Development of a Framework for Determining Minimum Testing Interval Requirements for Network Level Skid Testing

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ABSTRACT

As transportation agencies begin to shift the ownership and ultimate responsibility of their civil infrastructure assets such as highway networks and toll roads from the agency to the private sector, the importance of key performance indicators (KPI) such as level of safety are critical to ensure a high level of service. The safety of highway networks are usually assessed using various levels of service indicators such as ride quality (IRI), surface friction (SN), or number of collisions.

In 2006, approximately 1,800 km of the provincial highway network was surveyed for friction data. This friction data was collected to determine a baseline of the current network friction levels in terms of a skid number. Testing was carried out at an interval of 1.0 km across the length of each highway segment. Network level friction testing can be characterized as expensive and time-consuming due to the complexity of the test and the traffic control requirements. As a result, any reduction in the required number of test points is a benefit to the transportation agency, private sector (consultants and contractors) and most importantly, the public. This study demonstrates a method that could be used to minimize the number of required test locations along a highway segment using common statistical techniques. It is also very timely in light of Public Private Partnerships (PPP) where friction testing at the network level will become more commonplace. This study provides much needed advice on optimizing skid testing interval requirements.

INTRODUCTION

In Ontario, the Ministry of Transportation (MTO) is responsible for the maintenance and construction of approximately 39,000 lane-kilometres of highway. In 2004, the province estimated the value of the total highway system at $39 billion dollars [1]. Due to the size and significance of this considerable infrastructure asset, cost-effective maintenance and management practices are essential. These types of statistics are similar for other state Departments of Transportation (DOTs) and although Ontario is used as a case study in this analysis, the findings would be applicable for other state and provincial DOTs.

One of the most important indicators of level of service for a highway network is safety. Each year, thousands of motorists across North America are involved in motor vehicle collisions, which result in property damage, congestion, delays, injuries and fatalities. The Ontario Ministry of Transportation estimated that in 2002, vehicle collisions in Ontario cost the province nearly $11 billion. It also estimated that for every dollar spent on traffic management, 10 times that amount could be saved on collision-related expenditures, including health care and insurance claims [2].

In many jurisdictions, there is an effort to examine the feasibility of Public Private Partnerships (PPP). Network level friction data can provide valuable insight with regard to network level safety and possibly mitigate litigation. This paper examines friction data that was collected from approximately 1,800 km of highway, across 33 individual highway segments, at an interval of 1.0 km. Several state and provincial Departments of Transportation (DOT) such as the MTO, Pennsylvania DOT, Indiana DOT, and Ohio DOT collect skid data. No minimum skid testing interval requirements were found at the network level in a review of the literature or state of practice in the province of Ontario.

SURFACE FRICTION

Surface friction between the tire of the vehicle and the pavement surface has a profound affect on highway safety. A driver must be able to adapt their behaviour to changing friction conditions in order to maintain an acceptable level of safety [3]. When road surfaces are dry, the friction generated between the tires and pavement is generally sufficiently high to provide adequate levels of safety. During wet or winter weather conditions, water can create a critical situation by increasing the potential for hydroplaning or skidding, especially when skid resistance of a pavement is low [4]. When skid resistance is low, the driver may not be able to stop the vehicle or retain stability on wet pavement. Skid resistance is defined as the force that resists the sliding of tires on a pavement when the tires are prevented from rotating. Factors such as traffic and seasonal variations, vehicle speed, tire pressures, wheel loads, tire treads, and pavement factors all influence skid resistance.

The surface texture of a pavement can be described by the microtexture and macrotexture. Microtexture (0 mm to 0.2 mm) is what makes an aggregate smooth or rough to touch and contributes to friction through adhesion with the tire. The macrotexture is the result of the shape, size, and arrangement of the aggregates. Macrotexture (0.2 mm to 3 mm) effects skid resistance though hysteresis due to the deformation of the tire. The skid resistance of a pavement varies over time. Typically, it increases in the first two years following construction as the surface is worn away by traffic and rough aggregate surfaces become exposed, then decreases over the remaining pavement life as aggregates become more polished [4].

This is typically classified as functional deterioration since it adversely affects the highway user [5]. Maintenance and rehabilitation (M&R) treatments such as overlays, porous friction courses (PFC), chip seal and slurry seals can be used to increase skid resistance of asphalt concrete pavements.

