TRANSPORTATION DEPARTMENT
DIVISION OF HIGHWAYS

PAVEMENT WIDTH STANDARDS FOR
RURAL TWO-LANE HIGHWAYS

A Report Prepared for the
Pacific Northwest Regional Commission

IDAHO

MATERIALS and RESEARCH SECTION

NOTICE

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RECOMMENDATIONS

If a slight increase in pavement maintenance and slight increases in accident rates are acceptable, reductions can be made in Idaho's paved width standards.* Cumulative economic effects of the expected increases in maintenance and accident costs would not likely offset construction cost savings within 30 years unless a pronounced increase occurs in average accident cost or unless accident trends change. Assuming these effects to be acceptable, the following recommendations are made as a result of this study:

Current ADT	Minimum Paved Width, Ft.
0-249	20
250-399	20
400-749	24
750-999	28
1000-1999	34
2000-2999	40

If accident costs increase by 50% or more without a corresponding increase in construction costs or if accident trends change significantly, these suggested standards should be reevaluated.

*The term paved width refers to the combined width of paved travel lanes and paved shoulders. Shoulder structural section is assumed to be the same as that of travel lanes.

ABSTRACT

This report summarizes statistical and economic investigations of traffic accident records from selected Idaho and Washington rural two-lane highways. The primary area of concern is the relationship among construction cost, maintenance cost, and accident costs as related to paved width. Results are compared with the minimum paved widths currently specified by the Idaho Division of Highways (IDH). The only configuration of interest is full width roadway paving, or paving which covers both driving lane and shoulder. Structural section of the shoulder is assumed to be the same as that of the travel lane.

In this report the term "shoulder" refers to the roadway area immediately to the right of the driving lane when looking in the direction of travel. The shoulder is bounded on the right by the intersection of the roadway plane and the side slope plane.

LITERATURE SUMMARY

Preliminary Comments

The subject of highway shoulder standards has received intermittent research attention for at least twenty years. Traffic accident records associated with various shoulder types and widths have been analyzed. In a few cases construction and maintenance costs have been evaluated for comparison with the benefits resulting from shoulder improvements. Some recent reports* (15, 17) contain detailed reviews of the research literature on the subject.

Accident Studies

Numerous studies have been made of accident frequency versus geometric characteristics of rural two-lane highways (1, 3, 4, 7, 11, 13, 15, 16). Paved shoulders are generally believed to be safer than unpaved, and an informal study in Louisiana supports this belief (17). In cases where paved shoulder width was evaluated for its effect on accident rate, results varied considerably among the research projects. For examples, a California study (1) limited to predominantly straight and level sections indicated 6-foot paved shoulders were superior to narrower ones and under many conditions were no worse than wider shoulders with regard to accident frequency. In a Connecticut report (4), on the other hand, total surface width including shoulders showed no definite relationship to accident rate. An Oregon study (7) was confined to essentially straight and level sections. A finding of the Oregon project was that the mean rate of total accidents was lower for narrow paved shoulders (4 feet or less) than for wide ones (8 feet or more), for a range of average daily traffic (ADT) of 1000 to 5000 vehicles. In a second Connecticut study (15), roadway width was found to have a significant effect on total accident rate for rural two-lane highways only for ADT less than 1400. Total accident rate was found to decrease as width increased.

Some of the investigations reviewed in this project considered other factors in addition to width. In several instances other elements were found to be more influential than width in the derived relationships with accident rate. For example, in a Louisiana study (13) the single variables exerting the strongest influences on accident rate were found to be traffic volume, cross slope, vertical alignment (steepness of grade) and traffic conflicts (traffic access points). Each of these four items affected accident rate more strongly than either lane width or shoulder width. The effect of cross slope was concluded to be related to the relatively high rainfall in some parts of the State. This might not be expected to exert a strong influence in states such as Idaho, which have less rainfall. In the second Connecticut study (15) the relative importance of width was found to be different in different ADT ranges for rural roads. Roadway width, horizontal curvature, and sight distance were all found to have significant relationship with total accident

*Numbers in parenthesis are bibliographical references.

rate for ADT less than 1400, and width showed the strongest relationship. Width was not significant in the two higher ADT ranges investigated, but horizontal curvature was a significant factor in both these ranges. In an overall analysis of essentially the same data (16), sight distance and horizontal curvature were found to correlate better with accident rate than did width.

Vehicle Placement

Lateral positioning of vehicles within the driving lane has been measured for various combinations of driving lane and shoulder width and type (5, 6, 8). This factor has not been correlated directly with accident frequency, but possibly has some bearing on it. For a given width of driving lane, vehicles were operated progressively farther from roadway centerline as shoulder types changed from grass to gravel to surfaced (5). Also, vehicles were generally operated closer to roadway centerline at night than during daylight. As total paved width (driving lane plus shoulder) increased, vehicles were operated progressively farther from roadway centerline (7,8). When painted stripes were used to establish a visual distinction between driving lane and shoulder (7, 8), results were mixed. In some cases, this caused traffic to shift toward the shoulder, and in other cases an opposite shift occurred. In at least one instance the addition of a painted stripe caused almost no shift in vehicle positioning.

Lateral Support

A finding of the WASHO road test (2) was that paved shoulders provide an increase in the load-carrying capability of the roadway. This was attributed to the fact that the test trucks operated farther from the pavement edge on the sections having paved shoulders. As a result, the outer wheelpath area of the pavement structure was subjected to interior loading rather than edge loading and was better able to resist the traffic action. In the later AASHO road test (9), further attempts were made to evaluate the effect of paved shoulders. Unfortunately most of the paved shoulder test sections were underdesigned and failed early in the test, so results from these test sections were inconclusive. Data from inner and outer wheelpaths of sections without paved shoulders were next compared. Distress was consistently noted earlier in the outer wheelpaths than in the inner ones, a situation also reported in the WASHO test. The results were discussed in somewhat different terms in these two road tests, however. In the WASHO report, the difference between inner and outer lane performance is mentioned primarily in an analogy stating that the outer wheelpath area acts as a paved shoulder for the inner wheelpath insofar as structural effects are concerned. The report of the AASHO test, on the other hand, contains a discussion emphasizing the idea that the difference in behavior between inner and outer wheelpaths implies the pavement can be thinner in the inner wheelpath than in the outer.

Economics

Economic analyses appear less frequently in shoulder literature than do studies of operational characteristics. Only two economic investigations dealing specifically with shoulders were located in the literature review made for this project. The first of these (12) was restricted to rural roads carrying 400 or fewer vehicles per day. One conclusion was that no economic justification exists for constructing the roadbed any wider than needed to eliminate vehicle interaction. The type of interaction implied is the slowing down and acceleration which is necessary when meeting or overtaking another vehicle on a narrow road. Also, accident costs on low volume rural highways were found to be low compared to construction and operating costs, leading to the inference that wide shoulders might not offer a particularly attractive economic gain. The authors suggested that spot improvements such as improving sharp horizontal curves would likely be more attractive from an economic standpoint than would increasing the width of the entire highway.

The second economic study (14) was concerned with the question of paving existing unpaved shoulders. Shoulder pavement depth was assumed less than mainline pavement depth, in contrast to the previous study where shoulder and driving lane pavements were identical. A range of shoulder paving costs was found to be justified economically for two-lane rural highways with ADT greater than 2000.

A third report (18) differed from the previous two in that an attempt was made to evaluate the relative cost-effectiveness of several possible safety improvement measures in order to establish spending priorities. Shoulder widening was not included because of difficulties inherent in the available data. Nonetheless, the report is mentioned here because of its emphasis on cost comparisons among several different types of safety improvement. Such a program would seem more helpful in prioritizing expenditures than a study concentrating on a single type of improvement. Data collection and analysis, of course, require more effort when the number of options under study is increased.

STUDY SECTIONS

Preliminary Comments

Idaho Division of Highways (IDH) standard practice is to pave the entire roadway including shoulders. Until recently no visible distinction existed between driving lane and shoulder on most low volume rural two-lane roads in the State. The use of paint striping for lane-shoulder delineation is increasing, but during the years under study few low volume Idaho roads had shoulder striping. The width variable considered in this study is total paved width.

IDAHO STUDY SECTIONS

Selection

Study sections were initially chosen based on paved width. A computer program was available in the IDH Traffic Section to separate the State maintained highway system into constant-width sections and compute an average accident rate and ADT for each section. Accident records for 1972, 1973, and 1974 were available from computer storage; and the data for all three years were combined for this investigation. The program output was screened manually to eliminate urban sections, unpaved roads, sections with more than two lanes, and sections with ADT greater than 3000.

The sections resulting from this initial selection process varied in length from a few hundredths of a mile to 77 miles. In some earlier studies, (11, 15), section length was found to influence the results of accident analyses. In an attempt to minimize any such effect, additional steps in the selection process were made in the present study. All sections less than one mile long were eliminated, and all sections more than ten miles long were broken into sections of ten miles or less. The number of sections resulting from this selection procedure was 671, covering a total of 3396 miles.

After the study sections had been chosen, each was assigned a terrain classification. The three categories used were flat, rolling, and mountainous. Roads in flat terrain are predominantly straight and level, with very frequent opportunities for passing slower vehicles. Mountainous roads contain frequest sharp curves and/or steep grades, with relatively few passing opportunities. Highways in rolling terrain have characteristics intermediate between flat and mountainous.

Terrain classification was accomplished with the aid of the IDH photolog system. This system uses a series of 35 mm color transparencies taken at 100 ft. intervals along the highway by a forward-looking camera mounted in a light truck. When projected rapidly in sequence by a suitable device, the images of these slides form a moving picture of the highway and roadside as seen by a passenger in a vehicle. A particular road section can be viewed rapidly as many times as needed to determine the proper terrain category. In this work each section was evaluated in terms of the general nature of the topography throughout the section. The classification was entirely visual. Specific geometric features were not recorded nor directly compared.

