

**EVALUATION OF THE PAVEMENT STRUCTURAL CONDITION  
AT NETWORK LEVEL USING FALLING WEIGHT  
DEFLECTOMETER (FWD) DATA**

by

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**ABSTRACT**

Large amounts of seal coats and thin overlays are applied every year by state highway agencies to improve the surface condition of pavements, but these measures have not successfully prevented the problem from reoccurring. As a result, the overall pavement condition keeps deteriorating because of the structural deformation of pavement layers and the subgrade. To make effective decisions about the type of treatment needed, the structural condition of a pavement should be taken into consideration. The paper examines several different structural estimators that can be calculated using the FWD data and the available information stored in the Pavement Management Information System (PMIS) at the Texas Department of Transportation (TxDOT). The analysis considers pavement modulus and the Structural Number (SN) as the structural estimators of a pavement. The evaluation methodology is based on the sensitivity of the structural estimators to the deterioration descriptors. The deterioration per Equivalent Single Axle Loads (ESAL) of all major scores stored in the Texas PMIS was introduced as the major indicator of pavement deterioration. In addition, the paper suggests the subsequent use of the Structural Condition Index (SCI) as a screening tool to discriminate between pavements that need structural reinforcement from the ones that do not. Such index is calibrated for use at the network level M&R analysis.

Keywords: Asphalt Pavement, FWD, Structural Capacity, Pavement Deterioration, Structural Condition Index

## INTRODUCTION

Over the years many state highway agencies, including the Texas Department of Transportation (TxDOT), have applied extensive seal coats, thin overlays and other types of surface treatments to preserve and/or improve the surface condition of their highway pavements. Those measures provide a temporary improvement of the surface condition, but they do not provide the remedy to any structural deficiency associated with the pavements. As a result, the overall pavement condition keeps deteriorating because the structural deformation of pavement layers and the subgrade, even though surface treatments have been applied periodically.

To make a proper decision about the type of treatment that can help stop the deterioration of a pavement, one should consider characterizing the structural condition of the pavement. The structural condition of a pavement can be assessed through several different measurements, but the most comprehensive approach is to use the Falling Weight Deflectometer (FWD) data. The FWD is one of the widely used Non-Destructive Testing (NDT) techniques for the structural evaluation of a pavement. The Texas Department of Transportation (TxDOT) collects FWD data and stores it in the Pavement Management Information System (PMIS). The FWD measures deflections by applying known impulse loads on the pavement to be examined. The backcalculation of the layer's moduli is a procedure commonly used to analyze FWD data. Unfortunately, this backcalculation procedure cannot be used because the PMIS does not contain the thickness information for the pavement layers at the present time. Instead, the PMIS stores only an estimated total thickness for each section of the pavements [1].

To overcome the problem of estimating the structural condition of a pavement using FWD data without information about the thickness of each layer, the TxDOT PMIS currently uses a structural screening index called the Structural Strength Index (SSI) [2]. Recent internal studies at TxDOT indicated that the SSI was not sensitive enough to discriminate pavements that need structural reinforcement from those that do not. Therefore, there is an immediate need for a structural index that is sensitive to the real condition of a pavement.

The paper analyzes the sensitivity of different structural estimates to the pavement deterioration process where the pavement deterioration process is characterized in terms of the changes in the PMIS score values. Furthermore, the paper presents a new framework for using the FWD-based structural condition estimators, primarily the Structural Number (SN) and the Structural Condition Index (SCI), as a screening tool for pavement maintenance and rehabilitation (M&R) decisions at the network level.

## **THE FRAMEWORK USED IN THE ANALYSIS**

The methodology for evaluating the structural condition of pavements is based on a sequential analysis process as illustrated in Figure 1. Firstly, an assessment of the potential methods that can be used for the structural evaluation of the pavements was considered, through the assessment of the data available in the TxDOT PMIS. Secondly, the trend analyses were conducted to examine the sensitivity of the methods. Then, the validation of the trends established in the previous step, along with the overall methodology validation, was conducted using an expanded database, followed by the statistical analysis for determining the sample size (sampling frequency). Finally, the guidelines and recommendations for using the Structural Condition Index (SCI) were developed and validated with the pilot projects. Ultimately, the goal was to establish a reliable procedure that could be used to discriminate between pavements that need structural reinforcement from those that do not.

## **ESTIMATORS OF THE PAVEMENT STRUCTURAL CONDITION**

Through comprehensive studies in the highway and pavement design, researchers have proposed a number of methods to estimate the structural condition of an existing pavement. In general, the structural condition of a pavement can be expressed through the following characteristic values:

- 1) Pavement modulus; and
- 2) Structural Number (SN) of a pavement.

The SN is a concept developed during the AASHO Road Test. Following the completion of the Test, the AASHO Design Committee developed the AASHO Interim Guide for the Design of Rigid and Flexible Pavements where the Structural Number is used as a design parameter and an indicator of the pavement strength [3]. Since then, the structural design of a pavement using the Structural Number (SN) has become a common practice in the U.S. and many other countries.

### **The Current Structural Index Used by the TxDOT**

The current pavement structural index used in the TxDOT PMIS is the statistical Structural Strength Index (SSI) developed by the Texas Transportation Institute (TTI) [2]. The SSI was developed based on the Surface Curvature Index and the Falling Weight Deflectometer (FWD) deflection of Sensor 7 ( $W_7$ ) that is 72 inches away from the center of the applied FWD loading. The deflections are normally measured under an approximate 9,000 lb load with seven sensors (geophones) that are spaced 12 inches apart. The Surface Curvature Index is expressed as the difference between the deflection from the first sensor ( $W_1$ ) and that from the second sensor ( $W_2$ ):

$$\text{Surface Curvature Index} = W_1 - W_2$$

The SSI is calculated as a function of the Surface Curvature Index and  $W_7$  according to two tables, one for thin asphalt pavements and the other for intermediate and thick asphalt pavements [2]. The Statistical Structural Strength Index (SSIF) is then calculated by incorporating the rainfall factor (RF) and traffic factor (TF) into the index:

$$\text{SSIF} = 100(\text{SSI})^{1/(\text{RF}*\text{TF})}$$

The TxDOT conducted an internal study [4] where the SSI was applied to two highways in Texas: the US-79 in the Bryan District and US-77 in the Pharr District. The US-79 was in very good condition as it was reconstructed; whereas, the US-77 had substantial amounts of distress such as alligator cracking, pumping, and rutting. In other words, the conditions of the two highways were significantly different. However, the results from the study indicated that the calculated SSI values at an 85 percent confidence interval for the two highways were not very different: 90 for the US-79 and 79 for the US-77.

