Role of Roadway Elements in Pennsylvania Turnpike Accidents

PAUL K. ECKHARDT, Supervisory Engineer, Union Switch and Signal Division, Westinghouse Air Brake Company; and JOHN C. FLANAGAN, Director of Research American Institute for Research

This paper presents a few of the results from a 2-year study of accident causation on the Pennsylvania Turnpike, data from which serve as a barometer indicating how well the roadway in modern high speed highway design is working. The curve and grade elements are discussed from the standpoint of the accident rate and the vehicle involvement rate.

The broad combinations of curves and grades are tabulated against the percentage of accidents for each combination. The combinations considered are straight and level, straight and upgrade, straight and downgrade, curved level, curved upgrade, and curved downgrade.

The large number of critical incidents or the actions that led to the accidents were classified into nine broad driver-behavior groups. Certain groups of incidents which showed a statistically significant relationship to certain of the six road course combinations are indicated.

The total number of vehicles which used the pike and the vehicle miles of exposure were used to establish a perspective of the real boundaries encompassing the data used in the foregoing discussions.

The data indicate that the modern design is working well. It is strongly indicated that in this man-machine-roadway system, the roadway design is ahead of the man-machine part of the system. Two courses of action are briefly stated in conclusion and mention is made of the challenge which the statistically significant relationships between accidents and road course present to the designer.

● THE highways being built today are a tribute to the men designing and building them. They reflect an alertness to the present day needs for expediting our mass automotive traffic safely. They are a tribute to the advances made in the engineering and construction fields to meet todays demands.

If this advancement is to continue these men will need to know, from time to time, how well the driving public is adapting itself to the facilities they are providing. This knowledge must be objective rather than subjective if we are to progress most efficiently.

One barometer indicating the success of the designed facility, or in plain words how well the design is working, is the accident experience and the precipitating factors which produce the accident population. While the listing of accident figures alone provides some sense of proportion such a listing is lacking in meaning unless we know what took place to establish these proportionalities.

Such a barometer can be found in the design and accident experience on the Pennsylvania Turnpike.

The segments in the design being discussed today are the grade and curve combinations.

The setting for these combinations is the mountainous and valley areas across the State of Pennsylvania. These grades and curves go to make up the two 24-foot traffic lanes separated by a 10-foot medial strip bordered on each side by berm of at least 10 feet wide. There is a minimum sight distance of 1000 feet along the entire length of the pike and the roadway is isolated along its entire length by wire fencing.

The grades are gentle. The curves are superelevated and spiraled in from the tangents. The steepest grade is 3 percent and no curve has a greater curvature than 6 degrees.

There are several places in this design where economic considerations demanded the use of a series of 4-deg. to 6-deg. curves on the steepest 3-percent grade. These are the exception rather than the rule, and in the interest of indicating how well the public has accepted this modern design, these particular places will not be considered as special cases. Rather the paper today will deal with the general design characteristics of this turnpike. In this way we will get a better picture of the ability of the public to use a modern highway, recognizing that those special cases mentioned will be held to a minimum in modern design.

Briefly then the subject matter today will be the accident experience and the accident precipitating factors on one of todays best designed highways. It should be borne in mind that between 4 and 5 months of winter weather moderates the effect of the design.

The data from which the facts have been abstracted for this paper were gathered from two sources: (1) the more than 9,000 Pennsylvania state-police accident reports covering each accident that occurred on the pike from the year 1940 through the year 1953, and (2) an accumulation of facts through personal interviews with patrons on the turnpike.

The police accident reports gave the accident frequencies or the number of accidents according to grades or curves. These same reports for the years 1952 and 1953 gave one set of critical incidents which precipitated the accidents. By critical incident is meant the thing that actually triggered off the events resulting in an accident. The personal interviews with the patrons on the pike established the critical behaviors that almost resulted in an accident.

Before discussing the data it should be pointed out that by level roadway is meant any road surface up to 0.5 percent grade, also that straight means anything from dead straight to 0.5 deg. of horizontal curvature.

TABLE 1
PERCENTAGE OF VEHICLE INVOLVEMENT BY ROADWAY ELEMENT

Roadway	Percent of Involvements	
	Passenger Cars	Trucks
Straight and Level	38.4	33.9
Straight and Downgrade	22.1	21.1
Straight and Upgrade	15.6	24.9
Curved and Level	4.6	2.8
Curved and Downgrade	12.9	9.9
Curved and Upgrade	6 4	7.4

The accident records then show that the accident rate (that is, the number of accidents per million vehicle miles) is identical for both straight and curved road surfaces. The accident experience from 1940 through 1953 showed this rate to be 1.5 accidents per million vehicle-miles. When broken down on a yearly basis, the rate for the curved road and the straight road run very close to each other year after year. The vehicle-involvement rate (as opposed to the accident rate) for straight roadway ran 2.5 vehicles involved per million vehicle-miles, whereas that for the curved road ran 2.1 vehicles per million miles.

