingdom
1100-1115am	Presenter's Questions
1115-1145am	**ANALYSIS OF LTPP PAVEMENT LAYER THICKNESS VARIABILITY FOR RELIABILITY-BASED PAVEMENT DESIGN** Olga Selezneva, Jane Jiang, Goran Maldenovic, Michael Darter Applied Research Associates, ERES Division, Columbia, Maryland, USA
1145-1200noon	Presenters' Questions
1200-0100pm	Mid-Day Break
0100-0130pm	**EFFECT OF SOIL PARAMETERS ON SEASONAL VARIATION OF SUBGRADE MODULUS** Nishantha Bandara, Richard Bennett, Derek Pearson, and Mark Sharrock, Abatech Inc., Doylestown, Pennsylvania, USA, and Abatech International Ltd., Sheffield, United Kingdom
0130-0145pm	Presenters' Questions

0145-0215pm	**INITIAL EVALUATION OF THE SPS-8 EXPERIMENT – STUDY OF ENVIRONMENTAL EFFECTS IN THE ABSENCE OF HEAVY AXLE LOADS** Goran Mladenovic, Jane Jiang, Michael Darter Applied Research Associates, ERES Division, Columbia, Maryland, USA
0215-0230pm	Presenter's Questions
0230-0245pm	Afternoon Break
0245-0315pm	**DEVELOPMENT OF A MECHANISTIC-EMPIRICAL ROAD-ROUGHNESS MODEL ADAPTED TO THE ENVIRONMENT OF THE PROVINCE OF QUEBEC, CANADA** Guy Doré and Daniel Gagnon, Université Laval, Québec, Canada
0315-0330pm	Presenter’s Questions
0330pm	Close of Meeting

A NOTE ABOUT THE DAWG

The DAWG is an international forum for the discussion of methods of analysis of pavement performance data. Presentations at DAWG-sponsored forums address the technical interests of professionals engaged in highway research and engineering design, maintenance, and rehabilitation who are engaged in collecting, processing, and analyzing such data and developing insights into the behavior of pavements. Presentations offered by forum attendees (by prior arrangement) focus on work-in-progress concerning the development of techniques for extracting and analyzing data, and early results of recent applications of these techniques. Topics such as model building, sensitivity analysis, and development of transfer functions linking structural response to distress are especially popular and welcome.

A DAWG-sponsored forum has a minimum of formality to encourage open discussion among attendees and minimize the time between the presenters' preparation and dissemination of analytical results. The agenda is prepared in advance, based on responses to a call for abstracts. Abstracts are reviewed solely for conformity with DAWG guidelines, and as many as time permits are placed on the agenda. Presentations are not subjected to prior technical review. Copies of presentation materials are not distributed. Presentations are not published. Comments by forum attendees are not recorded.

DAWG-sponsored forums are held twice each year: immediately preceding the TRB Annual Meeting in Washington DC in January, and approximately at the midyear at another location. The midyear meeting is usually held in conjunction with a major highway pavement conference where it is expected that many attendees will also be interested in participating in a DAWG forum. If requested by the organizers, the DAWG will arrange and conduct a formal paper session conforming to all the policies and procedures of the conference.

As a TRB committee, the DAWG has appointed members who serve as a steering committee to guide the planning of future meetings. However, DAWG forums are open to everyone interested in the subjects to be discussed, and all attendees enjoy equal status. There is no registration requirement or fee required to attend meetings, but advance notice of the intent to attend a particular forum is recommended and appreciated.

Inquiries are welcome from those interested in adding their names to the DAWG's mailing list, and those wishing to submit abstracts of presentations for consideration for presentation at a particular forum. Inquiries and abstracts should be directed to:

Dr. A. Robert Raab, TNA-443
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PAVEMENT PERFORMANCE DATA ANALYSIS FORUM

TRB Data Analysis Working Group
Michael I. Darter, Chairman
A. Robert Raab, TRB Senior Program Officer

PRESENTATION ABSTRACT FORM

TITLE OF PRESENTATION:

ABSTRACT:

PRESENTER'S QUESTIONS: I would like to receive comments, suggestions, and feedback from the meeting's attendees on the following matters:

1-

2-

3-

PRESENTER'S STATEMENT: This work is still in progress, and has not been submitted for presentation or publication at another meeting.