This means that the current SSI is not sensitive enough to discriminate one pavement from another even if there is a significant difference in the structural capacity between the two pavements. In other words, the SSI cannot be effectively used at the network level to identify pavement sections with structural deficiencies. Furthermore, the SSI does not relate the FWD values to the structural capacity indicators such as the Structural Number (SN) that is used for pavement design. Therefore, it is difficult to decide whether a pavement needs strengthening or surface treatment just by looking at the SSI values. It is clear that an alternative method is needed in order to overcome the problems associated with the current structural index.

### **The Structural Number Estimates Using Modulus and Deflection Ratios**

Various methods for estimating the structural capacity of a pavement using the FWD data have been investigated by researchers. For example, the analysis presented by Wimsatt [5, 6] is based on the assessment of the modulus of the pavement structure as a whole in relation to the subgrade modulus using the ratio of  $W_7$  to  $W_1$  ( $W_7/W_1$ ), which is the ratio of pavement modulus to subgrade modulus. The deflection underneath the loading plate ( $W_1$ ) gives the stiffness of the pavement and the subgrade; whereas, the deflection 72 inches away from the plate ( $W_7$ ) gives the stiffness of the subgrade only.

The pavement to subgrade modulus ratio ( $E_p/E_{\text{subgrade}}$ ) can be calculated from the regression equations developed by Wimsatt [6]. Such equations are a function of the  $W_7/W_1$  ratio and the subgrade modulus ( $E_{\text{subgrade}}$ ). The subgrade modulus can be estimated using the equation from the AASHTO Guide for Design of Pavement Structures [3]:

$$E_{\text{subgrade}} = 0.192 * P / (W_7 * 72)$$

where,

$E_{\text{subgrade}}$  = backcalculated subgrade resilient modulus in psi.

$P$  = applied load in pounds.

$W_7$  = deflection at sensor 7 in mils.

The pavement to subgrade modulus ratio regression equation for 21-inch pavements is presented as follows:

$$E_p/E_{\text{subgrade}} = 516.94*(W_7/W_1)^{5/2} - 214.46*(W_7/W_1)^2 + 159.56*(W_7/W_1)^{3/2} - 6.143*(W_7/W) + 1.0826*(W_7/W_1)^{1/2}$$

where,

$(E_p/E_{\text{subgrade}})$  = pavement to subgrade modulus ratio.

$W_1$  = deflection at sensor 1.

$W_7$  = deflection at sensor 7 in mils.

The calculated modulus of the whole pavement is then compared to the required pavement modulus to see if the pavement is structurally adequate. This is a different approach than the approach presented in the AASHTO Guide for Design of Pavement Structures [3], where the pavement modulus is calculated from the equation that can be solved only by using numerical-iterative methods. The use of such complicated iterative equations is a major setback in the implementation of such a procedure. For this reason, it was more appealing for the authors to use equations developed by Wimsatt than the equation presented in AASHTO Guide for Design of Pavement Structures [3]. However, once the pavement modulus is determined, the relationship given in the AASHTO Guide for Design of Pavement Structures can be employed to calculate the existing (or effective) Structural Number (SN):

$$SN_{\text{eff}} = 0.0045 * D * E_p^{0.333}$$

where,

$D$  = total thickness of the pavement layers.

$E_p$  = existing pavement modulus of all layers above the subgrade.

### **Structural Number Estimates Obtained Directly from FWD Data**

The peak deflection measured below an FWD loading plate is a combination of the deflection in the subgrade and the elastic compression of the pavement structure. Irwin [7] suggested a “two-third” rule based on the fact that 95 percent of the deflections measured on the surface of a pavement originate below a line deviating 34 degrees from the horizontal, as illustrated in Figure 2. Rhode [8] concluded that, with this simplification, the surface deflection measured at an offset of 1.5 times the pavement thickness originates entirely in the pavement subgrade. By comparing this deflection value with the peak deflection under the loading plate, the Structural Index of a Pavement (SIP) could be defined. The SIP represents the amount of deflection that has occurred within the pavement structure:

$$SIP = D_0 - D_{1.5Hp}$$

where,

SIP = structural index of pavement.

$D_0$  = peak deflection measured under a standard 9,000-lb FWD load.  
 $D_{1.5H_p}$  = surface deflection measured at offset of 1.5 times of  $H_p$  under a standard 9,000-lb FWD load.  
 $H_p$  = total pavement thickness.

The structural number of the pavement was calculated with the known total thickness of the pavement and the SIP value. The function used in the analysis is as follows:

$$SN = k_1 SIP^{k_2} H_p^{k_3}$$

where,

SN = pavement structural number (in).

SIP = structural index of pavement (microns).

$H_p$  = total pavement thickness (mm).

$k_1, k_2, k_3$  = regression coefficients, as given in Table 1.

The procedure for calculating the Structural Number from the deflection data, with the “two-third” rule, is fairly simple and easily implementable in the PMIS. The more detailed overall accuracy of the method has been analyzed by Rhode [8]. Figure 3 was presented by Rhode to illustrate the very positive correlation between the SN calculated from the assumed moduli and from the surface deflections.

## PAVEMENT DETERIORATION DESCRIPTORS AND VARIABLES CONSIDERED IN THE ANALYSIS

In order to identify the best methodology for determining structural estimators that can be used to categorically assess different pavement structural conditions, one must consider the deterioration process of a pavement. The TxDOT PMIS stores three score values that represent the general condition of a pavement [1]. Those score are as follows:

- a) **Distress Score.** It indicates the amount of visible surface deterioration pavement distress. The values range from 1 (the most distress) to 100 (the least distress).
- b) **Ride Score.** It indicates a pavement’s roughness. The Ride Score ranges from 0.1 (the roughest) to 5.0 (the smoothest).
- c) **Condition Score.** It indicates a pavement’s overall condition in terms of distress and ride quality (SI values). The Condition Score values range from 1 (the worst condition) to 100 (the best condition).

It is known that the roughness of a pavement contributes significantly to the Pavement Serviceability Index (PSI) values [3]. The TxDOT PMIS does not use PSI values directly; rather, it uses the ride score as the roughness measurement.

Structural deterioration can be defined as any process that reduces the load-carrying capacity of the pavements; and it is a fact that the surface condition of a

pavement is implicitly correlated with the structural condition of the pavement. The Praxis shows that pavements become much more susceptible to the deterioration on the surface when their structural condition is poor.

