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Accident Implications of Shoulder Width on Two-Lane Roadways

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Previous studies regarding the accident implications of shoulder width have been inconclusive and their results contradictory. Engineering guidelines concerning shoulder width have been established, but emphasis is placed on the minimum shoulder width necessary for emergency parking and not on the effects of shoulder width on accident experience. The accident implications of shoulder width on two-lane roadways in an urban county in Michigan are investigated. Some liability claims against the county road agency have alleged that shoulders, which are at variance with shoulder-width guidelines, are hazardous because they do not adhere to the suggested guidelines. One intent of this paper is to determine whether these allegations are substantiated. Analyses were performed to determine whether there is a significant difference in accident frequency between two-lane roadways that meet shoulder-width guidelines and those that do not meet the guidelines. The results of this research do not support the premise that roadways with wider shoulders have significantly fewer accidents than roadways with narrow shoulders. No significant difference in accident frequency was found between roadways that meet shoulder-width guidelines and those that do not meet the guidelines. Accident data reviewed in this study reveal that shoulder width is not related to the frequency of overturn accidents, head-on type accidents, or to accident frequency in general, even after traffic volume and other variables are considered. A relation was discovered between the frequency of fixed-object accidents and shoulder width, but the findings indicate that fixed-object accident frequency is significantly lower on roadways with shoulders <7 ft wide than it is for roadways with wider shoulders. It was concluded from this research that (a) projects to reduce accident frequency should focus on factors that exhibit greater influence on accident frequency than does shoulder width; and (b) although it is desirable to adhere to current guidelines wherever possible, when undertaking certain types of construction projects it may be acceptable to retain existing shoulders of <8 ft in width unless a review of accident data for the project location indicates otherwise.

Previous studies regarding the accident implications of shoulder width have been inconclusive and their results contradictory (1-7). Engineering guidelines concerning shoulder widths have been established (8,9), but these guidelines emphasize the minimum shoulder width necessary for emergency parking and not the impact of shoulder width on accident experience. It would be advantageous to provide adequate facilities for emergency parking, but to adhere to these guidelines on all roadways would not be financially feasible.

It is more practical to investigate the effect of shoulder width on accident occurrences and pinpoint locations where accident experience can be related to shoulder width or a combination of shoulder width and other roadway factors. If such locations can be determined, then countermeasures to alleviate the accident situation could be implemented.

The accident implications of shoulder width on two-lane paved roadways are investigated in this paper. Analyses were performed to determine

1. Whether there is a significant difference in accident frequency between two-lane roadways with shoulder widths that meet the guidelines and those that do not meet the guidelines, and
2. Whether there is a relation between certain accident types and shoulder width.

The primary purpose of this research was to determine the relation between accident characteristics and shoulder width on two-lane roadways in Oakland County, Michigan. The research did not address the liability exposure of the residents of Oakland County or the Oakland County Road Commission (OCRC) due to shoulder widths less than those recommended by current engineering guidelines. Nevertheless, some liability claims against the Road Commission have cited narrow shoulders as contributing factors in certain accidents because the shoulders do not conform to the guidelines. If shoulder width is a contributing factor in certain accident types or the frequency of accidents, corrective action by OCRC may be justified.

PREVIOUS STUDIES

The multiplicity of studies concerning the effects of shoulder width on accident occurrences has resulted in an array of contradictory and often inconclusive findings. Transportation professionals have been forced to choose among these varied results for years.

In a critique of these past research attempts, Zeeger and Perkins (10) concluded that studies that found wider shoulders associated with safer conditions were the most reliable. They based their con-

Figure 1. Accidents by shoulder width.

