EVALUATION OF ACCIDENT RATE-SKID NUMBER RELATIONSHIPS FOR A NATIONWIDE SAMPLE OF HIGHWAY SECTIONS

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The objective of this study was to establish the relationship between accident rate and skid number for various combinations of highway type, area type (urban/rural) and traffic volume. Accident rate, skid number and related data were collected for two, 1-year periods on 428 highway sections located in 16 states. An extensive statistical analysis of the data was conducted using matched-pair comparisons, regression analysis and analysis of covariance. The analyses found a small, but statistically significant, effect of skid number on wet-pavement accident rate. A linear relationship with skid number explained the variation in wet-pavement accident rate as well, or better, than any simple logarithmic or polynomial function. The differences in the slope of this linear relationship for various highway type-area type-traffic volume combinations were not statistically significant, so a single common slope was used. Specific relationships between wet-pavement accident rate and skid number are presented. It was found that the slope of the wet-pavement accident rate-skid number relationship is sensitive to the dry-pavement accident rate. The sensitivity was quantified and is presented in the paper. Finally, the accident rate-skid number relationships developed in this study are compared with the relationships developed by previous researchers.

Skidding accidents have become an increasing problem in the United States in recent years. One researcher (1) has indicated that skidding accidents account for more than one-third of all vehicle accidents in some geographic areas. This trend is undoubtedly a reflection of increased vehicle speeds and traffic volumes. However, despite the observed accident trend, there has been little hard evidence to relate accidents to the skid resistance properties of the pavement.

The objective of this study was to establish the relationship between accident rate and skid number for various combinations of area type (urban/rural), highway type, and traffic volume (2). Such quantitative relationships are needed to compare the effectiveness of improving skid number through resurfacing with the effectiveness of other skidding accident countermeasures.

Experimental Plan

Study Sections

Accident rate, skid number and related data were collected for 428 highway sections located in 16 states. One hundred forty-two (142) of these sections are test sections that were resurfaced during the study period. Resurfacing of the test sections enabled the study to examine each highway at two levels of skid number without any major modifications of geometric or traffic characteristics. Because temporal changes in accident rate are not uncommon, some form of experimental control was needed to assure that a general trend in accident rate was not mistaken for an effect of resurfacing. Therefore, a matched-control section, similar in physical and traffic characteristics, was selected for each test section. No alteration was made to the pavement surface of the control sections during the study period. In order to obtain an adequate sample size, data were also obtained for 144 unmatched-control sections. These sections were not resurfaced and were not matched to any particular test section. Table 1 shows the distribution of test, matched-control and unmatched-control sections by area type and highway type.

Table 1. Distribution of highway sections by area type and highway type.

Highway Type	Section Type	No. of Sections by Area Type Rural	Urban
Two-Lane	Test	94	6
	Matched Control	94	6
	Unmatched Control	87	6
		275	18
Multilane Uncontrolled Access	Test	16	6
	Matched Control	16	6
	Unmatched Control	18	6
		50	18
Multilane Controlled Access	Test	14	6
	Matched Control	14	6
	Unmatched Control	25	2
		53	14

Data Needs

Several kinds of data with a known or postulated relationship to accident experience or pavement surface characteristics were collected for each study section. These included:

- Highway type
- Area type (urban/rural)
- Average daily traffic volume
- Wet-pavement accident rate
- Pavement type
- Skid number
- Skid number - speed gradient
- 85th percentile speed of traffic
- Exposure to wet-pavement conditions
- Geometrics (curves, grades, intersections)

These data were collected with the cooperation of highway and transportation agencies in the states where the study sections were located. The 16 cooperating states were: California, Connecticut, Florida, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Washington and West Virginia.

Study Periods

Two data collection periods were used--before and after resurfacing of the test sections. Data were collected for all 428 study sections in the period before resurfacing of the test sections. Missing data in the after period reduced the number of useable sections to 378.

The before period for each test section was a 12-month period during the 24 months immediately prior to resurfacing. The after period was a 1-year period beginning at least 2 months after completion of resurfacing to allow the new pavement some initial traffic wear before any accident or skid number data were collected. The dates of the before and after period for each matched-control section were the same as its matching test section. The study period for the unmatched-control sections was determined by the dates of the available skid test results.

