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CORRELATION BETWEEN DESIGN EXCEPTIONS AND ACCIDENTS (A SYNTHESIS)

BY

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ABSTRACT

Whenever rehabilitation is needed on New Jersey's highways, the highest design standards are usually followed. However, sometimes due to an almost impossible geometric condition which would cause the cost to be exorbitant, these design standards cannot be met. When this occurs, the Federal Highway Administration requests that an accident investigation be carried out to determine if the design exception at the particular site has an effect on the accidents. Because of this FHWA request, it was suggested that if a correlation between accidents and geometric design exceptions could be determined, time and money could be saved by eliminating the need for an accident evaluation on each individual design exception.

It became obvious after an extensive literature review that if safety is the main concern, no design exception would be preferred because roads which meet the design standards have better accident experience. However, due to the ever-tightening fiscal situation, the Department may need to begin looking for the largest return on the money that is spent on safety improvements. What this means is not maximizing the safety benefits for each project, but rather increasing the total safety benefits by the improvement of more miles of highway. This process would need a cost-effectiveness evaluation to determine the geometric characteristic to accident correlation. Research needed would include a full inventory of the road system to determine the geometric characteristics, an accident investigation, and a statistical correlation study. This research is expected to be very difficult and costly to obtain. An even more pressing problem, however, before any research can be done is for the Department to determine the limits of any deviation from the design exceptions. This is due to the fact that it would be very difficult for the Department to defend a position in which more accidents and even a fatality were allowed just to save money, especially when the design standards could have been met.

Introduction

One of the major functions of the Department of Transportation is the rehabilitation of our present roadway systems. This rehabilitation is usually done on a priority basis by need of repairs or by the location having a high accident rate. When these repairs are made, the traditional design standards are usually followed. However, sometimes due to an almost impossible geometric condition which would make the cost exorbitant, these design standards cannot be When this occurs, the Federal Highway Administration requests that an accident investigation be carried out to determine if the design exception at the particular site has an effect on the accidents.

The Bureau of Local Aid, which is responsible for determining high accident locations within the state, asked Research to determine if a correlation exists between accidents and such geometric items as lane width and shoulder width. The information found during such a study could be used to show what effect a particular design exception will have on accidents. Thus, time money could be saved by reducing the need for an accident evaluation on each individual project which includes such a design exception.

The first item to be determined was whether these relationships were already identified by past research studies. Therefore, an HRIS search was made and a literature review was accomplished. The main geometric characteristics researched were lane width, shoulder width, roadway width, bridge width, pavement cross slope, side slopes and ditches, horizontal curves, transition curves and superelevation. The next section will report on the findings of the literature search while the final section will discuss research that could be performed relating accidents to specific design features.

II - Findings of Literature Search

An annotated bibliography of the research reports reviewed is included at the end of this report. In this section, each geometric characteristic and its relationship to accidents will be discussed.

A) Lane Width

This geometric feature has been researched in many studies (1,2,3,4,11,12,13,15,22,25,26,28,29). However, all the studies have been done for two-lane, rural roads. No data for multilane or urban roadways was found. Some of the general conclusions that can be made about the studies are that the accident rates decrease as the lane width increases and lane width should be at least 10' and not more than 12', since lane widths of greater than 12' show no significant accident benefits, and constructing lane widths of greater than 11' does not appear to be cost effective. Figure 1 shows the relationship found by Dart and Mann (1) between accident rates and lane width.

B) Shoulder Width

Shoulder width also has been studied in much detail (1,2,3,4,5,6,7,12,13,15,22,24,25,27,28,29). Again all studies have been for rural, two-lane roadways. Some of the general conclusions that can be made about these studies are that the pre-1970 studies (1,7,13,15,24) reported either no relationship between accidents and shoulder width or that a relationship existed only at certain traffic volumes. The most recent studies (2,4,12,25,27,28) conclude that as shoulder width increases, the accident rate decreases. Shoulder widths of from six to nine feet should generally be used and shoulder widths are more critical on horizontal curves than on tangent sections and should therefore be of greater width. Table 1 shows the findings of the Zegeer et al. study (2). As can be seen, up to a 20 percent reduction in accidents occurred when certain shoulder improvements were made. Roy Jorgenson Associates (28) produced

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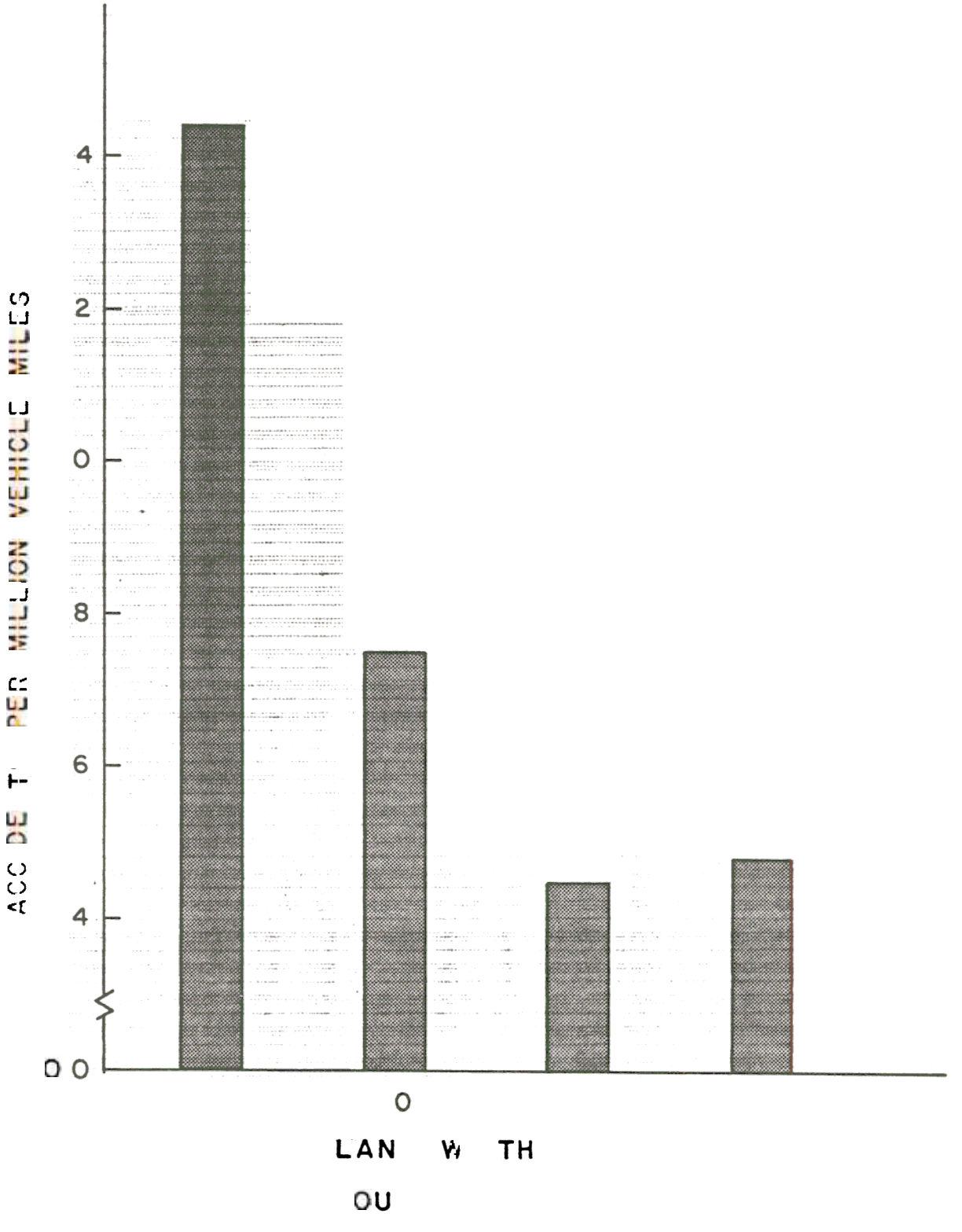


TABLE 1

REDUCTION IN ACCIDENT RATES FROM SHOULDER WIDENING ON TWO-LANE, RURAL ROADS

Shoulder Width in Feet		Reduction in Run-Off-Road & Opposite Direction Accidents in %
Before	After	
	1-3	6
	4-6	15
None	6-9	21
	7-9	16
	4-6	10
	7-9	8

SOURCE: Reference 2

Figure 2 which could be used to predict the accident rates for certain shoulder and pavement widths.

