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LOCATING SLIPPERY HIGHWAY SITES
BY ACCIDENT ANALYSIS

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by

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&

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Joint
Highway
Research
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PURDUE UNIVERSITY
LAFAYETTE INDIANA

Technical Paper

LOCATING SLIPPERY HIGHWAY SITES
BY ACCIDENT ANALYSIS

TO: K. B. Woods, Director
Joint Highway Research Project

June 8, 1960

FROM: H. L. Michael, Assistant Director
Joint Highway Research Project

File: 8-5-5

A technical paper entitled, "Locating Slippery Highway Sites by Accident Analysis" by V. G. Stover and H. L. Michael is attached. This paper was presented to the 46th Annual Purdue Road School in April 1960 at the research general session.

The paper is a summary of the material contained in the final report entitled, "The Location of Slippery Highway Sites by Accident Analysis" which was previously presented to the Board. It reports an economical and efficient method for locating slippery highway surfaces and for determining their priority for "deallicking". The method appears to be potentially important in Indiana and in other states in the attack on the slippery highway surface problem.

The paper is presented for the record and for release for publication in the Proceedings of the Road School and possibly in other technical publications.

Respectfully submitted,

Harold L. Michael

Harold L. Michael, Secretary

HLM:kmc

Attachment

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Technical Paper

Locating Slippery Highway Sites by Accident Analysis

by

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Joint Highway Research Project
File: 8-5-5
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Purdue University
Lafayette, Indiana

June 8, 1960

LOCATING SLIPPERY HIGHWAY SITES BY ACCIDENT ANALYSIS

INTRODUCTION

It is generally agreed that a wet pavement surface presents less resistance to skidding than does the same surface in a dry condition. It is also well known that ice and snow are very slippery, but on the other hand they are special conditions which do not reflect any skid characteristic of the pavement surface. It is, therefore, the wet surface condition that is critical relative to the minimum coefficient of friction that will be provided by a particular pavement surface.

In many instances a surface which does not indicate any particular difficulty with respect to skidding when dry will become quite slippery when wet and accidents as a consequence of slippery surfaces may result. The accident spot map of Indiana for 1958 is shown in Figure 1. Figure 2 shows the dry surface accidents occurring in a portion of Grant County during 1958. It is rather typical of the location of accidents occurring on dry surfaces anywhere in the state. There is a concentration of accidents on SR 9 south and west of Marion; however, there is no particular grouping of skidding accidents.

Figure 3 shows the same area of Grant County but indicates the wet surface accidents occurring in 1958. Here again there is a concentration of accidents on the heavily traveled portion of SR 9. However, a rather definite grouping of skidding accidents is now obvious at the junction of SR 9 and SR 15 as well as at the junction of SR 9 and SR 37. Although skidding was involved in several dry surface accidents throughout the shown portion of the county there was no indication that any sites were

FIGURE 1

LEGEND

● DRY SURFACE ACCIDENT
INVOLVING SKIDDING.

—— TOWNSHIP BOUNDARY

○ DRY SURFACE ACCIDENT,
SKIDDING NOT INVOLVED

PORTION OF GRANT COUNTY, INDIANA

FIGURE 2

LEGEND

- ▲ WET SURFACE ACCIDENT INVOLVING SKIDDING.
- WET SURFACE ACCIDENT, SKIDDING NOT INVOLVED.

— TOWNSHIP BOUNDARY

PORTION OF GRANT COUNTY, INDIANA

FIGURE 3

experiencing difficulty with respect to skidding. In Figure 3, however, it is noted that the wet surface accidents which involved skidding are clustered at those sites at which the drivers may have been required to make several difficult maneuvers and where the wet surface presented a reduced resistance to skidding that was below that necessary to complete the maneuvers safely. Skid tests conducted on SR 9 just north of its junction with SR 15 indicated an average distance to stop of 98 feet from 30 mph; a vehicle traveling at the average speed for this section of highway (40 mph) would require about 200 feet to stop.

It is not intended to convey the impression here that the road is the only part of the ~~driver-vehicle-road~~ system that contributes to skidding. It is, however, the only component over which the highway engineer has direct and substantial control. Moreover, by applying sound engineering practices to the highway it may be possible to minimize the deficiencies of the driver and the vehicle. The efficient and effective use of non-slippery highway surfaces for the purpose of reducing the number of accidents involving skidding requires that slippery sites at which accidents are occurring be identified and evaluated at the earliest possible date.

