LTPP Data Analysis

Task Order #03

"Effect of Multiple Freeze Cycles and Deep Frost Penetration on Pavement Performance and Cost"

Quarterly Progress Report

July, August, September 2004

Prepared for:

US Department of Transportation
Federal Highway Administration
400 Seventh Street, S.W.
Washington, D.C. 20590

Detailed Technical Summary of NCE Task Order #03 "Effect of Multiple Freeze Cycles and Deep Frost Penetration on Pavement Performance and Cost"

In this quarter, NCE has continued work on Task 8 and Task 9 of Task Order #03.

Task 8

Conduct detailed analysis of the effects of multiple freeze-thaw cycles verses deep frost penetration on pavement performance

The analysis team expended effort in the first part of the quarter reviewing simple statistical tools such as maximum, minimum, average, and standard deviation to identify data acquisition errors or problems with the calculations performed. Box plots, frequency graphs, and residual plots were also created to develop an understanding of the datasets and to study interaction, correlation, and the type of distribution that is present within the data. These tools were also used to verify whether the nature of the data violates any statistical assumptions made during the analysis. As part of this initial statistical review, the dataset was also inspected to identify and remove data collected after unrecorded pavement improvements were performed. Criteria were developed for each performance measure and applied to the dataset to flag instances of significant reductions in deterioration. Table 1 provides a summary of the checks used in this process.

Table 1. Criteria to Warrant Additional Investigation of Unrecorded Pavement Improvements.

Pavement Type	Performance Measure	Reduction Criteria that Warrants Investigation
A-CC	IRI	>0.4 m/km reduction
A-CC	DISTRESS	>30% reduction in sum of key distress types[1]
A-CC	RUTDEPTH	>10 mm reduction
P-CC	IRI	>0.4 m/km reduction
P-CC	DISTRESS	>30% reduction in sum of key distress types[2]
P-CC	FAULTING	>2 mm reduction

[1]Deduct values of fatigue cracking, block cracking, longitudinal wheelpath cracking, longitudinal non-wheelpath cracking, transverse cracking, and patching were summed for this evaluation.

[2]Normalized quantities of corner breaks, longitudinal cracking, transverse cracking, and patching were summed for this evaluation

Each test section flagged was thoroughly examined using all performance measures to determine if the reduction was most likely caused by an improvement to the pavement or if it could be attributed to data variability. In general, if the majority of the performance measures demonstrated a reduction in deterioration, it was concluded that an unreported pavement improvement was applied. Data collected after the improvement was removed from the dataset.

Upon completion of the review, NCE began working with the team statistician to develop regression models. Two regression methods are currently being utilized in the study; the general linear model and the robust regression model. The general linear model is susceptible to extreme outlying cases that cannot be definitively determined as erroneous data. Because this project incorporates national data with many contributing factors, extreme cases do exist that cannot be established as errors and which need to be accounted for in the model. The robust regression

techniques dampen the effect of these extreme cases by applying a weighting factor based on residuals. The robust model is used to make adjustments to and validate the general linear model using an iterative process.

As part of the model development activities, the analysis team is performing transformations on the data to reduce the violation of assumptions inherent in regression models. Figure 1 provides graphical results on the assumption validity check for the Absolute IRI model before transforming the data. As can be seen from the residual plot (upper-right corner of Figure 1), the shape of the plot indicates unequal error variance (signified by the diagonal orientation of the bottom boundary of data points). Additionally, the normal probability plot (lower left figure) indicates non-normality in the dataset (residual points depart from the straight red line). For these reasons, a natural logarithm transformation of the performance measure was performed. The results of the validity check after the transformation can be found in Figure 2. As the figure indicates, both the unequal error variance and non-normality have been reduced, thus improving the validity of assumptions in the model.

