TABLE 2.5 - REGRESSION ANALYSIS RESULTS FOR EQUATION 2.2

a) Analysis of Variance

	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Regression	4	7672.69	1918.17	17.12
Residual	73	8177.77	112.02	

b) Regression Equation

Parameter	Estimate	Standard Error	F-Value
Intercept	21.762	-	
RH	-7.521	3.727	4.07
ST	5.162	2.606	3.92
AGE	0.515	0.271	3.62
$(B \times LN)^2$	7.215×10^{-5}	1.077×10^{-5}	4.49

Multiple correlation coefficient squared: 0.484

Standard error for residuals : 10.584

are very stable. The approximate 95 percent confidence interval for QI* in Equation 2.2 is:

$$CI = QI^* \pm 21.1$$

3. Equation including Dynaflect deflection

$$LQI = 1.391 - 0.1315\ RH + 0.0414\ P + 0.00751\ AGE + 0.0248\ D \times LN \qquad (2.3)$$

R squared : 0.318
Standard error for residuals : 0.130

where

LQI = logarithm to the base 10 of quarter-car index;
P = percent area which received repairs in the form of deep patches; and
D = Dynaflect maximum deflection (0.001 in.).

Other symbols were defined previously. Detailed regression analysis results are given in Table 2.6. All regression coefficients are very stable. The approximate 95 percent confidence interval is:

$$CI = LQI \pm 0.26 \text{ or } 0.55\ QI \text{ to } 1.82\ QI$$

4. Equation including structural number and Benkelman beam deflection

$$QI^* = 12.63 - 5.16\ RH + 3.31\ ST + 0.393\ AGE + 8.66\ (LN/SNC) + 7.17 \times 10^{-5}\ (B \times LN)^2 \qquad (2.4)$$

R squared : 0.525
Standard error for residuals : 10.223

TABLE 2.6 - REGRESSION ANALYSIS RESULTS. FOR EQUATION 2.3

a) Analysis of Variance

	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Regression	4	0.575	0.1439	8.52
Residual	73	1.233	0.0169	

b) Regression Equation

Parameter	Estimate	Standard Error	F-Value
Intercept	1.39137	-	
RH	-0.13153	0.04547	8.37
P	0.04142	0.02989	1.92
AGE	0.00751	0.00334	5.06
DLN	0.02482	0.00932	7.09

Multiple correlation coefficient squared: 0.318

Standard error for residuals : 0.130

where

QI^* = quarter-car index (counts/km);
RH = state of rehabilitation indicator:
= 0 as constructed,
= 1 overlayed;
ST = surface type indicator:
= 0 asphaltic concrete,
= 1 surface treatment;
AGE = number of years since construction or overlay;
LN = logarithm to the base 10 of the number of cumulative equivalent axles;
SNC = corrected structural number; and
B = Benkelman beam deflection (0.01 mm).

Detailed statistical results pertaining to Equation 2.4 are presented in Table 2.7. The approximate 95 percent confidence interval is $CI = QI^* \pm 20.5$.

5. Equation including structural number and Dynaflect deflection

$$LQI = 1.299 - 0.1072\ RH + 0.0415\ P + 0.00623\ AGE + 0.0856\ (LN/SNC) + 0.0230\ D \times LN \qquad (2.5)$$

R squared : 0.356
Standard error for residuals : 0.127

All symbols are as previously defined. Other statistical results are shown in Table 2.8. The approximate 95 percent confidence interval for QI^* in Equation 2.5 is $CI = LQI \pm 0.25$, or $0.56\ QI^*$ to $1.78\ QI^*$.

TABLE 2.7 - REGRESSION ANALYSIS RESULTS FOR EQUATION 2.4

a) Analysis of Variance

	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Regression	5	8318.8	1663.76	15.90
Residual	72	7531.7	104.61	

b) Regression Analysis

Parameter	Estimate	Standard Error	F-Value
Intercept	12.631	-	
RH	-5.160	3.725	1.92
ST	3.307	2.626	1.59
LN/SNC	8.663	3.486	6.18
AGE	0.393	0.266	2.18
$(B \times LN)^2$	7.17×10^{-5}	1.041×10^{-5}	4.74

R squared : 0.523
Standard error for residuals: 10.228

TABLE 2.8 - REGRESSION ANALYSIS RESULTS FOR EQUATION 2.5

a) Analysis of Variance

	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Regression	5	0.6436	0.1287	7.96
Residual	72	1.1650	0.0162	

b) Regression Equation

Parameter	Estimate	Standard Error	F-Value
Intercept	1.29857	-	
RH	0.10718	0.0461	5.42
P	0.04151	0.0293	2.01
LN/SNC	0.08556	0.0417	4.21
AGE	0.00623	0.0033	3.50
D x LN	0.02300	0.0092	6.29

R squared : 0.356

Standard error for residuals: 0.127

6. <u>Equation including structural number, Benkelman beam deflection and initial roughness</u>

$$QI^* = QI^*_o + (155.5 + 2.07G - 163.8\frac{B}{B_o} - 165.9\frac{SNC_o}{SNC} + 172.9\frac{B}{B_o} \times \frac{SNC_o}{SNC}) \times N/10^6 \qquad (2.6)$$

R squared : 0.565

Standard error for residuals : 9.373

where

QI^*_o = an estimate of the pavement's initial roughness, *i.e.*, QI^* value at AGE = 0;

SNC_o = 5;

B_o = 55.

The values of B/B_o and SNC_o/SNC are held to not less than 1. G is a function of the road gradient given by:

$$G = 1 - \frac{1}{1 + 10^{GR-4}} \qquad (2.7)$$

where GR is the uphill gradient in percent. On the downhill GR = 0.

2.3 *DISCUSSION OF ROUGHNESS PREDICTION MODELS*

Six roughness prediction models were developed. The independent variables included represent various degrees of sophistication in the data required for analysis. As an example, Equation 2.3 may be used when only Dynaflect deflections are available, while the use of Equation 2.4 requires that the Benkelman beam deflection and structural number be known.

The latter is considered more appropriate for analysis at the project level (*e.g.*, designing an individual overlay), whereas Equation 2.3 may be suitable for analysis at the network level (*e.g.*, maintenance planning for a number of sections). Equation 2.6 may be used when an estimate of the pavement's initial roughness is available.

Efforts were made to improve the equations by including more information in the regression models, but the result was less significant and produced more unstable coefficients.

Forcing other transformed variables, such as logarithms or squares, into the equations caused similar problems. For instance, if $(D \times LN)^2$ enters Equation 2.3, both its coefficient and the coefficient of $D \times LN$ become very unstable. Concurrently, no significant improvement to R squared was obtained from the inclusion of $(D \times LN)^2$ in the equation.

From the foregoing, it seems reasonable to conclude that the data available on pavement roughness probably do not permit better models to be developed. It is expected that field data collection will continue until all of the sections exhibit high levels of roughness, so that more precise prediction models can be obtained. However, it is felt that the models derived have sound engineering basis, since pavement and subgrade strength, as well as traffic loads are adequately considered.