The ~~commonly-employed~~ field testing procedures (such as the stopping-distance method) effectively evaluate on a relative basis the skid resistance of the surfaces upon which the tests are conducted. They are, however, expensive and time consuming. Furthermore, some other method must be utilized to determine the locations that are suspected of being slippery and at which the field tests should be conducted. A procedure which would systematically evaluate the skid resistance of segments of the

entire highway system and which would indicate those sites which are "slippery" would be of considerable value. In the interest of economy it would be desirable if such a method would minimize the number of field tests required and would necessitate a minimum of labor.

The accident report files contain a wealth of information and it was this source that this study used. Previous investigations conducted in Great Britain (1, 2)*developed and utilized statistical methods for the analysis of highway sites having a low frequency of skidding accidents. After studies conducted at sites that had been so located and then "de-slicked" indicated a substantial reduction in skidding accidents as well as in total accidents (3).

SKIDDING IN REPORTED ACCIDENTS

The over-all problem of skidding in accidents occurring in 1958, as determined from the reported accidents on the state highways in ten counties of Indiana, is summarized in Table 1.

In order to compare the number of accidents by surface condition it is necessary to consider the amount of traffic which traversed these highways while the surfaces were dry, wet, or "icy" (i.e., covered with ice or snow). The number of vehicle-miles traveled under the different surface conditions is unknown and is impossible to obtain. However, there must be a relationship between the total number of accidents occurring while the surfaces were dry, or "icy" and the proportion of the time the surfaces were in each of these conditions as well as the amount of traffic using these facilities while these conditions prevailed. Therefore, if

* Numbers in parentheses refer to listings in the bibliography.

TABLE 1

SKIDDING AS A FACTOR IN REPORTED ACCIDENTS

1958 Data, Ten Counties in Indiana

Condition of Road Surface	Total Number of Accidents	Number of Accidents in which Skidding was Involved	Skidding* Rate
Dry	1776	713	41
Wet	779	469	60
Icy (i.e., covered with ice or snow)	275	199	72
Total	2830	1381	49

* The number of accidents involving skidding as a percentage of the total number of accidents.

the total number of accidents occurring while the surface was dry, wet, or "icy" is used as a measure of the exposure, a measure of the relative risk of skidding can be obtained by comparing the skidding rate (i.e., the percentage of accidents involving skidding).

The rather high skidding rate on dry surfaces is not surprising since most vehicles have braking systems of sufficient capacity to lock the wheels (4). Such locking is especially true when the driver perceives an accident as being imminent and attempts a "panic stop" and/or when the brakes are improperly adjusted. The skidding rate on wet surfaces, however, is considerably higher than on dry surfaces and it is still higher when the surface is "icy".

EVALUATION OF LOW FREQUENCY ACCIDENT SITES

The skidding rate is a useful method of indicating the relative risk of skidding on dry, wet, and "icy" surfaces because a large number of accidents have occurred. The accident frequency of the vast majority of specific sites is quite small, however, and some other method is necessary to consider the effect of chance occurrence and to determine when the frequency of skidding accidents is excessive. Such a method must also enable the highway engineer to determine when the frequency of skidding accidents is greater than some acceptable standard on some other length of highway. Statistical methods enable the solution of problems of this nature.

The statistical analysis used in this study is based on the binomial distribution which is a statistical distribution of occurrences which exhibit a particular characteristic which might be classified as either a success or a failure. With respect to skidding accidents this characteristic is skidding; an accident which did not involve skidding can be classified as a success and an accident in which skidding was involved can be classified as a failure. The minimum percentage of accidents in which skidding was, in all probability, involved can be calculated; this value will be referred to as the significant skidding rate or the SSR. In other words the long term value of the skidding rate is, in all probability, at least as large as the calculated SSR.

As an example of the necessity for utilizing this procedure for comparing low accident frequencies let us consider two sites, both of which have the same skidding rate. Such a situation is illustrated in Figure 4; 'n' is the total number of accidents which occurred when the surface was wet, and 'X' is the number of these accidents in which skidding occurred.