The deterioration process of a pavement represents the behavior of a non-linear system that can be characterized by different rates of deterioration in different stages of the pavement service life. The typical deterioration of a pavement in terms of the PSI during its life cycle is shown in Figure 4. The true condition of a pavement at any moment can be described more accurately if the deterioration rate is known. Unfortunately, a mathematical solution to this problem is impossible because there are no models that can be so accurate to represent the true deterioration process of a pavement. If the general mathematical formula describing the transition of a system from one state to another is not available, one can use the finite difference between the states. By doing so, even though the estimate will not be very accurate, it will help establish a general trend for the deterioration process.

The yearly difference between the score values, or the change over a unit time, represents the rate of deterioration. Furthermore, if the difference is normalized by its initial condition, it would give a more accurate picture of the pavement deterioration process. For example, a big drop in the score value at the beginning of the pavement life would represent a different pavement structural condition than one where the same drop occurs at the end of its life.

Another important factor in characterizing the deterioration process of a pavement is the traffic. The traffic for pavement design is generally expressed in the amount of the Equivalent Single Axle Loads (ESAL). An equal yearly drop in the condition score of a pavement subjected to different ESALs represents different structural conditions of the pavement. For example, without considering the traffic, the same drop in score values for two different pavement sections could mean that the two sections have the same structural condition; whereas in fact, the drop for one section could be caused by a much greater traffic loading. In other words, the pavement that carries more ESALs is structurally better than the other.

If the normalized drop in score values is divided with the yearly traffic in ESALs, a more accurate structural condition of the pavement at the time of the FWD testing can be obtained. This can also be viewed as a unit deterioration of the pavement in terms of the PMIS score values caused by a single ESAL. It can be expected that the pavements with sound structural conditions would give smaller values of the Unit ESAL Deterioration (UED) than the ones that are not in sound structural conditions.

In the analysis conducted by the authors, the Unit ESAL Deterioration (UED) was defined for the corresponding PMIS score values:

$$\text{UED ( Distress Score )} = \frac{dDS}{DS \times \text{ESAL}_y} \times 10^6$$

$$\text{UED ( Condition Score )} = \frac{\text{dCS}}{\text{CS} \times \text{ESAL}_y} \times 10^6$$

$$\text{UED ( Ride Score )} = \frac{\text{dRS}}{\text{RS} \times \text{ESAL}_y} \times 10^6$$

where,

DS = Distress Score in initial year.

RS = Ride Score in initial year.

CS = Condition Score in Initial year.

dDS = yearly drop in Distress Score.

dCS = yearly drop in Condition Score.

dRS = yearly drop in Ride Score.

ESAL<sub>y</sub> = amount of ESALs in one year

The advantages of the UED concept are obvious. For example, some pavements may have been constructed with a poor initial roughness condition, but with a perfect structural condition. Such scenarios suggest that the use of a UED would be more appropriate, since those pavements would experience a lower rate of deterioration than the ones constructed with a poor structural condition.

## **DATA SET USED IN THE ANALYSIS**

The data used in the analysis was extracted from the TxDOT PMIS. The raw data set consists of 7,460 different sections where the PMIS score values were available for two consecutive years and the FWD data for the first year. Since the PMIS does not store maintenance records, it was assumed that some maintenance other than seal coats was performed during the year if the sections show an increase in score values. Such an assumption is based on the fact that a pavement would not be able to improve itself without any external intervention. Consequently, such sections were excluded from the data set. The data set contained pavements with the total thickness of 9, 12, and 15 inches. The total thickness is defined as the sum of the thickness for all the layers above the subgrade. It should be pointed out that the total thickness of a pavement in the TxDOT PMIS might not be up to date because the maintenance and rehabilitation (M&R) activities add the dynamic dimension to the data.

## **SENSITIVITY OF PAVEMENT STRUCTURAL CONDITION ESTIMATORS TO THE UNIT ESAL DETERIORATION (UED)**

Since the objective of the evaluation is to examine the sensitivity of the calculated structural estimators to the real conditions of the pavements, the Unit ESAL Deterioration (UED) was used as an independent variable; whereas, the Structural Number (SN) was used as the response variable. Figure 5 shows the sensitivity of the SN calculated using methodology developed by Rhode [8] with respect to the UED of the PMIS Ride Score.

The UED of the Ride Score was considered for the reason that the Ride Score measurements showed the highest accuracy level among all of the PMIS scores.

Even though a general trend has been observed between the SN estimates and the UED of the ride score values as illustrated in Figure 5, unstable trends were observed for SN values less than 2. The reason for such unstable trends is that the yearly differences in ride scores (dRS) for many sections were very small, consequently producing very small values of UED. At the same time, the accuracy of the ride score is considered to be 2 units of the measurement. In other words, the accuracy of the measurement is the potential reason for the unstable trends. It is worth noting that the attempt of this analysis was not intended to establish a regression relationship between the SN and the UED, but rather to observe whether the structural estimators were sensitive enough to the PMIS condition measurements.

Another aspect of the research was to examine the potential impact of the environmental conditions on the trends. Based on the results of the analyses, the five environmental zones defined in the PMIS did not affect the sensitivity analysis in any significant way. Even though the environmental zones did not show a direct impact on the way the deterioration variables behave, it could be observed that some environmental zones have different distributions of ESALs, Structural Number (SN), resilient modulus of subgrade ( $M_r$ ) and yearly deterioration (dRS) than others. This was expected since in Texas one could find different types of soils associated with different regions. For example, the North and the coastal South regions have different types of subgrade materials.

The other method for estimating the SN values, using modulus and deflection ratios, demonstrated a similar trend as the method proposed by Rhode. Figure 6 shows a functional relationship between those two methods. It can be observed from Figure 6 that the two methods demonstrate almost a linear relationship for smaller values of SN, but on the other hand for higher SN values, the relationship takes an exponential form. Generally, the SN estimates obtained directly from FWD data using the Rhode methodology yielded higher SN values than the method using the modulus and deflection ratios.

In summary, both methods yielded the SN values that were sensitive to the deterioration variables. The SN values demonstrated the best trend with the respect to the UED of all three major PMIS score values. In other words, the structural estimators being investigated are good indicators of the structural condition of a pavement.