Name:
Title and Organizational Affiliation:
Mailing Address:
Telephone/Fax/Email:

GUIDELINES FOR PREPARATION OF ABSTRACTS AND BRIEFINGS
FOR PRESENTATION AT PAVEMENT PERFORMANCE DATA ANALYSIS FORUMS
SPONSORED BY TRB'S DATA ANALYSIS WORKING GROUP (DAWG)

1. Presentations at DAWG Forums are selected through the review and evaluation of completed abstract forms submitted in response to calls for abstracts.

2. Only abstracts describing work in progress will be accepted for presentation. Completed work that has been submitted for presentation or publication elsewhere will not be accepted.

3. Presentations should focus on techniques for collecting, processing, and analyzing pavement performance databases, as well as preliminary results of applications of these techniques.

4. In addition to submitting an abstract of the proposed presentation, the presenter must complete the abstract form by also supplying a set of questions for attendees' discussion and response during the Forum. These questions should address issues being considered or confronted by the presenter in the further development of his/her project.

5. The technical quality of the abstract and the questions will be evaluated separately, and will have equal value in the determination of appropriateness of the submission for presentation.

6. The presenter will have 30 minutes for presentation of material (including interruptions by attendees seeking clarification) and an additional 15 minutes for a dialog with attendees concerning the questions provided.

7. It is recommended that the presenter prepare a 20-minute presentation consisting of approximately 10-15 overhead transparencies. It is unlikely that the presenter will be able to present a higher number of transparencies in the time allotted. Projection equipment for overhead transparencies will be provided. Computer projection equipment will not be provided.

8. Time will be monitored closely. The presenter will be advised when his/her time is exhausted.

MODELING PAVEMENT ROUGHNESS BY COMBINING MULTIPLE DATA SOURCES

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ABSTRACT

Most pavement performance models available in the literature are inherently linear (linear in the parameters). This restriction imposed to the model specification may lead to biased parameter estimates and to erroneous performance predictions. Current computer capabilities facilitate complex non-linear models to be estimated in short time. The goal of this research is to determine the feasibility of developing non-linear performance models for the prediction of pavement roughness by combining multiple data sources. The proposed data sources are the AASHO Road Test, the Minnesota Road Research Project (MnRoad), and the Long-Term Pavement Performance (LTPP) Study. By combining multiple data sources new variables can be incorporated into the model, the size of the sample is increased, the estimated parameters are more reliable, and potential parameter biases can be evaluated and corrected. In addition, different measurement of the same independent variable can be considered. Initial models that combine two experimental data sources have already been developed and highlight the enormous potential of the proposed methodology. By incorporating LTPP data into the analysis, it is expected that the current models can be updated for predicting roughness of actual in-service pavements.

PRESENTER'S QUESTIONS: I would like to receive comments, suggestions, and feedback from the meeting's attendees on the following matters:

1- Do the attendees consider this methodology valid and/or helpful? Yes, no, why? Any suggestions for improving the suggested approach?

2- Are there any data sources readily available (other than LTPP) to verify the validity of the developed models? Has anybody access to reliable PMS information from their own state or country?

3- What are the most important variables that a roughness model should consider? Which variables are missing? Which of them are the most important?

PRESENTER'S STATEMENT: This work is still in progress, and has not been submitted for presentation or publication at another meeting.

USING GENETIC ALGORITHMS AND MULTI-CRITERIA ANALYSIS IN THE OPTIMIZATION OF A LOCAL AUTHORITIES HIGHWAYS MAINTENANCE SCHEDULE

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ABSTRACT

The purpose to this research is the find an answer to the following problem: "How can we optimize a maintenance schedule for a Local Authorities highways division, given that for N roads with x maintenance actions, there are N^x possibilities for creating a schedule?"

The second part of this question is a necessary statement. Were you to look for the best maintenance schedule available, the optimal method of doing so would be to take all possible schedules and search through them. Unfortunately, when a problem is presented to you that grows exponentially as this does headaches arise. The most obvious headache is running out of computational power when using large numbers – and we are using very large numbers. With 10 road sections and 6 different maintenance actions, we are already searching through a million possible schedules. Birmingham City Council has to deal with the maintenance of over 6000 road sections. 6000 to the power of anything (apart from 1 or 2) will create computationally useless numbers – the search space is simply way to big to look through effectively.