SITE "A" $n = 2$ $X = 2$

SKIDDING RATE = 100%

SIGNIFICANT SKIDDING RATE = 15%

SITE "B" $n = 4$ $X = 4$

SKIDDING RATE = 100%

SIGNIFICANT SKIDDING RATE = 45%

THE SIGNIFICANCE OF LOW ACCIDENT FREQUENCIES
GRAPHICALLY REPRESENTED

FIGURE 4

In the case of site "A" two out of two wet surface accidents involved skidding; therefore, the skidding rate is 100 percent. However, the two out of two may be due to chance, and we can only say, at the 5 percent significant level, that 95 percent of the time (19 times out of 20) we would expect the true long term skidding rate at this location to be at least 15 percent. It might be as high as 100 percent, but the chances are small (one chance in 20) that it is less than 15 percent. In the case of site "B" four out of four wet surface accidents involved skidding; thus, the skidding rate for this site is also 100 percent. However, since the frequency is higher (i.e., there are more accidents involved) we can determine the minimum value that the long-term skidding rate will have within narrower limits (i.e., the effect of chance occurrence is less). The SSR for this site is 45 percent. Here again the true skidding rate might be as high as 100 percent but the chances are only one in 20 that it is less than 45 percent. Thus, we see that the SSR is dependent upon the accident frequency and is in reality the lower confidence limit for the skidding rate.

As an aid in determining the SSR Table 2 has been prepared for a wide range of accident frequencies. Tables of the Cumulative Binomial Probability Distribution (5) were used to calculate the values indicated in the table and are for the five percent significance level. The table is most easily used by entering the table with the number of wet-surface accidents involving skidding (column X), then reading horizontally to the column farthest to the right which has a number larger than the total number of wet surface accidents which occurred. The SSR is then given at the top of this column. For example, if a total of seven wet surface accidents occurred and four

TABLE 2

TABLE FOR THE DETERMINATION OF THE SIGNIFICANT SKIDDING RATE

Number of Wet Surface Accidents Which Skidding Occurred X	The Skidding Rate* is significantly greater than the percentage given at the top of the column if the total number of wet surface accidents is less than that given in the body of the table.															Number of Wet Surface Accidents in Which Skidding Occurred X
	2%	4%	6%	8%	10%	12%	14%	15%	20%	25%	30%	35%	40%	45%	50%	
2	19	10	7	5	4	4	3	3	---	---	---	---	---	---	---	2
3	42	22	15	11	9	8	7	7	5	4	4	4	---	---	---	3
4	69	35	24	18	15	13	11	10	8	7	6	5	5	5	---	4
5	100	51	34	26	21	18	16	15	11	10	8	7	7	6	6	5
6	132	67	45	34	28	24	20	19	15	12	11	9	9	8	7	6
7	166	84	57	43	35	29	25	24	18	15	13	11	10	10	9	7
8	201	101	68	52	42	35	31	29	22	18	15	14	12	11	10	8
9	236	119	80	61	49	41	36	34	26	21	18	16	14	13	12	9
10	273	138	93	70	57	48	41	39	30	24	21	18	16	15	14	10
11	310	157	105	80	64	54	47	44	33	27	23	20	18	17	15	11
12	348	175	118	89	72	60	52	49	37	30	26	23	20	18	17	12
13	387	194	131	99	80	67	57	53	41	34	29	25	22	20	19	13
14	426	214	144	109	87	73	63	59	45	37	31	27	24	22	20	14
15	465	234	157	119	95	80	69	65	49	40	34	30	26	24	22	15