## **STRUCTURAL CONDITION INDEX (SCI)**

Since the SN estimates are sensitive to the pavement deterioration variables, the SN values can be used as a good indicator of the existing (or effective) structural condition of a pavement. With the existing and required SN values of a pavement, the Structural Condition Index (SCI) can be established for the pavement. The Structural Condition Index (SCI) can be expressed by the ratio of the existing SN and the required SN.

$$SCI = \frac{SN_{\text{eff}}}{SN_{\text{req}}}$$

where,

SCI = Structural Condition Index.

SN<sub>eff</sub> = existing Structural Number.

SN<sub>req</sub> = required Structural Number.

The required SN is usually calculated according to the estimated ESALs for the next 20 years. However, for the maintenance work, it is up to the agency to determine the time frame for which the accumulated ESALs will be estimated.

Because of the simplicity of the SCI, the interpretation of its meaning is straightforward. An SCI value equal or greater than one would indicate that the pavement is in a sound structural condition for the estimated future ESALs. However, an SCI less than one means that the pavement is no longer structurally adequate; as a result, rehabilitation work that will increase the structural capacity of the pavement should be considered.

## CASE STUDY

Several case studies have conducted to validate the SCI procedure. The first case study was conducted with data from five newly constructed sections, where the more detailed information about the thickness of each layer was available. Such information enabled the authors to calculate the SN values using the AASHTO design procedure, referred as the real SN. The SN values for the five sections were also estimated using the two methods described in the previous sections. Table 2 summaries the SN values using three different methods. It can be observed from Table 2 that the SN values from the Rhode method give a better estimation of the real SN values. However, there is some discrepancy in the SNs for one of the sections, due to the difference in thickness information stored in the PMIS and the total thickness used to calculate the real SN. Consequently, the authors decided to use the Rhode method to estimate the existing SN and calculate the SCI values for the case study.

Then the case study was extended to the data set extracted from the TxDOT PMIS. The data set had 13,522 sections representing different ESALs and subgrade modulus values. Figure 7 shows the distribution of the ESALs that have been normalized through a logarithmic transformation of the data for all the sections. Figure 8 shows a backcalculated subgrade modulus distribution that has been normalized by using the square root transformation. Figures 7 and 8 show that after the values were transformed back into the ESALs and pound per square inch (psi) units, the mean of the ESALs is around 1 million ESALs and the mean of the subgrade modulus is around 6,000 psi.

In order to portray the general structural condition of the pavements for the sections in the data set, the SCI must be determined for each section. To do so, the required SN for the sections must be determined first. The required SN is a function of the subgrade modulus and the accumulated ESALs. As a simplified procedure for potential implementation at the network level, the subgrade modulus was divided into 3 categories and the accumulated ESALs into 5 categories. Then, using the average values of each category, the required SN was estimated according to the AASHTO pavement design equation. Table 3 gives the values of the required SN calculated for each category. Having the required and existing (effective) SN determined, one can easily calculate the SCI values. The SCI distribution of all the sections in the data set is presented in Figure 9. It can be observed that the average SCI for the assumed 20-year ESALs obtained from the PMIS is 0.75.

## CONCLUSIONS

Based on the results of the study, some important conclusions were drawn as follows.

1. There is an urgent need to establish a procedure that will discriminate between pavements that need structural reinforcement and those that do not. Considering the current state of the TxDOT PMIS development and available information, a procedure based on estimating the existing structural condition is proposed.
2. The existing Structural Number (SN) can serve as a reasonable estimator of the current structural condition of a pavement for making M&R decisions. By doing so, one can assess the amount of the SN deficiency, and subsequently make decisions on the type of M&R action that can be used to adequately compensate the estimated deficiency. The analysis has shown that the SN estimates from the methodology proposed by Rhode [8] produces good estimates of the real SN values. In addition, the SN has shown a reasonable trend with respect to the pavement deterioration variables in terms of the PMIS scores. In particular, when the deterioration variables are normalized with the initial condition and the traffic in ESALs, the trends have become more obvious. The sensitivity analysis also showed that if the estimated SN value falls below two, such trends become unstable.
3. The use of the Structural Condition Index (SCI), a ratio of the existing SN and the required SN, has proven to be effective in discriminating between the pavements that need structural reinforcement from ones that are in sound structural condition. Furthermore, the amount of structural deficiency can be easily established when the existing and required SN values are known.

## ACKNOWLEDGMENTS

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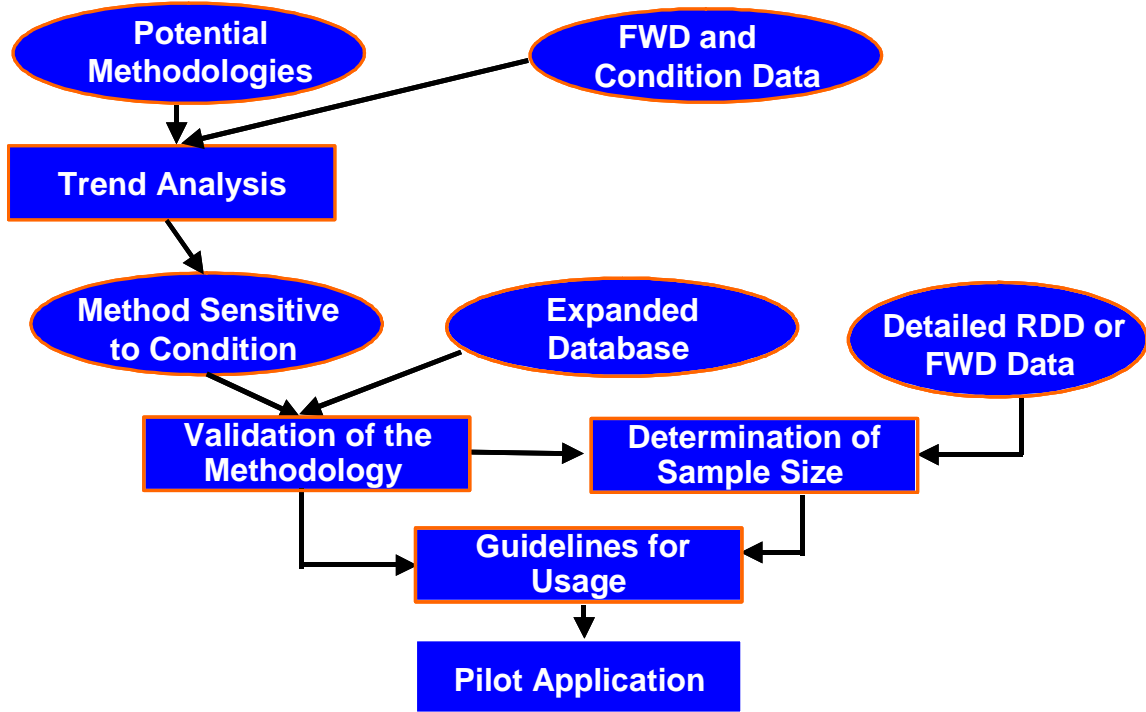