One major constraint in the selection of study periods was the energy crisis or gasoline shortage that began to have a pronounced effect on highway transportation in the United States during the Fall of 1973. This shortage resulted in a nationwide reduction of speed limits to 55 mph in late 1973 and early 1974, and was accompanied by a marked reduction in nationwide accident experience, especially fatalities. The initial effect of the gasoline shortage on travel and accident experience was probably not uniform throughout the 16 cooperating states because of regional differences in the price and availability of gasoline and in the date of the speed limit reduction. For this reason, all before data for the project, including accident data, were collected for a period before July 1, 1973. All after data were collected for a period after June 30, 1974.

Study Section Criteria

Great care was exercised in the selection of test and control sections for the study to assure that each section, although several miles in length, was homogeneous with respect to area type, highway type and ADT.

Test sections were selected from lists of resurfacing projects provided by the cooperating states. A minimum length for test sections was required to assure that each section had enough yearly wet-pavement accidents to carry out the planned statistical analysis. A minimum length of 4 miles was established from accident studies for sections on highways with ADT over 5,000. Sections as short as 2 miles were used on highways with ADT much greater than 5,000. In some states, very few sections with ADT over 5,000 were resurfaced, so it was necessary to select projects where ADT was less than 5,000. Minimum section lengths up to 6 miles were required in these cases.

A matched-control section was selected for each test section. The highway type and area type of matching test and control sections were identical and the ADT were matched within 20%. Whenever possible, the control section was at least as long as its matching test section.

Analysis Variables

The basic analysis variables used in the study were measures of accident rate and skid number. The following discussion presents the data gathered and the formulation used for each of these variables.

Skid Number

Skid resistance data for the study were obtained from locked-wheel skid trailer measurements made by the 16 cooperating states. The skid testing procedures used by the states generally accord with ASTM Specification E-274. Most project data were collected at the standard testing speed of 64 km/hr (40 mph). Each highway section was tested twice during the study--once in the before period and once in the after period.

Two-lane highways were skid tested in both directions of travel by 11 of the 16 cooperating states and in one direction only by the remaining five. All states tested multilane highways in both directions of travel. The testing frequencies used by the states ranged from 1 to 5 skid tests per mile. On multilane highways, only the results of skid tests conducted in the travel (right) lane were used in the analysis.

The skid trailers of 13 of the 16 cooperating states were calibrated during 1974 or 1975 at one of the three Field Test and Evaluation Centers established by the Federal Highway Administration in Ohio, Texas, and Arizona. The calibration relationships established by these centers were used to correct the raw skid data supplied by these 13 states. No correction was made to skid measurements made by trailers that were not calibrated. No correlations between the three FHWA centers were available in time to be used in this study.

The skid numbers of highway pavements are known to exhibit seasonal variations. However, these variations have not been adequately quantified in the literature as a function of climatic and pavement characteristics. For this reason, no adjustment for seasonal variation was made in this study. Also, no adjustment was made for the change in the ASTM standard test tire from 14 in. to 15 in. which occurred during the study. These factors remain as sources of residual variation in the data.

Two candidate measures of skid number for the highway sections were considered. The first was the mean skid number at 64 km/hr (40 mph), $\overline{SN40}$, adjusted in the manner described above. The second candidate measure was the mean skid number at the 85th percentile speed of traffic on each section, SN(85). It was postulated that, because most vehicles travel at speeds higher than 40 mph, the skid number at a higher speed might show a stronger correlation with accidents than SN40. To obtain SN(85), the skid number speed gradient (i.e., the slope of the skid number-speed curve) was estimated from photographs of the pavement surface of each section taken from a moving vehicle. The relationship used to calculate $\overline{SN(85)}$ from $\overline{SN40}$ is:

$$\overline{SN(85)} = \overline{SN40} - (V_{85} - 40)(0.52 - 0.06\ \bar{R}) \quad (1)$$

where $\overline{SN(85)}$ = Mean skid number at 85th percentile speed,

$\overline{SN40}$ = Mean skid number at 64 km/hr (40 mph),

V_{85} = Estimated 85th percentile speed of traffic for the section (mph), and

$\bar{R}$ = Mean gradient rating estimated from pavement photographs.

$\bar{R}$ is a pavement texture rating on a scale of 1 to 5 determined from pavement photographs. The quantity (0.52 - 0.06 $\bar{R}$) represents the skid number-speed gradient of the pavement. This gradient estimation technique was developed during the study and is presented in a recent paper by McDonald, Blackburn and Kobett (3). The 85th percentile speed of traffic on each section was estimated from spot speed data collected on typical highways of various types by 12 of the 16 cooperating states.