TABLE 2 CONTINUED

X	2%	4%	6%	8%	10%	12%	14%	15%	20%	25%	30%	35%	40%	45%	50%	X
16	504	252	170	128	103	87	75	70	53	43	37	32	29	26	24	16
17	543	272	183	138	112	93	81	75	57	47	40	34	31	28	25	17
18	582	293	197	148	120	100	86	81	61	50	42	37	33	30	27	18
19	623	313	209	159	128	106	92	86	65	53	45	39	35	31	29	19
20	664	334	224	169	135	113	98	92	70	57	48	42	37	33	31	20
21	706	354	237	179	144	121	103	97	74	60	51	44	39	35	32	21
22	748	375	251	190	152	125	110	102	78	63	54	47	41	37	34	22
23	788	396	265	200	161	134	115	108	82	67	56	49	43	39	36	23
24	829	417	279	209	169	142	122	113	87	70	59	51	46	41	38	24
25	871	438	292	221	177	148	128	120	91	73	62	54	48	43	39	25
26		459	307	230	186	157	134	125	95	77	65	56	50	45	41	26
27		480	321	242	194	163	140	131	99	81	68	59	52	47	43	27
28		501	335	251	202	170	146	136	103	84	71	61	54	49	45	28
29		519	349	263	210	177	152	142	107	87	74	64	57	51	46	29
30		542	364	273	220	184	158	148	111	91	77	66	59	53	48	30
31			378	284	227	191	164	154	116	94	80	69	61	55	50	31
32			392	295	236	198	171	160	121	98	82	71	63	57	51	32
33			406	305	245	204	177	165	125	101	85	74	65	59	54	33

TABLE 2 CONTINUED

X	2%	4%	6%	8%	10%	12%	14%	15%	20%	25%	30%	35%	40%	45%	50%	X
34		421	316	253	211	183	171	130	104	88	76	68	61	55		34
35		435	327	263	220	189	177	133	107	91	79	70	63	57		35
36			338	270	226	195	183	138	111	94	81	72	65	59		36
37			349	281	233	202	188	142	114	97	84	74	67	61		37
38			361	288	242	206	194	147	118	100	87	77	69	63		38
39			370	297	248	212	201	151	122	102	89	79	71	64		39
40			382	306	255	221	205	155	125	105	92	81	73	66		40
41				315	263	225	210	161	129	108	94	83	75	68		41
42				324	270	231	217	164	132	111	97	85	77	70		42
43				332	278	240	223	169	136	114	99	88	79	72		43
44				342	285	245	228	173	140	117	101	90	81	73		44
45									143	121	103	92	83	75		45
46									147	123	106	95	85	77		46
47									151	126	109	97	87	79		47
48									154	130	112	99	89	81		48
49									157	132	114	101	91	83		49
50									162	135	116	102	93	84		50

* At the 0.05 level of significance (i.e., there is only one chance in twenty that the true skidding rate is less than that indicated).

of these involved skidding, one enters column X with four and reads horizontally to the last column containing a number larger than seven, which in this case is eight; the number at the top of this column gives the SSR as being 20 percent. This means that 19 times out of 20 the true long term percentage of wet surface accidents at this location which involve skidding is at least 20 percent.

APPLICATION OF THE METHOD

This method of analysis was applied to all the State and US marked routes in ten counties of Indiana; county roads were not included because many of them have gravel surfaces and were therefore outside the scope of the study. The SSR was determined for each accident cluster (i.e., a site where numerous accidents occurred) and for each road length, a road length being a numbered highway route throughout one township.

Table 3 shows the results of the road length analysis and indicates that a few of the roads are causing the bulk of the skidding problem. Similar results were obtained for the accident cluster analysis.

TABLE 3

DISTRIBUTION OF ROAD LENGTHS ACCORDING TO THE SSR

Significant Skidding Rate	Number of Road Lengths
50	9
40	7
30	16
20	14
10	46
0	<u>175</u>
Total =	267

In order to check the effectiveness and the reliability of the SSR as a measure of the slipperiness of the surface, field skid tests were conducted on a sample number of locations. These sample locations were selected by statistical means which insured that the results obtained truly represented all of the road lengths (6).

The skid tests were conducted with the State Highway Department of Indiana skid vehicle (7). This vehicle has an electrically-activated, vacuum-braking unit and thus eliminates driver variation in the application of the brakes. It is also equipped so as to record the speed at which the vehicle was traveling when the brakes were applied and the distance required to stop. All tests were conducted on a thoroughly wet surface from 30 mph.

Upon the completion of the field skid testing the data were plotted as scatter diagrams. Visual inspection and some knowledge of the traffic conditions at the various locations indicated that speed and volume might be two additional factors which affect the SSR. Therefore, the over-all speeds were obtained for the sample locations by the license plate method (8). Although the speed data were obtained under dry rather than wet pavement conditions it is felt that little, if any, appreciable error is involved. Previous investigations (9) have found that even though speeds do drop when a rain-fall first begins, the drivers soon return to their former speed, provided that the intensity of rain-fall is not sufficient to cause a reduction in visability. The traffic volumes were obtained from the 1958 traffic flow map and the speed and volume factors were evaluated. The resulting scatter diagrams of the relationship between the SSR and the stopping distance, average speed and daily volume are

shown in Figures 5, 6 and 7, respectively, for the accident cluster analysis. Similar charts were obtained for the road length analysis.