C) Roadway Width

The combination of lane width and shoulder width has been studied (3,4,11,12,21) and the findings are that the accident rates decrease as the roadway width increases. Foody and Long (4) produced Figure 3 which shows this relationship. This figure was only for single vehicle accidents on two lane, rural roadways. Again, no studies were found dealing with multilane or rural roadways.

However, two studies (3,25) looked at using shoulders as travelled lanes to reduce congestion. Fambro et al. (25) produced Figure 4 which shows that a two-lane road with shoulders is safer than a four-lane road with no shoulders up to about 7,500 ADT and that a two-lane road with no shoulders is the least safe.

D) Bridge Width

Six studies (10,13,17,18,28,29) dealt with the effect of bridge width on accidents. All of these studies concluded that as the bridge width increases, the accident rates decrease. Bissell et al. (29) reported on a study done in 1979 which produced Table 2 showing the relationship between bridge width (minus the roadway width) and accidents. Figure 5 used this data to show the reduction in accidents to be expected when the original and newly constructed bridge width is known.

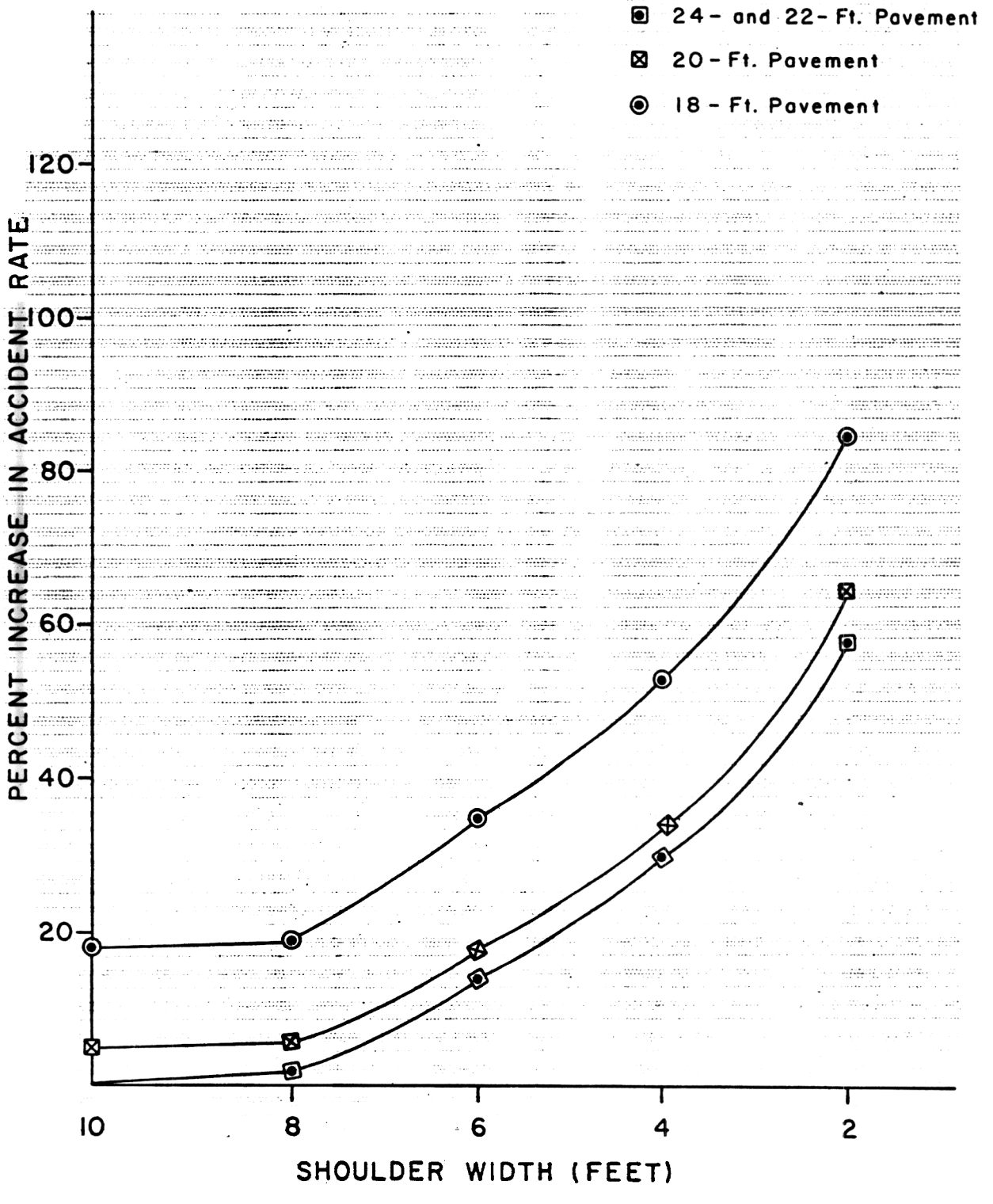
E) Pavement Cross Slope

Four studies (1,8,28,29) looked at the effect of pavement cross slope on safety. Two of these studies (1,8) reported that pavement cross slope was the most important geometric feature concerning accidents. Pavement cross slope allows water to drain from the roadway during wet weather and thus reduces the chance of accidents caused by hydroplaning. The Mann report presented this