Surface Friction and Highway Safety

The impact of surface friction on highway safety is a very complex problem. It consists of a relationship that involves the driver and vehicle, environmental conditions, and the pavement surface. The ability of a driver to accurately assess or estimate the friction conditions is poor [3]. This perspective is supported by several research studies such as speed measurements during different roadway conditions, driver interviews during slippery conditions, and vehicle simulator experiments. The main premise for these studies is that if the stopping distance for dry pavement conditions is considered an indicator of safe speed, then a reduction in speed as a result of poor surface friction (wet or icy conditions) should result in an equivalent stopping distance [3]. A study was carried out where vehicle speeds were recorded under different road conditions. For the studied highway (7-m wide, posted speed of 90 km/h), the average speeds were found to be 85 km/h to 95 km/h for dry pavement conditions. During winter conditions, a 6 to 10 km/h decrease in the posted speed limit was recorded despite icy and snow packed pavement conditions. To maintain equivalent “dry” pavement surface stopping distances, the speed of the vehicle should have been reduced to 56 km/h [3].

Several other studies have shown similar findings. Many research studies examining accident data and surface friction in European countries such as the Netherlands, Germany, and France have shown that the number of accidents and the relative proportion of accidents at skid-prone sites increase sharply when the friction coefficient decreases. For example, when the level of friction is 0.35 to 0.44, the accident rate is 0.20 (personal injuries/million veh-km). When the level of friction is less than <0.15, the accident rate increases by 300% [3]. Recent research has shown the benefits of mix design and hot mix asphalt technologies on the surface friction of newly constructed pavements [6].

SKID TESTING

Skid resistance is generally quantified using some form of friction measurement such as a friction factor or Skid Number (SN). The coefficient of friction of a pavement is given by,

$$f = F/L$$

[1]

Where:

f = coefficient of friction
F = frictional resistance to motion in plane or interface
L = load perpendicular to interface

The skid number is given by,

$$SN = 100 * f$$

[2]

Several methods are available for measuring surface friction. The following four methods are the most common methods for measuring surface friction;

- Locked-Wheel Mode
- Slip Mode
- Yaw Mode
- Laboratory and Texture Measurement Methods

Locked Wheel Tester

A locked wheel skid tester is a common device used to assess the friction level of pavements in terms of a Skid Number. A tow vehicle such as a pick up truck or van typically tows a specially designed two-wheel trailer. The test method and equipment are defined in ASTM E 274, Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire [7]. The specification for the standard ribbed tire is ASTM E 501, Standard Specification for
Standard Rib Tire for Pavement Skid-Resistance Tests [7]. The specification for the standard smooth tire is ASTM E 524, Standard Specification for Standard Smooth Tire for Pavement Skid-Resistance Tests1 [7].

To perform the test, water is dispensed onto the pavement immediately ahead of the tire on the trailer and the trailer braking system is actuated to lock the test wheel (typically, only the wheel on the driver’s side of the trailer is used to test). The system detects and records the horizontal tractive force, which is the force necessary to slide the locked test tire along the pavement at the test speed, the vertical load on the test wheel, and the vehicle speed [8].

A test cycle takes approximately 2.5 seconds. Water dispersion begins 0.1 seconds prior to wheel lock (and continues during the entire test cycle), it takes approximately 1 second to lock the wheel (the higher the speed, the longer it takes to lock the wheel), and measurements are made for 1 second while the wheel is locked (200 measurements are recorded during that 1 second interval). Water is dispensed at the rate of approximately 28 gallons per minute. The average skid number (SN) for each test cycle equals the Horizontal Tractive Force divided by the Vertical Load, multiplied by 100 [8].

FRAMEWORK APPROACH

The purpose of this study is to develop an approach or framework to determine the minimum test interval requirements for network level skid testing. As a part of this study, a significant data collection program consisting of network level skid data and highway attribute data was undertaken. The framework approach is based on common statistical techniques which were evaluated at the 95% confidence interval. The following sections provide background information on the data and analysis methodology. Three levels of analysis were examined;

- Network Level
- Highway Level, and
- Group Level Analysis

Three levels of analysis were performed to illustrate the affects of increasing the test interval requirements, The next sections outline the data attributes, statistical approach and results of analysis.