WASHINGTON STUDY SECTIONS

Preliminary analysis of the Idaho study sections showed very low numbers of sections in some categories, particularly for cases involving wide pavement and ADT levels near the upper end of the study range. To augment the Idaho data, compatible information was requested from the State highway agencies of Oregon and Washington. The records available from Oregon would have required considerable manual sorting, whereas the Washington data were available in an immediately usable form. For this reason, records from Washington were chosen to supplement the Idaho data.

A total of 332 Washington study sections were used. These were separated into various categories on the same basis as the Idaho sections, with one variation. Terrain classification of the Washington sections was not made on the basis of photolog viewing. Instead, the computerized record furnished by Washington assigned each section to one of the three AASHTO terrain categories based on section characteristics. This difference was assumed to be minor in view of the broad nature of terrain categorization.

ACCIDENT ANALYSIS

General Remarks

An accident analysis of the type described in subsequent sections was made on the Idaho data alone as well as on the combined Idaho and Washington records. Only minor differences were found between the results, leading to the inference that the two sets of data are compatible. The following discussion applies to the combined data.

Preliminary Analysis

The research methodology was statistical in nature and involved a two step approach. First, product-moment correlation and partial correlation procedures were employed to determine the extent of the relationship between accident rates and highway pavement widths. Secondly, variance and co-variance procedures were used in an analysis involving mean accident frequencies on highway sections with various lane widths.

The analysis was developed with data selected from Idaho and Washington highways, including a total of 1003 sections with average daily traffic (ADT) count between 0 and 3000. Pavement widths for these observations vary from 16 to 46 feet. Accident rates are grouped in three ways; (1) property damage only; (2) personal injury and/or fatal accidents only; (3) total accidents.

Table 1 and 2 illustrate the frequency and relative frequency distributions for the observations measuring separately property accident rates and injury accident rates. It is seen that pavement width has been broken into three classes; 16.00 - 22.00, 22.01 - 26.00 and 26.01 - 46.0 feet. In addition the ADT range has been subdivided into six classes as shown in the two tables. The accident rates are broken into one unit intervals between 0 and 6.0.

Tables 3 and 4 have been constructed to summarize some relevant information found in Tables 1 and 2. For example, Table 3 illustrates the relative frequencies and cumulative relative frequencies for property damage accident rates for each width class. It can be seen that lower property damage accident rates tned to be associated with wider pavement. For instance, 85.3 percent of the sections having a width between 16.0 and 22.0 feet had accident rates less than 3.0. This increases to 90.3 percent for sections with widths between 22.01 and 26.00 feet. Finally, 96.9 percent of the sections in the 26.01 to 46.00 foot class had accident rates below 3.0. This pattern is consistent for all levels of property accident rates.

Table 4 offers the same information for injury accidents. Again, as pavement width increases, the highway sections tend to have lower injury accident rates.

While these observations would tend to support the premise that wider pavement may result in lower accident rates, it is still necessary to determine whether or not the conclusions can be supported statistically. This is approached in the subsequent sections of this study.

Statistical Procedure

While the statistical analysis undertaken here involves a two-step approach, both the correlation and variance analysis techniques have the objective of identifying the relationship between highway paved width and accident rates.

Simple (product-moment) and partial correlation procedures are used to measure the linear relationship between paved width and accident rates.

The variance and co-variance procedures are used to determine whether there are significant differences in mean accident rates in the different width classes. The variance analysis determines whether the variabilities between classes is significant given the degree of variability within each class. That is, it determines whether the observations in the various classes are different enough such that they can be concluded to have come from statistically different populations.

Correlation Analysis

The initial step in the analysis involves the determination of whether or not a linear relationship exists between highway lane width and accident rate. The Pearson product-moment correlation coefficient provides a measure of this linear relationship. Values of r (r is the customary notation for the correlation coefficient) close to $\pm$ 1.0 indicate strong linear relationships between two variables whereas an r value close to 0 indicates a weak linear relationship. For example, if the correlation between width and injury accident rate is positive and large (close to +1.0) it would indicate that as width increases, injury accident rates also tend to increase. A negative correlation (close to -1.0) would imply the opposite. That is, increases in pavement width are likely to be associated with decreases in accident rates.

It should be noted that correlation cannot be used to infer cause and effect. That is, if two variables are highly correlated, it cannot be inferred that an increase in one variable will cause a corresponding increase in the second.

Also, just because a correlation coefficient takes on a value which differs from zero, it should not be automatically assumed that a linear relationship exists between the two variables. Rather, the significance of the correlation must be tested statistically. If the correlation coefficient is determined to be significant then the coefficient is said to be statistically different from zero and a linear relationship is present between the two variables.

A t-test is employed to determine the significance of the correlation coefficient. The t statistic is determined by:

$$t = \frac{r\sqrt{n - 2}}{\sqrt{1 - r^2}}$$

where:

r = correlation coefficient

n = sample size

The calculated t is then compared against the tabular t for the desired level of confidence. The table t represents the critical value for determining significance of the correlation. A calculated t value which exceeds this critical value is judged to be significantly different from zero.

Table 5 illustrates the correlation coefficients for terrain, width, section length and ADT with property, injury and total accident rates. The correlations were computed based upon the ADT ranges illustrated.

For property damage accidents, terrain is seen to have a significant relationship with accident rate in four of the six ADT ranges. The positive signs of these significant coefficients indicate accidents tend to increase as terrain changes from flat to rolling to mountainous.

It is seen that for the property damage correlations there was a significant linear relationship between width and accident rate in all but the 0-250 and 750-1000 ADT range. These correlations consistently exhibited negative signs which indicates that accident rates tned to decrease as pavement width is increased. It is also seen that the property accident rate is significantly correlated with ADT in the second largest ADT class. In this 1000-2000 range a negative relationship exists between ADT and accident rate which indicates that as traffic increases, the rate of property accidents tends to decrease.

Correlation between section length and property damage accident rate is significant in two ADT ranges. In each of these two ranges the correlation coefficient is negative, indicating the longer sections generally have lower accident rates. This agrees with the trend reported in two previous studies by others (11, 15).

Similar results occur for the injury correlations. For example, the correlations for paved width and accident rate are significant for all levels of ADT above 750. In each of these cases the relationship is negative indicating that lower accident rates are associated with wider pavement.

When the property and injury accident rates are combined to give total accident rates, the correlations between width and accident rates are significant for all ADT levels except the 0-250 class. Again, the negative correlations indicate that an increase in pavement width is associated with a decrease in total accident rate.

Significant correlation between terrain and total accident rate is found in three of the six ADT ranges. In each case, higher accident rate is associated with more mountainous terrain. Section length and ADT are significantly correlated with total accident rate in only two of the six ADT ranges. In each significant case, an increase in length or ADT is associated with a decrease in accidents.

Based upon the results shown in Table 5, it can be concluded that a decrease in accident rate tends to be associated with an increase in paved width. This tendency is greater in the total accident rate category as reflected by the size of the correlation coefficients. Similarly, as terrain varies from flat to rolling to mountainous, total accident rate tends to increase. These results do not, however, conclusively show that increases in width were responsible for decreases in accidents nor that more rugged terrain caused increases in accidents. Since no cause and effect inference can be attached to the coefficients, simple correlation analysis cannot provide this information. Rather, a procedure known as partial correlation analysis has been employed to help determine whether increasing paved width will "cause" a decrease in accident rates. The next section deals with the partial correlation analysis.

Partial Correlation

Partial correlation offers a single measure of association which describes the linear relationship between two variables while accounting for the effects of one or more additional variables.

Partial correlation is in some respects analogous to contingency analysis with control variables. The contingency analysis control is handled by examining the joint frequency distribution of two variables among two or more categories of one or more control variables. Thus, with contingency analysis the control is literal.

However, in partial correlation the control is statistical and is based upon the assumption of linear relationship among the variables. Basically, partial correlation allows for the removal of the effect that the control variables exert on the two variables in question without the necessity to physically manipulate the raw data.

This statistical control resulting from the use of partial correlation makes possible a variety of applications for the procedures. One such application, the determination of causal relationships between two variables, is employed in this study.

The partial correlation coefficients have the same quantitative interpretation as the simple correlation coefficients. Partials close to $\pm$ 1.0 indicate strong linear relationship while the sign on the coefficient indicates the direction of the relationship.

Table 6 contains the partial correlation coefficients for the same groupings as illustrated in Table 5. These correlations reflect the linear relationships between accident rates and the highway related variables, terrain, width, length, and ADT.

As was the case with the simple correlations, it is necessary to test the significance of these partials. The t-test is again employed where the calculated t is found by:

$$t = \frac{r_{ij \cdot k}\sqrt{n - 3}}{\sqrt{1 - r^2}}$$

where:

$r_{ij \cdot k}$ = correlation between variable i and j holding the effect of variable k constant

n = sample size

An insignificant partial would indicate that no statistical linear relationship exists between the two variables in question after the effects of the control variables have been partialed out.

Table 6 illustrates that for certain ADT ranges there does exist significant partial correlation. For example, in the property accident group, the partial correlation between paved width and accident rate holding constant the effects of terrain, ADT and section length is significant in four of the six ADT ranges. The negative sign on each of these coefficients is important. The indication is that an increase in width will "cause" a corresponding decrease in property accident rates.

The partial correlations in the injury accident group for width and accident rate holding the effects of the other variables constant show that a significant linear relationship exists in the three highest ADT ranges. In all cases where the partial correlation is significant, the sign on the coefficient is negative. This indicates that an increase in pavement width will result in a decrease in injury accident rates.

The partial correlations for total accident rates and width shown in Table 6 indicates significant linear relationships in the 250-400, 750-1000, 1000-2000 and 2000-3000 ranges. The signs on all significant coefficients are negative. As before, this would indicate that an increase in paved width will tend to decrease total accident rates.

It should be noticed that while the simple correlation for the 400-750 ADT range for total accident rate and paved width was seen to be significant in Table 5, this is not the case for the partial in Table 6. This would indicate that this simple correlation in Table 5 was affected by other highway related variables and actually was a spurious correlation.

