COMPUTATIONAL FRAMEWORK FOR PAVEMENT SENSITIVITY ANALYSIS USING THE MECHANISTIC-EMPIRICAL PAVEMENT DESIGN PROCEDURE

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Introduction

In civil engineering, the performance of a structure or project is the main objective. When designing a particular project it is important to explore an array of design options to determine which will perform best. This approach applies well to road design. Roads have many different characteristics that can be varied, from the thickness of different layers to the AADTT (average annual daily truck traffic). For this project a sensitivity analysis was performed to determine how particular output criteria would respond to variation in particular input variables. This analysis is done exclusively using computer modeling by the use of an array of programs.

Objective

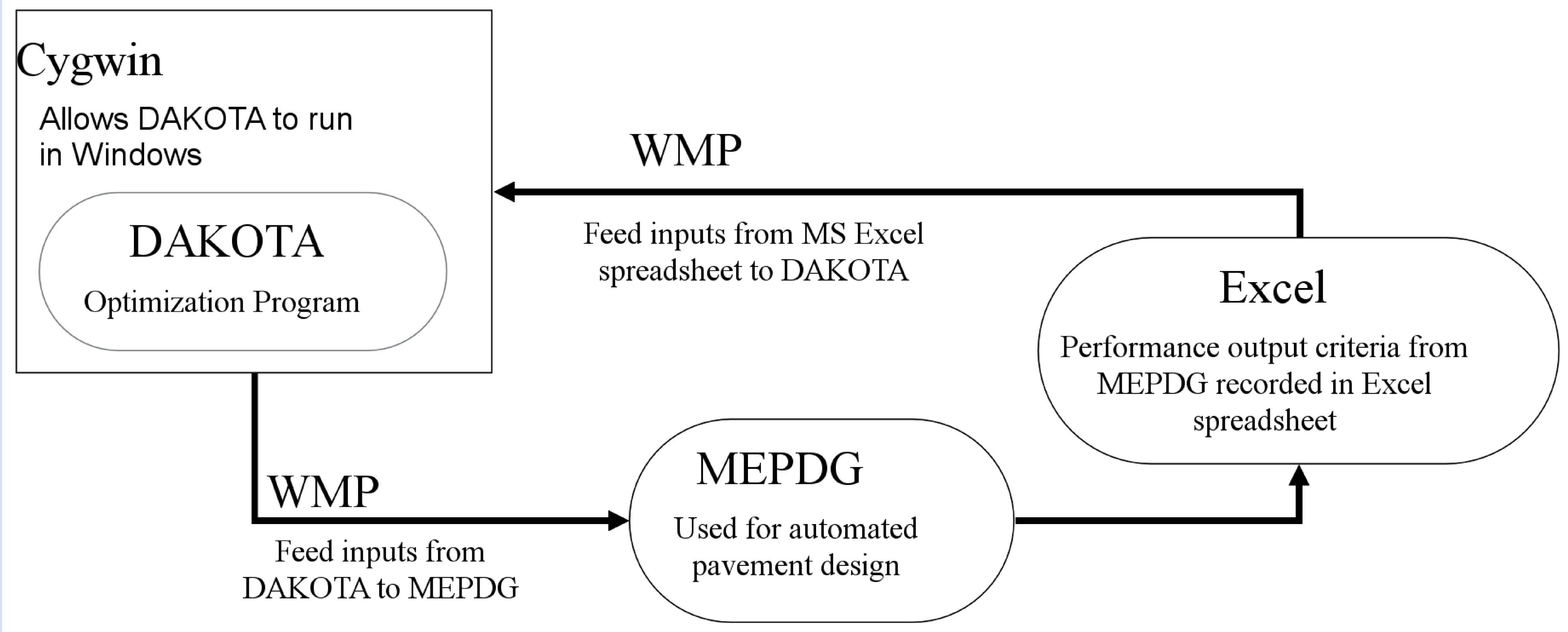
- Determine whether a 25 run LHS analysis is as accurate as a 200 run LHS analysis in determining the variation in performance over the specified input variable ranges.

