Driver Behavior and Highway Conditions As Causes of Winter Accidents

THEODORE W. FORBES and MILTON S. KATZ
American Institute for Research, Pittsburgh, Pennsylvania

A specialized segment is reported from research sponsored by the Pennsylvania Turnpike Commission on human and physical factors as causes of Turnpike accidents. State police accident reports are coded and analyzed continuously by IBM punchcard technique, thus furnishing indications of trends and clues and data for special studies.

Analysis by 3-month periods of the various physical and driver behavior factors showed "inadequate coping with road conditions" involved in a higher percentage of passenger-car-responsible than in truck-responsible accidents, especially in the fall and winter quarters. Further comparisons indicated that many of these accidents occurred on snowy and icy highway after the weather had cleared. These results indicated the importance of immediate cindering and the elimination of winter road conditions. The Pennsylvania Turnpike Commission instituted improved maintenance and enforcement procedures to accomplish reduction of the hazard.

A special study of driver behaviors and locations was undertaken to isolate possible combinations of driver behavior, weather, and road characteristics which contributed more than their share of winter road condition accidents. It was necessary to correct for traffic volume and exposure to winter weather conditions. Estimates of traffic volumes in each direction and of percentage of time exposed to winter road conditions were developed for each 10-mile strip of highway. Contingency analyses tested for greater-than-expected relationships between various factors, such as grade and curve combinations and accidents. Certain 10-mile segments showed a rate per million vehicle miles from five to ten times as high as other 10-mile segments. Eastbound and westbound accidents on the same segment often differed, and certain stretches in the mountain area showed the highest rates. On the basis of exposure to winter road conditions, such stretches showed higher than expected values under icy conditions but not necessarily under other conditions.

Use of the correction factors for exposure showed the hazards for the ordinary motorist to be much greater under the winter road conditions, even though the total number of accidents was often greatest for dry roadway on an over-all basis. Relationships of different driver behaviors and other factors in accidents under the different road conditions were analyzed. A further study is under way to investigate further underlying causes for the relationships indicated.

●IN research on accident causes for the Pennsylvania Turnpike Commission, analysis of state police reports on Turnpike accidents is carried out by IBM punchcard techniques. Comparisons by three-month periods furnish indications of trends and clues for further studies of special problems and factors in the causation of accidents. It also makes data available for the conduct of special studies. The accident reporting of the Turnpike Troop of the Pennsylvania State Police is of very good quality and includes both the usual type of standardized accident report and an additional statement from drivers and from the investigating officer summarizing any special features.

The uncorrected figures in analyses of fall and winter quarter accidents indicated that driver behavior coded as "inadequate coping with road conditions" was involved in a higher percentage of passenger-car-responsible than in truck-responsible accidents. Totals indicated that more accidents occurred on icy highway than under snowing and sleeting weather conditions; that is, many must have occurred after the storm had cleared. These results suggested the importance of immediate cindering, clearing

snowy and icy road conditions, and warning of motorists. The Pennsylvania Turnpike Commission instituted maintenance and enforcement procedures to accomplish reduction of the hazard in February 1956.

In the meantime, a further study of relationships in these winter accidents was undertaken to investigate combinations of driver behavior, weather, and road conditions. This study, utilizing corrections for exposure in terms of motor vehicle miles and percentage of winter road conditions pointed to relationships between driver behaviors and physical factors and further indicated the importance of reducing winter hazards and improving driver behavior. It furnishes a basis for evaluating results by later comparisons.

Analyses using the corrections for exposure confirmed and strengthened the interpretation which had been made on the basis of raw percentages obtained quarter by quarter. A double sort of the passenger car accident punch cards for the 1954-55 winter[1] by dry, wet, and icy road conditions and then by clear, raining, and snowing weather conditions, showed interrelationships as follows:

A double breakdown of uncorrected figures gives the over-all number of accidents. Table 1 shows mainline passenger-car-responsible accidents and truck-responsible accidents in which two-fifths of the passenger car accidents in clear and cloudy weather occurred on icy highway, but only about one-fifth of truck accidents. The largest proportion of snowy, sleeting, and rainy-weather accidents were on icy highway, as would be expected. Clear-weather dry-highway accidents were more numerous than expected on a relative proportions basis without correction for exposure, a finding often reported in many analyses.