Simple regression analyses and analyses of covariance comparisons between SN40 and SN(85) found that SN40 had a much stronger correlation with accident experience than SN(85). For this reason, SN40 was used as the primary measure of skid resistance in the analyses.

Accident Rate

The primary sources of accident data for the study were the computerized accident records systems maintained by the 16 cooperating states. The project obtained listings that identified the location, date and pavement condition of each traffic accident that occurred on each section during the before and after periods. The study excluded accidents that occurred on roads that intersected the sections and accidents that occurred on interchange ramps, whenever such accidents could be identified. Such accidents were not included because no skid tests were conducted on either crossroads or interchange ramps and because traffic volumes for crossroads and ramps were not available.

An early decision was made to study all wet-pavement accidents rather than just those accidents identified as involving skidding. Only five of the 16 cooperating states were able to identify whether or not accidents involved skidding in their computer-generated accident data. Furthermore, there are obvious questions as to the completeness of the reporting of skidding involvement, even in those states which use this item. On the other hand, pavement conditions at the time of the accident are easily observed and universally reported. Although the study of wet-pavement accident experience was the focus of the project, dry-pavement accident experience was also analyzed for comparative purposes as described below. The wet-pavement accident data for the study sections were normalized with three factors: (1) section length, (2) exposure to wet-pavement conditions, and (3) traffic volume. The wet-pavement accident rate was calculated as:

$$AR = \frac{(N_w)(2.4 \times 10^7)}{(L)(E_w)(ADT)} \quad (2)$$

where AR = Wet-pavement accident rate (accidents/10^6 vehicle-kilometers or accidents/10^6 vehicle-miles)

N_w = Number of wet-pavement accidents during study period

L = Section length (kilometers or miles)

E_w = Exposure to wet-pavement conditions during study period (hours)

ADT = Average Daily Traffic (vehicles)

The dry-pavement accident rate was computed analogously as:

$$DAR = \frac{(N_d)(2.4 \times 10^7)}{(L)(E_d)(ADT)} \quad (3)$$

where DAR = Dry-pavement accident rate (accidents/10^6 vehicle-kilometers or accidents/10^6 vehicle-miles)

N_d = Number of dry-pavement accidents in study period

E_d = Exposure to dry-pavement conditions in study period (hours)

The ADT of each section was obtained from ADT maps, log books and other information provided by the cooperating states. The exposure to various pavement conditions was estimated from hourly weather records for a station near each section using a modification of a technique developed in NCHRP Project 6-11/1 (2,4).

Analysis of Accident Rate-Skid Number Relationships

An extensive statistical analysis was undertaken to examine the relationship between wet-pavement accident rate and skid number at 64 km/hr (40 mph). The basic types of analysis used were matched-pair comparisons, regression analysis and analysis of covariance. This section of the paper presents the highlights of the analysis approach and the results obtained. Further details are available in the complete report of this investigation (2).

Investigation of Non-Linearity

A preliminary analysis was made to determine whether a linear wet-pavement accident rate--skid number relationship should be used or whether the relationship was significantly non-linear. First, we examined possible log and log-log forms of the relationship. Several regressions were calculated with AR as a function of SN40 for rural, two-lane highways in the before period. The correlation coefficients for these regressions are given in Table 2. Neither the log nor the log-log form of the accident rate-skid number relationship fits the data significantly better than the simple linear form.

A polynomial relationship between wet-pavement accident rate and skid number was also considered. The data were divided into eight skid number ranges and a one-way analysis of variance was used to examine contribution of various polynomial terms to explaining the variation in wet-pavement accident rate.

Table 2. Correlation coefficients for linear, log and log-log regressions, for rural, two-lane highways in the before period.

Form of Relationship	Dependent Variable	Independent Variable	Correlation Coefficient (r)
Linear	AR	SN40	0.23075
Log	AR	log SN40	0.23990
Log-Log	log AR	log SN40	0.20108

The analysis of variance showed that the linear term had an F-ratio of 9.357, which is significant at the 99% confidence level. The quadratic and higher order terms were not significant.