DATA ATTRIBUTES

The data from this study was obtained from a highway network located in Southern Ontario. Each data element was checked for completeness; Quality Control and Assurance (QA/QC'd), and formatted prior to analysis.

The Highway Network

In 2006, approximately 1,800 km of highway network was surveyed across three regions in Southern Ontario. This data was collected across 33 individual highway segments consisting of an assortment of functional classes (2 lane undivided, 4 lane divided, interstate, etc.).

Surface Friction

Due to the sensitivity of the data and the potential risk to the agency, the regions will be referenced within this paper as Regions A, B, and C. Friction data was collected to determine a baseline of the current network friction levels in terms of a skid number. A trailer mounted locked-wheel skid tester was used to collect the skid data in terms of a skid number (SN). A 1.0 km sampling interval was selected as a reasonable measuring interval to perform the skid testing. At each test point, the skid number (SN), average test vehicle speed, and kilometre post were recorded. The average network level skid number is 37.5.

STATISTICAL APPROACH

To determine the minimum skid testing interval requirements, an analysis approach consisting of statistical techniques was developed. The first step was to examine the descriptive or summary statistics of the skid data collected within each region. Next, tests for goodness of fit for normal distribution analysis were performed. Finally, a comparison of means was conducted using a Student's T-test and an Analysis of Variance (ANOVA) to evaluate the differences between groups at the 95% confidence interval. These tests are used to determine if the testing interval could be increased. A similar analysis approach was carried out to examine the testing interval requirements for network level Falling Weight Deflectometer (FWD) testing along a number of interstates in the State of Virginia [8]. This research study demonstrated that the FWD testing interval could be increased (number of tests reduced) using statistical techniques.

Descriptive Statistics and Normality Tests

A detailed analysis examining the descriptive statistics was performed to determine the variability and distribution of the collected skid data. The mean, standard deviation and coefficient of variation as well as maximum, minimum and range were calculated for the skid data collected within each Region. In addition, skewness and kurtosis tests of the skid data for each region were also performed. The skewness and kurtosis tests are used to determine if the collected skid data followed a normal distribution.

Regions A and B have similar friction properties and similar distributions and were combined into a single region (Region A&B). The third region is located within the Canadian Shield, which is well known for its very hard rock formations, the aggregate sources in this region have excellent skid resistance properties. This region was treated as a single region (Region C). Presented in Table 1 are descriptive statistics for Regions A&B and C.

TABLE 1 Summary Statistics for Regions A&B and C

Summary Statistic	Region A&B	Region C
Mean	37.6	52
Standard Deviation	6.5	5.5
Coefficient of Variance	0.17	0.11
Kurtosis	0.1	1.74
Skewness	0.3	0.657
Range	54.6	46.3
Minimum	10.3	22.3
Maximum	64.9	68.6
N	905	869

Comparison of Means

Statistically, any parameter can be estimated from a data set either by a point estimate or a confidence interval. Frequently, however, the objective of an investigation is not to estimate a parameter but to decide which two contradictory statements about a parameter is correct. The outcome of these tests is the acceptance or rejection of the null hypothesis (H_0). For the skid data, the objective was to determine if the number of test locations across a highway network or segment could be reduced. For this case, the Null Hypothesis is that the means of the two data sets are equal, while the alternate hypothesis is that the means of the two data sets are statistically different.

This test was performed to determine if a statistical difference was present between the various alternatives. If the data sets are found to be equal at the 95% confidence interval, then we can conclude that both groups are the same and the number of skid tests can be reduced. For two groups, a Student's T-test was used to test for differences. For three or more groups, an Analysis of Variance (ANOVA) was performed.

RESULTS AND ANALYSIS

As a part of this study, three levels of analysis were performed. The first level of analysis was conducted at the Network Level. The second level of analysis consists of a Highway Level Analysis which was performed on three individual highway segments. The third level of analysis performed is a Group Level Analysis on 33 individual highway segments within the network.

Network Level Analysis

For the Network Level Analysis, skid data was examined across three regions in Southern Ontario. The skid data was grouped into a number of subsets to see if the testing interval could be extended from the current 1-km interval up to an interval of 5 km. The grouping of skid data into subsets is presented in Table 2.