Methods

This research integrates a pavement design program and a sensitivity program in order to analyze the sensitivity of specified output criteria of a pavement design to a Latin Hypercube Sampling (LHS) of particular input variables. The Mechanistic-Empirical Pavement Design Guide (MEPDG) [1] program runs in Windows while thesensitivityprogram, DAKOTA [2], runs in UNIX. To run the full analysis, the two programs must communicate with each other. To deal with this issue, DAKOTA is run in Cygwin [3], a program that creates a UNIX environment in Windows. In order to link DAKOTA to the MEPDG, a macro must be used. For this purpose Workspace Macro Pro is employed [4].

To integrate DAKOTA and the Design Guide (MEPDG), it is necessary to have the inputs taken from the DAKOTA input file and appropriately fed into the Design Guide. To accomplish this task Workspace Macro Pro (WMP) is used as an intermediate layer between the two programs. WMP is an automation software and macro recorder, which can record a set of mouse movements, clicks and key press sequences and replay them again and again. Using WMP, the input parameters are taken from DAKOTA and fed into the Design Guide. The Design Guide will run along with the macro recording and when the Excel output opens at the end of the MEPDG analysis, a certain set of response criteria are fed back into the DAKOTA output file. This creates a cyclical analysis (see diagram to the right).

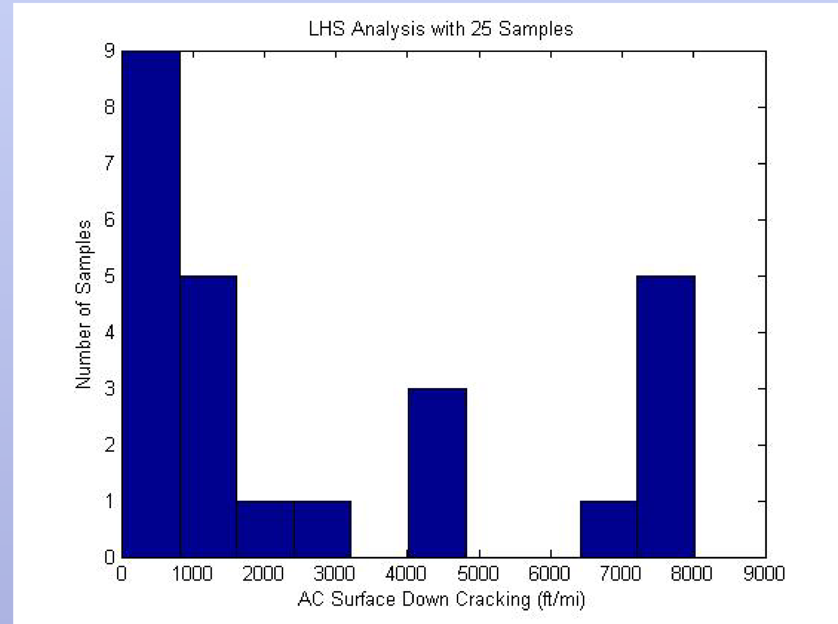
For this study, LHS was performed using a 25 and a 200 evaluation data set. This cyclical analysis takes from days to weeks to perform. From this analysis, the two cases can be compared by way of statistical analysis.