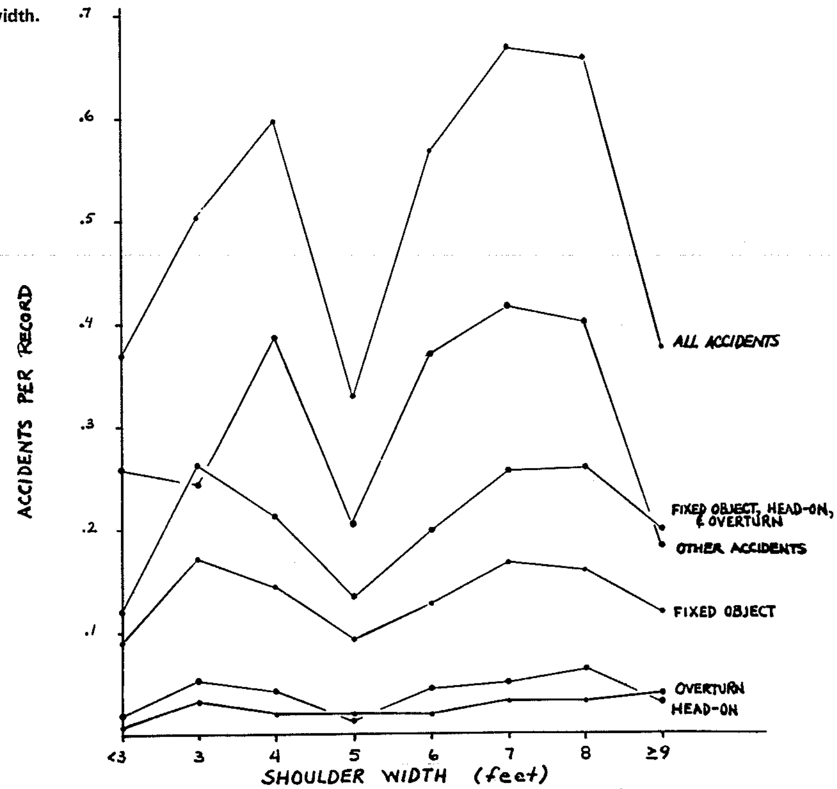
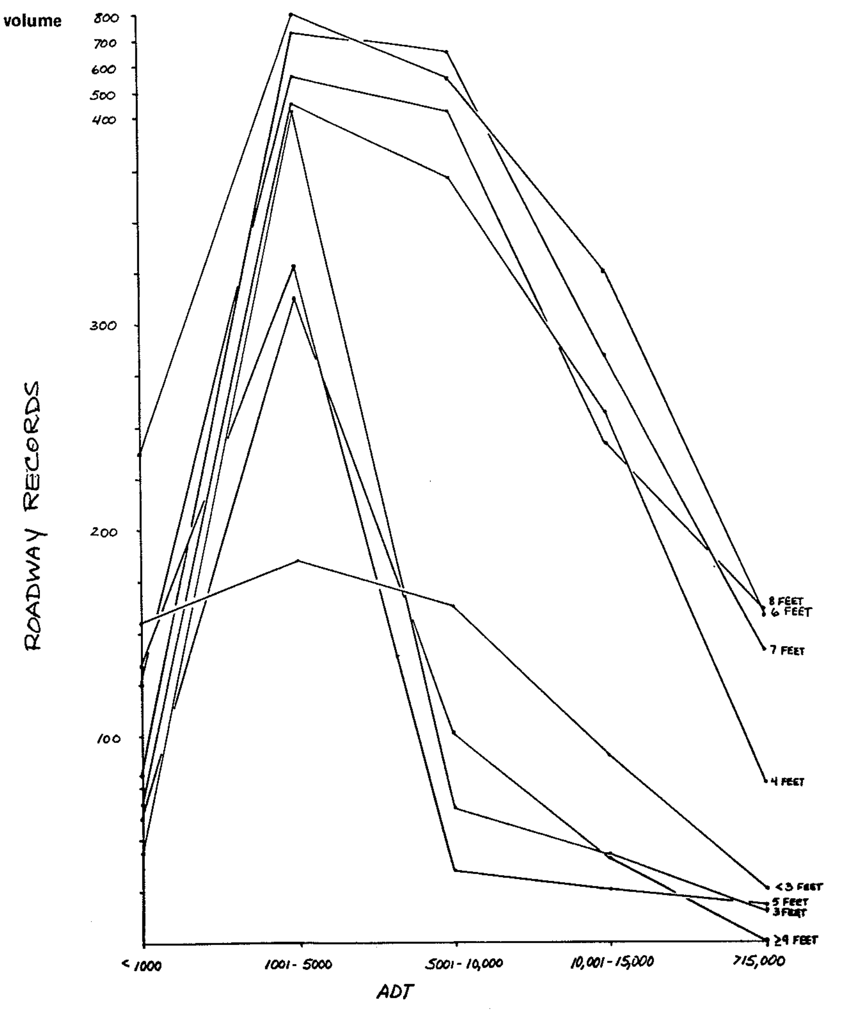