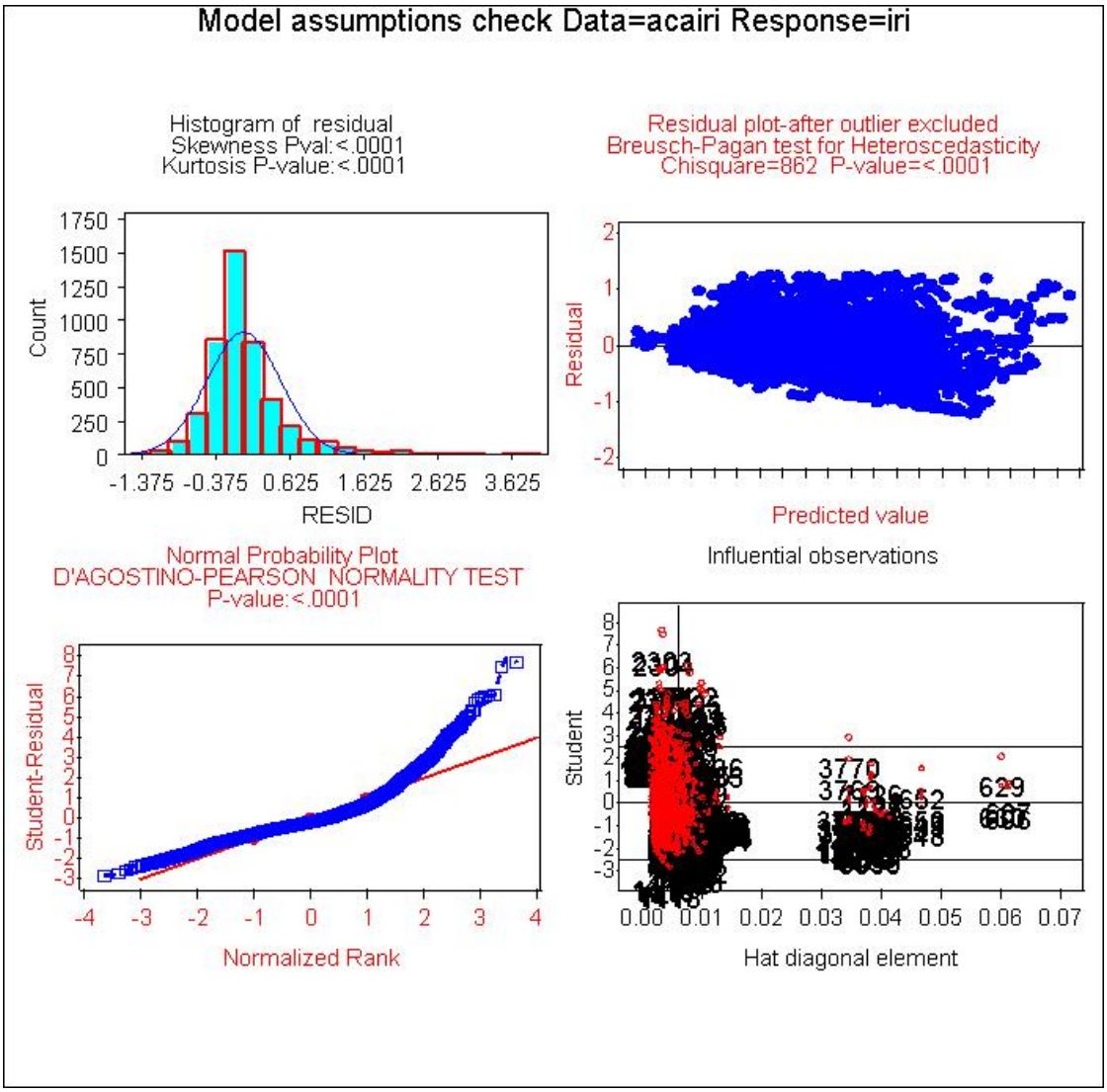

Figure 1. Assumption validity check for Absolute IRI model (before transformation).