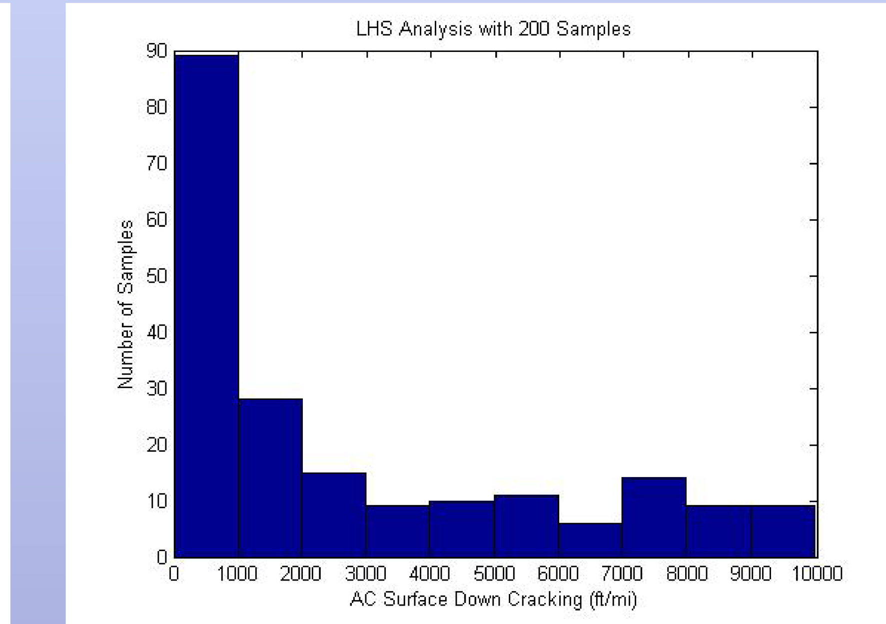


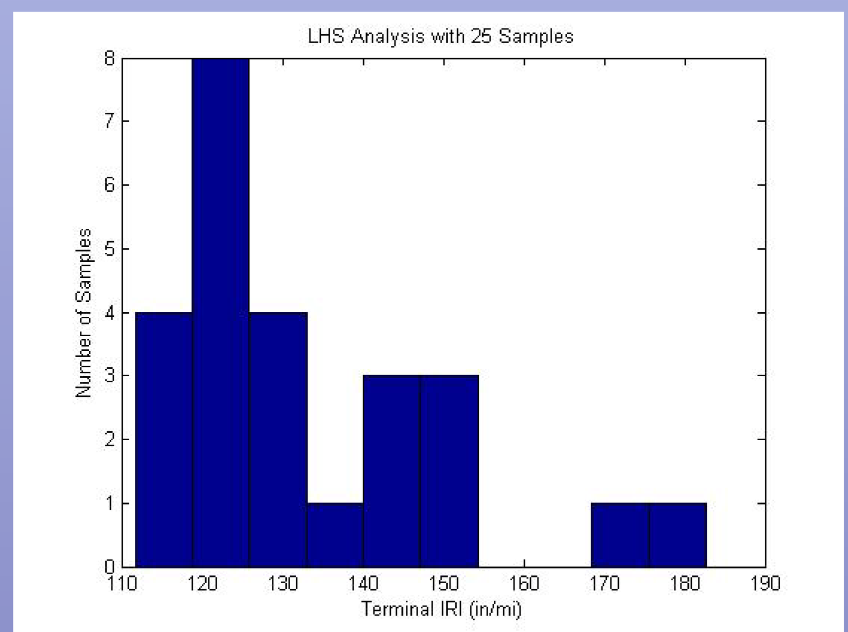
Results

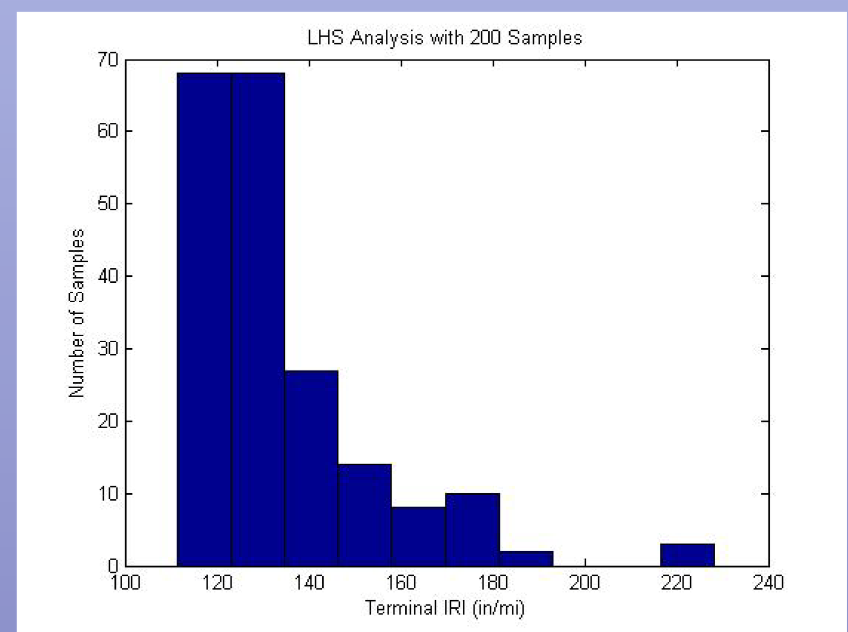
Distresses

		Terminal IRI	AC Surface Down Cracking	AC Bottom Up Cracking	AC Thermal Fracture	Permanent Deformation (AC Only)	Permanent Deformation (Total Pavement)
		in/mi	ft/mi	%	ft/mi	in	in
25 runs	μ	1.33684E+02	2.84790E+03	1.29840E+01	1.00000E+00	2.88800E-01	7.07200E-01
	σ	1.77176E+01	2.99613E+03	1.47208E+01	0.00000E+00	8.56505E-02	1.83247E-01
200 runs	μ	1.33996E+02	2.70094E+03	1.28460E+01	1.00000E+00	2.87900E-01	7.06950E-01
	σ	1.98629E+01	3.02584E+03	1.58998E+01	0.00000E+00	8.72332E-02	1.76485E-01









Input and Output

Input - Uniform Uncertain Variables

Parameter	Range	Units
HAC	3 - 9.	in
Base Thickness	6 - 24.	in
Base Modulus	20000 - 40000	psi
Subgrade Modulus	8000 - 20000	psi
AADTT	200 - 2000	trucks/day

Output Criteria

Performance Criteria	Units
Terminal IRI	in/mi
AC Surface Down Cracking	ft/mi
AC Bottom Up Cracking	%
AC Thermal Fracture	ft/mi
Permanent Deformation (AC Only)	in
Permanent Deformation (Total Pavement)	in

Conclusions

- The output distresses from the 25 and 200 run cases produced strikingly similar mean and standard deviation values. Therefore these quantities are not sensitive to the variation in sample size.

- The histograms of all the output criteria for both the 25 run and the 200 run cases yielded interesting results. The distributions were fairly similar between the 25 and 200 run cases for four of the outputs.