TABLE 1

WEATHER CONDITIONS

Comparison of Accidents Under Various Winter Road Conditions
(Expected Values in Parenthesis Based on Marginal Proportions)

Weather Conditions	Road Conditions at Time of Accident							
	Passenger Cars				Trucks			
	Dry	Wet	Icy	Total	Dry	Wet	Icy	Total
Clear and cloudy	156 (83.4)	30 (49.5)	105 (158.0)	291	83 (56.5)	9 (19.9)	23 (38.6)	115
Raining	0 (22.1)	61 (13.1)	16 (41.8)	77	1 (11.8)	17 (4.2)	6 (8.0)	24
Snow, sleet, and freezing rain	4 (54.5)	4 (32.3)	182 (103.3)	190	1 (16.7)	4 (5.9)	29 (11.4)	34
Total	160	95	303	558	85	30	58	173
	Chi-Square = 433.37 df = 4 p < .01				Chi-Square = 116.63 df = 4 p < .01			

The clear-weather dry-road accidents, however, were actually fewer than expected when exposure in terms of motor vehicle mileage on each road condition was used. Table 2 shows resulting figures comparable to those of Table 1, but with expected accidents calculated on the basis of estimated exposure. The much greater hazard presented by icy highway and by wet highway during rain is shown by this table. Note that accidents on icy highway were two to nine times as numerous as expected, but on dry highway were less than expected.

[1] October through December 1954, and January through March 1955.

TABLE 2

WEATHER CONDITIONS

Comparison of Accidents with Expected Accidents Under Various Winter Road Conditions (Expected Values Based on Percentage of Motor Vehicle Miles on Each Road condition)

Weather Conditions	Road Conditions at Time of Accident							
	Passenger Cars				Trucks			
	Dry	Wet	Icy	Total	Dry	Wet	Icy	Total
Clear and cloudy	156 (203.6)	30 (57.8)	105 (29.6)	291 (291.0)	83 (80.2)	9 (23.2)	23 (11.5)	115 (114.9)
Raining	0 (53.9)	61 (15.3)	16 (7.8)	77 (77.0)	1 (16.7)	17 (4.8)	6 (2.4)	24 (23.9)
Snow, sleet and freezing rain	4 (132.9)	4 (37.7)	182 (19.4)	190 (190.0)	1 (23.7)	4 (6.9)	29 (3.4)	34 (34.0)
Total Expected	160 (390.4)	95 (110.8)	303 (56.8)	558 (558.0)	85 (120.6)	30 (34.9)	58 (17.3)	173 (172.8)
	Chi-Square = 1,933.4				Chi-Square = 287.2			
	df = 4				df = 4			
	p < 0.001				p < 0.001			

ANALYSIS BY 10-MILE SEGMENTS

Accident rates of mountain area segments were several times as high as those of eastern and western areas. Analysis of western, mountain and eastern sections of the Turnpike by 10-mile segments was made and an accident rate per million vehicle miles was calculated. The rate varied markedly between 10-mile segments as shown in Table

Much higher passenger car accident rates on icy highway were found in each area, however, as shown by Table 4. The higher rates for 10-mile segments in the mountain area in the previous table may have resulted from a larger proportion of exposure to winter road conditions in these areas. Therefore, from weather reports[2], estimates were made of the proportion of the time winter weather and roadway conditions were experienced on each segment. From these, expected numbers of accidents were calculated and compared with the actual number reported.

Segments with definitely higher-than-expected accident frequency were shown largely for icy highway in or near the mountain area. On this basis (which might not hold in other seasons) wet and dry conditions showed very few segments with higher than expected experience. Several 10-mile segments, however, in the foothill and mountainous area did show considerably greater than expected experience under icy conditions and wet conditions (Tables 5 and 6). The superscript numbers show the 10-mile segments where reported accidents were much greater than expected from vehicle mileage and winter road condition exposure.