The preceding discussion and the partial correlations shown in Table 6 indicate that a true linear relationship between highway paved width and accident rates is not present in all ADT ranges. However, in certain ADT ranges, the available data does indicate that increasing the width will result in lower accident rates.

Significant partial correlations between accident rate and variables other than width are also seen to exist in some ADT ranges. In particular, terrain is seen to exert a statistically significant effect in three of the six ADT ranges. A second point of interest is that the significant terrain coefficients are often larger numerically than the width coefficients. Therefore, terrain frequently is more strongly correlated with accident rate than is pavement width.

Variables Omitted from the Analysis

The variable of most interest in this project is total pavement width, and this dominant interest is reflected in the relatively large proportion of the discussion devoted to width. As mentioned in the foregoing sections, other variables can have significant effects on accident rate. A few variables other than width have been included in the study, but some factors known to influence accident rate have been excluded. As an example, intersections and approaches have been shown to have considerable influence on accident rate (11, 13). They were excluded from this study because their effects were of secondary interest and their inclusion would have caused a large increase in the time needed to compile basic data. Similarly, other factors such as driver error, alcohol, mechanical failure, skid resistance, and percentage of trucks in the traffic stream, were not analyzed in this work.

The influence of operating speed on accident rate has been a topic of widespread interest in recent years, particularly since the imposition of the nationwide 55 mph speed limit. An attempt was made to analyze how speed affects accident rate on some of the study sections used in the width study. Correlation and partial correlation procedures were tried, but results were inconclusive. This resulted from a lack of speed data. IDH operates only 28 fixed-location speed recording stations, and only ten of these are on study sections used in the width study. None of these ten speed stations are in mountainous terrain. As a result the available sample is much too small and is not truly representative, so detailed statistical analysis was not possible.

In summary, the correlation and partial correlation analysis has attempted primarily to identify the existence of a linear trend between width and accident rate. The next sections are concerned with determining whether or not there is a significant difference between the average accident rates in highway sections of differing paved width. The statistical procedures which will be employed are analysis of variance and covariance analysis.

Analysis of Variance

Analysis of variance is a versatile statistical tool for studying the relationship between a dependent variable and one or more independent variables. It is employed in this study in an attempt to discern whether or not a statistical difference in mean accident rates exists between different levels of pavement width.

The analysis of variance design which is employed here is called factorial analysis of variance. The factorial design makes it possible to study the interaction of the factors involved. For example, accident rates may decrease in certain paved width levels, but increase in others. This type of effect can only be studied if both factors are combined in the same analysis. Thus the conclusions reached in the analysis have broader application due to the fact that the behavior of each factor is studied with varying combinations of other factors.

As was the case with the simple and partial correlation sections, the analysis has grouped the data by accident rate type (property, injury and total). The data was further subdivided according to the width intervals 16-22 feet and 26-46 feet and according to the ADT ranges, 0-249.99, 250-399.99, 400-749.99, 750-999.99, 1000-1999.99 and 2000-2999.99. Tables 7 - 9 illustrate the groupings as they relate to the analsysi of variance.

The sources of variation in the factorial analysis design are pavement width, ADT range, interaction, and error. The effects of terrain and section length were not analyzed in this part of the project. The error or residual represents that portion of the total variation in the data not accounted for by the other sources.

The F statistics in the right hand portion of Table 7 - 9 indicate the significance of the variation accounted for by pavement width, ADT range, and the interaction between paved width and ADT range. Since the F statistic is calculated by the ratio of the mean square error (MSE) for each of these sources to the MSE for the error or residual source, large F values indicate that a particular source of variation explains a significant portion of the total variation in the data.

Table 7 illustrates the results for property accident rates. The F values indicate that the variation accounted for by both width and ADT is significant, while the interaction effect is not significant. For example, the significant F for width indicates that the average accident rates in the two width levels are significantly different. When the means for the two width levels are examined, the inference is that the highway sections with wider pavement had lower property accident rates. The interpretation of the significant F for the ADT source is that all ADT levels do not have equal property accident rates.

Table 8 illustrates the analysis of variance results for injury accidents. The F value for lane width is seen to be significant indicating that average injury accident rates in the two width intervals differ significantly. The sample means for these two levels of width would infer that lower injury accident rates resulted on highway sections with wider pavement. However, no significant difference can be detected for the average injury accident rates between levels of ADT.

The results of combining injury and property accidents are illustrated in Table 9. Both the width and ADT sources are shown to be significant. The width results indicate a significant difference in average accident rates between widths. The values of the sample means would indicate that significantly lower accident rates occur on wider pavements.

While the analysis of variance technique indicates the tendency for lower accident rates to occur on highways with wider pavement, this procedure cannot imply that wide pavements are the cause of lower accident rates.

To arrive at a cuase and effect conclusion requires the employment of a statistical procedure called covariance analysis. The analysis using the covariance procedure is discussed in the following section.

Coavariance Analysis

Covariance analysis has the advantage of being able to control the effect of secondary factors so that the true effect of the primary factor can be determined. The data have again been grouped according to property accident, injury accidents, and total accidents. The effect of ADT has been controlled using the covariance analysis and only paved width and error remain as sources of variation.

Table 10 illustrates the results of the covariance analysis using three levels of lane widths. The results indicate that the variation in width accounts for a significant part of the total variation when the effect of ADT is controlled. These results are consistent for property, injury, and total accident rates.

The interpretation concerning the results in Table 10 is that a significant difference exists in accident rates between the width levels. The mean accident rates support the conclusion that wider pavements result in lower accident rates. Since the effect of ADT has been controlled, it may be stated with some certainty that total paved width is responsible for the level of accident rates.

ECONOMIC ANALYSIS

Preliminary Comments

The accident study has revealed a tendency for accident rates to decrease as paved width increases on rural two-lane highways. Roadway cost increases as width is increased. Expenditures for greater width need to be evaluated in comparison with the potential cost savings resulting from accident reduction. A present worth type of evaluation was chosen for this project, similar to the one used in (14).

Basic Cost Derivations

Construction costs were estimated by using 1975 IDH contractor bid prices. Costs per mile were estimated for two different terrain conditions. The first of these was perfectly flat terrain requiring no earthwork. This would represent a minimum expected cost. The second condition was an average fill height of four feet, representing construction in more difficult terrain. In each case, asphalt paving 0.3 feet thick and aggregate base 1.2 feet thick were assumed, as was a post-construction seal coat. Total extra construction costs for 4 feet of additional width were estimated to be $12,000 per mile on flat ground or $18,000 per mile for the more difficult topography. With a width increase of 6 feet, construction costs were estimated to be $18,000 or 27,000 per mile respectively for the two terrain conditions.

Major maintenance operations were assumed to be seal coats at six-year intervals and a 0.3 ft. thick overlay at 18 years. Estimated costs were $600/mile for seal coating and $6,000/mile for the overlay.

An attempt was made to estimate routine maintenance costs by searching IDH financial records. Unfortunately the cost accounting system used in the past does not contain suitable information for this type of study. Maintenance costs have been reported only for each complete maintenance section, which nearly always includes several different widths of pavement. Therefore, it was impossible to compare maintenance costs for different widths in most cases. A few maintenance sections were found to have the same pavement width throughout most of their length, but their total mileage represented only a small fraction of the overall two-lane mileage. This was believed to be too small a sample for reliable cost comparisons.

State highway maintenance officials in Washington and Oregon were contacted and asked whether they could furnish maintenance costs for various pavement widths. Accounting problems similar to Idaho's were found in each instance. A small amount of maintenance cost information was received from Washington. Just as in the case of the Idaho data, however, the sample wasn't large enough to give confidence that the figures were truly representative.

The Nevada Department of Highways has used for several years an improved cost accounting system similar to one adopted by IDH in July 1976. Under this system maintenance costs are reported separately for each mile of highway. A record of minor pavement maintenance costs for the period of July 1, 1973 through October 31, 1974 was obtained from Nevada for use in this project. The majority of one-mile sections of two-lane pavement listed in this record were 20 or 24 feet wide. Pavement maintenance costs were averaged over about 1400 miles of 20 ft. pavement and about 2300 miles of 24 ft. pavement. The average annual patching and minor repair cost for 24 ft. pavement was very close to $50 per mile lower than that for 20 ft. wide pavement.

The approach outlined in (14) was adopted for treatment of interest rate in the economic calculations. Separate computations were made using annual interest rates of six and twelve percent to bracket a range of suitable values.

Economic values associated with individual accidents were furnished by the IDH Traffic Section. The values used were $10,000 for an accident involving injury or loss of life and $500 for an accident involving property damage only. Accident rates from the combined Idaho-Washington records were used in conjunction with these Idaho cost figures to estimate yearly accident costs. Average accident costs per mile were computed separately for each combination of ADT and terrain type mentioned in the statistical analysis, with each such group further subdivided on the basis of pavement width. Sections 18 through 21 feet wide were used to compute accident cost for a nominal pavement width of 20 feet. A width of 24 feet was represented by sections 22 through 25 feet wide, and sections 26 feet through 30 feet wide were used to estimate accident cost for a nominal paved width of 28 feet. Nominal pavement widths of 34 feet, 40 feet, and 44 feet were represented by width groupings of 31 through 36 feet, 37 through 41 feet, and 42 through 46 feet respectively. This was done to increase the sample size representing each of the five nominal pavement widths. Nonetheless, some of the resulting groups contained so few study sections that the accident cost estimates derived from them might have been unreliable. Some sample categories were merged in a later stage of the project to increase the number of sections in each sample. This is described further under Results and Discussion.