FIGURE 2

PERCENT ACCIDENT RATE INCREASE

FROM BASE RATE



SOURCE: Reference 28

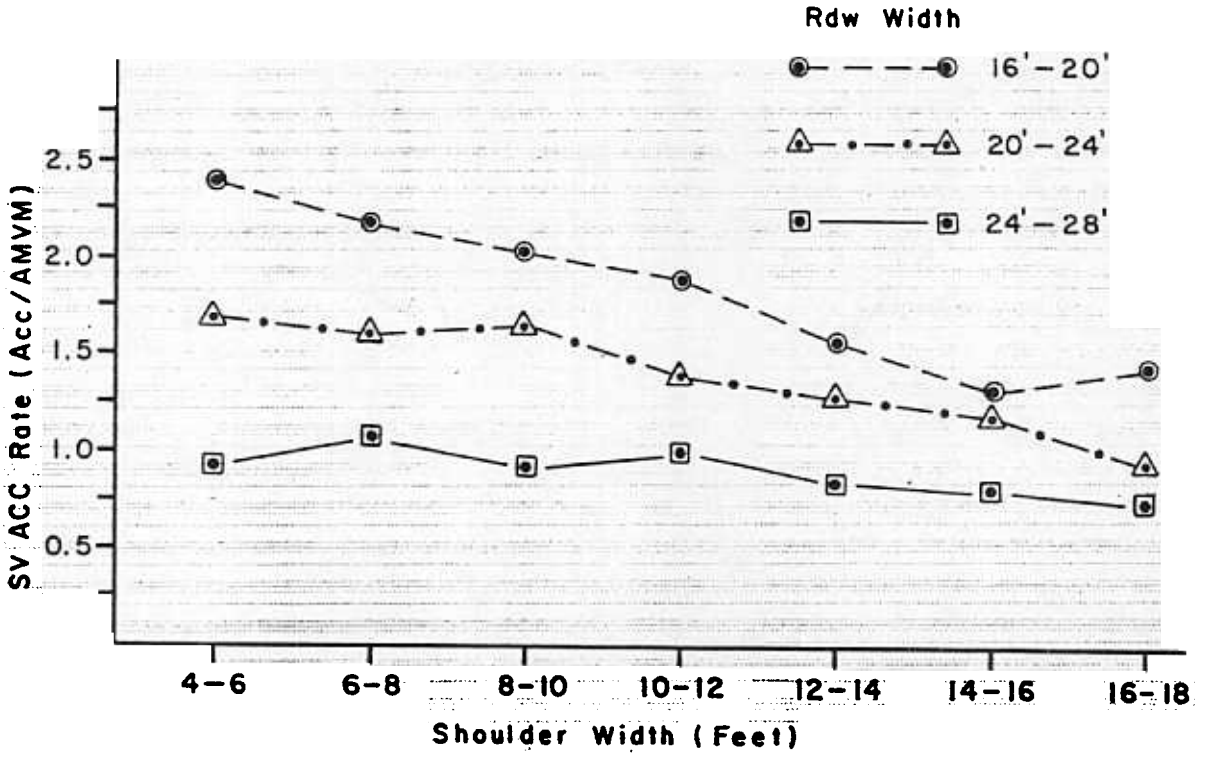


FIGURE 3. RELATIONSHIP BETWEEN SHOULDER WIDTH AND SV ACCIDENT RATE GIVEN THE ROADWAY WIDTH

SOURCE: Reference 4

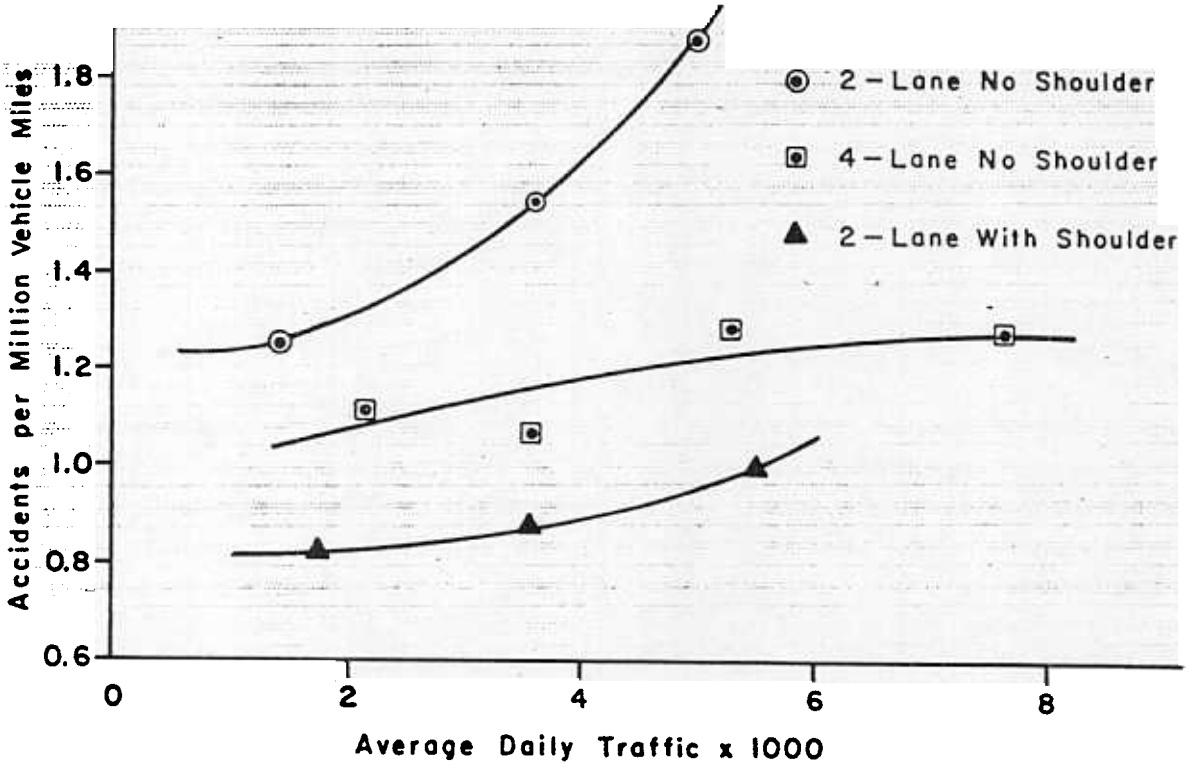


FIGURE 4. ACCIDENT RATES FOR DIFFERENT CLASSES OF TEXAS HIGHWAYS

SOURCE: Reference 25

TABLE 2

SAFETY OF NARROW BRIDGES

Bridge Width Minus Roadway Width* in Feet	-6	-4	-2	0	2	4	6	8	10	12
Accidents per 100 Million Vehicles	120	103	87	72	58	44	31	20	12	7

*Roadway width includes traveled lanes and shoulders.