Further analysis provided some indirect evidence that the wet-pavement accident rate-skid number relationship may be slightly non-linear, with a flatter slope at high than at low skid number. However, no simple functional relationship could be found that fit the data significantly better than a linear relationship. For this reason, a linear relationship was used in subsequent analyses.

Evaluation of Before-After Differences in Accident Rate

A matched-pair analysis of differences between before and after wet-pavement accident rates for the test and control sections was conducted to identify any time trend. A time trend in the control section accident rates was anticipated, because the beginning of the energy crisis and the national speed limit reduction, which are known to have affected nationwide accident rates, intervened between the before and after periods. A time trend in the test section accident rates (after any trend in the control section rates has been corrected for) would indicate an effect of resurfacing carried out on the test sections.

The first step in this evaluation was to examine the control sections for a time trend using the null hypothesis that the mean change in control section accident rate is zero:

$$H_o: \mu(C_{ai} - C_{bi}) = 0 \quad (4)$$

where C_{bi} = Control section accident rate for i^{th} section in before period, and

C_{ai} = Control section accident rate for i^{th} section in after period.

The mean wet-pavement accident rate for matched control sections in the before period is 1.86 accidents per million vehicle-kilometers (3.00 accidents per million vehicle-miles); the after period accident rate is 1.84 accidents per million vehicle-kilometers (2.97 accidents per million vehicle-miles). The sample mean difference in the before and after period rates is:

$$\hat{\mu}(C_{ai} - C_{bi}) = -0.02 \text{ accidents/MVKm}$$

which is not significantly different from zero ($t(129) = -0.09$). Therefore, there is no time trend in the wet-pavement accident data for the matched-control sections. This unexpected result indicates that events between the before and after periods, including the energy crisis, did not introduce a bias into the analysis.

The next step in the analysis was to examine the test section accident rates for a time trend using:

$$H_o: \mu(T_{ai} - T_{bi}) = 0 \qquad (5)$$

where T_{bi} = Test section accident rate for i^{th} section in before period, and

T_{ai} = Test section accident rate for i^{th} section in after period.

The mean wet-pavement accident rate for test sections in the before period is 2.11 accidents/MVKm (3.39 accidents/MVM); the after period accident rate is 1.90 accidents/MVKm (3.06 accidents/MVM). The sample mean difference in the before and after accident rates is:

$$\hat{\mu}(T_{ai} - T_{bi}) = -0.20 \text{ accidents/MVKm}$$

which is not significantly different from zero ($t(129) = -0.86$). Further statistical analyses that were conducted all supported the initial finding that there were no time trends in accident rate between the before and after periods. This finding serves as a justification for combining the before and after data to increase the available sample size in subsequent analyses. With the combined data set, 806 data points are available: 428 from the before period and 378 from the after period.

In interpreting the matched-pair analysis results, it should be kept in mind that there was virtually no change in the mean skid number for test sections from the before to the after period; i.e., on the average the skid number of test sections was not improved by resurfacing. Thus, it cannot be determined from the matched-pair before-after analysis whether or not there is a significant relationship between wet-pavement accident rate and skid number, because there was no change in the mean skid number brought about through resurfacing. Therefore, subsequent analyses used an analysis of covariance approach, because that type of analysis explicitly considers the skid number of each section both before and after resurfacing.

Influence of Area Type, Highway Type and ADT

Analysis of covariance is a statistical technique to examine the relationship between a quantitative dependent variable and one or more quantitative independent variables (known as covariates) within cells defined by levels of one or more non-quantitative factors. An analysis of covariance approach was used to examine the effect of factors area type, highway type and ADT on the relationship between wet-pavement accident rate (dependent variable) and skid number at 64 km/hr (independent variable) using the combined before and after data. The area type factor had two levels (urban and rural), the highway type factor had three levels (two-lane, multilane uncontrolled access, and multilane controlled access) and the ADT factor had two levels (under and over 10,000 vehicles per day).

The structure of an analysis of covariance that could be used to examine these factors was limited by the available sample. Only 50 of the 428 study sections were located in urban areas. Because of the small number of urban sections, it was not possible to examine the three-way interaction between the area type, highway type, and ADT factors explicitly. Instead, these factors were considered two at a time, in all possible combinations, and thus all three two-way interactions were evaluated.