Consider now the combination of grades and straight or curved roadway. It was not practical to assess accurate values of vehicle mile exposures for the combinations of grades and degrees of curvatures while making the study. Our data in these cases, therefore, are given in terms of accident percentages for these combinations. Reference to Table 1 will show the percentages broken down according to the broad combinations for both passenger cars and trucks.

A combination breakdown showing the percentage of vehicle involvements for the broad combinations is shown in Table 2.

Listed according to their accident frequencies these combinations are: (1) straight and level, (2) straight and downgrade, (3) straight and upgrade, (4) curved and downgrade, (5) curved and upgrade, and (6) curved and level.

In summary, the overall straight roadway data as compared to the overall horizontal curved roadway data indicates that the curved roadway has served the patron of the Pennsylvania Turnpike as well as or better than the straight roadway. We, therefore, need to look further if we are to determine why a supposedly ideal roadcourse, such as straight and level, has not served the driver appreciably better than the curved roadway.

Let us then consider the combination of external events or conditions and human behaviors which triggered off the events leading to the accidents and which in effect established the percentages and rates just given. It has been possible to group these incidents under nine broad categories on the first level of reasoning. It must be remembered that the task of determining such things as psychological behaviors from police accident reports is a rather difficult one. For that reason some of the categories may appear rather broad in nature. Nevertheless, they are adequate at this point in the turnpike safety-research program to give a clearer picture of how the driving public makes use of the road course. The nine behavior categories into which all accidents on the turnpike were classified are as follows:

1. Failure on the part of the driver to cope with the road conditions was important in 22 percent of all accidents.

These failures, by and large, resulted in skids on wet, snowy, or icy road surfaces. Unfortunately there was not enough information available to determine what manipulations the operator went through to produce the skid. If this fact were known many of the accidents under this category would quite likely appear under the category of deficiencies in routine driving skills, or under illegal or unsafe actions.

2. Drivers commission of illegal and unsafe actions, were involved in 21. 5 percent of all accidents.

These behaviors ranged from parking on the slow speed lane to entering the pike from the exit lane and pulling out into the high speed lane in the face of a passing vehicle.

3. Driver inattention appeared to have been primarily responsible for 17. 2 percent of all accidents.

This inattention ranged from falling asleep to reading a road map while driving.

TABLE 2
PERCENTAGE OF ACCIDENTS BY ROADWAY ELEMENT

Roadway	Percent of Accidents	
	Passenger Cars	Trucks
Straight and Level	32 1	35. 6
Straight and Downgrade	21. 3	20. 9
Straight and Upgrade	17. 4	19. 2
Curved and Level	6. 1	3. 4
Curved and Downgrade	14. 6	11. 4
Curved and Upgrade	8. 5	9. 5

4. Vehicular failures which were not successfully handled accounted for 13. 8 percent of all accidents.

Blow outs, loss of steering, failure of brakes, trouble with hitches on tractor house trailer combinations, etc., constitute the category of vehicle failures not successfully handled.

5. Deficiencies in routine driving skills accounted for 11. 7 percent of all accidents.

These driving skills are exemplified by the driver who, detecting that he has a wheel or wheels off the pavement cuts back sharply rather than making the correction gradually and safely.

6. Misperception was the primary factor in 8. 2 percent of all accidents.

Misperception as it is used here is two-fold in nature: (1) loss of vision because of snow, slush, mud or rain deposited on windshield and (2) ambiguity of cues resulting in the driver doing such things as following in behind a vehicle ahead of him which has gone to the berm to park. This driver follows the one preceding him onto the berm with the impression that the leading vehicle has actually taken a turn in the roadway.

7. Failure to avoid objects in the road accounted for 3. 6 percent of all accidents.

While everything from a fallen rock to a deer in the road was hit the most frequent objects causing this trouble were animals in spite of the fact that the roadway is isolated by a fence.

8. Intoxication or drunken driving accounted for only 1. 2 percent of the accidents on the Pennsylvania Turnpike.

9. Miscellaneous behaviors or failures accounted for the remaining 0. 8 percent of all accidents.

The foregoing are not only the behaviors and failures which caused property damage, injury and loss of life on the turnpike but are also the same behaviors and failings described by patrons when interviewed about near-miss accidents. This indicates an accident potential emcompassing most drivers, over and above those represented by the accident statistics.