Figure 1. The Framework of the Evaluation Methodology

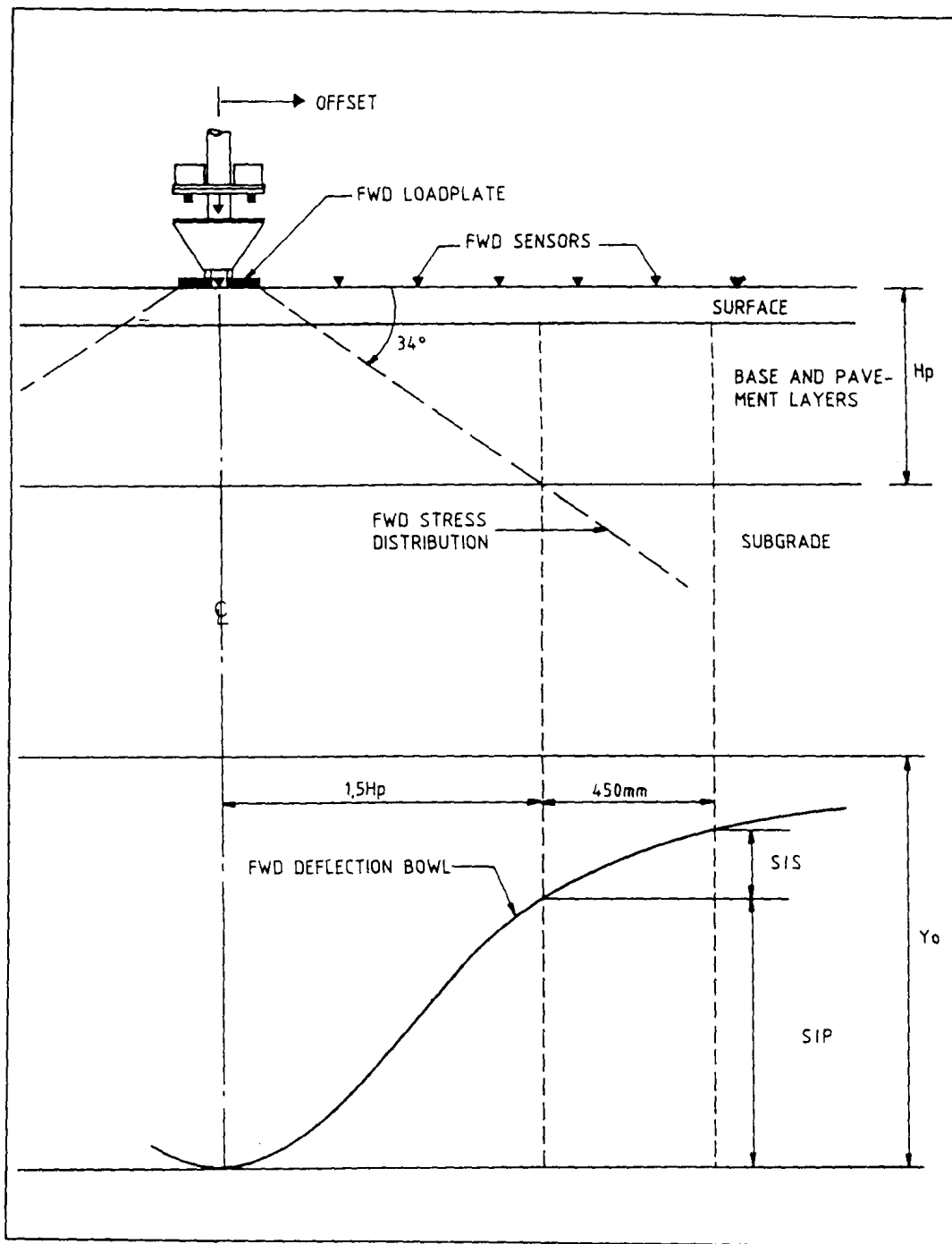


Figure 2. The Stress Distribution and Measured Deflection Bowl Beneath FWD Load [8]

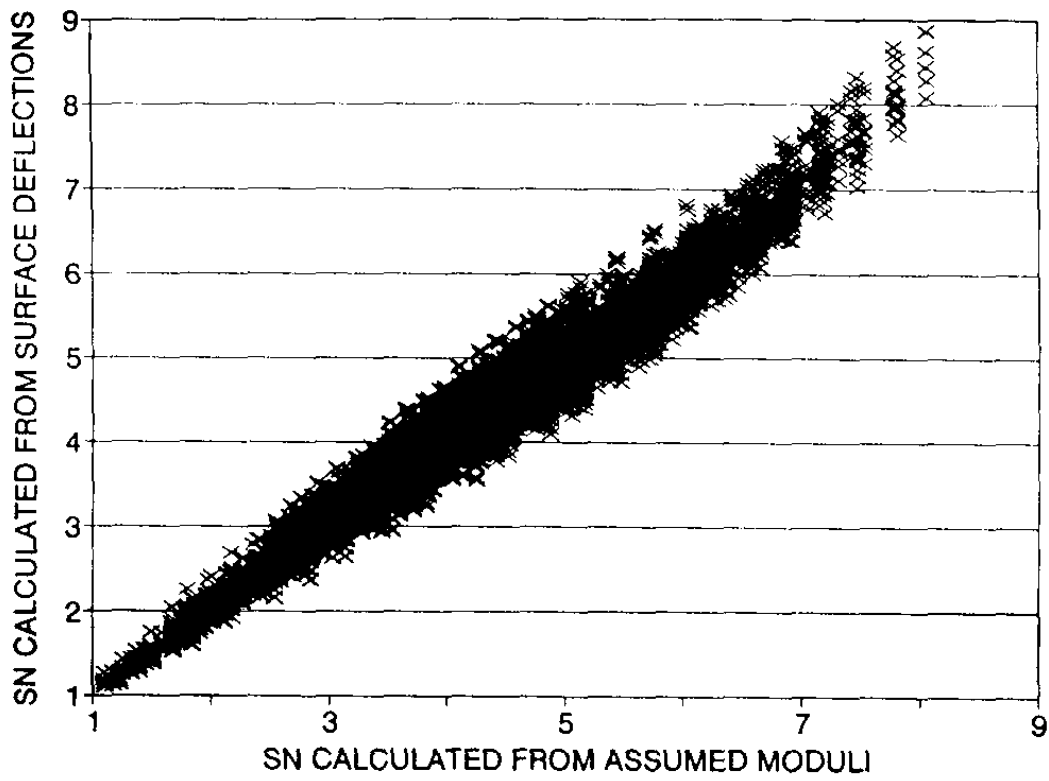


Figure 3. The Correlation of SNs Calculated From Surface Deflections and From Assumed Moduli [8]