The results of a correlation analysis for the accident cluster data is summarized in Table 4.

TABLE 4

SUMMARY OF THE CORRELATION ANALYSIS
FOR THE ACCIDENT CLUSTER DATA

Factors Correlated	Correlation Coefficient	Significant at the 0.05 Level
SSR - Slipperiness of the surface	$r_{y1} = 0.76$	yes
SSR - mean over-all speed	$r_{y2} = 0.27$	no
SSR - ADT	$r_{y3} = 0.58$	yes
SSR - Slipperiness of the surface, mean over-all speed, and ADT	$R = 0.86$	yes

Although the correlation between the SSR and the mean over-all speed is not significant, visual inspection of the center portion of Figure 6 indicates a relationship between these two factors at some speeds. Further analysis indicated significant positive correlation between these two factors for the values of the SSR between five and 35.

In the examination of the simple correlation coefficients (the r_{y1} values) it must be remembered that they are a measure of the dependence between the two factors under consideration and may include influence of other variables. The multiple correlation coefficient (R) is perhaps more

SCATTER DIAGRAM OF THE DISTANCE REQUIRED TO STOP
AND THE SIGNIFICANT SKIDDING RATE BY ACCIDENT CLUSTER

SCATTER DIAGRAM OF THE MEAN OVER-ALL SPEEDS
AND THE SIGNIFICANT SKIDDING RATE BY ACCIDENT CLUSTER

SCATTER DIAGRAM OF THE AVERAGE ANNUAL DAILY TRAFFIC
AND THE SIGNIFICANT SKIDDING RATE BY ACCIDENT CLUSTER

valuable since it measures the degree of linear association between all the factors under consideration. The square of this coefficient is the portion of the total variation in the SSR (74 percent) that is dependent upon the distance required to stop, the mean over-all speed, and the ADT.

POSSIBLE PROCEDURES FOR A STATE-WIDE ROUTE SKID ANALYSIS

The question which now arises is: How might this procedure be utilized for the analysis of the paved streets and highways of a state? The first step necessary for locating slippery sites is to obtain the following information:

1. The total number of accidents which occurred when the pavement was wet.
2. The number of these accidents in which skidding was involved.
3. The locations at which these accidents occurred.

No differentiation should be made between skidding before and after braking; that is, the number of accidents in which skidding was involved should be the total number of accidents in which skidding, before and after braking, occurred.

The accident spot map is the best method for recording skidding accident data. With appropriate identification this information could be plotted on the accident map currently prepared in Indiana and in many other states. Visual inspection would then reveal those locations at which skidding accidents are grouping. A state-wide analysis could be performed as often as desired and individual troublesome locations could be analyzed as they become apparent.

As noted in Figure 1 this map is often some-what crowded. Therefore, it may be advantageous to maintain a separate map for wet surface accidents. It would then be a very simple matter to differentiate between those accidents which involved skidding and those which did not. This would necessitate a minimum of information on any one map and would, therefore, simplify initial visual inspection. The additional time required to plot the information necessary for a route skid-analysis would be quite nominal.

A separate location map for wet surface accidents might also be adapted so as to show the previous twelve months accidents rather than just those occurring since January 1st of any particular year. For example, this might be done by using pins with the numbers "1" through "12" on their heads to indicate the month in which the accident occurred. With such a system, the map could be studied to determine if any cluster existed at the end of each month and the pins representing the accidents which occurred during the earliest month of the preceeding year would then be removed. Such a procedure would permit an analysis with a full twelve months accident history at the end of each month and at any time for a minimum of eleven months.

For most efficient results, accurate information as to the location of the accident is required and care must be exercised when plotting the accident. For example, since the analysis should indicate which of the approaches to an intersection is slippery, the location of each accident must be accurately reported and plotted so as to indicate the proper approach on which the accident occurred instead of simply indicating that an accident occurred at a given intersection. Similarly, indication should be made as to the roadway on which each accident occurred on a multi-lane divided highway since one roadway may be "slick" while the other is not.