- As seen in the distributions for the AC Surface Down Cracking, the distribution for the 25 run case exhibited a bimodal distribution while the distribution for the 200 run case appears to be heavy tailed to the right. This suggests that the 25 run case is not sufficient to model the response of this variable, as the case with more runs always better represents the true behavior.

- The other distribution that varied a significant amount is the Terminal IRI. As seen in the distributions to the left, the 25 run case yielded a distribution that is less heavy tailed to the right than the 200 run case. The 25 run case also had a less smooth distribution curve. This is most likely due to having quite a few less samples with which to model the response.

References

[1] *Mechanistic-Empirical Pavement Design Guide*. Computer software. *NCHRP Design Guide*. Vers. 1.0. National Cooperative Highway Research Program. Web. 26 Aug. 2009. <www.trb.org/mepdg/>.
[2] *Design Analysis Kit for Optimization and Terascale Applications*. *The DAKOTA Project*. Vers. 4.0. Sandia National Laboratories. Web. 26 Aug. 2009. <http://www.cs.sandia.gov/DAKOTA/software.html>.
[3] *Cygwin*. Computer software. Red Hat, Inc. Web. 26 Aug. 2009. <http://www.cygwin.com/>.
[4] *Workspace Macro Pro*. Computer software. Vers. 6.5. Tethys Solutions. Web. 26 Aug. 2009. <http://www.tethyssolutions.com/default.htm>.

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