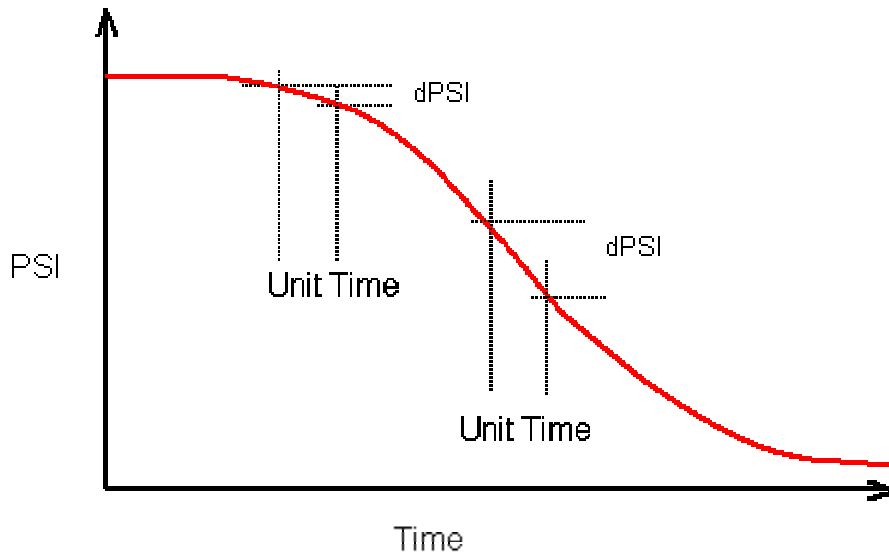


Figure 4. The Deterioration of Pavement Serviceability Index (PSI) Over Time

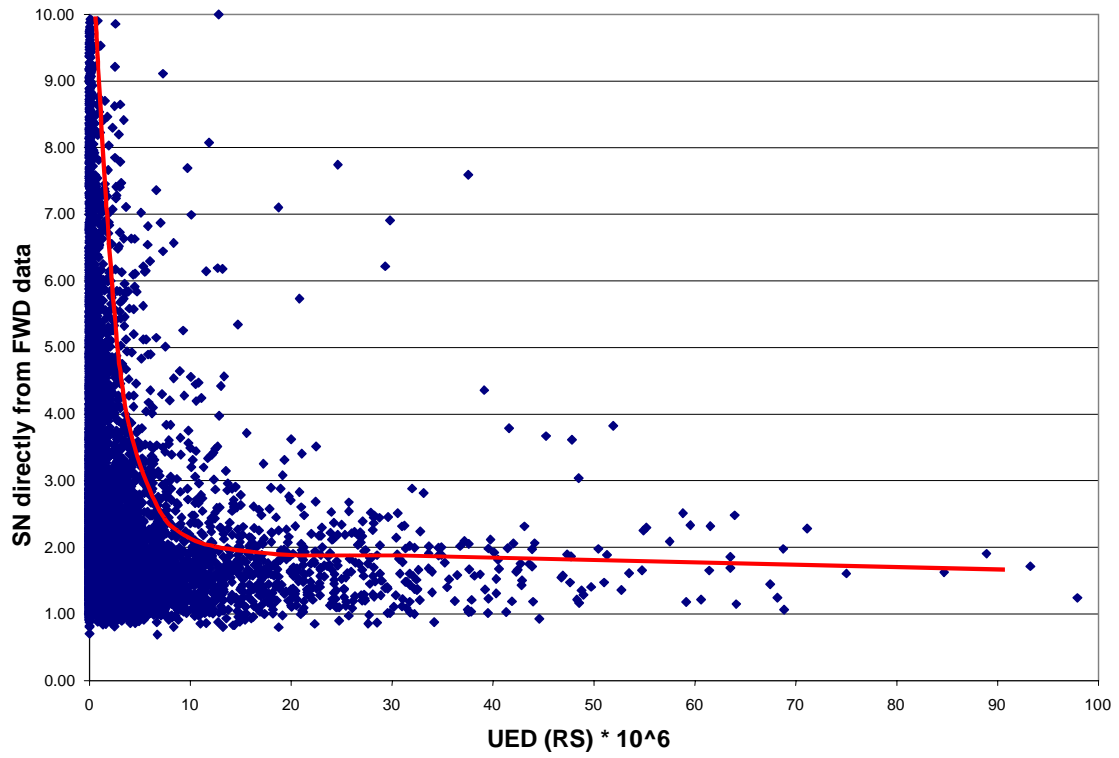


Figure 5. The Sensitivity of the Unit ESAL Deterioration Values to the SN Values Estimated Directly From FWD Data (Rhodes Methodology)