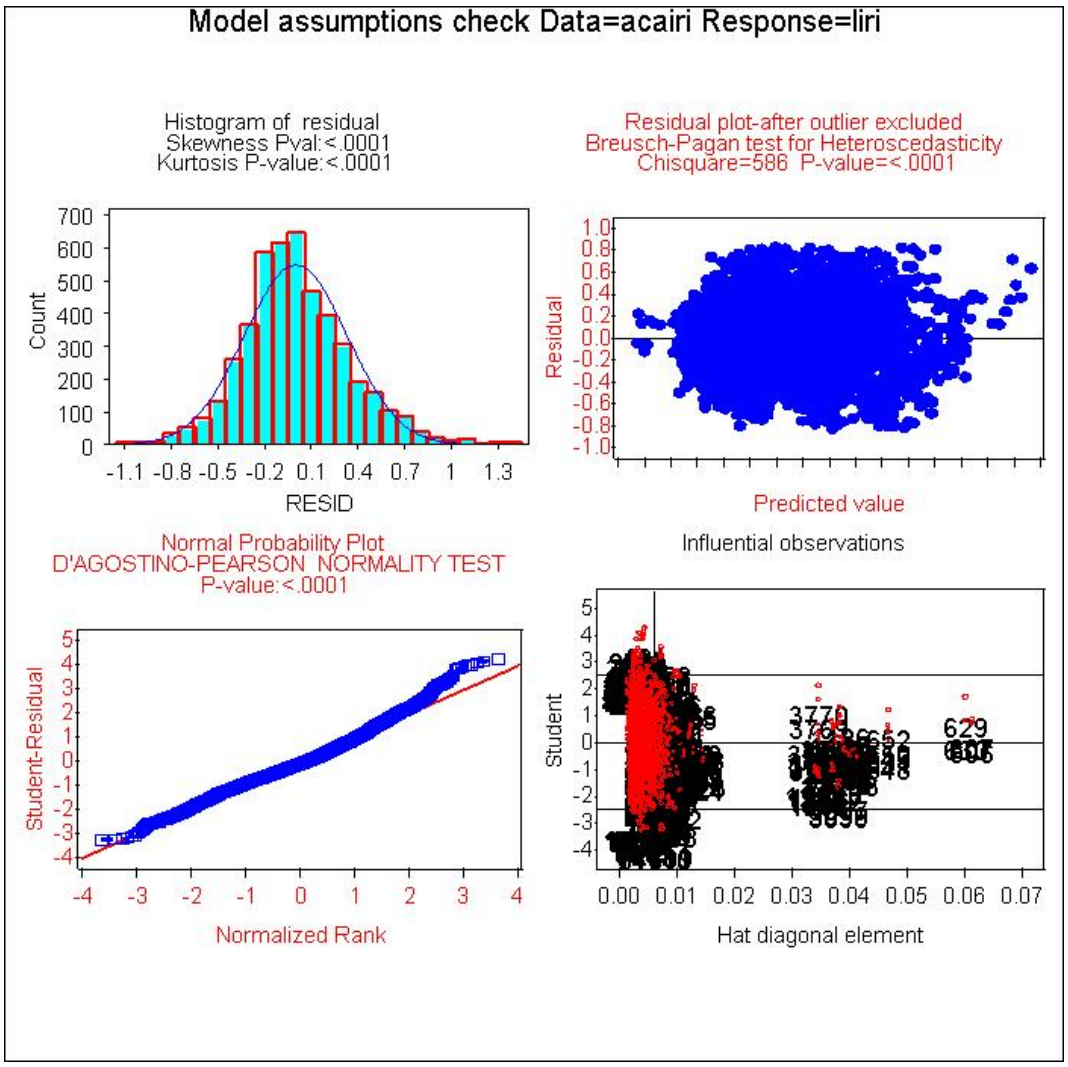

Figure 2. Assumption validity check for Absolute IRI model
(after natural logarithm transformation of the performance measure).

It should be noted that the lower right plots in both figures have a cluster (in the center of each plot) of influential observations in the dataset which graphically depict the need to use robust regression techniques to dampen the effect of these extreme values. As discussed previously, these values cannot be classified as erroneous outliers and need to be incorporated into the model.

NCE will also investigate the application of transformations on the predictor variables (i.e., freezing index, freeze-thaw cycles, age, precipitation, etc.) to enhance the fit and predictability of the model. Inspection of the general relationships between variables will be used in this process as well as relationships developed in published literature.

As work progresses, a review of predicted values and actual values will be made on sample of test sections in the dataset to evaluate the capabilities of the models. Additionally, the analysis team will begin comparing pavement performance in different climatic conditions to determine the differences in areas of deep freeze, multiple freeze-thaw cycles, and no freeze.

Task 9

Conduct detailed analysis of the extent to which local adaptations of materials standards and empirical pavement design practices have been effective at reducing the rate of pavement deterioration

As of the end of the quarter, all but two of the Pooled Fund States have responded to the questionnaire sent out in April. The questionnaire that was distributed is included as Appendix C.

NCE is in the process of compiling the information that was submitted by those states that responded to the questionnaire. NCE has neither analyzed the data nor made any conclusions at this time.

Resources Used

Figure D.1 in Appendix D shows the current work schedule for Task Order #03 through September 2004.