We have seen the accident distribution by roadway element and we have seen the factors that precipitated these accidents. Let us now consider the relationships found between these two. In other words, what part did the road design play in these accidents as we know it at this point in the research study.

Interestingly enough some statistically significant relationships were found and are listed in Table 3. These are the behaviors and errors that proved to be significantly higher for one of the six types of roadway element than for the others.

TABLE 3
BEHAVIORAL AREAS OF HIGHER THAN EXPECTED ACCIDENT FREQUENCY BY ROADWAY ELEMENT

Pennsylvania Turnpike (1952-1953)

Roadway Element	Passenger Cars	Trucks
Straight Level	Failure to Avoid Objects in Road	-
Straight Up	Asleep Misperception	Asleep Misperception
Straight Down	Vehicle Failures	-
Curved Level	Deficiencies in Routine Driving Skills	-
Curved Up	-	-
Curved Down	Failure to Cope with Road Conditions Deficiencies in Routine Driving Skills	Failure to Cope with Road Conditions

The significantly high number of accidents classified as failure to avoid objects in the road for the straight and level roadway combination tie in with other factors such as higher speed. The higher speed ranges as you well know afford the passenger car driver less time to avoid objects in the road. This fact is probably amplified to some extent by the driver's lapsing into a feeling of well being. Laxity and higher speed would contribute to the surprise element too. Consider a driver's surprise at night should a deer suddenly jump into the path of the car or should a pheasant appear in the windshield, even during the daylight hours. Note that trucks did not experience this same difficulty, possibly because of weight and size, the lower speed, and the greater ability of the truck driver to handle his vehicle.

The straight-and-upgrade roadway apparently is the place where drivers really feel at ease. It is here that falling asleep was a factor in the accidents significantly more often. Perhaps he relaxes his attentiveness and also overtakes more vehicles.

The straight-and-downgrade segment of the road is significantly high in passenger-car vehicular failures which were not successfully handled. It would be expected that tire and brake failures would be much more difficult to cope with on the downgrade. It is, therefore, not surprising to find a larger proportion of vehicular failure accidents on this type of roadway. It is interesting to note that trucks did not experience the same difficulty. This suggests the hypothesis that truck drivers are better prepared to cope with such vehicular failures.

The curved-and-upgrade combination showed no significant relationship to driver behaviors. This means that the eight precipitating factors (omitting the miscellaneous category) mentioned previously took place on curved-and-upgrade roadway in accordance with the observed frequency of these types of behaviors on the other types of roadway.

The curved-and-downgrade sections of the roadway are the places where drivers precipitated skids significantly more often. Such things as tangential steering to get around curves particularly when traction is low is conducive to this occurrence. As mentioned, it is unfortunate that the source of data did not carry statements that would allow us to determine the actual manipulation that led to the skid. The other factor significantly high in curved down driving is deficiencies in routine driving skills for the passenger car driver. This is the point where the driver gets his greatest test of skill and we would expect to find this category statistically high.

These behaviors and failures in relation to the roadway element are the only ones which showed significant relationships to the design of the highway for this type of analysis. It must be remembered that all of the behaviors and failures still occurred on each of the roadway combinations, even though no significant relationship was found. To clarify this point, passenger-car drivers did fall asleep on the curved-and-downgrade combination, causing 25 accidents, even though the analysis did not show any special relationship between this behavior and curved-down roadway.

Let us now look briefly at the boundaries encompassing this data, thereby gaining a better perspective of the overall picture. The data set up in this paper today was the result of 57 million vehicles using the turnpike from 1940 through 1953. These vehicles established an exposure of 5.57 billion vehicle-miles. From this exposure some 9,000 accidents involving only 13,400 vehicles were recorded ranging from a scratched fender to a multiple fatality. Only a small part of these accidents showed a statistically significant relationship with the various types of roadway element. A continuation of the study is now examining in greater detail such relationships. For example, an analysis based on accidents per mile for the various types of roadway is now in progress.

What conclusions can be drawn from this perspective and the information preceding it?

Considering the three main components in the driving operation, the driver, his vehicle, and the roadway, it is strongly indicated that the roadway design is well ahead of the driver and his vehicle. The future, therefore, calls for two courses of action: First, to improve the driver and vehicle and present the challenge for improvement to the highway designers in those cases where significant relationship of behavior to design can be shown. Second, as these improvements are made continue with objective studies to determine how well the improved components are working together.