The following results were obtained from this analysis. All three factors (area type, highway type and ADT) were significant and so were all of their two-way interactions. This indicates that each area type-highway type-ADT combination has a specific effect on the mean wet-pavement accident rate. The covariate, SN40, was significant in all three analyses. The correlation coefficients for the three analyses ranged from 0.28 to 0.43, indicating that much of the variation in accident rate is not explained by skid number or the other variables examined.

The analysis of covariance calculates an overall "common" slope for the wet-pavement accident rate-skid number (AR-SN40) relationship for each analysis framework. If the slopes of the AR-SN40 regression lines in the individual cells defined by the factors are tested and no significant difference is found, the common slope is the best estimate of the true slope in each cell. The slopes of the regression lines in individual cells were not significantly different in any of the three analyses conducted and the common slopes determined in each case are virtually identical: -0.0286 accidents per million vehicle-kilometers per skid number (-0.046 accidents per million vehicle-miles per skid number). Therefore, it is sufficient to assign the common slope to all AR-SN40 regression lines. However, the relationship in each cell will have a different intercept.

The magnitude of the common slope indicates that skid number does have a substantial effect on accident rate. For example, if the skid number of a highway was increased by 10 units, the wet-pavement accident rate would, on the average, be reduced by 0.286 accidents/MVKm (0.46 accidents/MVM), which is about 15% of the mean wet-pavement accident rate.

The results of the three analysis of covariance calculations were combined to obtain AR-SN40 predictive relationships for the 12 cells defined by two levels of area type, three levels of highway type, and two levels of ADT. These predictive relationships have the form:

$$AR-\overline{AR} = -0.0286\ (SN40-\overline{SN40}) \qquad (6)$$

in units of accidents per million vehicle-kilometers, and

$$AR-\overline{AR} = -0.046\ (SN40-\overline{SN40}) \qquad (7)$$

in units of accidents per million vehicle miles.

Specific values of $\overline{AR}$ and $\overline{SN40}$ for use in individual area type-highway type-ADT cells are given in Table 3. The family of wet-pavement accident rate-skid number relationships found for rural highways is illustrated in Figure 1 and for urban highways in Figure 2.

The reader is cautioned that the usefulness of these relationships for predicting the effect of skid number on the accident rate of a given highway in a given year is limited by the low correlation coefficients found in the analysis. The relationships do give an accurate estimate of the long-term expected value of accident rate, however. The predictive ability of the relationships can'be improved by employing them to predict accident rates for multi-year periods or for groups of similar highway sections.

Relationship Between Wet- and Dry-Pavement Accident Rate

Simple correlation analyses found a strong relationship between wet-pavement accident rate (AR) and dry-pavement accident rate (DAR), as expected. The overall correlation coefficient for the combined before and after data for all area types and highway types is 0.67.

The influence of dry-pavement accident rate on the wet-pavement accident rate-skid number relationship was investigated. It was postulated that, where dry-pavement accident rate was high, there would be more-than-average demand for skid resistance to avoid accidents. The analysis described below indicated that this postulate was generally true for rural and multilane uncontrolled access highway sections.

Table 3. Mean wet-pavement accident rate and skid number used in predictive relationships.

Area[a] Type	Highway[b] Type	ADT[c]	Mean Wet-Pavement Accident Rate (AR) (accidents/10^6 veh-km)	(accidents/10^6 veh-mi)	Mean Skid Number at 64 km/hr (40 mph) (SN40)
1	1	1	1.83	2.95	48.36
1	1	2	2.54	4.08	40.13
1	2	1	1.13	1.82	49.51
1	2	2	2.48	3.99	40.66
1	3	1	0.47	0.70	50.28
1	3	2	0.40	0.65	41.51
2	1	1	2.15	3.45	42.49
2	1	2	2.93	4.72	40.14
2	2	1	4.35	7.01	40.27
2	2	2	5.95	9.57	38.05
2	3	1	1.02	1.63	40.65
2	3	2	1.39	2.23	38.41
All Data			1.82	2.94	46.30

[a]Area Type: 1 = Rural; 2 = Urban.

[b]Highway Type: 1 = Two-Lane, Uncontrolled Access; 2 = Multilane, Uncontrolled Access; 3 = Multilane, Controlled Access.

[c]ADT: 1 = Under 10,000 veh/day; 2 = Over 10,000 veh/day.

Figure 1. Relationship between wet-pavement accident rate and skid number at 64 km/hr (40 mph) for rural highways.