Source: Reference 29

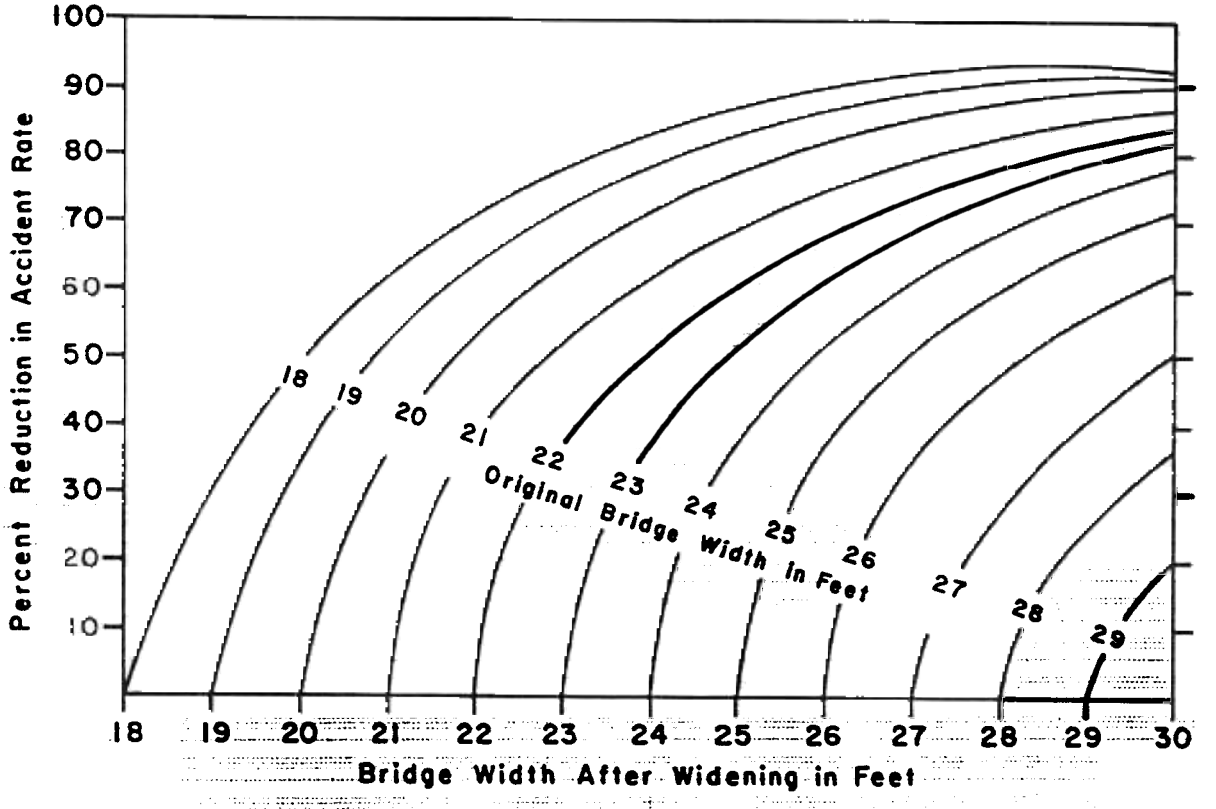


FIGURE 5. PERCENT REDUCTION IN ACCIDENT RATE ASSOCIATED WITH INCREASES IN BRIDGE WIDTH. SOURCE: Reference 29

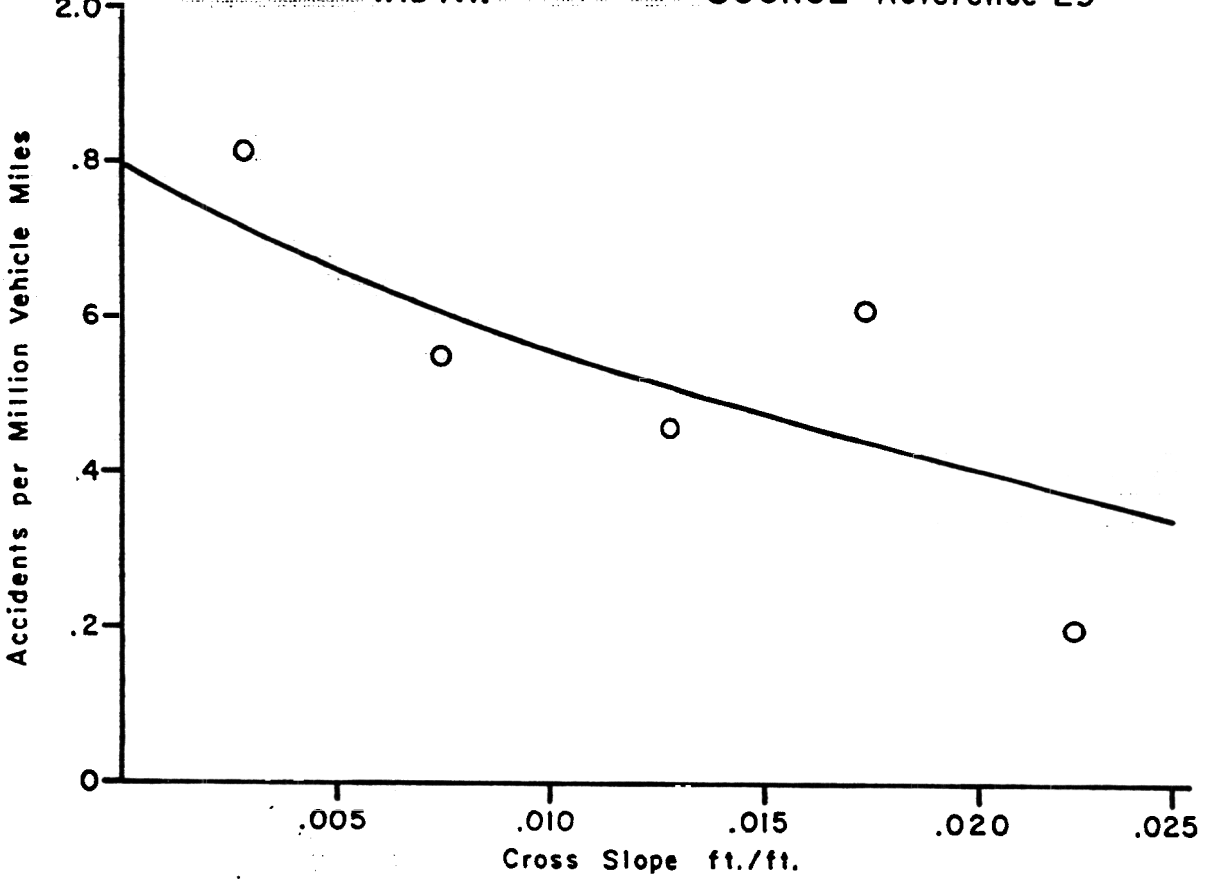


FIGURE 6. ACCIDENT RATE VERSUS PAVEMENT CROSS SLOPE.
SOURCE: Reference 1

relationship in Figure 6. The general recommendation was that a two percent cross slope be the minimum design standard.

F) Side Slopes and Ditches

Five studies (8,19,20,28,29) looked at the effects of side slopes and ditches on accidents. The major conclusions were that front slopes steeper than 4:1 are not desirable because they severely limit the choice of backslopes that can be used to produce a safe ditch configuration and the trapezoidal ditch configuration represents the most desirable cross section from a safety standpoint, particularly those wider than eight feet.

Figures 7 and 8 deal with slopes. Figure 7 was developed by Weaver (19) to show roadway slope combinations which are acceptable, while Figure 8 was developed by Glennon and Tamburri (20) to show when the possible accident severity would be reduced by installling guardrail for particular slopes and embankment height.

Horizontal Curves

feature was reviewed in many reports (1,5,8,9,11,13,14,15,26,28,29). The major results of nearly all studies performed was that the accident rate increases as the degree of curvature increases. Other findings were that curved sections with a degree of curvature in excess of 5^{o}-6^{o} should be avoided, particularly on downgrades, a sharp curve following a long tangent section has a high accident potential, widening of the pavement on curves could reduce the accident rates, and as the number of curves in a section increase so does the accident rate.

Raff (13) looked at accident data from 15 states covering about 5,000 miles of roadway. Two-lane, three-lane, four-lane divided and undivided roadways were analysed. Table 3 represents the results of this study. As can be seen, for all types of roadways, the expected safety-curvature relationship exists.