Certain of these segments involved down-grade in one direction, and not in the other, which may account for the fact that the higher-than-expected segments were not in all cases the same for eastbound as for westbound initiating vehicle. Although the mileage of different road elements was not available for each 10-mile section, an over-all analysis was made based on total vehicle mileage and estimated proportion of the total highway represented by curve and grade combinations. This indicated that on icy highway, "straight-and-level" and "right-curve, down-grade" were higher than expected but not "left-curve, down-grade" taking the highway as a whole. Two other combinations of grade and curve showed somewhat higher than expected accidents. A more detailed

[2] Filed at Turnpike radio headquarters and made available through the courtesy of the Turnpike Commission staff.

TABLE 3

ACCIDENTS AND RATES BY 10-MILE HIGHWAY SEGMENTS
(Rates Per Million Vehicle Miles, Passenger Cars)

Total Vehicle Miles, 1,000's	Number	Rate
	(a) Western	
7,724	8	1.04
8,720	15	1.72
9,146	10	1.09
9,541	15	1.57
11,486	22	1.92
10,806	13	1.20
10,136	7	0.69
	(b) Mountain	
11,065	17	1.54
10,417	33	3.17
10,276	46	4.48
10,264	40	3.90
9,871	36	3.65
9,871	55	5.57
9,871	19	1.93
10,292	13	1.26
10,807	16	1.48
	(c) Eastern	
8,888	13	1.46
8,087	12	1.48
7,767	12	1.55
7,788	12	1.54
7,744	5	0.65
7,737	6	0.78
7,824	6	0.77
8,376	11	1.31
10,295	13	1.26
9,096	4	0.44
9,177	13	1.42
9,320	5	0.54
9,547	12	1.26
10,115	10	0.99
11,277	13	1.15
11,028	14	1.27
9,820	11	1.12
8,738	11	1.26
7,805	8	1.03
3,334	1	0.30

study is under way of relationships of grade and curve to get at underlying causes of apparently contradictory or unexpected relationships (Table 7).

ANALYSIS OF DRIVER BEHAVIORS

Analysis of driver behaviors showed that passenger car drivers got into trouble to a considerably greater extent under winter highway conditions than did truck drivers. This probably was the effect of greater driving "know-how" of the latter. Relationships to driver behaviors were as follows:

Ten major classifications of driving behavior with two to ten subclassifications each were used in coding the behavior judged to have been most related to the precipitation of the accident. The main categories, condensed into four, are shown in Table 8 and indicate somewhat more than expected "coping with road conditions" on icy highway and more "sleep" accidents and "other" accidents on dry highway. However, comparison with "expected" numbers of accidents based on exposure shows "sleep" and "other" accidents about as expected, whereas the "inadequate coping with road conditions" was much greater than expected.

In this category the number of passenger-car-responsible drivers involved was almost one-half the total, whereas drivers in truck-responsible accidents were only about one-third of the total (see Table 8). The former represented six times as many accidents as the latter, apparently showing the value of the greater training and experience of the professional drivers. It was known rather than unexpected winter road conditions which drivers misjudged. Further breakdown of precipitating behaviors in icy road accidents is shown in Table 9. Surprise winter road conditions (such as icy spots and indications that the driver had not anticipated the icy highway) comprised only about one-third of the accidents. For truck accidents this was an even more marked difference.

Four different driving behavior categories were frequent in winter accidents, both as a first and a second "precipitating behavior." In addition to "inadequate coping with road conditions" in Table 8, "inadequate driving skills," "misperception" and "unsafe action" accidents also were higher than expected on icy road conditions. Second precipitating behaviors in "coping with road conditions" accidents included these factors, also, in some cases on the part of the same driver or another one (Table 10). In accidents not classified as due to "inadequate coping with road conditions," a second driving behavior fell in this category

TABLE 4

ACCIDENTS AND RATES BY GEOGRAPHICAL AREAS

(Rates Per Million Vehicle Miles, Passenger Cars)