Figure 2. Roadway records by traffic volume and shoulder width.



clusion on a set of criteria concerning the type of analysis used, the reliability of the data, the sample size, and the importance of categorizing shoulder-width effects by accident type.

Attempts were made in this study to integrate the conclusions of Zeeger and Perkins in order to improve the reliability of the findings of this paper. A comparative analysis of accident experience by shoulder width on all paved two-lane major roadways (637 miles) in Oakland County was conducted. Roadway geometric data and accident data were derived from computer files established in 1980 and 1981. More than 5,000 accidents, categorized by various types, were reviewed for almost 9,000 computer records. The control of variables other than shoulder width was facilitated by the statistical methods used to test the research hypotheses.

BACKGROUND

In 1978 OCRC initiated a highway risk management program (11) in order to identify elements of risk to Oakland County's traveling public and to the Road Commission and to treat those risks in a systematic, cost-effective manner. In order to effectively manage the risk, information concerning the county road network and traffic accidents was a necessity.

The OCRC maintains almost 1,500 miles of county primary and local roads and approximately 1,100 miles of subdivision streets. In 1980 and 1981 OCRC completed an inventory of roadway features for all major county roadways and compiled the information on computer tape. To supplement the roadway inventory, the Statistical Package for the Social Sciences (SPSS) (12,13) was obtained to allow the manipulation of data concerning roadway features, roadside obstacles, and accident characteristics. The development of this comprehensive roadway information system (CRIS) enhanced OCRC's research capabilities and allowed detailed analysis of the relation between shoulder width and accidents.

Approximately half of the 1,500 miles of major county highways are paved, and 637 miles of this total are two-lane uncurbed roadways. The data in Table 1 give the number of miles of two-lane paved roadways by shoulder width. The mean shoulder width on these roadways is 5.9 ft, with a standard deviation of 2.32.

Shoulders are defined in this study as the maintained portion of the roadway between the paved, traveled surface and the roadside ditch. In most cases the shoulder surface consisted of gravel, although minimal paved shoulders (i.e., 3 to 4 ft) existed at a negligible number of selected spot locations. Shoulder widths were derived from a review of photologs, wherein a grid overlay, which facilitated lateral measurement, was placed over the photolog viewing screen.

ACCIDENT TRENDS

The frequencies of various accident types by shoulder width are given in Table 2. These accident data were derived from 1980 accident files available from the Traffic Improvement Association of Oakland County. It would be advantageous to analyze accidents over a 3-yr period, but because of the recent completion of the CRIS, accident data for only 1 yr were available for the analysis. Nevertheless, the size of the accident and roadway samples compensated for this situation. Although all nonintersection accidents for 1980 were reviewed in this analysis, primary emphasis was placed on accident types that are commonly associated with shoulder width (i.e., fixed-object, overturn, head-on, and opposite-direction sideswipe accidents). Another accident type commonly associated with shoulder width--vehicles striking other vehicles stopped on the road--was not analyzed because of the low frequency of accidents of this type.

The distribution of accident frequencies per roadway record for each accident type and shoulder width is shown in Figure 1. Because of the small number of roadway records for extremely narrow shoulder widths and for shoulder widths ≥10 ft, new shoulder width categories were formed by combining records for shoulder widths <3 ft and ≥9 ft.

As indicated by the data in Figure 1, the relations between the frequencies of various accident types and shoulder widths appear to follow a general pattern. Accidents tend to increase with increasing shoulder widths up to 5 ft. For 5-ft shoulders, a decrease in accident frequency is indicated for most accident types. For shoulder widths >5 ft, accidents again increase. For shoulder widths ≥9 ft, there is a decrease in accidents.