TABLE 2 Skid Data Grouped Into Subsets Based on Testing Interval

Region	Highway	Distance (km)	2 km Interval	3 km Interval	4 km Interval	5 km Interval	Random 5 km Interval	Skid Number (SN)
Region A	1	1.324	1	1	1	1	2	44.3
Region A	1	2.324	2	2	2	2	1	45.8
Region A	1	3.324	1	3	3	3	4	45.2
Region A	1	4.324	2	1	4	4	5	44.8
Region A	1	5.324	1	2	1	5	3	43.3
Region A	1	6.324	2	3	2	1	3	44.5
Region A	1	7.324	1	1	3	2	5	49.8
Region A	1	8.324	2	2	4	3	2	10.3
Region A	1	9.324	1	3	1	4	1	50.8
Region A	1	10.324	2	1	2	5	4	47.0

Case 1: Extend Test Interval from 1 km to 2 km

To investigate whether the testing interval could be extended from 1 km to 2 km, two subsets of data were compared. The first subset included data from every even kilometre post (Subset 1A → 0, 2, 4, 6, etc.) for each highway segment. The second subset included data from every odd kilometre post (Subset 1B → 1, 3, 5, 7, etc.) for each highway segment. This comparison was performed for all highway segments within the three Regions. To determine if there were any statistical differences between the two subsets, a test of "comparison of means by a two sample t-test with 95% level of confidence" was performed. The two subsets were compared to the population (all regions) as well as to each other. For all scenarios, Subsets 1A and 1B were not found to be statistically different at the 95% confidence interval indicating that the two subsets are similar and that the testing interval can be extended to 2 km. Results of the Student's T-test for Case 1 are presented in Table 3.

TABLE 3 Results of T-Test (Two Sample Assuming Unequal Variances) for 2 km Test Interval

Results of T-Test	Subset 1A	Subset 1B
Mean	44.64	44.65
Variance	86.35	89.64
Observations	897	877
Hypothesized Mean Difference	0	
df	1769	
t Stat	-0.0180	
P(T<=t) one-tail	0.493	
t Critical one-tail	1.646	
P(T<=t) two-tail	0.986	
t Critical two-tail	1.961	

Case 2: Extend Test Interval from 2 km to 3 km

To investigate whether the testing interval could be extended from 2 km to 3 km, three subsets of data were compared. The first subset includes data starting at the first test location within the highway segment and every 3 km thereafter (Subset 2A → 0, 3, 6, etc.). The second subset includes data starting at the second test point within the highway segment and every 3 km thereafter (Subset 2B → 1, 4, 7, etc.). The third subset includes data starting from the third test point within the highway segment and every 3 km thereafter (Subset 2C → 2, 5, 8, etc.).

This comparison was performed for all highway segments within the three Regions. To determine if there were any statistical differences between the three subsets, an Analysis of Variance (ANOVA) was performed. Results of the ANOVA indicate that the three subsets are not statistically different at the 95% confidence interval indicating that the three subsets are similar and that the testing interval can be extended to 3 km. Results of the ANOVA for Case 2 are presented in Table 4.

Case 3: Extend Test Interval from 3 km to 5 km

To investigate whether the testing interval could be extended from 3 km to 5 km, five subsets of data were compared. The first subset includes data starting at the first test location within the highway segment and every 5 km thereafter (Subset 3A → 0, 5, 10, etc.). The second subset includes data starting at the second test point within the highway segment and every 5 km thereafter (Subset 3B → 1, 6, 11, etc.). The third subset includes data starting from the third test point within the highway segment and every 5 km thereafter (Subset 3C → 2, 7, 12, etc.). The fourth subset includes data starting from the fourth test point within the highway segment and every 5 km thereafter (Subset 3D → 3, 8, 13, etc.). The fifth subset includes data starting from the fifth test point within the highway segment and every 5 km thereafter (Subset 3E → 4, 9, 14, etc.).

This comparison was performed for all highway segments within the three Regions. To determine if there were any statistical differences between the five subsets, an Analysis of Variance (ANOVA) was performed. Results of the ANOVA indicate that the three subsets are not statistically different at the 95% confidence interval indicating that the five subsets are similar and that the testing interval can be extended to 5 km. Results of the ANOVA for Case 3 are presented in Table 4.