Direction	Dry		Wet		Icy	
	Number	Rate	Number	Rate	Number	Rate
			(a) Western			
Eastbound	15	.67	4	.54	18	4.48
Westbound	21	.94	9	1.22	23	5.74
			(b) Mountain			
Eastbound	24	.83	25	2.51	79	9.69
Westbound	27	.96	18	1.86	102	12.88
			(c) Eastern			
Eastbound	43	.66	14	.90	36	7.51
Westbound	33	.51	21	1.34	44	9.15

TABLE 5

WESTBOUND ACCIDENTS, BY GEOGRAPHICAL AREAS

(Expected Computed for Each Area from Vehicle Miles Corrected for Percent Time for Each Road Condition)

Number of Accidents					
Dry		Wet		Icy	
Observed	Expected	Observed	Expected	Observed	Expected
		(a) Western			
2	2.5	1	1.0	2	2.7
3	2.8	2	1.1	1	3.0
1	2.9	0	1.2	3	3.1
5	2.9	0	1.3	6[1]	3.2
6	3.5	1	1.6	7[1]	3.9
2	3.3	4	1.5	1	3.7
2	3.1	1	1.3	3	3.5
		(b) Mountain			
4	3.1	3	2.3	2	12.1
2	2.6	5	2.3	7	14.6
2	2.6	2	2.2	20[1]	14.5
3	2.7	0	1.8	11	16.6
2	2.6	1	1.7	29[1]	16.0
5	2.9	2	1.9	19[1]	10.4
4	3.1	3	1.9	5	8.1
2	3.4	1	1.9	5	6.0
3	3.9	1	1.9	4	3.8
		(c) Eastern			
2	1.7	1	1.1	6[1]	2.2
2	1.5	1	1.0	1	2.2
2	1.5	0	1.0	5[1]	2.1
0	1.5	2	1.0	5[1]	2.1
1	1.5	1	1.0	1	2.0
1	1.5	1	1.0	3	2.0
1	1.5	1	1.0	1	2.0
1	1.6	0	1.0	2	1.9
2	2.1	1	1.3	1	2.4
1	1.8	1	1.1	0	2.2
3	1.8	4	1.1	2	2.3
1	1.8	1	1.1	2	2.7
5[1]	1.9	2	1.1	1	3.0
3	2.0	4	1.2	1	3.2
2	2.2	0	1.4	5	2.8
1	2.2	0	1.4	2	2.7
2	1.9	0	1.2	1	2.3
2	1.7	1	1.0	3	1.9
1	1.5	0	0.9	2	2.1

[1] 10-mile segments where reported accidents were much greater than were expected from vehicle mileage and winter road condition exposure.

TABLE 6

EASTBOUND ACCIDENTS, BY GEOGRAPHICAL AREAS

(Expected Computed for Each Area from Vehicle Miles Corrected for Percent Time for Each Road Condition)

Number of Accidents					
Dry		Wet		Icy	
Observed	Expected	Observed	Expected	Observed	Expected
		(a) Western			
1	1.7	0	0.4	2	2.0
3	2.0	1	0.5	5	2.3
3	2.0	0	0.5	3	2.4
2	2.1	1	0.6	1	2.5
2	2.5	1	0.7	5	3.0
3	2.4	1	0.7	2	2.9
1	2.2	0	0.6	0	2.7
		(b) Mountain			
2	2.8	2	3.2	4	9.3
4	2.4	0	3.2	15	11.5
4	2.3	5	3.1	13	11.2
2	2.4	2	2.5	22[1]	12.8
0	2.3	1	2.4	3	12.3
4	2.6	10[1]	2.6	15[1]	8.1
2	2.7	3	2.6	2	6.2
1	3.1	1	2.6	3	4.6
5	3.4	1	2.6	2	2.9
		(c) Eastern			
2	2.2	2	0.8	0	1.9
3	2.0	0	0.7	5[1]	1.8
1	1.9	1	0.8	3	1.7
3	1.9	0	0.7	2	1.7
0	1.9	0	0.7	2	1.7
0	1.9	0	0.7	1	1.7
1	1.9	1	0.7	1	1.7
2	2.1	1	0.7	5[1]	1.5
3	2.6	3	0.9	3	1.9
1	2.3	0	0.7	1	1.8
2	2.3	1	0.7	1	1.9
1	2.3	0	0.7	0	2.2
3	2.4	1	0.7	0	2.4
0	2.5	0	0.8	2	2.6
3	2.8	0	0.9	3	2.2
6[1]	2.8	3	0.9	2	2.2
8[1]	2.5	0	0.8	0	1.9
2	2.3	1	0.7	2	1.6
2	2.0	0	0.6	3	1.7

[1] 10-mile segments where reported accidents were much greater than expected from vehicle mileage and winter road condition exposure.