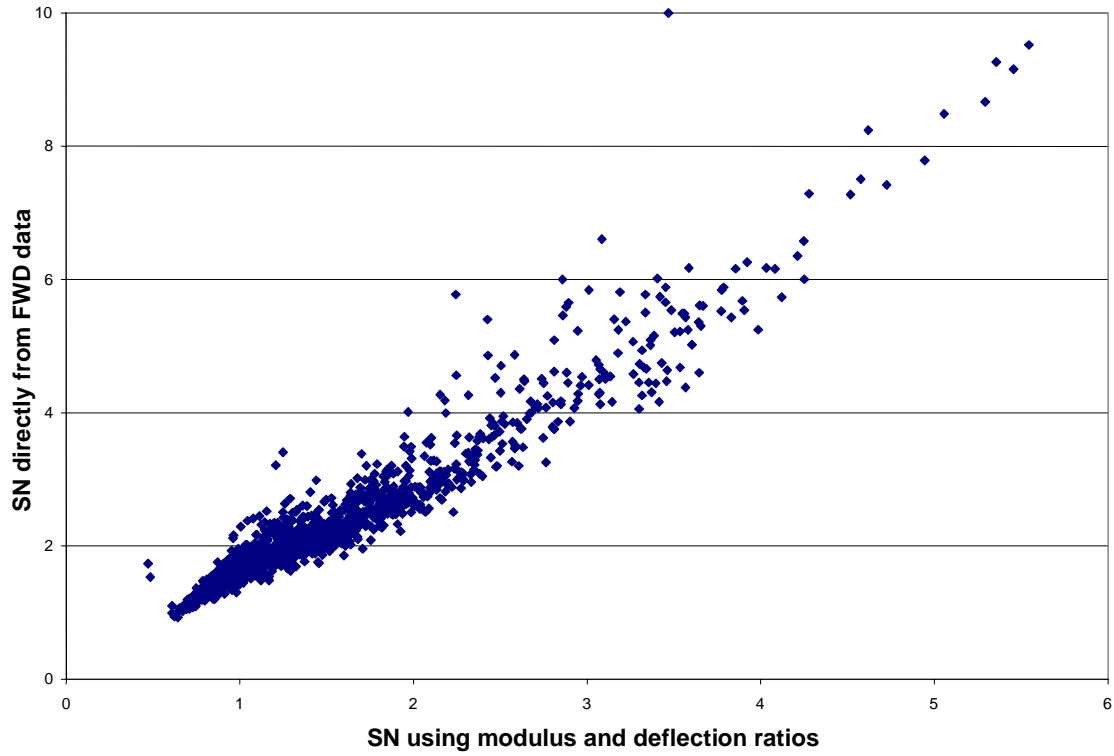


Figure 6. The Relationship Between SN Values Calculated Using Rhodes Method and SN Values Calculated Using Modulus and Deflection Ratios

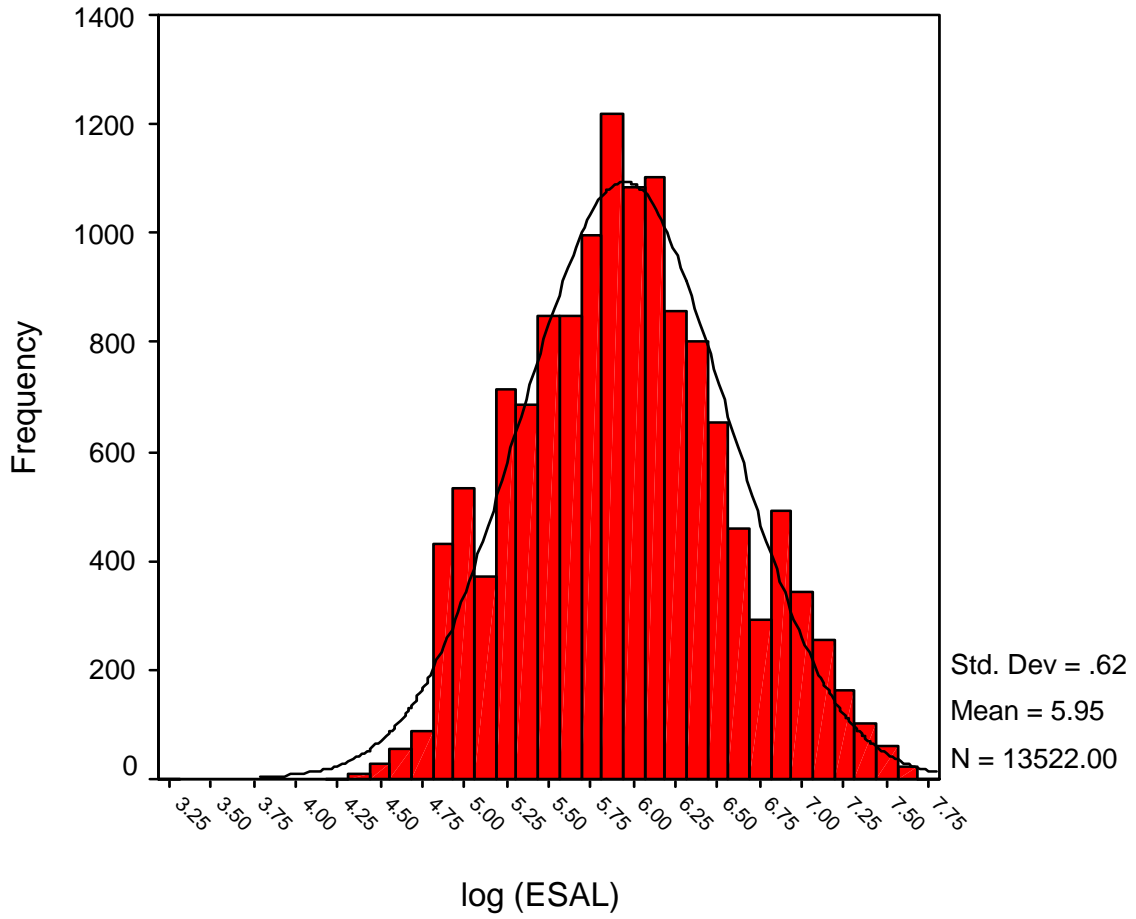


Figure 7. The Distribution of the Traffic in Log (ESAL)