Case 4 – Extend Skid Test Interval Based on Random Testing

The results from the three previous cases are based on grouped subsets with a known or regular interval (i.e. even and odd test points). This may result in each subset having distributions of data which are similar to the original data set since it contains all subsets within its population. Therefore, to ensure a sound approach in conducting the Analysis of Variance (ANOVA) between the various subsets, a final analysis was performed where the grouped subsets were developed using a random number generator. This ensures that a friction test could be performed anywhere within each 5 km interval along the highway segment and still produce statistically significant results.

The average level of SN for each of the 5 randomly generated subsets (1A through 1E) is 36.64, 36.39, 36.54, 37.15, and 36.87. To determine if there were any statistical differences between the five subsets, an Analysis of Variance (ANOVA) was performed.

Results of the ANOVA indicate that the five subsets are not statistically different at the 95% confidence interval indicating that the 5 subsets are similar and that the testing interval can be extended to 5 km. Results of the ANOVA for Case 4 are presented in Table 4.

TABLE 4 Results of ANOVA for Network Level Analysis

RESULTS OF ANALYSIS OF VARIANCE FOR CASE 2 – 3 KM INTERVAL

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	42.342	2	21.171	0.241	0.786	3.001
Within Groups	155862.033	1771	88.008			

RESULTS OF ANALYSIS OF VARIANCE FOR CASE 3 – 5 KM INTERVAL

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	62.986	4	15.746	0.178741	0.949	2.377
Within Groups	155841.4	1769	88.096			

RESULTS OF ANALYSIS OF VARIANCE FOR CASE 4 – 5 KM RANDOM INTERVAL

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	172.409	4	43.102	0.490	0.743	2.377
Within Groups	155732	1769	88.034			

Summary of Network Level Analysis

Based on the results of the Student's t-test and Analysis of Variance (ANOVAs), the skid testing interval can be extended from 1 km up to 5 km since there is no significant difference (at the 95% confidence interval) within each of the subsets for all cases. The testing interval was not increased beyond 5 km since testing beyond this distance may not provide a meaningful representation of the friction properties along a highway section or network. Since the level of friction is function of the material properties and characteristics of the pavement surface layer, increasing the distance beyond 5 km may increase the variability in the skid data across a highway segment due to the variations in asphalt mixes or aggregates being used along a section of highway or project.

Highway Level Analysis

The results of the Network Level Analysis demonstrated that the skid testing interval could be increased from 1 km to 5 km and statistically provide the same level of friction at the 95% confidence interval. A Highway Level Analysis was performed to test if extending the testing interval affected the significance of the results along three individual high segments. Due to the sensitivity of the skid data, the three highways are referred to as Highway I, Highway II, and Highway III within this study.

Similar to the Network Level Analysis, skid data was grouped into five subsets. The first subset includes data starting at the first test location along each highway and every 5 km thereafter (Subset 1A → 0, 5, 10, etc.). The second subset includes data starting at the second test point along each highway and every 5 km thereafter (Subset 1B → 1, 6, 11, etc.). The third subset includes data starting from the third test point along each highway and every 5 km thereafter (Subset 1C → 2, 7, 12, etc.). The fourth subset includes data starting from the fourth test point along each highway and every 5 km thereafter (Subset 1D → 3, 8, 13, etc.). The fifth subset includes data starting from the fifth test point along each highway and every 5 km thereafter (Subset 1E → 4, 9, 14, etc.).

Case 1 - Extend Skid Testing Interval from 1 km to 5 km along Highway I

Highway I is located within Region A in the province of Ontario. It is generally a two lane undivided highway. In total, approximately 200 km of pavement were tested along Highway I. Since testing was conducted every 1 km, 203 individual skid tests were performed along the length of this highway segment. Similar to the approach for the Network Level Analysis, skid data was grouped into 5 subsets. The average level of SN for each of the 5 subsets (1A through 1E) is 36.64, 36.39, 36.54, 37.15, and 36.87. To determine if there were any statistical differences between the five subsets, an Analysis of Variance (ANOVA) was performed. Results of the ANOVA indicate that the five subsets are not statistically different at the 95% confidence interval indicating that the three subsets are similar and that the testing interval can be extended to 5 km along Highway I. Results of the ANOVA for Case 1 are presented in Table 5.