TABLE 7

ROAD ELEMENT AND DIRECTION

Comparison of Actual and Expected Winter Accidents (Expected Values in Parenthesis Based on Total Vehicle Mileage and Estimated Proportion of Highway)

Road Element	Dry		Wet		Icy	
	East	West	East	West	East	West
Straight, level	17 (14)	22[a] (13)	6 (8)	14 (7)	29 (25)	52[a] (25)
Straight, down	25 (22)	13 (22)	8 (12)	14 (12)	37 (42)	34 (41)
Straight, up	20 (22)	18 (22)	5 (12)	3 (12)	20 (42)	37 (41)
Right, level	2 (2)	3 (2)	2 (1)	3 (1)	2 (4)	4 (4)
Left, level	2 (2)	2 (2)	1 (1)	2 (1)	3 (4)	3 (4)
Right, down	7 (5)	5 (5)	12[a] (3)	4 (3)	22[a] (9)	14[a] (9)
Left, down	3 (5)	6 (5)	6 (3)	5 (3)	8 (9)	7 (9)
Right, up	4 (5)	4 (5)	1 (3)	1 (3)	9 (9)	11 (9)
Left, up	2 (5)	8 (5)	2 (3)	2 (3)	3 (9)	8 (9)
Total Expected	82 (82)	81 (81)	43 (46)	48 (45)	133 (153)	170 (151)

[a] For estimated proportion see:
Eckhardt, Paul K., Flanagan, John C., and Forbes, T. W., "Road Elements and Precipitating Behaviors in Turnpike Accidents." Proc. 37th Ann. Tennessee Highway Conf., Univ. Tenn. Record, 58: 4, 53-58 (July 1955).

in 44 out of 58 accidents (not shown in table).

Fixed-object collisions, rear-end-and-sideswipes, "other" and crossover accidents were most frequent in that order under icy road conditions; all were higher than expected taking account of exposure factors (Table 11). "Inadequate coping with road condition" accidents on icy road most frequently involved collisions with guardrail on the right for passenger car accidents, with rear-end accidents second. Both were equally frequent for truck-responsible accidents (Table 12).

SPEEDS AT TIME OF ACCIDENT

Maximum safe speed as judged by the investigating officer and estimates of initial speed in the accident indicate that drivers had slowed under winter road conditions but still misjudged or reacted in such a way as to get into trouble.

Although estimates by the police officer of maximum safe speed and of initial speed are difficult to make with reliability, they gave some important information. The former have shown some relation to weather and road conditions and the latter probably reflect indirect indications, such as skid marks, the officer's experience with damage and other indications of effects of speed, and his evaluation of drivers' reports. Under icy road conditions speed estimates were, in the lower ranges, more frequently-than-expected (statistically); but for wet and dry highway greater-than-expected estimates tended toward the higher speeds (Tables 13 and 14).

TABLE 8a

GENERAL PRECIPITATING BEHAVIOR

Relative Share of Accidents Under Winter Road Conditions
(Expected Values in Parenthesis Based on Marginal Proportions)

General Precipitating Behavior	Road Conditions at Time of Accident: Passenger Cars Dry	Wet	Icy	Total	Trucks Dry	Wet	Icy	Total
Coping with road conditions	3 (82.6)	33 (47.6)	247[a] (152.8)	283	0 (24.0)	6 (8.4)	42[a] (15.6)	48
Sleep, fatigued attention	60[a] (23.4)	13 (13.4)	7 (43.2)	80	33[a] (21.0)	7 (7.3)	2 (13.7)	42
Inadequate driving and perception	24 (24.5)	30 (14.1)	30 (45.3)	84	12 (9.5)	2 (3.3)	5 (6.2)	19
Unsafe action	34[a] (17.8)	7 (10.2)	20 (32.9)	61	17 (16.5)	8 (5.7)	8 (10.8)	33
Other (vehicular failure, object on road, etc.)	44[a] (16.6)	12 (9.6)	1 (30.8)	57	27[a] (18.0)	8 (6.3)	1 (11.7)	36
Total	165	95	305	565	89	31	58	178
	Chi-square = 345.43				Chi-square = 104.03			
	df = 8				df = 8			
	p < 0.01				p < 0.01			