These fluctuations may be attributed, in part, to the variation in the number of records for each shoulder-width category. For shoulder-width categories where the number of records is small, the accident frequency per record decreases. Nevertheless, other factors, such as traffic volume [i.e., average daily traffic (ADT)], may also influence these relations.

The relation between shoulder width and traffic volume is shown in Figure 2. As indicated by the data in Figure 2, the number of records for roadways with shoulder widths ≤3 ft, 5 ft, and ≥9 ft drop dramatically as traffic volume increases to greater than 5,000 vehicles/day. The relation between accident frequency and traffic volume has been accepted for many years (14), and this relation may account for the low accident frequencies for roadways with these shoulder widths.

A review of the data in Figure 3 reveals that a positive relation between accident frequency and

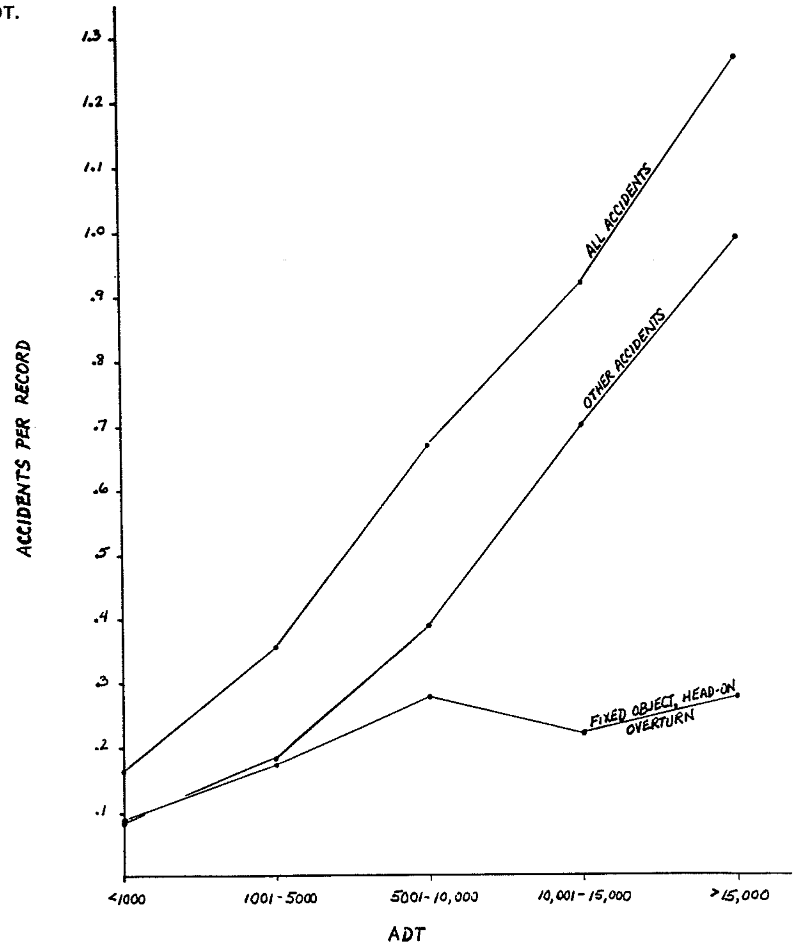
Table 1. Roadway records and mileage by shoulder width.

Shoulder Width (ft)	No. of Roadway Records	Approximate Roadway Miles
≤2	617	44
3	588	41
4	1,222	87
5	537	38
6	2,068	147
7	1,886	134
8	1,511	107
9	515	36
≥10	48	3
Total	8,992	637

Table 2. Accident types by shoulder width.

Shoulder Width (ft)	No. of Accidents: Fixed Object	Overturn	Head-On and Opposite Direction Sideswipe	Other	Total
≤2	54	4	14	156	228
3	101	21	32	142	296
4	177	27	54	470	728
5	49	13	9	106	177
6	264	46	92	770	1,172
7	321	61	97	785	1,264
8	244	47	99	605	995
9	56	20	13	88	177
≥10	10	2	4	18	34
Total	1,276	241	414	3,140	5,071

Figure 3. Accidents by ADT.



traffic volume exists. Therefore, the fluctuations in accident frequency for various shoulder widths can be partly attributed to the relation between shoulder width and traffic volume.