The greater the accuracy in reporting and plotting of the accidents the more accurately a cluster can be determined and, therefore, the shorter the length of highway that needs to be "de-slicked". Figure 3 shows the wet surface accidents which occurred in a portion of Grant County. Although a considerable length of SR 9 is probably slippery, the "de-slicking" of the approaches to the intersections of SR 9 with SR 15 and SR 9 with SR 37 could substantially reduced the problem of skidding as well as the total number of accidents in this area.

When the resistance to skidding is increased to a previously slippery site, this fact should be clearly noted. Accidents occurring after the corrective measure has been completed would continue to be plotted and the effectiveness of the "de-slicking" should be evaluated. The same procedure should be followed when any portion of a highway has had its surface characteristics changed through resurfacing in reconstruction.

The most beneficial results for the smallest expenditure of funds can be realized by the proper "de-slicking" of rather limited lengths of highway which have been identified as being slippery and troublesome by this method of accident report analysis.

RESULTS, CONCLUSIONS AND RECOMMENDATIONS

Several interesting and valuable results were obtained from the investigation; the more important are as follows:

1. There is an extremely good correlation between the SSR and the slipperiness of the surface as measured by the stopping-distance method. Therefore, the SSR is a reliable measure of the relative slipperiness of the wet highway surfaces.

2. There is a significant correlation between the SSR and ADF.

The importance of this relationship is that the SSR inherently involves a consideration of the traffic volume. Therefore, separate study of the traffic volumes on the various facilities is not necessary when determining the priority that a particular section should be given for the application of a "de-skidding" treatment. Priority should be given to those sites which have the highest significant skidding rate.

3. Regardless of speed, skidding occurs in an extremely high percentage of wet surface accidents when a wet surface provides a low resistance to skidding. Conversely, a very low percentage of wet surface accidents will involve skidding if a wet surface exhibits a uniformly high resistance to skidding. In the region between these two limiting conditions there is a relationship between speed and skidding.

4. The use of the accident cluster is superior to using the road length. Better correlation between the SSR and the various factors affecting skidding can be expected when accident clusters are used. Furthermore, an analysis using the accident cluster will facilitate greater economy because shorter and more specific sites will be indicated as being in need of "de-skidding" treatment.

5. A location map of wet surface accidents is recommended as the most practical, flexible, and simplest method of identifying wet surface accident clusters and for obtaining the information necessary for performing an analysis utilizing this method.

The more accurately accidents are reported and plotted the more detailed the information obtained and, therefore, the greater the economy of the "de-slicking" operation.

6. It is recommended that slippery locations on the state highways of Indiana be determined at least once a year by the method just discussed and that high priority be given to proper "de-slicking" of these locations.

BIBLIOGRAPHY

1. Giles, C. G., and Sabley, Barbara E., "Accident Reports and Skidding Accident Sites," A Reprint from The Public Works and Municipal Works Congress, November, 1956.
2. Sabley, Barbara E., "Accident Reports as a Guide to Slippery Lengths of Road," A Reprint from Roads and Road Construction, July, 1956.
3. The Report of the Road Research Board with the Report of the Director of Road Research, Road Research 1955, Department of Scientific and Industrial Research, p. 21, 1956.
4. Petring, F. William, "Stopping Ability of Motor Vehicles Selected from the General Traffic," Public Roads, Vol. 29, No. 8, p. 195, June, 1957.
5. The Staff of the Computational Laboratory, "Tables of the Cumulative Probability Distribution," The Annals of the Computation Laboratory of Harvard University, Vol. XXXV, Harvard University Press, 1955.
6. Ostle, Bernard, Statistics In Research, The Iowa State College Press, 1954.
7. Michael, H. L., and Grunau, D. L., "Development of Skid Testing in Indiana," Report No. 13, Joint Highway Research Project, Purdue University, 1956, also Bulletin No. 139, Highway Research Board, 1956.
8. Walker, William P., "Speed and Travel Time Measurement in Urban Areas," Bulletin No. 156, Highway Research Board, 1956.
9. Stohner, Walter R., "Speeds of Passenger Cars on Wet and Dry Pavements," Bulletin No. 139, Highway Research Board, 1956.