This Task Order remains a couple of months behind schedule compared to the planned time line. This is a carry over from the delay in starting on Phase 2 from the previously planned schedule and the added work of developing the additional databases that were used in the trend analysis for Task 3.

NCE will continue to concentrate on getting back on schedule within the next two quarters.

Figure D.2 in Appendix D shows the planned costs versus actual costs for Task Order #03 through September 2004.

The expenditures have continued to be about 30 percent below planned expenditures as a carry over from the two month delay between presentation of the Phase 1 Report and startup on Phase 2 as well as some time lost in waiting for the information from the States in response to the questionnaire. As NCE gets further into Phase 2 of the project, the expenditures will come more in line with the planned expenditure rate.

Appendix C

Task Order #03

Questionnaire for Pooled Fund States

Pooled Fund States Questionnaire

Dear State Pooled Fund Panel Members

As you remember one of the primary research objectives for this pooled fund study was to determine:

> "The extent to which local adaptations of materials standards and pavement thickness designs have compensated for and/or mitigated the effects of seasonal frost penetration,…"

To accomplish that goal NCE proposed to look at this issue using a couple of standard pavement design sections. NCE anticipates that the roadway design sections as well as the materials and their related specifications may change between states to provide better pavement performance in their respective environment.

To develop these standard section and related material information, we are asking the Pooled Fund States to provide the following information.

Standard Roadway Section

What is your standard pavement section for both flexible and rigid pavements that meets the following design criteria? If you don't have standard sections then what would your designed section be?

Rural Interstate (four lanes) Rigid and Flexible

30 year design
30,000,000 ESALs
Frost susceptible fine grained soil M_R 10,000 PSI

Rural Primary (two lanes) Rigid and Flexible

30 year design
5,000,000 ESALs
Frost susceptible fine grained soil M_R 10,000 PSI

Please provide layer unit names as well as dimensions for both the traveled lanes as well as the shoulder sections. For example the first section of Rural Interstate Flexible might be shown as follows.

Pavement Course	Main line	Shoulders
Wearing Course	3 in. Class A HMA	3 in. Class A HMA
Leveling Course	3 in. Class B HMA	3 in. Class B HMA
Base/Binder Course	5 in. Class E HMA	

Granular Base Course	6 in. Class 1 UTBC	11 in. Class 1 UTBC
Granular Sub Base Cr.	6 in. Class 3 UTBC	6 in. Class 3 UTBC
Total Depth	23 in.	23 in.

The item names noted above are entirely fictional, and are used only to show that the bid item names are important. Each State Transportation Agency has its own naming conventions.

If special drainage features are included in the roadway section please note those as well.

If possible provide a cross section of the roadway section which shows the configuration of the pavement layers as well as the typical ditch section and depth, subgrade slopes, drainage features, etc.

Standard Specifications

We will also need copies of your Standard Specifications that apply to the bid items listed, for the material properties as well as the placement procedures or in place properties. Where these are available at your agencies web site please let us know and we will download the PDF files. If only paper hard copies are available please provide copies of the applicable specifications or simply send us a specifications book that applies to the materials placed at the LTPP test sites and we will make copies and return the book.

The ongoing adoption of Super Pave mixes will complicate this process. If you agency has adopted Super Pave mixes please reference the materials that were used in your GPS and SPS test sites that represents the performance data included in the LTPP database.

If your agency has adopted Super Pave please provide copies of those specifications as well. Please note that many agencies have developed their own Super Pave mix specifications, based to varying degrees on the national guidelines. This is the reason we are asking for your specific specifications rather than use the national guidelines.

Test Procedures

Please review your specifications before you send them. If they reference standard AASHTO test procedures we can access that information. If however, they reference test procedures that are unique to your agency please provide copies of those test procedures or provide a reference to the web site where those test procedures are available.

Average Unit Bid Prices

In addition to the specifications we will also need the average unit bid prices or the prices you would prefer we use in this study, for each of the bid items noted in your standard or design roadway section.

Typical Service Life for Standard Section

We would also like your best estimate of the average service life of the pavement sections until major pavement repair, rehabilitation or overlay is usually required. Please also provide a description of that treatment as well as the typical pavement condition (amount of fatigue cracking, ride values etc.), when treatment is applied.

Adjacent State Treatments

If there are any unique designs processes or treatments that are used by any adjacent states that seems to help mitigate frost effects please describe that treatment and if possible indicate a contact person to check on that treatment.