Computational Procedure

For each combination of terrain type, ADT range, and width, weighted average ADT and accident rates for one-mile section were computed. Future ADT was then estimated for each of the next 30 years. Two different series of future ADT estimates were made, using annual traffic growth rates of 2% and 5% respectively. In this work traffic growth was computed on a compound basis. That is the ADT for each year was predicted by multiplying the previous year's ADT by 1.02 under the 2% growth assumption or by 1.05 under the 5% growth assumption. This type of computation yields an accelerating nonlinear growth curve, whereas actual traffic growth in Idaho has been found to be nearly linear in the recent past. The traffic growth effects found in this study are somewhat exaggerated compared to linear traffic growth effects. To illustrate, linear growth rates of 2% and 5% would predict 30-year ADT values of 1.6 and 2.5 times the initial ADT, whereas the corresponding factors for compounded growth are 1.8 and 4.3 respectively.

For each year of the 30 year analysis period, a summation of costs and benefits was made. Costs were given a negative sign and benefits a positive sign. Construction costs were always negative. Accident cost comparisons were made based on the estimated ADT for the year in question. Accident rates for the two widths being compared in a particular case were used in conjunction with estimated ADT to establish an accident cost or benefit attributable to widening. For simplicity a constant accident rate was used over the entire 30 year period. In cases where the wider study sections had a lower mean accident rate than the narrower group, a monetary benefit was indicated, helping to offset the construction cost. In some categories the wider sections had higher accident rates. When this happened, the monetary value associated with the difference in accident rates was given a negative sign, thus increasing the debit due to construction. The maintenance cost difference of $50 per mile was given a positive sign because the Nevada data indicated the wider pavement to have a lower maintenance cost. After summing the costs and benefits for a given year, the total for that year was multiplied by the appropriate present worth factor. Then a cumulative summation was made of these annual discounted totals. The year in which the cumulative sum changed from negative to positive was taken as the payoff year. Table 11 illustrates the procedure. In the situation represented by Table 11, the investment needed to increase pavement width from 20 to 24 feet would not be offset by accident reduction benefits within 30 years.

Results and Discussion

Trial computations indicated the $50 per mile maintenance benefit associated with 4 foot wider pavement would have very little effect on the overall results of the economic analysis. This agrees with a finding of earlier work by others (14) that a maintenance cost difference of less than $100 does not materially affect the results of this type of economic analysis. The $50 per mile maintenance cost difference is nevertheless included in all results given in this section.

Figures 1 and 2 illustrate graphically the effects of changes in some variables. Both figures show the general effects of changes in construction cost, interest rate, and traffic growth rate. The curves have been approximated by straight line segments for simplicity.

Increased construction cost merely moves each curve downward, maintaining each segment parallel to the corresponding segment of the original curve. The effect of different construction costs can thus be visualized by shifting the entire curve along the vertical axis.

Higher traffic growth rate leads to an earlier payoff. This occurs even though the total number of hypothetical accidents increases as ADT increases. The model is not being used to evaluate the total number of accidents, but only the difference between the numbers of accidents associated with the two pavement widths. As the total number of accidents rises, the number of accidents prevented by the width effect rises also, which accounts for the increased benefit associated with a higher traffic growth rate. In some categories more accidents occur on the wider pavement. When that happens, an increase in ADT merely increases the loss associated with the wider pavement. No curves of this type have been plotted, but it should be apparent that the cumulative monetary balance can never become positive in such a case.

The effect of interest rate is also clearly shown in Figures 1 and 2. The choice of an appropriate interest rate for public works projects is subject to widely differing philosophies and policies. No position is taken here regarding the most suitable interest rate for this type of analysis. Instead, a range of values has been used in the computations to show the effects of changes in this factor. The graphs show that an increase in interest rate tends to delay the payoff year.

Another effect can be seen by comparing each curve of Figure 1 with the corresponding curve of Figure 2. The differences reflect the influences of a change in the monetary loss assigned each accident involving an injury or a fatality. For Figure 1, the $10,000 figure mentioned in a previous section has been used. For Figure 2, the loss has been taken as $12,000, and an increase of this size is seen to result in a noticeably earlier payoff. When the cost of each accident goes up, the saving attributable to each prevented accident goes up also, thus reducing the time to payoff. It is apparent that the economic value assigned to each accident has considerable influence on the outcome of the analysis.

As mentioned earlier, IDH practice is to use the figure of $10,000 for each accident involving injury or fatality. Some analysts assign values as high as $125,000 to each fatal accident, while using values near $10,000 for injury accidents (18). Idaho's assigned costs might therefore appear low at first glance, but are probably not unrealistically low in view of the fact that the $10,000 figure represents an average for the two types of accidents. The ratio of injury accidents to fatal accidents in the State is currently about 100:1 so the average cost in the combined category would be changed only about $1000 by a change of $100,000 in the cost of each fatal accident. In the economic analysis of combined Idaho-Washington data, a cost range of $10,000 to $20,000 has been used for the injury-fatality category. This illustrates the effect of a much larger average cost change than would be caused by an increase of $100,000 per fatal accident.

The general features of the analysis are illustrated by Table 11 and Figures 1 and 2. Presentation of all data in either of these two forms would make direct comparison among the various possible conditions very cumbersome. To reduce the amount of data and simplify the presentation, a compact tabular form of data summary has been used for the overall results. The amount of data to be viewed has been greatly reduced by eliminating all intermediate results and indicating only whether or not a praticular combination of variables results in payoff within 30 years. The payoff year is listed if it is 30 years or less. Additionally, a distinction is made between two situations in which payoff doesn't occur within 30 years. The first is the case where increasing pavement width results in a very small decrease in accidents, so the monetary benefits are small and the break-even point is delayed. In the second case an increase in accidents is associated with increased pavement width. Of course, no accident benefit occurs in this situation, and the investment in the extra width is never recovered.

Tables 12 through 18 contain the summarized data described in the foregoing paragraph. Trends are inconsistent in some cases and the data are still voluminous. Nonetheless, some conclusions can be drawn from these tables. First, differences associated with terrain type do occur. Second, by comparing Table 12 with Table 17 and Table 13 with Table 18, it is seen that doubling the cost assigned to an injury or fatal accident can appreciably reduce the payoff period.

In several categories, Tables 12 through 18 indicate that widening the pavement increases the accident rate instead of reducing it. This is contrary to the general trend noted in the overall accident analysis. The disparity is partly a result of the difference in sample partitioning between the two parts of the project. The economic analysis used a more detailed sample breakdown than did the accident analysis, resulting in smaller subsamples. For this reason the subsample associated with each category in the economic analysis cannot always be expected to reflect exactly the general trends found in the accident analysis.

Inconsistencies in Tables 12 through 18 might be suspected to indicate some sample groups are too small to yield generalized results. Additionally, the number of table entries is too large for convenient interpretation. Improvements could be made in both areas by combining some data groups. Another set of computations was made with all terrain classes combined, thus reducing output data volume by two-thirds and increasing the sample size in each ADT group. Furthermore, eliminating terrain type facilitates comparisons with existing IDH width standards. Minimum paved widths specified in IDH design standards are the same for all terrain types. Only minimum acceptable standards for speed, foreslope steepness, curvature, grade, and stopping distance are changed to reflect terrain type. Results of computations with no terrain categorization are given in Tables 19 through 25 and 27 through 30.

Based on Tables 19 through 25 and the initial assumption that a minimum paved width of 20 ft. is necessary to minimize operator apprehension when meeting another vehicle, a table of minimum widths has been prepared using the following reasoning. First, widening beyond 20 feet will seldom pay off for ADT below 1000 unless a major increase occurs in the average cost of accidents involving injury or fatality. The few situations where payoff is indicated with 5% traffic growth can safely be ignored because the 5% compounded growth used in the calculations is higher than any realistically expected growth in Idaho. The long payoff periods using the 5% growth assumption would be extended beyond 30 years by a slight reduction in the assumed growth rate. In spite of the foregoing comments, minimum widths of 24 ft. for ADT 400-749 and 28 feet for ADT 750-999 have been suggested to provide transition steps between 20 feet and 34 feet.

For ADT from 1000-1999 a minimum width of 34 feet is suggested. The reversals of payoff trends in this ADT range when going from Table 19 to 20 to 21 reduce confidence in the generality of the tabulated results, so the greatest payoff width has been chosen for conservatism. Likewise, the greatest payoff width has been selected in the ADT range 2000-2999 giving 40 feet as the minimum.

The minimum widths suggested above are compared to existing IDH minimums in Table 26. All suggested values are lower than the corresponding existing minimums, so their adoption would entail reductions in width.

The discussion so far has emphasized width increases, but Tables 19 through 25 and 27 through 30 can also be used to assess the effects of decreasing pavement width. When the tables are viewed in this way, a single star indicates reducing the width also reduces accidents, thus representing a saving in addition to the reduced construction cost. A double star indicates reducing the width increases accidents, but the cumulative discounted cost associated with the increase in accidents does not exceed construction savings for at least 30 years. A number in the table indicates the cumulative discounted increased accident costs outweigh construction savings in the year indicated. Any decrease in pavement width would be expected to increase pavement maintenance cost slightly.

Using the tables as described in the foregoing paragraph, some effects of the suggested decreases in width standards are readily appraised. Decreasing the minimum width from 44 to 40 feet in the 2000-2999 ADT range (Table 23) would be indicated to result in fewer accidents and would therefore be beneficial. This is opposite to the general trend noted in the statistical analysis but does reflect accident records for this particular width and ADT combination. Reducing minimum width from 40 to 34 feet in the 1000-1999 ADT range (Table 22) would be expected to result in a slightly higher accident rate. The discounted increases in accident and maintenance costs would not likely exceed the construction cost saving within 30 years. The same result is indicated for a width decrease from 34 to 28 feet in the 750-999 ADT category (Table 21). Similarly, the other suggested reductions involve the expectation of slightly increased accident rates. In no realistic case, however, do the likely extra accident costs offset the construction cost savings within 30 years unless a sharp increase occurs in the average accident cost. As shown in Table 25, doubling the average cost of an accident involving injury or fatality would cause construction cost savings to be offset in less than 30 years in the 750-999 ADT group for the suggested width reduction from 34 to 28 feet.