Creating a model using Genetic Algorithms could prove to be a fast and effective method of searching through such large areas effectively. Not only are Genetic Algorithms designed to work with large search spaces, but we can add further constraints to help the algorithm 'home in' on the desired answer by nudging it in the correct direction. A large helping point within this algorithm is that it need not know anything about our problem: we are simply encoding it in a computationally simple manner and asking it to go out and seek for the best it can find. Separating the model into three parts; a Genetic Algorithm, a Schedule Builder and a Schedule Evaluator can do this. The line of information passes from one to another, and hopefully the Schedule Evaluator will provide us with an optimal solution dependent on the criteria that the user inputs into the system. This also has the added advantage of finding a number of different 'optimal solutions'. For example, the optimal solution for reducing backlog can be found, or the optimal solution for finding the schedule, which improves the condition of the roads by the highest percent.

PRESENTER'S QUESTIONS: I would like to receive comments, suggestions, and feedback from the meeting's attendees on the following matters:

1- Do we expect to find an absolute optimal solution?

2- How sensitive is the model to the users inputs?

3- Is it possible to use only parts of the model, dependent on a users requirements?

PRESENTER'S STATEMENT: This work is still in progress, and has not been submitted for presentation or publication at another meeting.

ANALYSIS OF LTPP PAVEMENT LAYER THICKNESS VARIABILITY FOR RELIABILITY-BASED PAVEMENT DESIGN

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ABSTRACT

Reliability analysis is a requirement in pavement design due to the stochastic nature of the inputs to the design as well as the predicted outputs from the design. Reliability of a given design is the probability that the performance of the pavement predicted for that design will be satisfactory over the time period under consideration. To estimate this probability, the analyst should know the variability of the key pavement design inputs. Variability in the mean inputs provided to the design could have a significant impact on the reliability of the design procedure.

One of the objectives of the LTPP layer thickness data evaluation project was to assess pavement layer thickness variability. Two types of variability associated with layer thickness, as a design input parameter, were investigated: (1) spatial variability caused by "along the project" variations in the layer thickness measurements data obtained from different locations along the section; (2) construction variability caused due to differences between target or "as-designed" thickness and measured or "as-constructed" thickness.

Layer thickness information from SPS 1, 2, 5, 6, 7, and 8 experiments were analyzed using several statistical methods. The "along the project" variations in layer thickness data from SPS experiments obtained at different locations within sections was analyzed and characterized using theoretical statistical distributions. The analysis included layers with different material and functional types, including AC surface courses, combined AC surface and binder courses, AC binder courses, dense-graded aggregate bases, dense-graded AC-treated bases, permeable AC-treated bases, lean concrete bases, PCC surface layers, and PCC overlay layers. To assess layer thickness distribution characteristics, descriptive statistics such as mean, standard deviation, skewness, and kurtosis were computed for each section. A combined test for skewness and kurtosis was selected to test the normality of layer thickness distributions for 1,034 SPS layers. The statistical analysis results indicated that, for 84 percent of all layers, thickness variations within a section indicate a normal distribution.

"As-constructed" core and elevation layer thickness measurements were compared to the "as-designed" (or target) thickness values for newly constructed SPS layers. The data were evaluated to determine the percentage of the individual measurements either within or outside specific values from the target thickness. Statistical analyses of the measured mean thickness values versus the designed values were performed using t-tests. Two sided t-tests with 95 percent confidence level were used for each section and layer to estimate whether the differences between as-designed and as-constructed thicknesses are significant. One-sided t-tests with 95 percent confidence level were used for each layer to analyze the difference between as-designed thickness and the mean as-constructed thickness. The results of the analysis indicate that for the same layer and material type, the mean constructed layer thicknesses tend to be above the designed value for the thinner layers, and below the design value for the thicker layers. The

computed summary statistics for the differences between as-designed and mean as-constructed layer thicknesses can be used as benchmarks for use in pavement design reliability and other research studies.

Mean layer thickness deviations from the target values were analyzed to determine whether they follow typical statistical distributions for different pavement and material types. Skewness and kurtosis analyses were conducted for this purpose. The conclusion was to assume that the mean thickness deviations are normally distributed for a given layer type and target thickness, because:

- It is reasonable to assume the mean thickness deviations follow the same kind of distribution;
- There is no trend being skewed to only one side; and
- A sizeable part of the data appears normal.