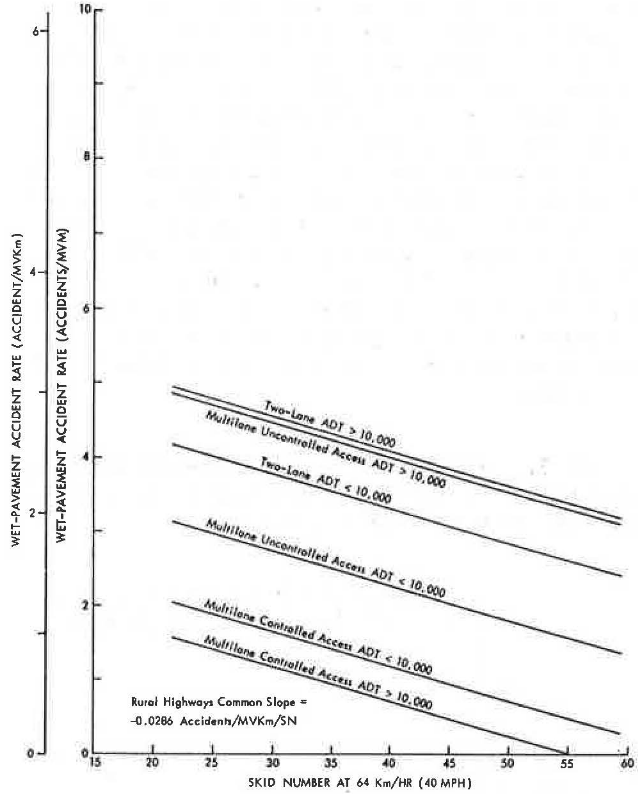
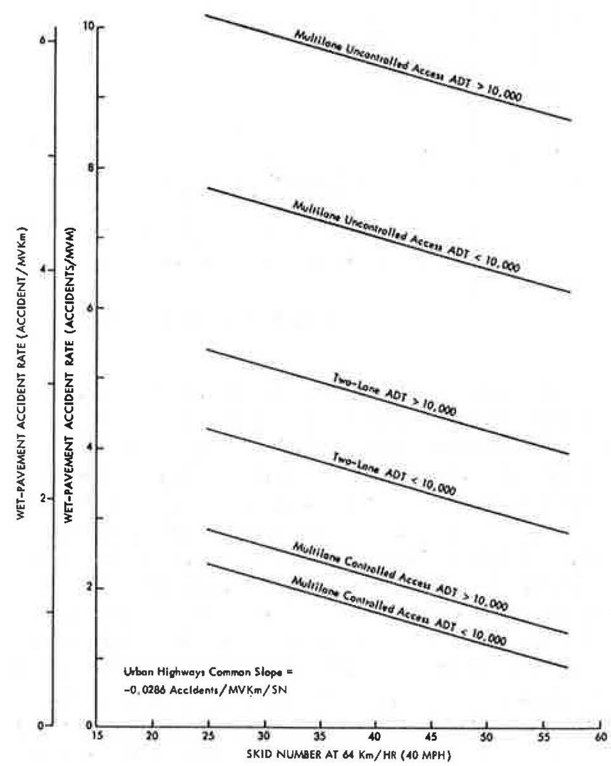
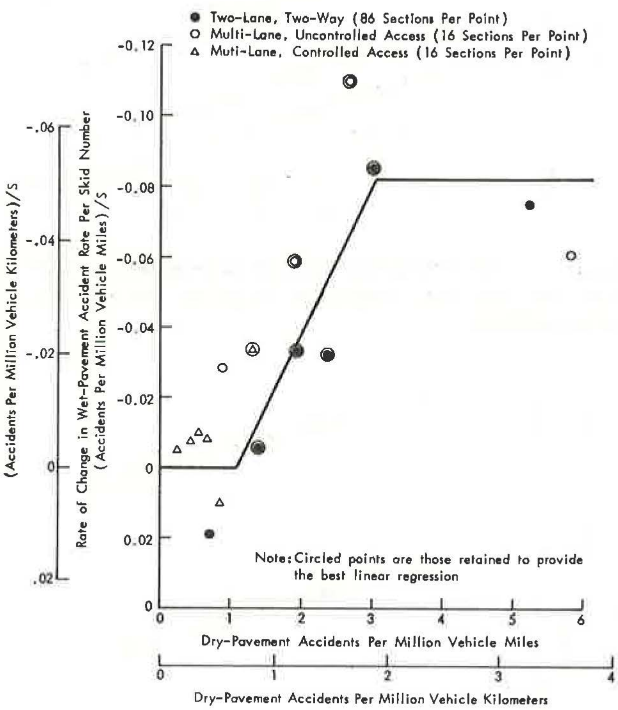


Figure 2. Relationship between wet-pavement accident rate and skid number at 64 km/hr (40 mph) for urban highways.