The accident rates used in the economic analysis are based on historical information. Future changes in traffic behavior may alter accident patterns in ways not considered in this project. An example of a change which might affect accident rates is an increase in vehicle width. If vehicle width increases, vehicle placement in the travel lane is likely to change which would have an unknown effect on accident rate. Changes in shoulder striping practice might also affect accident rates.

SUMMARY AND CONCLUSIONS

A statistical analysis of traffic accident rates on rural Idaho and Washington two-lane paved highways during 1972 through 1974 has been carried out. The analysis has revealed a general tendency for accident rates to decline as pavement width is increased. A second observation resulting from this work is that terrain type sometimes has a stronger influence on accident rate than does pavement width.

An economic analysis has been undertaken to compare long term monetary effects associated with several pavement width options. Traffic accident data were used to estimate annual accident costs for several pavement widths under various assumptions about traffic growth, interest rate, and the cost of an individual accident. Construction and maintenance costs were estimated using recent Idaho and Nevada data. Overall economic comparisons were made among various widths in six different ADT ranges.

Results of the economic analysis have been used in attempting to determine reasonable minimum pavement widths for various ADT ranges. The suggested minimums are:

Construction Year ADT	Minimum Paved Width, Ft.
0-249	20
250-399	20
400-749	24
750-999	28
1000-1999	34
2000-2999	40

The suggested minimum widths above are lower than existing Idaho minimums. Their adoption could be expected to result in slightly increased pavement maintenance cost and slightly increased traffic accident frequency in most cases. The cumulative economic effect of these increases over a thirty year period would not be expected to offset the construction cost saving unless a pronounced increase occurs in average accident cost or unless major shifts occur in accident trends.

This project has dealt primarily with the influence of pavement width on accident rates and with associated economic effects. This emphasis does not imply a belief that pavement width is the most important factor in studies of economic interactions between highway design and traffic accidents. Other design factors are known or believed to influence accident rates, and significant economic effects may be caused by changes in such factors. Some parameters of this kind are terrain type, access control, pavement widening on curves, steepness of sideslope beyond the shoulder edge, and the percentage of trucks in the traffic stream. In order to obtain a more balanced view of the relative economic importance of various design details, economic study of factors other than pavement width would be desirable.

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APPENDIX

GLOSSARY OF ABBREVIATIONS
USED IN THE TABLES AND GRAPHS

ADT . . . Annual average daily traffic: number of vehicles

CRF . . . Cumulative relative frequency: cumulative sum of RF values

DF . . . Degrees of freedom: the number of independent measurements available for estimating a statistical parameter

F . . . Frequency: number of occurrences

F_{st} . . . F statistic: ratio of an individual MSE value to the residual MSE; used as an indicator of statistical significance in analysis of variance

MSE . . . Mean square error: ratio of individual sum of squares to the corresponding DF

RF . . . Relative frequency: F of a given type of sample element divided by the total number of sample elements in the group under consideration

TABLE 1

PROPERTY DAMAGE

ADT

Paved Width	Accident Rate*	0.00-249.99		250.00-399.99		400.00-749.99		750.00-999.99		1000.00-1999.99		2000.00-2999.99		Totals	
		F	RF	F	RF	F	RF	F	RF	F	RF	F	RF	F	RF
	0- .99	4	.200	12	.375	22	.386	8	.174	9	.127	5	.250	60	.244
	1.0-1.99	6	.300	11	.344	21	.368	18	.391	34	.479	9	.450	99	.402
	2.0-2.99	3	.150	4	.125	8	.140	12	.261	19	.268	5	.250	51	.207
16.00-22.00	3.0-3.99	4	.200	3	.094	4	.070	3	.065	7	.099	1	.050	22	.089
	4.0-4.99	2	.100	0	0.000	2	.035	3	.065	2	.028	0	0.000	9	.037
	5.0-5.99	1	.050	2	.063	0	0.000	2	.043	0	0.000	0	0.000	5	.020
Totals		20	1.000	32	1.000	57	1.000	46	1.000	71	1.000	20	1.000	246	1.000
	0- .99	17	.586	13	.448	27	.409	8	.308	9	.161	2	.091	76	.333
	1.0-1.99	5	.172	8	.276	21	.318	12	.462	29	.518	14	.636	89	.390
	2.0-2.99	3	.103	4	.138	15	.227	5	.192	10	.179	4	.182	41	.180
22.00-26.00	3.0-3.99	2	.069	1	.034	3	.045	0	0.000	6	.107	2	.091	14	.061
	4.0-4.99	1	.034	1	.034	0	0.000	1	.038	2	.036	0	0.000	5	.022
	5.0-5.99	1	.034	2	.069	0	0.000	0	0.000	0	0.000	0	0.000	3	.013
Totals		29	1.000	29	1.000	66	1.000	26	1.000	56	1.000	22	1.000	228	1.000
	0- .99	1	.333	11	.674	37	.451	23	.451	89	.422	72	.456	233	.446
	1.0-1.99	0	0.000	3	.176	35	.427	16	.314	90	.427	74	.468	218	.418
	2.0-2.99	1	.333	1	.059	9	.110	8	.157	27	.128	9	.057	55	.105
26.00-46.00	3.0-3.99	1	.333	1	.059	1	.012	0	0.000	3	.014	2	.013	8	.015
	4.0-4.99	0	0.000	1	.059	0	0.000	4	.078	2	.009	0	0.000	7	.013
	5.0-5.99	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	1	.006	1	.002
Totals		3	1.000	17	1.000	82	1.000	51	1.000	211	1.000	158	1.000	522	1.000

*Accident rate throughout this report is expressed as the number of accidents per million vehicle miles.

TABLE 2

INJURY AND FATALITY

ADT

Paved Width	Accident Rate	0.00-249.99 F	0.00-249.99 RF	250.00-399.99 F	250.00-399.99 RF	400.00-749.99 F	400.00-749.99 RF	750.00-999.99 F	750.00-999.99 RF	1000.00-1999.99 F	1000.00-1999.99 RF	2000.00-2499.99 F	2000.00-2499.99 RF	Totals F	Totals RF
	0- .99	12	.600	14	.438	36	.632	20	.435	21	.296	8	.400	111	.451
	1.0-1.99	3	.150	13	.406	9	.158	16	.348	36	.507	10	.500	87	.354
16.00-	2.0-2.99	3	.150	4	.125	10	.175	5	.109	10	.141	2	.100	34	.138
22.00	3.0-3.99	1	.050	1	.031	0	0.000	4	.087	3	.042	0	0.000	9	.037
	4.0-4.99	1	.050	0	0.000	2	.035	0	0.000	1	.014	0	0.000	4	.016
	5.0-5.99	0	0.000	0	0.000	0	0.000	1	.022	0	0.000	0	0.000	1	.004
Totals		20	1.000	32	1.000	57	1.000	46	1.000	71	1.000	20	1.000	246	1.000
	0- .99	17	.607	16	.552	40	.615	14	.538	26	.464	9	.409	122	.535
	1.0-1.99	5	.179	8	.276	17	.262	6	.231	21	.375	7	.318	64	.281
22.00-	2.0-2.99	3	.071	4	.138	9	.123	2	.077	8	.143	6	.273	30	.132
26.00	3.0-3.99	4	.143	0	0.000	0	0.000	3	.115	1	.019	0	0.000	8	.035
	4.0-4.99	0	0.000	0	0.000	0	0.000	1	.038	0	0.000	0	0.000	1	.004
	5.0-5.99	0	0.000	1	.034	0	0.000	0	0.000	0	0.000	0	0.000	1	.004
Totals		29	1.000	29	1.000	66	1.000	26	1.000	56	1.000	22	1.000	228	1.000
	0- .99	2	.667	12	.706	48	.592	33	.647	124	.588	96	.608	315	.603
	1.0-1.99	0	0.000	5	.118	27	.332	14	.275	68	.322	55	.348	169	.324
26.00-	2.0-2.99	0	0.000	0	.176	6	.074	4	.078	14	.066	5	.032	29	.056
46.00	3.0-3.99	1	.333	0	0.000	1	.012	0	0.000	4	.019	2	.013	7	.013
	4.0-4.99	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
	5.0-5.99	0	0.000	0	0.000	0	0.000	0	0.000	1	.005	0	0.000	1	.002
Totals		3	1.000	17	1.000	82	1.000	51	1.000	211	1.000	158	1.000	522	1.000

TABLE 3

CUMULATIVE RELATIVE FREQUENCY

Property Damage

Total Pavement Width	Accident Rate	RF	CRF
16.00-22.00	0- .99	.244	.244
	1.0-1.99	.402	.646
	2.0-2.99	.207	.853
	3.0-3.99	.089	.942
	4.0-4.99	.037	.979
	5.0-5.99	.020	1.000
22.01-26.00	0- .99	.333	.333
	1.0-1.99	.390	.723
	2.0-2.99	.180	.903
	3.0-3.99	.061	.964
	4.0-4.99	.022	.986
	5.0-5.99	.013	1.000
26.01-46.00	0- .99	.446	.446
	1.0-1.99	.418	.864
	2.0-2.99	.105	.969
	3.0-3.99	.015	.984
	4.0-4.99	.013	.997
	5.0-5.99	.002	1.000

TABLE 4

CUMULATIVE RELATIVE FREQUENCY

Injury and Fatality

Total Pavement Width	Accident Rate	RF	CRF
16.00-22.00	0- .99	.451	.451
	1.0-1.99	.354	.805
	2.0-2.99	.138	.943
	3.0-3.99	.037	.980
	4.0-4.99	.016	.996
	5.0-5.99	.004	1.000
22.01-26.00	0- .99	.535	.535
	1.0-1.99	.281	.816
	2.0-2.99	.132	.948
	3.0-3.99	.035	.983
	4.0-4.99	.004	.987
	5.0-5.99	.004	1.000
26.01-46.00	0- .99	.603	.603
	1.0-1.99	.324	.927
	2.0-2.99	.056	.983
	3.0-3.99	.013	.996
	4.0-4.99	.000	.996
	5.0-5.99	.002	1.000