Generally, accidents increase as traffic volume increases, but when accident types are segregated, some types reveal a stronger relation to traffic volume than others. As shown by the data in Figure 3, fixed-object, head-on, and overturn accidents increase at a lesser rate than other accident types as traffic volume increases. A review of the data in Figure 4 indicates that the relation between these accident types and traffic volume is strongly influenced by the relation between head-on and fixed-object accidents and traffic volume, whereas overturn accidents remain relatively constant as traffic volume increases. These relations, and how other factors in combination with shoulder width influence accident frequency, are examined in greater detail later in this paper.

METHODOLOGY

The objectives of this study were to

1. Determine whether there is a significant difference in accident frequency between two-lane roadways with shoulder widths that meet the AASHO guidelines and those with shoulder widths that do not meet the guidelines, and
2. Determine whether there is a significant relation between certain accident types and shoulder width.

The first hypothesis to be tested states that roadways with shoulders ≥8 ft wide experience significantly lower frequencies of accidents (especially fixed object, overturn, and head-on) than roadways with narrower shoulders. The critical shoulder width of 8 ft was chosen based on AASHO guidelines (9) for urban arterial streets. Although AASHO recommends 10-ft shoulders, the guidelines state that 8-ft shoulders work "moderately well" when 10-ft shoulders are not feasible. Because the number of roadways with shoulder widths ≥10 ft is too small to allow valid comparisons, the study objective was altered to reflect this situation. Thus the research hypothesis can be stated as follows:

$$H_1 : \mu_1 < \mu_2 \quad (1)$$

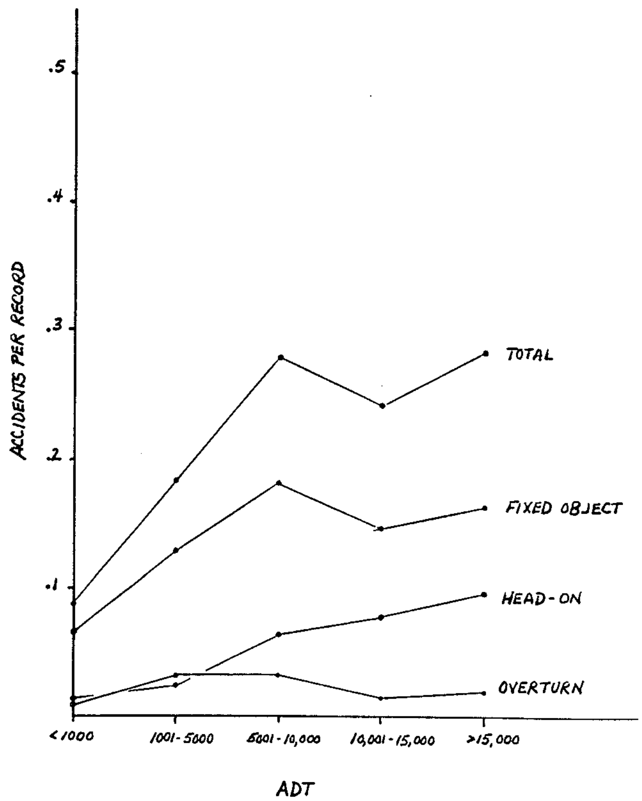
$$H_0 : \mu_1 \geq \mu_2 \quad (2)$$

where

H_1 = research hypothesis,
H_0 = null hypothesis,
μ_1 = mean frequency of accidents on roadways with shoulders ≥8 ft wide, and
μ_2 = mean frequency of accidents on roadways with shoulders <8 ft wide.

T-tests were performed to compare the record of mean accident frequencies per roadway on roadways with shoulders <8 ft wide and those with shoulders ≥8 ft wide. A significance level of 0.01 was chosen for the T-tests.

Figure 4. Fixed-object, overturn, and head-on accidents by ADT.