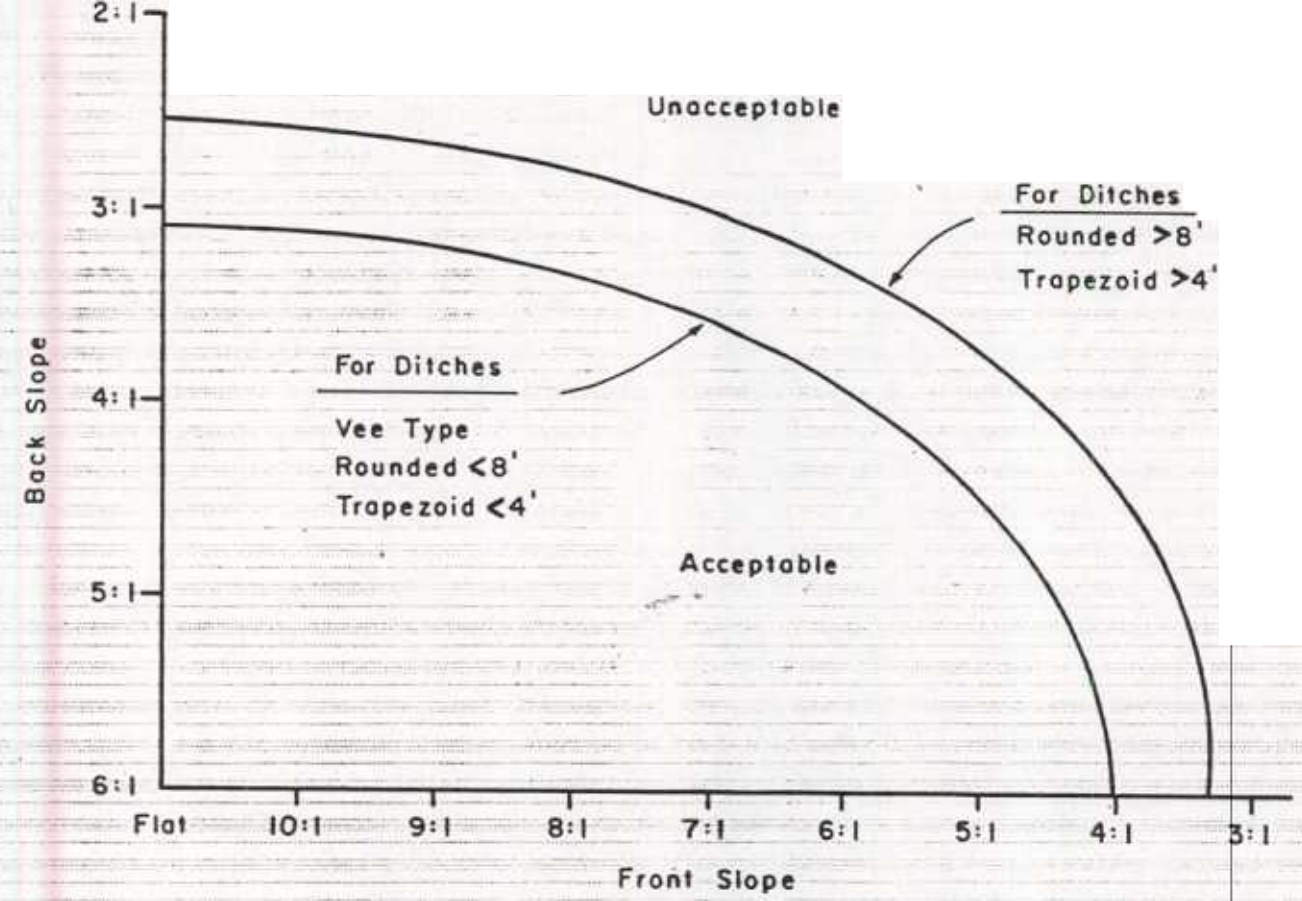


FIGURE 7. DITCH EVALUATION FOR ROADSIDE SLOPE COMBINATIONS

SOURCE: Reference 19

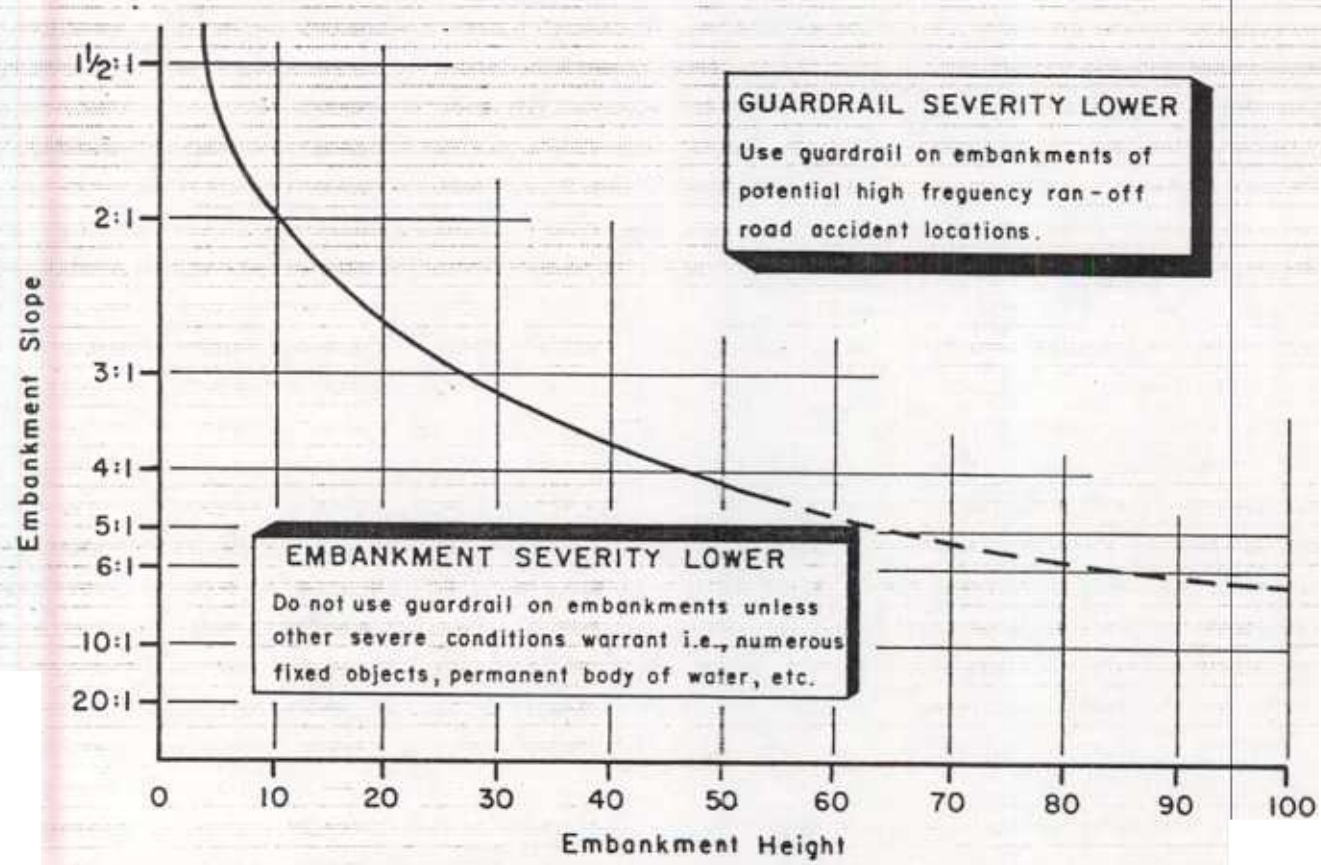


FIGURE 8. SEVERITY COMPARISON OF EMBANKMENTS VS GUARDRAIL.