TABLE 8b

GENERAL PRECIPITATING BEHAVIOR

Relative Share of Accidents Under Winter Road Conditions
(Expected Values Based on Percent of Motor Vehicle Miles on Each Road Condition)

General Precipitating Behavior	Road Conditions at Time of Accident: Passenger Cars Dry	Wet	Icy	Total	Trucks Dry	Wet	Icy	Total
Coping with road conditions	3 (198.0)	33 (56.2)	247[a] (28.8)	283 (283.0)	0 (33.5)	6 (9.7)	42 (4.8)	48 (48.0)
Sleep, fatigued attention	60 (56.0)	13 (15.9)	7 (8.2)	80 (80.1)	33 (29.3)	7 (8.5)	2 (4.2)	42 (42.0)
Inadequate driving and perception	24 (58.8)	30[a] (16.7)	30[a] (8.6)	84 (84.1)	12 (13.3)	2 (3.8)	5 (1.9)	19 (19.0)
Unsafe action	34 (42.7)	7 (12.1)	20[a] (6.2)	61 (61.0)	17 (23.0)	8 (6.7)	8 (3.3)	33 (33.0)
Other (vehicular failure, object on road, etc.)	44 (39.9)	12 (11.3)	1 (5.8)	57 (57.0)	27 (25.1)	8 (7.3)	1 (3.6)	36 (36.0)
Total	165	95	305[a]	565	89	31	58	178
Expected	(395.4)	(112.2)	(57.6)	(565.2)	(124.2)	(36.0)	(17.8)	(178.0)
	Chi-square = 192.0				Chi-square = 33.5			
	df = 8				df = 8			
	p < 0.001				p < 0.001			

TABLE 9

SUBCLASS PRECIPITATING BEHAVIOR OF "ICY" ACCIDENTS

(Expected Road Condition, Collision, and Other Characteristics of Accidents in Table 8a, Icy)

Subclass Precipitating Behavior	Road Conditions at Time of Accident					
	Passenger Cars			Trucks		
	Icy	Wet	Total	Icy	Wet	Total
Coping with road conditions						
Expected road condition, off roadway	9	2	11	7	0	7
Expected road condition, collision	124	7	131	21	0	21
Unexpected road condition, off roadway	8	4	12	1	1	2
Unexpected road condition, collision	80	16	96	2	2	4
Roadway blocked, collision	20	0	20	2	1	3
Roadway blocked, off roadway	1	0	1	0	0	0
Trailer weaving	2	0	2	3	0	3
Other	2	1	3	5	0	5
Total	246	30	276	41	4	45

SUMMARY

In the winter of 1954-5, the accident rate per million vehicle miles for icy highway was many times higher than for wet and for dry road conditions, although the uncorrected accident total was highest for clear weather, as has been so often reported. More frequent-than-expected accident experience (on the basis of vehicle miles and exposure to winter road conditions) was shown for some 10-mile segments in and near the mountain area.

Passenger car drivers had more difficulty than did truck drivers, indicating the effect of better training, experience, and "know-how" of the latter. More occurrence of driver behaviors classed as "inadequate coping with roadway conditions," "inadequate driving skills," "mis-perception," and "unsafe actions" were involved. The majority of the accidents were under winter road conditions known to the driver rather than under surprise conditions. Drivers had apparently reduced speeds considerably as compared with wet and dry road condition accidents, but they had still misjudged or used inadequate driving behavior to cause accidents.