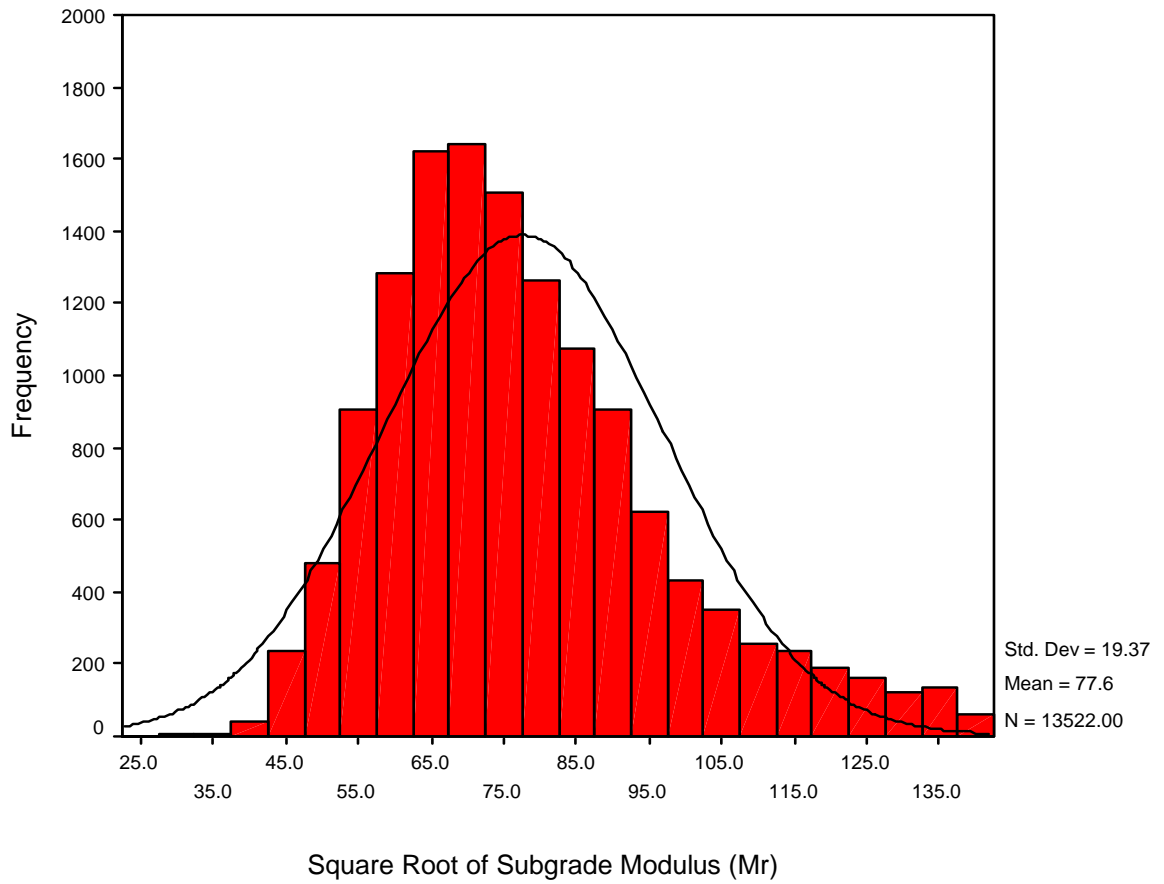


Figure 8. The Distribution of the Square Root of the Subgrade Modulus (Mr)

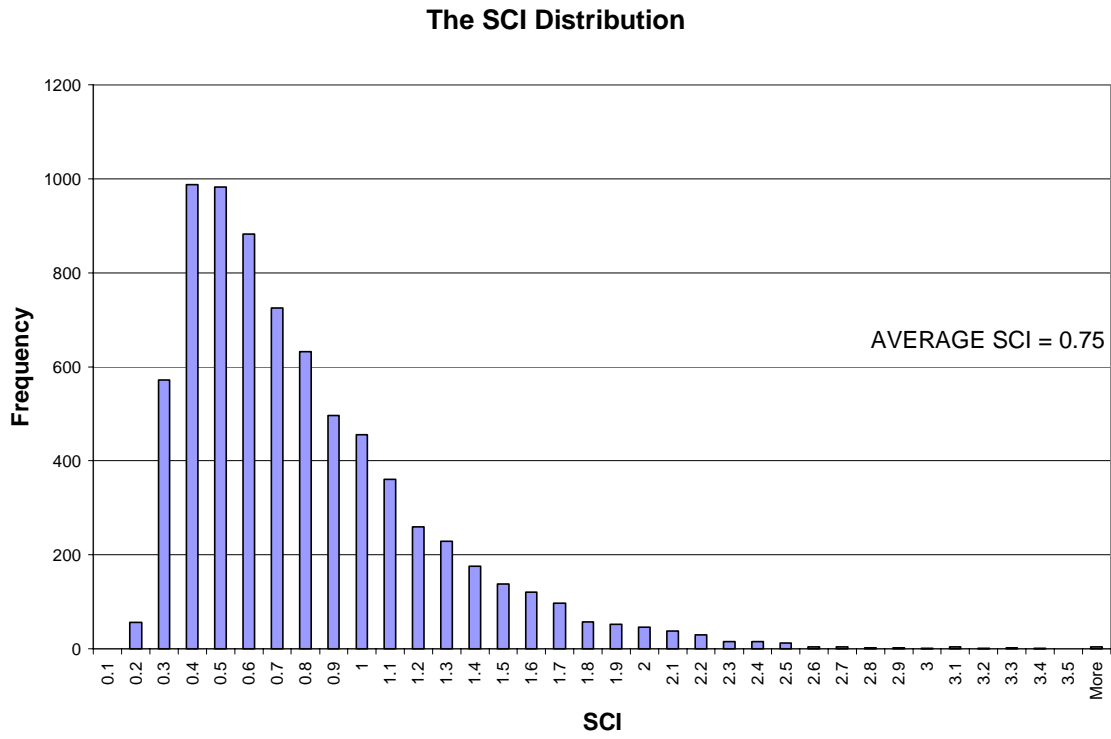


Figure 9. The Distribution of the Structural Condition Index (SCI) in the TxDOT PMIS

Table 1. Coefficients for SN Versus SIP Relationship [8]

Surface Type	k1	k2	k3	r <sup>2*</sup>	n**
Surface Seals	0.1165	-0.3248	0.8241	0.984	1944
Asphalt Concrete	0.4728	-0.4810	0.7581	0.957	5832

\* Coefficient of Determination

\*\* Sample Size

Table 2. The Average SNs Calculated Using Modulus and Deflection Ratios and Directly From FWD (Rhode) with SN Estimated Using AASHTO Guide for Design of Pavement Structures

ID Section	Average SN Using Modulus and Deflection Ratios	Average SN Directly From FWD Data	SN From AASHTO Guide
FM0004 K	3.09	4.63	4.65
FM0051 K	3.33	5.29	5.15
FM0917 K	1.88	3.64	3.95
FM1810 K	2.39	2.85	4.44
FM2280 K	2.00	2.54	1.64

Table 3. The Required SN for Different Categories of Accumulated ESALs and Subgrade Modulus

		Traffic						
		Category	Very Low	Low	Median	High	Very High	
		Range	50000~ 945000	945000~ 1687000	1687000~ 2430000	2430000~ 3172000	3172000~ 50000000	
Mr	Category	Range	Average	498000	1316000	2059000	2801000	26586000
	Low	1000~ 5400	3200	4.3	5.1	5.3	5.6	7.1
	Median	5400~ 7500	6400	3.5	3.9	4.2	4.3	6.0
	High	7500~ 40000	24000	2.3	2.6	2.8	2.8	3.9