SOURCE: Reference 20

TABLE 3

ACCIDENT RATES ON CURVES,
BY DEGREE OF CURVE AND ROADWAY TYPE

	Two-Lane Roads		Three-Lane Roads		Four-Lane Roads					
					Undivided		Divided		Controlled Access	
Curvature	Number of Accidents	Per Mil. Vehicle-Miles	Number of Accidents	Per Mil. Vehicle-Miles	Number of Accidents	Per Mil. Vehicle Miles	Number of Accidents	Per Mil. Vehicle Miles	Number of Accidents	Per Mil. Vehicle Miles
0 - 2.9°	504	1.6	11	1.7	98	1.9	95	1.8	180	1.6
3 - 5.9°	596	2.5	11	2.8	90	2.6	65	2.4	162	2.3
6 - 9.9°	338	2.8	6	3.5	16	3.3	5	3.1	38	4.5
10° or more	354	3.5	11	7.3	3	1.2	12	6.7	0	
Tangents	6,474	2.3	227	2.5	1,348	2.7	982	2.9	774	1.7

SOURCE: Reference 13

Gupta and Jain (26) looked at accidents on 2,013 miles of Connecticut two-lane roadways. The major finding was that horizontal curvature had the highest correlation with the accident rates on roads with ADT larger than 1,500 vehicles.

H) Transition Curves and Superelevation

Very few studies have looked at this feature and its relationship to safety (16,28,29).

The Bissell Study (29) commented on a 1980 report which looked at transition curves using the Highway-Vehicle-Object Simulation Model (HVOSM) for the analysis of 8^{o}, 31^{o}, and 38^{o}curves. It concluded that no transition was the worst case, compound transition was better, while the spiral transition allowed the easiest path to follow.

The NCHRP report (16) looked at over 15,000 accidents on the Pennsylvania and Ohio Turnpikes during the late 1960's. Its major finding was that conformance with AASHTO recommendations for superelevation of long radius curves would substantially improve pavement surface drainage and therefore would reduce the number of wet weather accidents.

These reports agree that the highest practical maximum superelevation rate should be selected for horizontal curve design.

III - Possible Research

As can be seen from the literature review, if safety is the main concern, no design exception would be preferred. This is due to the fact that roads that meet the geometric design standards, with very few exceptions, have better accident experience than roads with lesser designs. However, with the ever-tightening fiscal situation, the Department may need to begin looking for the largest return on the money that is spent on safety improvements. What this means is not maximizing the safety benefits for each project, but rather increasing the total safety benefits by the improvement of more miles of

highway. In this way monies being spent on meeting the design standards which are not cost effective could be spent on other projects where the accident savings would be greater

Before this is done, however, the policy makers of the Department must be consulted to determine the limits of any deviation from the design standards. This is due to the fact that it would be very difficult for the Department to defend a position in which more accidents and even a fatality were allowed just to save money, especially when the design standards could have been met

After this decision is made, a study like the Roy Jorgenson Associates' study (28) could be performed to determine the cost-effectiveness of certain geometric characteristics in comparison to accident rates. Such a study would include a full inventory of the road system to determine the geometric characteristics, an accident investigation, and a statistical correlation to determine accident rates for specific geometric configurations. The geometric data needed will be very difficult and costly to obtain and the accident data must have a very precise reference system so that an accurate comparison between geometric features and accidents can be made. A more specific discussion of this research effort is presented in the Appendix.

APPENDIX

The NCHRP report (28) prepared by Roy Jorgenson Associates, Inc. developed a cost-safety effectiveness methodology for rural two-lane highways dealing with pavement width, shoulder width, and shoulder surface type. Existing geometric and accident files from three states were used to quantify the safety effect of the three geometric features. These safety relationships were then expressed as accident rate adjustment factors for a base accident rate associated with a maximum design. These rates can be used by any agency once it has calculated its own base accident rates, which include the fractional property damage only accidents and the injury to fatality ratio. Also needed for this methodology is the incremental cost of the improvement, such as shoulder widening costs per foot. In this way the costs for each design alternative can be compared to the cost savings due to the reduction in accidents.

Using this methodology, the Department could begin optimizing its cost-safety effectiveness as it relates to pavement width, shoulder width and shoulder types as soon as these accident rates and construction costs were developed for two-lane rural roads.

Two other geometric features were looked at in the Jorgenson study. Pavment cross slope and superelevation, although they do reduce the number of accidents, are not very expensive to implement. Therefore, it was concluded that reducing the design standards of these geometric features would not save an agency a great deal of money and therefore projects should always meet the maximum design standards for pavement cross slope and superelevation.

This leaves us with three geometric features that haven't been looked at as to their cost-safety effectiveness. A research project could be introduced to determine the specific effect of bridge width, side slopes and ditches, and horizontal curves on safety. This would demand three data collection intensive steps.

First, a collection of new geometric information would need to be done. The Bureau of Data Resources has a geometric file for state highways which includes shoulder width and pavement width but no other geometric data. Thus, the additional geometric data would need to be collected through a large scale field data collection program. The data would be obtained by a field crew travelling throughout the state making measurements on the different geometric features. This data would be of paramount importance if a project to determine a geometric feature's effect on accidents were initiated.

Then, an accident investigation would need to be performed to match up the accidents to the specific geometric configurations. Two problems could arise in such a procedure. First, it must be determined that the features which were observed in the field have not changed through the period that we are reviewing for the accident history. Second, the accident records must have a nearly precise reference system and accurate reporting techniques so that the accidents for a specific type geometric feature will match the actual location.

The third step would be the statistical correlation between the geometric feature and the accidents. After all this is done, we still may not have enough data to make a statistically significant statement about a specific geometric feature due to the lack of locations with that feature.

This procedure could be done for the three geometric features and incorporated into the Jorgenson methodology for two-lane, rural roads. For other types of roads such as urban or four-lane roadways the same procedure would have to be followed but all eight geometric features would need to be studied.

DESIGN EXCEPTIONS VS. ACCIDENT RATE

ANNOTATED BIBLIOGRAPHY

1. Relationship of Rural Highway Geometry to Accident Rates in Louisiana - Olin K. Dart, Jr. and Lawrence Mann, Jr., HRR #312, 1970

   This report looked at nearly 6,000 accidents from 1962 to 1966 on approximately 1,000 miles of two lane rural roads. The geometric features looked at were lane width, shoulder width, cross slope, vertical alignment, and horizontal alignment. The major findings were that pavement cross slope had the most effect on accident rates. As the cross slope increased, the accident rate decreased. Also, as lane width increased, the accident rate decreased. The remaining geometric factors showed no significant effect on the accident rates.

2. Effect of Lane and Shoulder Widths on Accident Reduction on Rural, Two-Lane Roads - Charles V. Zegeer, Robert C. Deen, and Jesse G. Mayes, TRR #806, 1981

   This report looked at accidents on 15,000 miles of highways. It showed that run-off-the-road and opposite direction accidents were the only ones significantly reduced by widening the lane and shoulder widths. Tables were produced which show that widening lanes can reduce these accidents by 10 to 39 percent while increasing shoulder width can reduce accidents by 6 to 21 percent. There was no relationship found between lane width and degree of severity .

3. Freeway Modifications to Increase Traffic Flow, William R. McCasland and Raymond G. Biggs, FHWA-TS-80-203, January 1980

   This report deals with reducing lane widths and using shoulders to increase roadway capacity. It reports that accident rates do drop when these type projects start up but concedes that this rate will probably reach or surpass the before rate once the demand grows to the new capacity.