These results presented in this paper could serve as a very important input to pavement engineering applications involving reliability of pavement design and also for quality assurance construction specifications.

PRESENTERS' QUESTIONS: We would like to receive comments, suggestions, and feedback from the meeting's attendees on the following matters:

1- What additional analysis is suggested regarding layer thickness variability characteristics?

2- What are the key outcomes you feel are needed from this study for the reliability based pavement design?

3- Any suggestions as to why the thicknesses measurements from elevation are different from core measurements?

4- Any other recommendations for?

PRESENTERS' STATEMENT: This work is still in progress, and has not been submitted for presentation or publication at another meeting.

EFFECT OF SOIL PARAMETERS ON SEASONAL VARIATION OF SUBGRADE MODULUS

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ABSTRACT

Subgrade soil modulus is a required parameter for the AASHTO method of flexible pavement design and an indirect input parameter for rigid pavement design. Falling Weight Deflectometer (FWD) testing is often performed to determine the insitu subgrade modulus of in-service pavement structures for pavement rehabilitation. Seasonal variations of subgrade modulus often complicate the pavement design process and hence the 1993 AASHTO flexible pavement design guide introduced an effective subgrade modulus concept to estimate the effect of seasonal variation of subgrade modulus on pavement performance. The seasonal variation of the subgrade modulus will be an important issue for the proposed AASHTO mechanistic pavement design methods as well. This study was conducted to determine the seasonal variation of back calculated subgrade modulus values with different subgrade soil parameters such as percentage fines, plasticity index etc. The Long Term Pavement Performance (LTPP) program under the Strategic Highway Research Program (SHRP) provides a substantial data source to evaluate the seasonal variation of subgrade modulus values. FWD deflection data were back calculated using different soil models included in the DAPS back calculation program and evaluated with different subgrade soil parameters. This evaluation provides a better insight for future research to characterize the seasonal variation of subgrade modulus with different subgrade soil parameters.

PRESENTERS' QUESTIONS: We would like to receive comments, suggestions, and feedback from the meeting's attendees on the following matters:

1- The 1993 AASHTO pavement design guide recommends a correction factor of 0.33 to modify the back-calculated subgrade modulus (using the back-calculation equation given in the design guide) to suitable for use in the AASHTO design equations. What approaches need to be taken for subgrade moduli values calculated using popular back-calculation software programs to use in the AASHTO equations?

2- In the mechanistic pavement design approach, what steps need to be taken to incorporate back-calculated subgrade moduli into designs (average value, 15th percentile low value, 85th percentile value etc.)?

3- The 1993 AASHTO design guide recommends an effective subgrade modulus to incorporate seasonal variation of subgrade modulus values. What changes are we expecting in mechanistic design approaches?

PRESENTERS' STATEMENT: This work is still in progress, and has not been submitted for presentation or publication at another meeting.

INITIAL EVALUATION OF THE SPS-8 EXPERIMENT – STUDY OF ENVIRONMENTAL EFFECTS IN THE ABSENCE OF HEAVY AXLE LOADS

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ABSTRACT

A project is under way to conduct a comprehensive review of LTPP SPS-8 experiment titled "Study of Environmental Effects in the Absence of Heavy Axle Loads). This experiment is meant as an extension of SPS-1 (flexible pavements) and SPS-2 (rigid pavements) experiments. It called for the construction of project sites in all four LTPP climatic regions and on active, fine-grained, and coarse-grained subgrades. This makes it possible to cover a large inference space of the continental United States. However, it is known that some of the originally planned SPS projects were not constructed in some climatic areas due to lack of interest by the SHAs or lack of suitable sites, leaving a portion of the desired inference space with no performance data. It is also known that some of the SPS projects, as constructed, are not in absolute conformity with the original experimental plans. Despite best efforts, the amount of inventory and monitoring data that have been collected from these sections during construction and for several years afterward may include some deficiencies.

The original objectives of this study are as follows:

- "The SPS will develop a comprehensive database with information on construction, materials, traffic, environment, performance, and other features pertaining to the test sections."
- "The objective of the experiment on environmental effects in the absence of heavy loads is to develop conclusions concerning environmentally induced serviceability loss and contribution of environment and subgrade to distress of flexible and rigid pavements. Accomplishing this objective will lead to improved environmental effects models that will enhance the design and construction of flexible and rigid pavements."