Analysis of variance (ANOVA) was used to determine whether accident types are associated with shoulder width. Accident types were segregated into four categories: all accidents, fixed-object accidents, overturn accidents, and head-on or opposite-direction sideswipe accidents. A significance level of 0.01 was chosen for the ANOVA.

The ANOVA allows the analyst to determine whether there is a significant difference in at least two category means for the frequency of each accident type categorized by shoulder width. The research hypothesis for the ANOVA can be stated as

$$H_1 : \mu_{1a} < \mu_{2a} < \mu_{na} \quad (3)$$

where

- μ_{1a} = mean accident frequency of accident type a for the widest shoulder width,
- μ_{2a} = mean accident frequency of accident type a for the next widest shoulder width, and
- μ_{na} = mean accident frequency of accident type a for the narrowest shoulder width.

If a significant difference in at least two of the category means was found, further tests were conducted to determine which of the category means differ significantly.

RESULTS

The data in Table 3 give the mean number of accidents for roadways with shoulders <8 ft wide and for roadways with shoulders ≥8 ft wide. Accident types were broken down into six categories.

At a level of significance of 0.01, the critical T-score is approximately 2.326. The computed T-scores are given in Table 3 for comparison. As indicated by the data in Table 3, none of the accident types demonstrated a significant difference in mean accident frequency between the two shoulder-width categories. Therefore, the research hypothesis is rejected.

The results of the T-test demonstrated that roadways with shoulders ≥8 ft wide do not experience fewer accidents than roadways with shoulders <8 ft wide. A review of the data in Table 3 reveals that most of the computed T-scores are negative, which indicates that the mean accident frequencies for roadways with shoulders <8 ft wide are less than the mean accident frequencies for roadways with wider shoulders.

An ANOVA was conducted to determine which accident types are related to shoulder width. The data in Tables 4-7 give the results of the ANOVA for total accidents, fixed-object accidents, overturn accidents, and head-on accidents. Because traffic volume has been shown to be influential in accident frequency, it has been included as a covariate in the ANOVA. Another variable that has been shown to be influential in the frequency of certain accident types is roadway curvature (15-19). This variable has also been included as a covariate. A significance level of 0.01 was chosen for each test.

The data in Table 4 give the results of the ANOVA for all accidents. When traffic volume and roadway curvature are included in the model as covariates, no significant relation between accident frequency and shoulder width is noted. Most of the explained variation is due to the effect of traffic volume on accident frequency. This finding corresponds to the relation shown in Figure 3.

The data in Table 5 indicate that the frequency of fixed-object accidents is related to shoulder width, even when traffic volume and roadway curvature are included as covariates. The data in Table 6 review the ANOVA for overturn accidents. The results indicate that the frequency of overturn accidents is not related to shoulder width or traffic volume, but it is related to roadway curvature. The data in Table 7 indicate that head-on accident frequency is related to traffic volume and roadway curvature, but not to shoulder width.

It appears that only fixed-object accidents are related to shoulder width. Although this relation was significant at the 0.008 level, the amount of variance in fixed-object accident frequency explained by shoulder width after traffic volume and roadway curvature were considered was not great.

Because only fixed-object accidents were related to shoulder width, T-tests were performed to determine which of the category means differ significantly. The results of these T-tests are given in Table 8.

Traffic volume and sample size appear to influence the significant relation found between fixed-object accident frequency and shoulder widths <3 ft and 5 ft. After traffic volume and sample size were considered, the comparison of means for 6- and 7-ft shoulders demonstrated the only significant difference in fixed-object accident frequency. Further dissection of these results indicates that this finding only applies to roadways that carry 1,000 to 5,000 vehicles/day.

One further test was conducted to determine a range of shoulder widths that provide adequate safety in terms of fixed-object accident frequency when conditions prevent adherence to the guidelines. Shoulder-width categories were combined in order to analyze fixed-object accident frequency between pairs of shoulder-width ranges. T-tests were performed for each pair of ranges in a manner such that fixed-object accident frequency on roadways with shoulders <3 ft wide was compared with the acci-

Table 3. T-test results: shoulders <8 ft wide versus shoulders ≥8 ft wide.