Time Line

If possible we would like to receive the Typical or Design Roadway Sections as well as the Standard Specifications and Test Procedures by June 21th. We would like to receive the rest of the material (bid prices, service life estimate, and adjacent state treatments) by July 9th.

Sincerely,

Newton Jackson, P. E.
Project Manager
Nichols Consulting Engineers Chtd.

Appendix D

Task Order #03

Work and Costs Summaries

July - September 2004

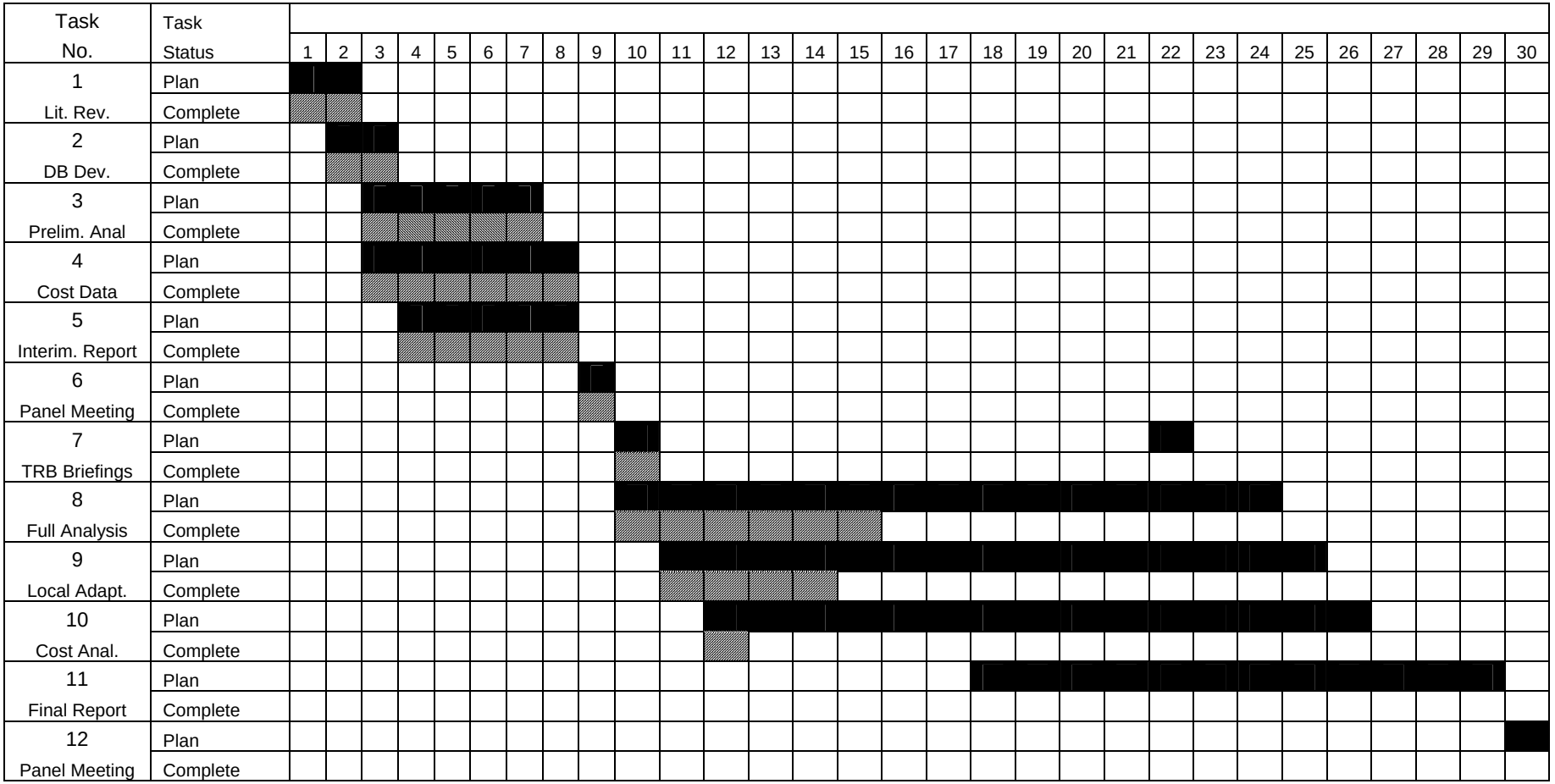

Figure D.1 Work Schedule for Task Order #03 through September 2004