TABLE 5

PRODUCT-MOMENT CORRELATIONS

Property Damage

ADT Range	Terrain	Width	Length	ADT	# of Cases
0-250	-.1052	-.1908	.1952	-.0285	52
250-400	.3202*	-.2566*	-.1220	-.1296	78
400-750	.2149*	-.2601*	.0785	-.1039	205
750-1000	.3939*	-.1595	-.3281*	.0746	123
1000-1999	.1456*	-.3939*	-.0150	-.1787*	338
2000-3000	-.0364	-.3401*	-.2394*	-.0205	200

Injury and Fatality

ADT Range	Terrain	Width	Length	ADT	# of Cases
0-250	.0759	-.0121	-.0002	.0229	52
250-400	.3193*	-.1759	-.2197	-.0202	78
400-750	.0975	.0180	-.1317*	-.1283	205
150-1000	.3739*	-.2887*	-.2704*	.0993	123
1000-2000	.0257	-.2759*	-.0588	-.1015	338
2000-3000	-.1226	-.3480*	-.1386	.0138	200

Total Accidents

ADT Range	Terrain	Width	Length	ADT	# of Cases
0-250	-.0203	-.1457	.1399	-.0038	52
250-400	.4022*	-.2819*	-.2027	.0873	78
400-750	.1833*	-.1335*	-.0423	-.1418*	205
750-1000	.4526*	-.2855*	-.3545*	.1014	123
1000-2000	.1035	-.3942*	-.0417	-.1657*	338
2000-3000	-.0851	-.3855*	-.2167*	-.0054	200

*Significant at .05 level.

TABLE 6

PARTIAL CORRELATIONS

Property Damage

ADT Range	Terrain	Width	Length	ADT	# of Cases
0-249.99	-.08982	-.13408	.13260	.01100	52
250-399.99	.32785*	-.24429*	-.07289	.17164	78
400-749.99	.18364*	-.23651*	.01687	-.02750	205
750-999.99	.36249*	-.09051	-.31579*	.05246	123
1000-1999.99	.13326*	-.39143*	-.07879	-.15331*	338
2000-2999.99	-.02546	-.36605*	-.28040*	-.00558	200

Injury and Fatality

ADT Range	Terrain	Width	Length	ADT	# of Cases
0-249.99	.07591	-.01216	.00676	.02166	52
250-399.99	.27806*	-.18523	-.18134	.00723	78
400-749.99	.07220	.00650	-.13696*	-.10973	205
750-999.99	.32252*	-.23822*	-.25868*	.07123	123
1000-1999.99	.00842	-.27988*	-.10385*	-.08493	338
2000-2999.99	-.11085	-.35919*	-.17564*	.00570	200

Total Accidents

ADT Range	Terrain	Width	Length	ADT	# of Cases
0-249.99	-.00756	-.10385	.09887	.02374	52
250-399.99	.39585*	-.28840*	-.15572	.14021	78
400-749.99	.14803*	-.12735	-.08191	-.08761	205
750-999.99	.41701*	-.20009*	-.35414*	-.07662	123
1000-1999.99	.08665	-.39525*	-.10873*	-.14309*	338
2000-2999.99	.07476	-.40838*	-.26534*	-.00040	200

*Signigicant at .05 level

TABLE 7

ANALYSIS OF VARIANCE

Property Damage

Source of Variation	Mean Acc. Rate	Sum of Squares	DF	MSE	F
Paved Width					
16.00-22.00	1.83				
26.00-46.00	1.21				
		66.611	1	66.61	77.815*
ADT Range					
0-249.99	1.68				
250-399.99	1.42				
400-749.99	1.31				
750-999.99	1.70				
1000-1999.99	1.49				
2000-2999.99	1.25				
		39.352	5	7.87	9.193*
Interaction		3.903	5	.7806	.90
Residual (Error)		648.718	756	.856	
Totals		739.443	767		

*Significant at any reasonable level of alpha

TABLE 8

ANALYSIS OF VARIANCE

Injury and Fatality

Source of Variation	Mean Acc. Rate	Sum of Squares	DF	MSE	F
Paved Width					
16.00-22.00	1.27				
26.00-46.00	.95				
		19.725	1	19.725	28.42*
ADT Range					
0-249.99	1.26				
250.399.99	1.09				
400-749.99	1.03				
750-999.99	1.18				
1000-1999.99	1.12				
2000-2999.99	.99				
		5.254	5	1.050	1.51
Interaction		5.654	5	1.130	1.168
Residual (Error)		524.925	756	.694	
Totals		552.830	767		

*Significant at any reasonable level of alpha

TABLE 9

ANALYSIS OF VARIANCE

Total Accidents

Source of Variation	Mean Acc. Rate	Sum of Squares	DF	MSE	F
Paved Width					
16.00-22.00	3.10				
26.00-46.00	2.16				
		158.398	1	158.398	75.78*
ADT Range					
0-249.99	2.9531				
250-399.99	2.5204				
400-749.99	2.3409				
750-999.99	2.8909				
1000-1999.99	2.6116				
2000-2999.99	2.2497				
		68.379	5	13.67	6.54*
Interaction		16.551	5	3.31	1.58
Residual (Error)		1584.508	756	2.09	
Totals		1790.90	767		

*Significant at any reasonable level of alpha

TABLE 10

ANALYSIS OF COVARIANCE

Three Levels of Total Paved Width
(Controlling ADT)

Property Damage

Source of Variation	Mean Acc. Rate	Sum of Squares (Adjusted)	DF	MSE	F_{st}
Paved Width					
16.00-22.00	1.8265				
22.00-26.00	1.5391				
26.00-46.00	1.2064				
		60.23	2	30.115	31.242*
Error		954.29	990	.9639	
Total		1014.52	992		

Injury and Fatality

Source of Variation	Mean. Acc. Rate	Sum of Squares (Adjusted)	DF	MSE	F_{st}
Paved Width					
16.00-22.00	1.2726				
22.00-26.00	1.1992				
26.00-46.00	.9529				
		18.5237	2	9.2618	10.954*
Error		837.052	990	.8455	
Total		855.575	992		

Total Accidents

Source of Variation	Mean. Acc. Rate	Sum of Squares (Adjusted)	DF	MSE	F_{st}
Paved Width					
16.00-22.00	3.099				
22.00-26.00	2.738				
26.00-46.00	2.159				
		143.763	2	71.881	29.821*
Error		2386.307	990	2.410	
Total		2530.071	992		

*Significant at any reasonable level of alpha

TABLE 11

PRESENT WORTH INVESTMENT RETURN ANALYSIS

Interest Rate of 6 Percent   Traffic Growth of 2 Percent

Year	Estimated ADT	Const. Cost	Maint. Benefit	20 Foot Acc. Cost	24 Foot Acc. Cost	Accident Benefit	Net Cash	Net Cash Pres. Worth	Cum. Bal. Per Mile
0	875	12000	0	0	0	0	-12000	-12000	-12000
1	893	0	50	4080	3314	766	816	770	-11230
2	911	0	50	4162	3381	781	831	740	-10491
3	929	0	50	4245	3448	797	847	711	-9780
4	948	0	50	4330	3517	813	863	683	-9097
5	967	0	50	4416	3587	829	879	657	-8440
6	986	600	50	4505	3659	845	295	208	-8231
7	1006	0	50	4595	3732	862	912	607	-7625
8	1026	0	50	4687	3807	880	930	583	-7041
9	1046	0	50	4780	3883	897	947	561	-6481
10	1067	0	50	4876	3961	915	965	539	-5942
11	1089	0	50	4974	4040	933	983	518	-5424
12	1110	600	50	5073	4121	952	402	200	-5224
13	1133	0	50	5174	4203	971	1021	479	-4745
14	1155	0	50	5278	4287	991	1041	460	-4285
15	1178	0	50	5383	4373	1010	1060	442	-3842
16	1202	0	50	5491	4461	1031	1081	425	-3417
17	1226	0	50	5601	4550	1051	1101	409	-3008
18	1250	6600	50	5713	4641	1072	-5478	-1919	-4927
19	1275	0	50	5827	4734	1094	1144	378	-4549
20	1301	0	50	5944	4828	1116	1166	363	-4185
21	1327	0	50	6063	4925	1138	1188	349	-3836
22	1353	0	50	6184	5023	1161	1211	336	-3500
23	1381	0	50	6308	5124	1184	1234	323	-3177
24	1408	600	50	6434	5226	1208	658	162	-3015
25	1436	0	50	6562	5331	1232	1282	299	-2716
26	1465	0	50	6694	5437	1256	1306	287	-2429
27	1494	0	50	6828	5546	1281	1331	276	-2153
28	1524	0	50	6964	5657	1307	1357	265	-1887
29	1555	0	50	7103	5770	1333	1383	255	-1632
30	1586	600	50	7245	5886	1360	810	141	-1491