Case 2 - Extend Skid Testing Interval from 1 km to 5 km along Highway II

Highway II is located within Region A in the province of Ontario. It is generally a two lane undivided highway. In total, approximately 160 km were tested along Highway II. Since testing was conducted every 1 km, 158 individual skid tests were performed along the length of this highway segment. Similar to the approach for the Network Level Analysis, skid data was grouped into 5 subsets. A comparison was then performed for the five subsets along Highway II. To determine if there were any statistical differences between the five subsets, an Analysis of Variance (ANOVA) was performed. Results of the ANOVA indicate that the five subsets are not statistically different at the 95% confidence interval indicating that the three subsets are similar and that the testing interval can be extended to 5 km along Highway II. Results of the ANOVA for Case 2 are presented in Table 5.

Case 3 - Extend Skid Testing Interval from 1 km to 5 km along Highway III

Highway III is located within Region B in the province of Ontario. It is generally a two lane undivided highway. In total, approximately 90 km were tested along Highway III. Since testing was conducted every 1 km, 87 individual skid tests were performed along the length of this highway segment. Similar to the approach for the Network Level Analysis, skid data was grouped into 5 subsets. A comparison was then performed for the five subsets along Highway III. To determine if there were any statistical differences between the five subsets, an Analysis of Variance (ANOVA) was performed. Results of the ANOVA indicate that the five subsets are not statistically different at the 95% confidence interval indicating that the three subsets are similar and that the testing interval can be extended to 5 km along Highway III. Results of the ANOVA for Case 3 are presented in Table 5.

Summary of Highway Level Analysis

Based on the results of the Analysis of Variance (ANOVAs), the skid testing interval can be extended from 1 km up to 5 km since there is no significant difference (at the 95% confidence interval) within each of the subsets for the three highway segments. This analysis demonstrates that reducing the skid testing interval along three independent highway sections results in similar friction levels to testing at an interval of 1 km. These results support the findings of the Network Level Analysis.

TABLE 5 Results of ANOVA for Highway Level Analysis

RESULTS OF ANALYSIS OF VARIANCE FOR HIGHWAY I

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38.021	4	9.505	0.547	0.701	2.431
Within Groups	2656.837	153	17.365			

RESULTS OF ANALYSIS OF VARIANCE FOR HIGHWAY II

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38.021	4	9.505	0.547	0.701	2.431
Within Groups	2656.837	153	17.365			

RESULTS OF ANALYSIS OF VARIANCE FOR HIGHWAY III

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	116.616	4	29.154	0.828	0.511	2.483
Within Groups	2885.78	82	35.192			

Group Level Analysis

For the Group Level Analysis, skid number values were categorized into three classes based on the following criteria;

- Poor: SN <31.5
- Fair: 31.5<=SN<=35
- Good: SN >=35.0

These levels were established based on a review of the TAC pavement design guide and using engineering judgement. A similar analysis approach to the previous two levels was performed to examine if the skid testing interval could be extended to 5.0 km for all highway segments. Skid data was grouped into the five subsets. A rating of Poor (1), Fair (2) or Good (3) was assigned to each skid number value. The group average was then calculated for each of the five subsets for all highways. Since the results of the network and highway level analysis showed that all subsets were not significantly different at the 95% confidence interval, it was expected that the group level analysis should produce similar results.

For this level, the rating of each subset was expected to be equal to the overall "subjective" rating of the highway segment. Presented above in Table 6 are a summary of each highway and the subjective rating of each subset and the overall highway. As can be seen in Table 6, for the 33 highway segments, 7 are categorized as "Fair" and 26 are categorized as "Good". In addition, only two of the highway segments (Highway 10 and 27) have the overall condition differing from one or more of the five subsets. The results of this analysis show that reducing the number of required skid tests does not result in an over-or under estimation of the friction levels along a highway segment.