It is also expected that the SPS-8 data along with the rest of the SPS and GPS sections of LTPP will provide data to support cost-allocation studies. The specific products of this experiment will include reliable knowledge about environmentally induced performance loss and the specific effects of environment and subgrade type and properties on pavement distress and smoothness in the absence of heavy traffic loads. This knowledge will be incorporated into the general products to develop improved design procedures for flexible and rigid pavements.

The following parameters were evaluated:

- Longitudinal profile
- Transverse cracking
- Longitudinal cracking
- Transverse profile (AC sections)
- Faulting (PCC sections)

The SPS-8 sections are relatively young, and a large majority show little distress. As of June 2001, 15 out of 30 SPS-8 sections (50 percent) with flexible pavement and 12 out of 16 SPS-8 sections (75 percent) with rigid pavements have no distresses.

Fatigue, longitudinal cracking in the wheelpath and transverse cracking are present on just a few AC sections. The most prevalent distress is longitudinal cracking outside of wheelpath; distress that is related to environmental influence. The mean rut depths for all sections are below 6 mm. The statistical analysis showed that there is no significant difference between IRI slopes for all experimental factors.

None of PCC sections have noticeable distresses. Just a very few of them have some transverse cracking and joint spalling. Faulting on all sections is below 0.4 mm and is well below the limits of the Georgia Faultmeter precision.

Initial IRI values showed that SPS-8 flexible pavements were constructed much smother than rigid. The statistical analysis showed that subgrade is most important factor for flexible, while precipitation appears to be the most important for rigid pavements. However, none of the experimental factors is statistically significant.

The analysis of the condition of SPS-1 and SPS-2 sections that match with SPS-8 sections showed that relatively small number of them have noticeable distresses, as of June 2001. The mean rut depths for SPS-1 sections are significantly higher that mean rut depths for SPS_8 AC sections. There is no significant difference between IRI trends, although mean values for some of compared groups are quite different.

PRESENTERS' QUESTIONS: We would like to receive comments, suggestions, and feedback from the meeting's attendees on the following matters:

1- What additional analysis can be conducted now for SPS-8?

2- What additional analysis can be conducted now to compare SPS-8 with SPS-1 and SPS-2?

3- Recommendations for additional data collection?

4- Recommendations for future data analysis?

PRESENTERS' STATEMENT: This work is still in progress, and has not been submitted for presentation or publication at another meeting.

DEVELOPMENT OF A MECHANISTIC-EMPIRICAL ROAD-ROUGHNESS MODEL ADAPTED TO THE ENVIRONMENT OF THE PROVINCE OF QUEBEC, CANADA

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ABSTRACT

Road-roughness models increasingly used to assist engineers in pavement design. The main objective of the present study is to develop a mechanistic-empirical road-roughness model adapted to the road networks of the province of Quebec, Canada.

Based on the hypothesis that the deterioration of pavement longitudinal profile, and consequently, of the ride quality is essentially the result of differential movements, it is assumed that road-roughness will be mainly influenced by the variability of the intrinsic properties of materials, the variability generated by construction operations and the variability associated with pavement surface distresses. The objective of the project is thus to quantify these phenomena and their effect on road roughness.

The first step of this project was to find in literature and existing databases relevant information about pavement variability and it's effect on road roughness. A first look at the data reveals the potential of these sources of information but also the associated shortfalls. The continuation of the project was thus directed towards filling these gaps. This activity was partially carried out during fall 2001.

The presentation will focus on the progress of our study on the variability of the parameters related to pavement permanent deformation. These analyses were carried out with the following data: longitudinal profile of the road-surface, information from cores of AC sampled at close interval (2 m) (thickness, bulk specific gravity, maximum specific gravity and asphalt content) and measurements of the thickness and strength of pavement layers using the ground penetrating radar and the dynamic cone penetrometer.

PRESENTERS' QUESTIONS: We would like to receive comments, suggestions, and feedback from the meeting's attendees on the following matters:

1- Can we assume that our results constitute a good representation of AC pavement variability?

2- How should we take into account the variability associated to the measurement itself?

3- How should we relate dynamic loading of the road to its variability?

PRESENTERS' STATEMENT: This work is still in progress, and has not been submitted for presentation or publication at another meeting.