NOTE: This example uses Idaho data only

FIGURE 1

PRESENT WORTH INVESTMENT RETURN ANALYSIS

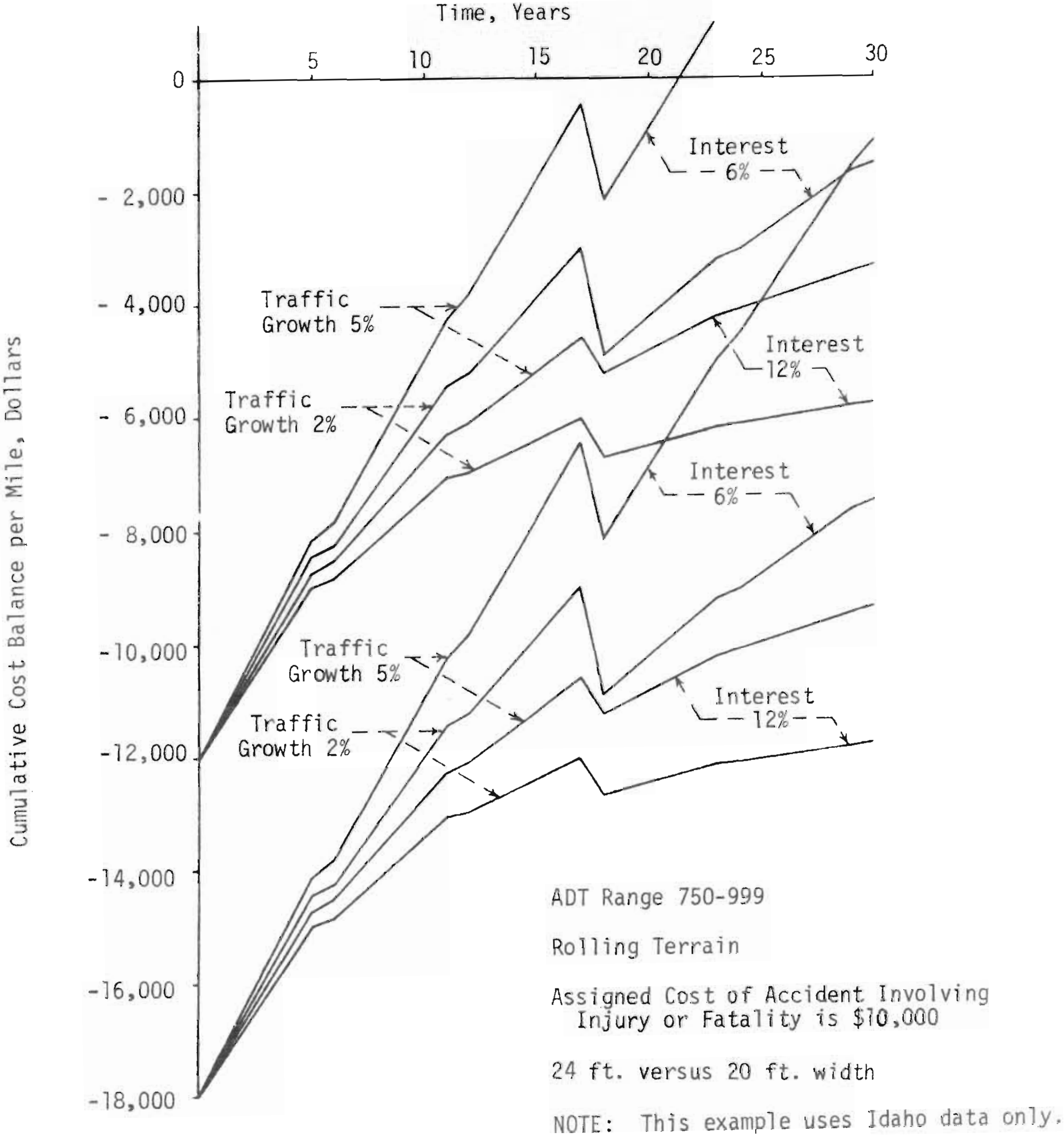
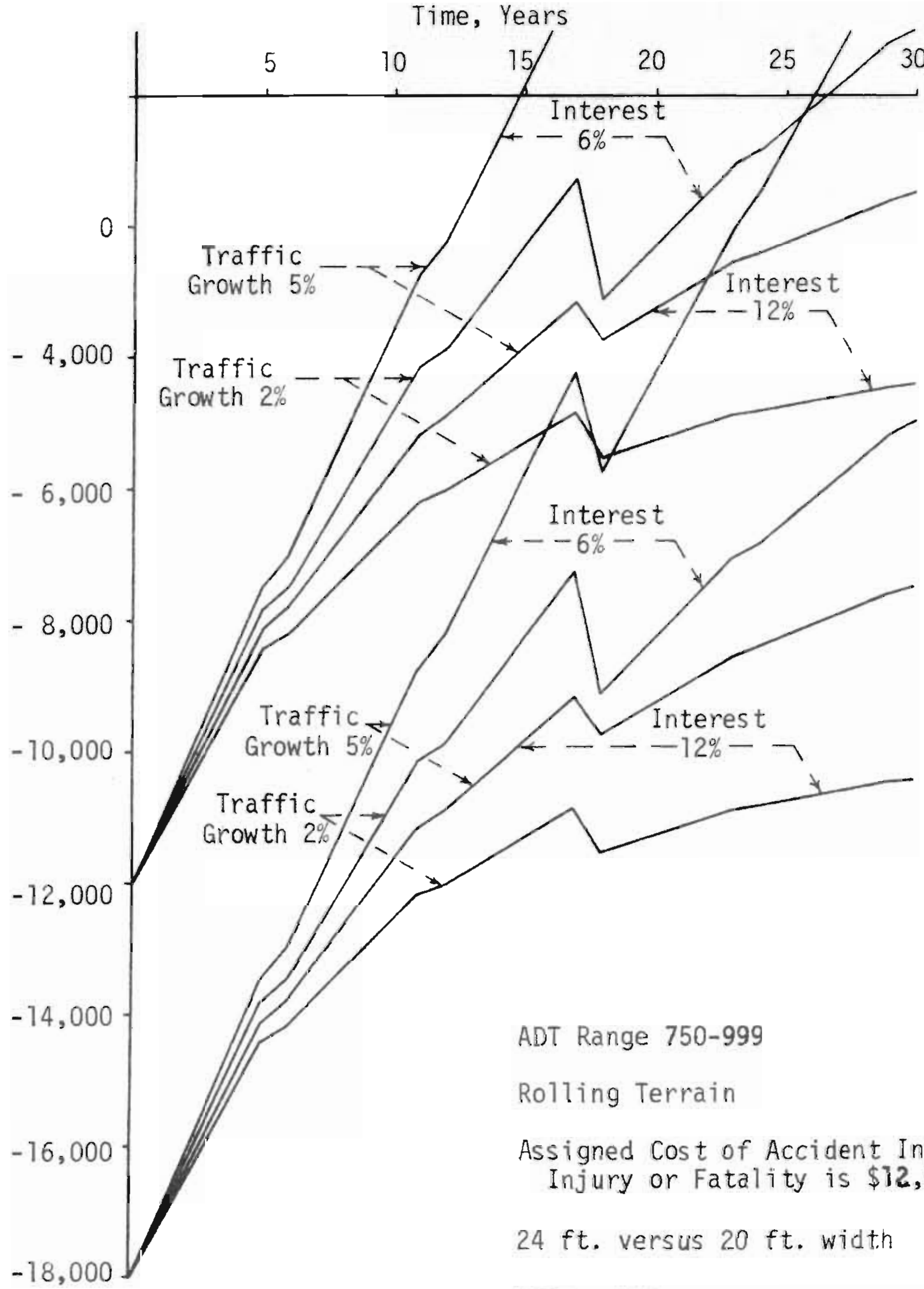


FIGURE 2

PRESENT WORTH INVESTMENT RETURN ANALYSIS



ADT Range 750-999

Rolling Terrain

Assigned Cost of Accident Involving Injury or Fatality is $12,000

24 ft. versus 20 ft. width

NOTE: This example uses Idaho data only.

TABLE 12

NO. OF YEARS REQ'D TO PAY BACK INVESTMENT IN 4 FT. WIDER PAVEMENT
BASED ON ACCIDENT COST SAVINGS - 24 FT. VS. 20 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $10,000

	$12,000/Mi. Construction Cost Difference												$18,000/Mi. Construction Cost Difference											
Terrain	Flat				Rolling				Mountainous				Flat				Rolling				Mountainous			
Annual Interest	6%		12%		6%		12%		6%		12%		6%		12%		6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT																								
0-249	*	*	*	*	*	*	*	*	21	13	**	29	*	*	*	*	*	*	*	*	**	23	**	**
250-399	**	25	**	**	**	21	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
400-749	**	**	**	**	**	**	**	**	*	*	*	*	**	**	**	**	**	**	**	**	*	*	*	*
750-999	**	21	**	**	**	23	**	**	*	*	*	*	**	30	**	**	**	**	**	**	*	*	*	*
1000-1999	*	*	*	*	**	24	**	**	6	5	7	6	*	*	*	*	**	**	**	**	9	8	14	11
2000-2999	8	7	12	10	*	*	*	*	o	o	o	o	14	11	**	19	*	*	*	*	o	o	o	o

*24 ft. pavement has higher accident rate than 20 ft.
**24 ft. pavement has lower accident rate than 20 ft., but cost break doesn't occur within 30 years.
oThe group of study sections representing this category didn't contain any sections in one or both width classes

TABLE 13

NO. OF YEARS REQ'D TO PAY BACK INVESTMENT IN 4 FT. WIDER PAVEMENT
BASED ON ACCIDENT COST SAVINGS - 28 FT. VS. 24 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $10,000

	$12,000/Mi. Construction Cost Difference												$18,000/Mi. Construction Cost Difference											
Terrain	Flat				Rolling				Mountainous				Flat				Rolling				Mountainous			
Annual Interest	6%		12%		6%		12%		6%		12%		6%		12%		6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT 0-249	29	19	**	**	*	*	*	*	**	29	**	**	**	28	**	**	*	*	*	*	**	**	**	**
250-399	**	**	**	**	**	**	**	**	30	19	**	**	**	**	**	**	**	**	**	**	**	28	**	**
400-749	*	*	*	*	*	*	*	*	**	**	**	**	*	*	*	*	*	*	*	*	**	**	**	**
750-999	*	*	*	*	**	**	**	**	4	4	5	4	*	*	*	*	**	**	**	**	6	6	8	7
1000-1999	*	*	*	*	*	*	*	*	26	15	**	**	*	*	*	*	*	*	*	*	**	26	**	**
2000-2999	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

*28 ft. pavement has higher accident rate than 24 ft.
**28 ft. pavement has lower accident rate than 24 ft., but cost break doesn/t occur within 30 years.