4. The Identification of Relationships Between Safety and Roadway Obstructions - Thomas J. Foody and Michael D. Long, January 1974

   This report looked at the frequency of single vehicle accidents on rural, two-lane roads. The findings were that increasing roadway width, increasing shoulder width, and improving shoulder quality decreased the number of accidents.

5. A Detailed Study of Accidents as Related to Highway Shoulders in New York State - C. E. Billion and Walter R. Stohner, HRB Proceedings, Volume 36, 1957

   This report studied approximately 1,750 accident reports from 1947 to 1955 on two-lane, rural roads and tried to relate them to shoulder width, horizontal curves and vertical curves. The findings were that medium width (5-7') shoulders had lower accident rates than narrow (3-4') shoulders under all alignment configurations. Wide shoulders (8' or over) had lower accident

rates than narrow or medium shoulders when a horizontal curve exists and horizontal curvature had more effect on accidents than shoulder width. There was not enough pavement width data to show a relationship between it and accidents.

6. Relation of Highway Accidents to Shoulder Width on Two-Lane Rural Highways in New York State - Walter R. Stohner, HRB Proceedings -Volume 35, 1956

This report concluded that pavement width had no definite relationship to accidents but that there was a measurable relationship between shoulder width and accidents, especially property damage only accidents.

7. The Relationship Between Accident Data and the Width of Gravel Shoulders in Oregon - J. A. Head and Dr. Noel F. Kaestner, HRB Proceedings - Volume 35, 1956

This report studied the accident history from 1952 to 1954. It concluded that accidents and shoulder width were not related where the average daily traffic (ADT) was less than 3,600 vehicles, were statistically significantly related where ADT was between 3,600 and 5,500 vehicles, and were related but not statistically significant at ADT of over 5,500 vehicles.

8. Traffic Control and Roadway Elements - Their Relationship to Highway Safety/Revised - Chapter 7 - Cross Section and Pavement Surface - John A. Dearinger and John W. Hutchinson, 1970

This report summarized the existing data on the relationship between certain geometric characteristics and accidents. It reported that a Louisiana study stated that the pavement cross slope is the most important geometric feature concerning accidents. That there is disagreement on the relationship between shoulder width and accidents, but that is not as important a factor as alignment. It also states that as lane width increases, accident decrease; and, finally, that side slopes of more than 6:1 ratio have a higher accident experience.

9. Traffic Control and Roadway Elements - Their Relationship to Highway Safety/Revised - Chapter 12 - Alinement - Jack E. Leisch and Associates, 1971

This report summarized the existing data concerning the relationship of alinement to accidents. It reported that as sharpness of curves increase, the accidents increase. For curves of 0-2.9 degrees, the accident rate was 1.66 acc/mvm while for curves of 6.0 degrees or more the accident rate was 3.13 acc/mvm. Also that as the number of curves increase, the accidents decrease. For example, for intermediate curves ($3\text{-}6^{\circ}$), when there is one curve per mile, an accident rate of 4.5 acc/mvm exists, while when there are four curves per mile, an accident rate of 2.5 acc/mvm exists.

10. Some Case Studies of Highway Bridges Involved in Accidents - M. H. Hilton, HRR #432, 1973

This report stated seven situations where accident potential was high at bridge structures. They were where the bridge width to approach width

rate is less than .8, where there is a curve on the bridge approach especially to the left, where there is transition from 4 to 2 lanes or 2 to 4 lanes on the bridge approach, where there is an intersection adjacent to the bridge, where there is a downhill grade on the approach, where there is a curve on the bridge itself, and finally any combination of these factors.

11. Effects of Certain Roadway Characteristics on Accident Rates for Two-Lane, Two-Way Roads in Connecticut - R. C. Gupta and R. P. Jain, TRR #541, 1975

This report deals with approximately 31,200 accidents from 1964 to 1969 on 1,548 roadway segments. The features studied were roadway width, horizontal curvature, vertical clearance, and sight distance. A linear regression was done and only about 5% of the variation was accounted for by these four variables. Pavement width and vertical clearance had no effect while sight distance and horizontal curvature had a small effect.

12. Shoulder Upgrading Alternatives to Improve Operational Characteristics of Two-Lane Highways - Daniel S. Turner, Ramey O. Rogness, and Daniel B. Fambro, TRR #855, 1982

This report deals with the accident experience of two types of improvements, paving shoulders and using existing shoulders for traveled lanes. The findings were that paving shoulders reduced total accidents. On low volume roads (1,000-3,000 vpd), it reduced the number of single vehicle accidents only. On moderate volume roads (3,000-5,000 vpd), it reduced the number of total accidents and their severity, while on high volume roads (5,000-7,000 vpd), it reduced the number of total accidents but severity actually increased. As for converting shoulders into traveled lanes, on low volume roads, accidents increased, while on high volume roads, the accidents decreased as the volumes increased. The severity of accidents with this type of improvement increased during the night and decreased during the day.

13. Interstate Highway - Accident Study - Morton S. Raff, HRR Bulletin #74, 1953

This report used accident data from fifteen states covering about 5,000 miles of roadway. The findings were that sharp curves had higher accident rates than flat curves, wider pavement on curves reduced the accident rates, but had no effect on tangent sections, and as bridge width increased the accident rate decreased. Finally, grades and shoulder width had no effect on accidents.

14. Accident Rates as Related to Design Elements of Rural Highways, Jaakko K. Kihlberg and K. J. Tharp, NCHRP #47, 1968

This report deals with accidents from the states of Louisiana, Ohio, and California and their relationships to curves, grades, intersections, and structures. The findings were that the presence of any of these elements increased the accident rate, a combination of these elements increased the accident rate more than an individual geometric element, curvature by magnitude had no effect on accident rates, but going from no curve to a 4 or more degree curve did, and finally these geometric elements had no effect on accident severity.

15. A Methodology to Relate Traffic Accidents to Highway Design Characteristics, Kishore Shah, Ohio, 1968

The author studied 312 accidents on 196 miles of rural highways in Athen County, Ohio in 1965. He tried to relate curvature, gradient, pavement width and shoulder width to these accidents. The results were that as curvature increased the accident rate increased, as grades increased the accident rate increased, but this relationship was not as strong as that for curvature. Pavement width had a strong relationship with widths of 22 to 24 feet having a lower accident rate than narrower or wider widths. Shoulder width had no clear relationship. Non-linear multiple regression equations were develped using these variables, but it only accounted for about 42 percent of the variability in accidents.

16. Recommended Modification of Superelevation Practice for Long-Radius Curves, NCHRP Research Results Digest #72, 1975

This report looked at over 15,000 accidents on the Pennsylvania and Ohio Turnpikes in the late 1960s. It found that there is a general lack of conformance with AASHTO recommendations for superelevation of long-radius curves which would substantially improve pavement surface drainage and, therefore, reduce the number of accidents.

17. Accidents Associated with Highway Bridges, Kenneth R. Agent, 1975

This report analyzed 1972-1973 accidents associated with bridges. Roadways were divided into two groups: interstates and parkways; and primary and secondary roadways. The major findings were a significant percentage of total and severe accidents on the interstates and parkways are bridge related. The severity of bridge-related accidents was higher than the severity of all accidents. Bridges with full shoulders had less accidents. A high percentage of bridge-related accidents occurred in darkness and snowy or icy conditions.