TABLE 6 Group Level Analysis – Subjective Rating

Region	Highway	Subjective Rating					
		Subset	Subset	Subset	Subset 4	Subset 5	Overall
A	1	Fair	Fair	Fair	Fair	Fair	Fair
	2	Good	Good	Good	Good	Good	Good
	3	Good	Good	Good	Good	Good	Good
	4	Fair	Fair	Fair	Fair	Fair	Fair
	5	Good	Good	Good	Good	Good	Good
	6	Fair	Fair	Fair	Fair	Fair	Fair
	7	Fair	Fair	Fair	Fair	Fair	Fair
	8	Fair	Fair	Fair	Fair	Fair	Fair
	9	Good	Good	Good	Good	Good	Good
	10	Fair	Fair	Fair	Good	Good	Fair
B	11	Good	Good	Good	Good	Good	Good
	12	Good	Good	Good	Good	Good	Good
	13	Good	Good	Good	Good	Good	Good
	14	Good	Good	Good	Good	Good	Good
	15	Good	Good	Good	Good	Good	Good
	16	Good	Good	Good	Good	Good	Good
	17	Good	Good	Good	Good	Good	Good
	18	Good	Good	Good	Good	Good	Good
	19	Good	Good	Good	Good	Good	Good
	20	Good	Good	Good	Good	Good	Good
	21	Good	Good	Good	-	-	Good
	22	Good	Good	Good	Good	Good	Good
	23	Good	Good	Good	Good	Good	Good
	24	Good	Good	Good	Good	Good	Good
	25	Good	Good	Good	Good	Good	Good
	26	Good	Good	Good	Good	Good	Good
	27	Good	Poor	Fair	Good	Good	Fair
	28	Good	Good	Good	Good	Good	Good
	29	Good	Good	Good	Good	Good	Good
	30	Good	Good	Good	Good	Good	Good
	31	Good	Good	Good	Good	Good	Good
	32	Good	Good	Good	Good	Good	Good
	33	Good	Good	Good	Good	Good	Good

BENEFITS OF REDUCING NUMBER OF SKID TESTS

The results of this paper demonstrate that the skid testing interval can be extended from 1.0 km up to 5.0 km in length without jeopardizing the accuracy of the results for network level skid testing. All results were found to be statistically significant at the 95% confidence interval. By extending the skid testing interval, this results in a reduction in the number of required skid tests along a highway segment or network. This is a benefit to the transportation agencies, data collection providers, contractors, and most importantly the public.

Transportation Agency

Network level skid testing is an important tool that can be used to assess the level of safety of a highway network. Consultants typically collect data such as deflection or skid data by the test-point and charge agencies based on the number of tests performed. With a reduction in the total number of required test points, agencies are able to survey higher percentages of their networks more frequently. This savings will allow for resources to be allocated to project or detailed level skid testing at accident prone or “black spot” locations.

Data Collection Providers

The cost of skid testing is considerable in terms of equipment costs, operating and maintenance costs, staffing, mobilization, and training. If the number of required skid test points can be reduced, data collection providers can complete projects earlier and move on to their next assignments. This also reduces the wear-and-tear and depreciation of the skid testing equipment.

Contractors

As transportation agencies begin to shift the ownership and ultimate responsibility of their civil infrastructure assets such as highway networks to the private sector, contractors are going to be required to survey their networks on a regular basis. A reduction in the total number of tests is an obvious savings in costs and allows budgets to be spent on maintenance or other improvements.

DISCUSSIONS

The importance of network level testing to assess pavement performance is an essential component of any pavement management system. Skid testing is an important tool that can be used to assess the level of friction and safety of a highway network. It is important to note that the results of this research study should not be applied to other agencies highway networks. This is due to the obvious facts that the materials, traffic loadings, subgrade conditions, aggregate types, environmental conditions, etc. are all specific to this region of this study. Extrapolating the results from this study onto another agency’s highway network may result in an over or under estimation of the network level friction levels.

However, it is recommended that the analysis methodology or framework developed as a part of this research study be used to determine if the total number of skid test points can be reduced for another agency’s highway network. This analysis should be carried out on a year-to-year basis prior to the testing cycle.

CONCLUSIONS AND RECOMMENDATIONS

Based on this research study, the authors present the following conclusions and recommendations;

- Network level friction testing is an important component of any pavement management system and for determining the level of safety of a highway network. Therefore, it is recommended that skid testing be considered in any transportation agency’s data collection cycle. Network level friction testing should be carried out on an annual or bi-annual basis to screen the network and identify potential collision prone locations.
- This study provides a methodology or framework to examine if the skid testing interval can be reduced for a highway network. The results from this study indicate that the skid testing interval can be increased from 1.0 km to 5.0 km and provide statistically the same results at the 95% confidence interval.
- Reducing the number of skid test points results in an immediate savings to the transportation agency, the data collection providers, and contractors.
- It is important to note that the results from this study should not be extrapolated onto another agency’s highway network. However, the framework’s methodology developed as a part of this study can be used to determine if the skid testing interval can be reduced for another agency’s highway network.

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