The dry-pavement accident rate was used as a factor with area type, highway type and ADT in several analyses of covariance. This analysis found that the wet-pavement accident rate-skid number relationship was sensitive to the level of dry-pavement accident rate. This sensitivity is illustrated by the analysis results in Figure 3. It was found that there is essentially no influence of skid number on accident rate for sections where the accident rate is very low. In the middle range, the slope of the AR-SN40 relationship changes from zero to -0.051 accidents per million vehicle-kilometer per skid number (-0.0825 accidents per million vehicle-mile per skid number). The slope of the AR-SN40 relationship reaches a maximum and becomes constant at high dry-pavement accident rate. This unanticipated finding was indicated at a high confidence level.

Figure 3. Rate of change of wet-pavement accident rate with skid number as a function of dry-pavement accident rate for rural highways.



The amount of variation explained by the dry-pavement accident rate is quite large. In fact, analyses of covariance with dry-pavement accident rate as the only factor and skid number as the only covariate, explained the variance of wet-pavement accident rate as well as the more complex multi-factor analysis described above. Because there is no direct causal relationship between wet- and dry-pavement accident rate, the observed sensitivity must represent the influence of factors related to the causation of both wet- and dry-pavement accidents. This finding suggests that factors such as highway geometry (horizontal curves, vertical grades, intersections, etc.) may influence the AR-SN relationship.

Comparison of Results with Previous Work

A series of studies were conducted by the Kentucky Department of Transportation to develop an accident rate-skid number relationship for two-lane highways and for multilane controlled access highways (5,6,7,8). These studies represent one of the few attempts, prior to the current study, to develop explicit accident rate-skid number relationships.

Figures 4 and 5 illustrate the difference in the form of accident rate-skid number relationships developed here and in the Kentucky studies. Figure 3 contains linear accident rate-skid number relationships developed here for rural multilane controlled access highways: with ADTs under and over 10,000. Figure 4 illustrates one of the non-linear relationships developed in the Kentucky study for the same highway type and area type. For comparison, the Kentucky results were converted to wet-pavement accident rates based on weather data for Boone County which indicated pavements were wet 20% of the time. The skid numbers are not directly comparable, because the Kentucky data were measured at 113 km/hr (70 mph), but the distributions have substantial overlap.

Figure 4. Accident rate-skid number relationships developed in this study.

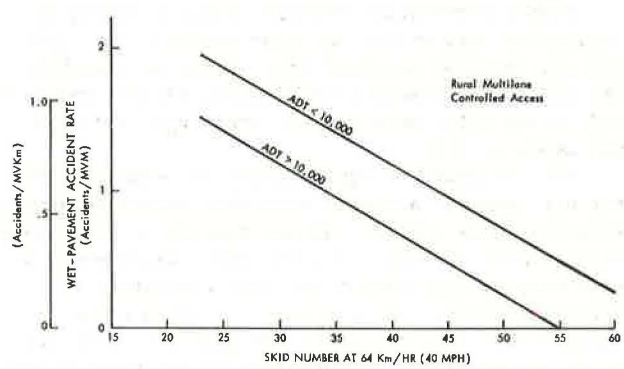
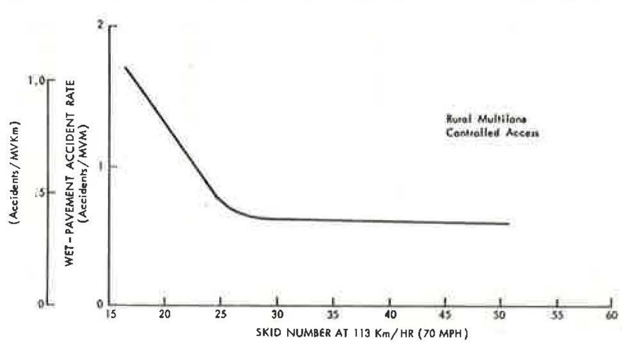


Figure 5. Accident rate-skid number relationship from Kentucky study (5).