		Accident Frequency per Record				
Shoulder Width (ft)	All Accidents	Fixed-Object, Overturn, and Head-On Accidents	Total of Other Accident Types	Fixed Object	Overturn	Head-On
<8	0.5587	0.2076	0.3511	0.1396	0.0249	0.0431
≥8	0.5815	0.2387	0.3428	0.1495	0.0333	0.0559
T scores	-0.70	-2.09	0.27	-0.85	-1.90	-2.25
Significance	NS	NS	NS	NS	NS	NS

Note: $\alpha = 0.01$, T = 2.326, and NS = not significant.

Table 4. ANOVA: all accidents by shoulder width, with traffic volume and roadway curvature.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	F Probability	Significance
Covariates	2	924.264	462.132	291.559	0.000	SIG
ADT	1	891.195	891.195	562.255	0.000	SIG
Curvature	1	50.920	50.920	32.125	0.000	SIG
Main effect—shoulder width	13	34.982	2.691	1.698	0.054	NS
Explained	15	959.250	63.950	40.346	0.000	SIG
Residual	8,976	14,227.285	1.585			
Total	8,991	15,186.535	1.689			

Note: $p < 0.01$, SIG = significant, and NS = not significant.

Table 5. ANOVA: fixed-object accidents by shoulder width, with traffic volume and roadway curvature.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	F Probability	Significance
Covariates	2	23.399	11.700	55.841	0.000	SIG
ADT	1	5.085	5.085	24.270	0.000	SIG
Curvature	1	19.184	19.184	91.563	0.000	SIG
Main effect—shoulder width	13	5.960	0.485	2.188	0.008	SIG
Explained	15	29.360	1.957	9.342	0.000	SIG
Residual	8,976	1,880.642	0.210			
Total	8,991	1,910.002	0.212			

Note: $p < 0.01$, and SIG = significant.

Table 6. ANOVA: overturn accidents by shoulder width, with traffic volume and roadway curvature.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	F Probability	Significance
Covariates	2	0.526	0.263	8.460	0.000	SIG
ADT	1	0.026	0.026	0.839	0.360	NS
Curvature	1	0.488	0.488	15.706	0.000	SIG
Main effect—shoulder width	13	0.583	0.045	1.442	0.131	NS
Explained	15	1.109	0.074	2.378	0.002	SIG
Residual	8,976	279.184	0.031			
Total	8,991	280.293	0.031			

Note: $p < 0.01$, SIG = significant, and NS = not significant.

Table 7. ANOVA: head-on accidents by shoulder width, with traffic volume and roadway curvature.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	F Probability	Significance
Covariates	2	6.374	3.187	62.088	0.000	SIG
ADT	1	5.993	5.993	116.754	0.000	SIG
Curvature	1	0.534	0.534	10.401	0.001	SIG
Main effect—shoulder width	13	1.310	0.101	1.964	0.020	NS
Explained	15	7.684	0.512	9.980	0.000	SIG
Residual	8,976	460.722	0.051			
Total	8,991	468.406	0.052			

Note: $p < 0.01$, SIG = significant, and NS = not significant.

Table 8. T-tests: fixed-object accidents.

Mean Accident Frequency	Shoulder Width (ft)	Signicance of T-Test by Shoulder Width (ft)							
		<3	3	4	5	6	7	8	⩾9
0.087	<3								
0.0912	5								
0.1172	⩾9								
0.1277	6								
0.1448	4	SIG			SIG				
0.1615	8	SIG			SIG				
0.1702	7	SIG			SIG	SIG			
0.1718	3	SIG			SIG				

Note: $\alpha = 0.01$, T = 2.326, and SIG = significant difference.

Table 9. T-tests: fixed-object accidents for combined shoulder-width categories.