Many of the accidents on icy road during snowy, sleeting, and freezing rain storms apparently involved misjudgments and driving behavior inadequate for winter road conditions during storms, but others may have included misjudgment of winter road conditions when the weather had cleared. Both suggest the importance of immediate cindering, clearing of ice and snow from the highway, and of warnings to unwary

TABLE 10

SECOND AND THIRD PRECIPITATING BEHAVIORS

Coping with Road Conditions in Accidents (General Precipitating Behavior)

Second and Third Precipitating Behaviors	Road Conditions at Time of Accident							
	Passenger Cars				Trucks			
	Icy		Wet		Icy		Wet	
	2nd	3rd	2nd	3rd	2nd	3rd	2nd	3rd
Vehicular failures	1	2	9	0	1	0	0	0
Objects on road	1	0	0	0	0	0	0	0
Road condition	16	2	0	0	5	1	0	0
Sleep	3	0	1	0	0	0	0	0
Attending other tasks	4	0	1	0	0	0	0	0
Inadequate driving skills	33	2	3	5	5	0	1	0
Unsafe action	22	7	1	0	3	2	1	0
Preception errors	15	5	1	2	2	0	0	0
Chemical agents and intoxicants	0	0	0	0	0	0	0	0
No additional driver behavior	151	228	14	23	25	38	2	4
Total	246	246	30	30	41	41	4	4

TABLE 11

HOW VEHICLE WAS INVOLVED

Comparison with Expected Accidents Under Each Road Condition (Expected Values in Parenthesis Based on Percent of Motor Vehicle Miles on Each Road Condition)

How Vehicle Was Involved	Road Conditions at Time of Accident							
	Passenger Cars				Trucks			
	Dry	Wet	Icy	Total	Dry	Wet	Icy	Total
Rear end, sideswipe	58 (102.1)	10 (29.0)	78 (14.9)	146 (146.0)	43 (50.2)	9 (14.6)	20 (7.2)	72 (72.0)
Crossover	6 (39.2)	11 (11.1)	39 (5.7)	56 (56.0)	2 (4.9)	1 (1.4)	4 (0.7)	7 (7.0)
Fixed object	35 (126.6)	31 (35.9)	115 (18.4)	181 (180.9)	12 (26.5)	10 (7.7)	16 (3.8)	38 (38.0)
Other	66 (127.3)	43 (36.1)	73 (18.5)	182 (181.9)	32 (42.6)	11 (12.3)	18 (6.1)	61 (61.0)
Total	165	95	305[a]	565	89	31	58[a]	178
Expected	(395.2)	(112.1)	(57.5)	(564.8)	(124.2)	(36.0)	(17.8)	(178.0)
	Chi-Square = 31.4				Chi-Square = 25.9			
	df = 6				df = 6			
	p < 0.001				p < 0.001			

TABLE 12

HOW VEHICLE WAS INVOLVED IN "ICY" ACCIDENTS

General Precipitating Behavior - "Coping With Road Conditions" Accidents (Table 8a - Icy) Further Analysis by How Vehicle Was Involved

How Involved	Road Conditions at Time of Accident: Passenger Cars Icy	Passenger Cars Wet	Passenger Cars Total	Trucks Icy	Trucks Wet	Trucks Total
Collision·						
Rear end	53	1	54	10	0	10
Sideswipe	2	0	2	0	0	0
Vehicle, crossed median	30	3	33	3	0	3
Fixed object, or off road, crossed median	22	1	23	3	0	3
Fixed object, right shoulder (guard-rail)	91	17	108	8	2	10
Guardrail in median	7	1	8	2	0	2
Other object	2	0	2	0	0	0
Overturning	9	3	12	4	2	6
Stopping or parked	3	0	3	0	0	0
Other	27	4	31	11	0	11
Total	246	30	276	41	4	45

TABLE 13

MAXIMUM SAFE SPEED

Relative Share of Accidents Under Winter Road Conditions (Expected Values in Parenthesis Based on Marginal Totals)