The graphs in Figures 4 and 5 both have negative slopes and indicate a roughly comparable range of accident rates. The most obvious difference between the figures is the form of the accident rate-skid number relationship. The Kentucky study found a "critical skid number" in the wet-pavement accident rate-skid number curve. Above this skid number, the Kentucky curve has a very small slope; i.e., further improvement of skid number does not have much effect on accident rate. In contrast, the linear form developed here has no "break-point" or point of diminishing returns beyond which an improvement of skid number no longer produces a comparable decrease in accident rate. The "critical skid number" found by the Kentucky study is within the range of skid numbers used to develop the linear relationship in Figure 4. The slope of this linear relationship is greater than the slope of the Kentucky curve in the region above the "critical skid number." Thus, these two studies appear to conflict on whether or not a "critical skid number" exists in the low to medium range of skid number. If a "critical skid number" does exist, it is a logical minimum skid resistance requirement or, at least, a goal toward which pavements should be improved. If such a point does not exist, as the results developed herein imply, then the skid number of every pavement should be as high as possible.

These contrasting results are not necessarily in conflict, because entirely different analysis approaches were used in this and the Kentucky study. The current study used a formal statistical analysis to develop an accident rate-skid number relationship. The analysis showed that a linear relationship was the "best" only in the sense that there was no other simple function that fit the data significantly better. The Kentucky study used curve-smoothing techniques, such as the moving-average method, to develop the relationship graphically. Curve-smoothing techniques are also useful for examining such relationships, but they should not be misinterpreted as representing the "best" statistical relationship between the variables.

The best interpretation of these contrasting results is simply that the variability of accident rate is so great and dependent on so many factors other than skid resistance that several interpretations of the accident rate-skid number relationship are possible. The current study and the Kentucky study do not conflict in the basic strategy that a reduction of wet-pavement accidents can be accomplished through improvement of skid number.

The Kentucky data for two-lane roads also was interpreted by the authors (8) to indicate a break-point in the relation between accident rate and skid number. However, the break-point is present only in data for roads with ADT $\leq$ 2,701.

Additional sources in the literature indicated a break-point in the mid-range of typical skid numbers. This concurrance was noted in Kummer and Meyer's summary (9). It was difficult to make direct comparisons between such sources and the data reported here because a variety of dependent variables were used by investigators. However, it should be recognized that the data reported here were dominated by rural highway sections with further emphasis on the two-lane type. These data indicate that there is not a break-point in the accident rate-skid number curve within the range of typical skid numbers. This does not exclude the possibility that a break-point would be found for urban sections or for spot sites where the accident rate is not averaged over several geometric situations.

Conclusions

The following conclusions were drawn from the study:

1. There is a small, but statistically significant, inverse relationship between skid number and wet-pavement accident rate. However, the large variability of accident rate limits the usefulness of the relationship for predicting the accident rate for a given section for a given year.

2. The linear form for the wet-pavement accident rate-skid number relationship fits the data as well or better than any other simple function. Other research studies suggest the existence of a "critical skid number" or "break-point" in the accident rate-skid number relationship. No direct evidence of such a "break-point" was found in this study. Indirect evidence suggests that the relationship may be non-linear with a smaller slope at higher than at lower skid number.

3. Area type, highway type and ADT are factors with significant effects on the wet-pavement accident rate-skid number relationship. Predictive equations constructed from the analysis of covariance have a common slope, but a different intercept, in each cell defined by these factors.

4. The overall slope of the wet-pavement accident rate-skid number relationship is -0.0286 accidents/MVKm/SN (-0.046 accidents/MVM/SN).

5. The slope of the wet-pavement accident rate-skid number relationship is greater at high than at low dry-pavement accident rate, at least for rural two-lane and multilane uncontrolled access highway sections. A predictive relationship describing this sensitivity has been developed.

6. The sensitivity of the slope of the wet-pavement accident rate-skid number relationship to dry-pavement accident rate suggests the importance of other factors related to accident causation, such as highway geometrics.

7. The predictive ability of the accident rate-skid number relationships developed in this study can be increased through the use of multi-year accident rates and by use of the relationships for groups of sections rather than for individual sections.

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