Shoulder-Width Range (ft)	Mean Frequency of Fixed-Object Accidents	Variance	No. of Cases	Significance
<3	0.0875	0.106	617	SIG
⩾3	0.1478	0.220	8,375	
<4	0.1419	0.177	1,205	NS
⩾4	0.1440	0.218	7,787	
<5	0.1434	0.176	2,427	NS
⩾5	0.1438	0.226	6,565	
<6	0.1339	0.162	2,964	NS
⩾6	0.1485	0.237	6,028	
<7	0.1314	0.163	5,032	SIG
⩾7	0.1593	0.279	3,960	
<8	0.1396	0.209	6,918	NS
⩾8	0.1495	0.223	2,074	
<9	0.1455	0.215	8,429	NS
⩾9	0.1172	0.171	563	

Note: $\alpha = 0.01$, T = 2.326, SIG = significant, and NS = not significant.

dent frequency on roadways with shoulders ≥3 ft wide; the accident frequency on roadways with shoulders <4 wide was compared with the accident frequency on roadways with shoulders ≥4 ft wide; and so on.

The results of these tests are given in Table 9. The tests demonstrate that roadways with shoulders <3 ft wide have significantly fewer fixed-object accidents than roadways with wider shoulders, and that roadways with shoulders <7 ft wide have significantly fewer fixed-object accidents than roadways with wider shoulders. Although traffic volume and sample size may have influenced the significant difference in fixed-object accident frequency between roadways with shoulders <3 ft wide and those with wider shoulders, the significant difference found between roadways with shoulders <7 ft wide and those with shoulders ≥7 ft wide can be attributed to shoulder width.

CONCLUSIONS AND OPERATIONAL CONSIDERATIONS

The impact of shoulder width on accident experience for two-lane paved roadways in Oakland County has been addressed. The liability exposure of the county road agency has not been discussed, although liability claims against the agency have cited shoulder width, which is at variance with suggested guidelines, as a contributing factor in specific accidents.

Analyses were performed to determine whether there is a significant difference in accident frequency between two-lane roadways with shoulder widths that meet the guidelines and those that do not meet the guidelines, and whether there is a relation between certain accident types and shoulder width. The results of this study do not support the premise that roadways with wider shoulders experience fewer accidents than roadways with narrow shoulders. Although it is advantageous to construct shoulders to the minimum width necessary for emergency parking, the results do not indicate a significant difference in accident frequency between two-lane roadways that meet shoulder-width guidelines and those that do not meet the guidelines. Accident data reveal that shoulder width is not related to overturn accidents, head-on type accidents, or to accident frequency in general. A relation was discovered between fixed-object accident frequency and shoulder width. Nevertheless, the findings indicate that fixed-object accident frequency is significantly lower for roadways with shoulders <7 ft wide than it is for roadways with wider shoulders. These findings are similar to those reported by Blensley and Head (3) and Perkins (4).

Drivers may perceive roadways with wider shoulders differently than they perceive roadways with narrow shoulders. Wider shoulders may give drivers a false sense of security, wherein they are likely to drive at speeds faster than conditions tolerate. Although analysis of this hypothesis is beyond the scope of this paper, factors other than shoulder width were found to influence the frequency of fixed-object accidents more than shoulder width.

A step-wise regression analysis indicated that horizontal curvature, traffic volume, pavement width, vehicle speed, and vertical curvature influence the frequency of fixed-object accidents to a greater extent than shoulder width. Even after all of these roadway-related variables are considered in a multiple regression, only 1.3 percent of the variance (represented by r^2) in fixed-object accident frequency was explained. Shoulder width, by itself, only explained 0.06 percent of the variance in fixed-object accident frequency.

Variables that were not analyzed in this study, but which may also influence fixed-object accident frequency, include the condition of the shoulder, roadway delineation, weather and lighting conditions, the lateral distance of obstacles from the roadway, and driver-related factors (e.g., intoxication, inattention, improper passing, recklessness). Further research is needed to evaluate these factors.

Because of the influence of other factors on fixed-object accident frequency, and because of the substantial costs involved in shoulder alteration, projects designed to reduce fixed-object accident frequency through shoulder alteration would not be cost effective. Therefore, it was concluded that

1. Projects to reduce accident frequency should focus on factors that exhibit greater influence on accident frequency than does shoulder width, and
2. Although it is desirable to adhere to current guidelines wherever possible when undertaking certain types of construction projects, it may be acceptable to retain existing shoulders <8 ft wide

unless a review of accident data for the project location indicates otherwise.

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