18. Case for Removing Bridge or Culvert Rails on Low-Volume Rural Roads, Bob L. Smith, T.R.R. 875, 1982

This study states that in situations on low volume rural roads where a culvert or bridge is six feet deep or less, a bridge rail end is probably more a hazard than the ditch it protects. The removal would also increase road width which would also increase safety. A benefit/cost analysis is performed based on accident costs by severity of the accidents and costs of removal of the bridge rail.

19. Selection of Safe Roadside Cross Sections - Graeme D. Weaver, Eugene L. Marquis, and Robert M. Olson, NCHRP Report #158, 1975

The objective was to investigate vehicle behavior at different configurations of ditches. The Highway Vehicle Objective Simulation Model was used in this evaluation. Major findings were front slopes steeper than 4:1 are not desirable because their use severely limits the choice of back slopes producing a safe ditch configuration; the severity of traversal of ditches less than about eight feet wide is essentially the same for comparable slope combinations regardless of ditch shape; the trapezoidal ditch configuration

represents the most desirable cross section from a safety standpoint, particularly those wider than eight feet.

Objective Criteria for Guardrail Installation - John C. Glennon and Thomas N. Tamburri, H.R.R. #174, 1967

This report tries to set warrants for where guardrail should be installed on embankments. By using number of accidents and accident severity of 1963-1964 accidents a multiple regression formula was computed with the variables being height, slope, size of material, and slope of original ground at toe of embankment. The result was a graph of slope vs. height showing where guardrail would increase safety.

21. Accident Rates vs. Shoulder Width - E. A. Rinde, California Department of Transportation - 1977

A before and after accident study was performed to evaluate 37 widening projects representing 143 miles of improved road. Widening widths of 28, 32, and 40 feet were studied. For all three widths, accident rates were reduced except where a 24 ft. roadway was widened to 28 ft. Only the 32 ft. and 40 ft. accident reduction was statistically significant however. Tables were produced which match the recommended pavement widths to the average daily traffic on the roadway.

22. The Safety Implications of Geometric Standards, J. R. McLean, Proceedings of the Workshop on Economics of Road Design Standards, 1980

This report summarizes the past projects dealing with accident experience versus pavement width, shoulder width, and horizontal curvature. The conclusions were that the accident rate went down as the pavement width increased with 22 ft. the most safety effective. The safety effectiveness of shoulder width still is clouded although it seems that wider shoulders are safer. Horizontal curvature appeared to be related to the consistency with which the standard is applied as much as to the standard itself. This means that as the number of a certain radius curve increases per mile, the accident rate decreases.

Achievement of Safety Objectives in a Road Funding Program, D. P. Murray and A. J. Carter, Proceedings of the Workshop on Economics of Road Design Standards, 1980

This report states that road and traffic factors contribute to about 20 percent of road accident costs. It also compared low-cost site improvement projects to high cost construction projects applying high design standards. It concluded that the site improvements can make a substantial contribution to safety while being a small portion of the overall transportation budget. The high standard roads can contribute to safety but could not be justified on safety alone.

24. The Relationship Between Accident Data and the Width of Gravel Shoulders in Oregon, J. Al. Head, 1955

This study looked at accidents within 344 one-mile sections of homogeneous rural roadways from 1952 to 1954. The findings were that accident frequency was not affected by shoulder width for roadways with ADT lower than 3,600 vehicles, accident frequency was statistically affected by shoulder width for roadways with ADT from 3,600 to 5,000 vehicles, and for roadways with ADT greater than 5,500 vehicles, the accident frequency was affected but not statistically. The relationship in the latter two cases was that as shoulder width increased, the accident frequency decreased.

25. Operational and Safety Effects of Driving on Paved Shoulders in Texas, D. B. Fambro, D. S. Turner, and R. O. Rogness, 1981

This study looked at accident experience on three types of roads: two lane with no shoulder, two lane with full width shoulders, and four lane with no shoulders. In a comparative study, two lanes with no shoulders had the highest accident rate followed by four lane with no shoulders and finally two lane with shoulders. A before-after analysis was also done. The addition of full width shoulders to a two lane roadway was effective in reducing the total number of accidents, while converting existing shoulders on a two lane road to travelled lanes had varied results. At low volumes, the accidents actually increased with four lane-no shoulder, while at higher volumes the accidents decreased.

26. Effects of Certain Geometric Design Characteristics of Highways on Accident Rates for Two-Lane, Two-Way Roads in Connecticut, Ramesh C. Gupta and Rajendra Jain, 1973

This study looked at 34,158 accidents from 1964 to 1969 on 2,013 miles of Connecticut state maintained two-lane, two-way roadways. Geometric characteristics considered through the use of multiple regression analysis were roadway width, horizontal curvature, vertical clearance and sight distance. Each characteristic was given a rating based on its adequacy or sufficiency. The major findings were that on rural roads, horizontal curvature has the highest correlation with the accident rate on roads with ADT of 1,500 to 6,900 vpd, whereas for roads with ADT of less than 1,400 vpd, roadway width has the highest correlation with the accident rate. On urban roads, horizontal curvature has the highest correlation with the accident rates on roadways with ADT of 3,000 to 7,900 vpd and roadway width had no significant effect on accident rates.

27. Shoulder Geometrics and Use Guidelines, Hugh G. Downs, Jr. and David W. Wallace, NCHRP #254, 1982

This report dealt with the many uses of shoulders. It reviewed the literature on shoulder use, reported on interviews with personnel from 17 highway agencies, and updated the results of a 1977 questionnaire about shoulder use with the highway agencies which weren't interviewed. The main result of this study is a table which gives standards for the selection of optimum shoulder geometric design criteria for each shoulder use identified in the study.

28. Cost and Safety Effectiveness of Highway Design Elements, Roy Jorgensen Associates, Inc., NCHRP 3-25, 1978

This study's purpose was to establish a procedure to determine the cost-effectiveness of certain geometric characteristics in comparison to accident rates. It first looked at individual characteristics to determine their potential for cost savings without loss of safety. It was found that pavement cross slope and superelevation costs were not enough to save money by reducing standards while other characteristics could produce cost savings by reducing standards but not increase accidents. Regression analysis was done on the effects of pavement width, shoulder width and shoulder surface on accidents for two lane rural roads. From this came a table which when used with any state's base accident rate for rural roads would give the expected accident rate for any improvement with these three characteristics. If you then compare the costs associated to the accident rates for each alternative to the construction cost for each alternative, the alternative which is most cost-effective can be chosen. This procedure will not maximize the safety benefits for each project, but the total safety benefits are increased by the improvement of more miles of facilities, rather than a few miles of improvements that are built to designs that are not cost effective.

29. Synthesis of Safety Research Related to Traffic Control and Roadside Elements - Chapter 1 - Roadway Cross Section and Alinement, Howard H. Bissell, George B. Pilkington II, John M. Mason, and Donald L. Woods, 1982

This study reported on the existing research performed to relate accident data to geometric characteristics. The findings were that as lane width increases accident rates decrease up to 11 ft. on two-lane rural roads, shoulder widths related to accidents have shown mixed results, as bridge width increases accident rates decrease, roadways with relatively flat cross slopes are more accident prone than those with steeper slopes, the trapezoidal ditch configuration represents the most desirable cross section from a safety standpoint particularly for ditches wider than 8 ft., as the degree of horizontal curvature increases so does the accident rate, and superelevation reduces water depth on the roadway and thus reduces the wet weather accident rate.