Maximum Safe Speed, mph	Road Conditions at Time of Accident: Passenger Cars Dry	Passenger Cars Wet	Passenger Cars Icy	Passenger Cars Total	Trucks Dry	Trucks Wet	Trucks Icy	Trucks Total
Stopped	7 (2.6)	1 (1.5)	1 (4.9)	9	7 (3 5)	0 (1.2)	0 (2.3)	7
1 - 9	0 (0.9)	0 (0.5)	3 (1.6)	3	1 (1.5)	1 (0.5)	1 (1.0)	3
10 - 19	1 (5.8)	1 (3.4)	18 (10.8)	20	1 (6.4)	0 (2.3)	12[a] (4.3)	13
20 - 29	9 (22.9)	0 (13.4)	70[a] (42.7)	79	0 (9.4)	1 (3.3)	18 (6.3)	19
30 - 39	7 (37.4)	10 (21.8)	112[a] (69.8)	129	8 (16.3)	6 (5.8)	19[a] (10.9)	33
40 - 49	9 (28.4)	20 (16.6)	69[a] (53.0)	98	16 (18.3)	16[a] (6.5)	5 (12.2)	37
50 - 59	16 (20.9)	34[a] (12.2)	22 (38.9)	72	54[a] (31.6)	7 (11.3)	3 (21.1)	64
60 - 69	70[a] (29.3)	22 (17.1)	9 (54.6)	101	-	-	-	-
70 - 79	44[a] (14.8)	7 (8.6)	0 (27.6)	51	-	-	-	-
Total	163	95	304	562	87	31	58	176
	Chi-square = 367.44 df = 16 p < 0.01				Chi-square = 122.76 df = 12 p < 0.01			

TABLE 14

INITIAL SPEED

Relative Share of Accidents Under Winter Road Conditions (Expected Values in Parenthesis Based on Marginal Totals)

Initial speed, mph	Road Conditions at Time of Accident: Passenger Cars Dry	Wet	Icy	Total	Trucks Dry	Wet	Icy	Total
Stopped, Parked	9 (4.6)	2 (2.8)	5 (8.6)	16	7 (4.9)	1 (1.7)	2 (3.4)	10
1 - 9	2 (1.1)	1 (0.7)	1 (2.2)	4	0 (0.5)	0 (0.2)	1 (0.3)	1
10 - 19	0 (2.0)	1 (1.2)	6 (3.8)	7	7 (5.9)	1 (2.0)	4 (4.1)	12
20 - 29	2 (6.6)	0 (4.0)	21[a] (12.4)	23	4 (9.3)	2 (3.2)	13[a] (6.4)	19
30 - 39	8 (20.4)	4 (12.2)	59[a] (38.4)	71	9 (15.2)	4 (5.2)	18[a] (10.5)	31
40 - 49	16 (39.0)	12 (23.4)	108[a] (73.6)	136	31 (29.0)	13 (10.0)	15 (20.0)	59
50 - 59	55 (46.7)	41[a] (28.1)	67 (88.2)	163	21[a] (15.7)	6 (5.4)	5 (10.8)	32
60 - 69	52[a] (31.2)	30[a] (18.8)	27 (59.0)	109	4 (2.9)	2 (1.0)	0 (2.0)	6
70 - 79	12[a] (5.7)	4 (3.4)	4 (10.8)	20	1 (0.5)	0 (0.2)	0 (0.3)	1
80 - 89	2 (0.6)	0 (0.3)	0 (1.1)	2	-	-	-	-
Total	158	95	298	551	84	29	58	171
	Chi-square = 149.64 df = 18 p < 0.01				Chi-square = 34.92 df = 16 p < 0.01			

motorists during and after the storm while roadway conditions are still slippery. Such procedures have been introduced by the Pennsylvania Turnpike Commission and a follow-up study of their effectiveness is under way.

Accident figures corrected by estimates of exposure in vehicle miles on each type of road condition (derived from Turnpike records) indicated that combinations of road condition, curvature, and grade were more misjudged by drivers than statistically expected. A more specialized study of these factors is under way.

Thus, research using corrections for both mileage and other types of exposure can point out specific principles and combinations of human and physical factors causing hazards. Such specific information and resulting specific remedial action and driver training will increase effectiveness of safety activities in enforcement, engineering, and education. Such research is, therefore, of great importance.