TABLE 14

NO. OF YEARS REQ'D TO PAY BACK INVESTMENT IN 6 FT. WIDER PAVEMENT
BASED ON ACCIDENT COST SAVINGS - 34 FT. VS 28 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $10,000

Construction Year ADT	$12,000/Mi. Construction Cost Difference												$18,000/Mi. Construction Cost Difference											
Terrain	Flat				Rolling				Mountainous				Flat				Rolling				Mountainous			
Annual Interest	6%		12%		6%		12%		6%		12%		6%		12%		6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%
0-249	o	o	o	o	*	*	*	*	o	o	o	o	o	o	o	o	*	*	*	*	o	o	o	o
250-399	*	*	*	*	**	**	**	**	**	20	**	**	*	*	*	*	**	**	**	**	**	**	**	**
400-749	*	*	*	*	**	**	**	**	o	o	o	o	*	*	*	*	**	**	**	**	o	o	o	o
750-999	**	23	**	**	**	**	**	**	6	5	7	6	**	**	**	**	**	**	**	**	9	8	14	11
1000-1999	**	**	**	**	10	9	19	13	7	6	9	8	**	**	**	**	19	14	**	28	11	9	20	13
2000-2999	19	13	**	25	5	5	6	5	3	2	3	3	**	21	**	**	8	7	10	9	4	3	4	4

*34 ft. pavement has higher accident rate than 28 ft.
**34 ft. pavement has lower accident rate than 28 ft., but cost break doesn't occur within 30 years.
oThe group of study sections representing this category didn't contain any sections in one or both width classes.

TABLE 15

NO. OF YEARS REQ'D TO PAY BACK INVESTMENT IN 6 FT. WIDER PAVEMENT
BASED ON ACCIDENT COST SAVINGS - 40 FT. VS. 34 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $10,000

	$18,000/Mi. Construction Cost Difference												$27,000/Mi. Construction Cost Difference											
Terrain	Flat				Rolling				Mountainous				Flat				Rolling				Mountainous			
Annual Interest	6%		12%		6%		12%		6%		12%		6%		12%		6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT 0-249	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
250-399	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
400-749	o	o	o	o	**	**	**	**	o	o	o	o	o	o	o	o	**	**	**	**	o	o	o	o
750-999	**	**	**	**	**	**	**	**	o	o	o	o	**	**	**	**	**	**	**	**	o	o	o	o
1000-1999	*	*	*	*	12	10	29	15	*	*	*	*	*	*	*	*	23	15	**	**	*	*	*	*
2000-2999	9	8	14	11	**	**	**	**	5	5	6	5	15	12	**	22	**	**	**	**	8	7	10	9

*40 ft. pavement has higher accident rate than 34 ft.
**40 ft. pavement has lower accident rate than 34 ft., but cost break doesn't occur within 30 years.
oThe group of study sections representing this category didn't contain any sections in one or both width classes.

TABLE 16

NO. OF YEARS REQ'D TO PAY BACK INVESTMENT IN 4 FT. WIDER PAVEMENT
BASED ON ACCIDENT COST SAVINGS - 44 FT. VS. 40 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $10,000

	$12,000/Mi. Construction Cost Difference												$18,000/Mi. Construction Cost Difference											
Terrain	Flat				Rolling				Mountainous				Flat				Rolling				Mountainous			
Annual Interest	6%		12%		6%		12%		6%		12%		6%		12%		6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT																								
0-249	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
250-399	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
400-749	o	o	o	o	*	*	*	*	*	*	*	*	o	o	o	o	*	*	*	*	*	*	*	*
750-999	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
1000-1999	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2000-2999	*	*	*	*	**	20	**	**	o	o	o	o	*	*	*	*	**	29	**	**	o	o	o	o

*44 ft. pavement has higher accident rate than 40 ft.
**44 ft. pavement has lower accident rate than 40 ft., but cost break doesn't occur within 30 years.
°The group of study sections representing this category didn't contain any sectionsin one or both width classes.

TABLE 17

NO. OF YEARS REQ' TO PAY BACK INVESTMENT IN 4 FT. WIDER PAVEMENT
BASED ON ACCIDENT COST SAVINGS - 24 FT. VS. 20 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $20,000

	$12,000/Mi. Construction Cost Difference												$18,000/Mi. Construction Cost Difference											
Terrain	Flat				Rolling				Mountainous				Flat				Rolling				Mountainous			
Annual Interest	6%		12%		6%		12%		6%		12%		6%		12%		6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT 0-249	*	*	*	*	*	*	*	*	8	7	11	9	*	*	*	*	*	*	*	*	13	10	**	16
250-399	12	10	**	15	10	9	19	12	27	15	**	**	24	15	**	**	19	13	**	27	**	26	**	**
400-749	**	**	**	**	**	**	**	**	*	*	*	*	**	**	**	**	**	**	**	**	*	*	*	*
750-999	10	8	15	11	11	10	29	14	*	*	*	*	19	13	**	25	23	15	**	**	*	*	*	*
1000-1999	*	*	*	*	11	10	26	14	3	3	3	3	*	*	*	*	23	15	**	**	5	4	5	5
2000-2999	4	4	5	4	*	*	*	*	o	o	o	o	6	6	8	7	*	*	*	*	o	o	o	o

*24 ft. pavement has higher accident rate than 20 ft.
**24 foot pavement has lower accident rate than 20 ft., but cost break doesn't occur within 30 years.
oThe group of study sections representing this category didn't contain any sections in one or both width classes.

TABLE 18

NO. OF YEARS REQ'D TO PAY BACK INVESTMENT IN 6 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 34 FT. VS. 28 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $20,000

$18,000/Mi. Construction Cost Difference

Terrain	Flat				Rolling				Mountainous			
Annual Interest	6%		12%		6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT 0-249	o	o	o	o	*	*	*	*	o	o	o	o
250-399	*	*	*	*	*	*	*	*	11	9	20	13
400-749	*	*	*	*	**	**	**	**	o	o	o	o
750-999	12	10	30	15	**	24	**	**	3	3	3	3
1000-1999	27	16	**	**	5	5	6	5	4	3	4	4
2000-2999	8	7	10	8	3	3	3	3	2	2	2	2

$27,000/Mi. Construction Cost Difference

Terrain	Flat				Rolling				Mountainous			
Annual Interest	6%		12%		6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT 0-249	o	o	o	o	*	*	*	*	o	o	o	o
250-399	*	*	*	*	*	*	*	*	20	14	**	29
400-749	*	*	*	*	**	**	**	**	o	o	o	o
750-999	23	15	**	**	**	**	**	**	4	4	5	5
1000-1999	**	27	**	**	8	7	11	9	5	5	6	6
2000-2999	12	10	26	15	4	4	4	4	2	2	2	2

*34 ft. pavement has higher accident rate than 28 ft.
**34 ft. pavement has lower accident rate than 28 ft., but cost break doesn't occur within 30 years.
oThe group of study sections representing this category didn't contain any sections in one or both width classes.

TABLE 19

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 4 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 24 FT. VS. 20 FT. WIDE PAVEMENT

ALL TERRAIN TYPES COMBINED

Assigned Cost of Accident Involving Injury or Fatality is $10,000

		$12,000/Mi. Initial Cost Difference				$18,000/Mi. Initial Cost Difference			
	Annual Interest	6%		12%		6%		12%	
	Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT	0-249	**	**	**	**	**	**	**	**
	250-399	**	25	**	**	**	**	**	**
	400-749	*	*	*	*	*	*	*	*
	750-999	**	**	**	**	**	**	**	**
	1000-1999	14	11	**	22	**	20	**	**
	2000-2999	*	*	*	*	*	*	*	*

*24 ft. pavement has higher accident rate than 20 ft.
**24 ft. pavement has lower accident rate than 20 ft., but cost break doesn't occur within 30 years.

TABLE 20

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 4 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 28 FT. VS. 24 FT. WIDE PAVEMENT

ALL TERRAIN TYPES COMPINED

Assigned Cost of Accident Involving Injury or Fatality is $10,000

		$12,000/Mi. Initial Cost Difference				$18,000/Mi. Initial Cost Difference			
	Annual Interest	6%		12%		6%		12%	
	Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT	0-249	**	21	**	**	**	**	**	**
	250-399	**	**	**	**	**	**	**	**
	400-749	**	**	**	**	**	**	**	**
	750-999	**	**	**	**	**	**	**	**
	1000-1999	*	*	*	*	*	*	*	*
	2000-2999	*	*	*	*	*	*	*	*

*28 ft. pavement has higher accident rate than 24 ft.
**28 ft. pavement has lower accident rate than 24 ft., but cost break doesn't occur within 30 years.

TABLE 21

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 6 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 34 FT. VS. 28 FT. WIDE PAVEMENT

ALL TERRAIN TYPES COMBINED

Assigned Cost of Accident Involving Injury or Fatality is $10,000

	$18,000/Mi. Initial Cost Difference				$27,000/Mi. Initial Cost Difference			
Annual Interest	6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT 0-249	*	*	*	*	*	*	*	*
250-399	*	*	*	*	*	*	*	*
400-749	*	*	*	*	*	*	*	*
750-999	**	26	**	**	**	**	**	**
1000-1999	13	11	**	16	25	16	**	**
2000-2999	9	8	14	11	15	12	**	23

*34 ft. pavement has higher accident rate than 28 ft.
**34 ft. pavement has lower accident rate than 28 ft., but cost break doesn't occur within 30 years.

TABLE 22

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 6 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 40 FT. VS. 34 FT. WIDE PAVEMENT

ALL TERRAIN TYPES COMBINED

Assigned Cost of Accident Involving Injury or Fatality is $10,000

		$18,000/Mi. Initial Cost Difference				$27,000/Mi. Initial Cost Difference			
	Annual Interest	6%		12%		6%		12%	
	Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT	0-249	o	o	o	o	o	o	o	o
	250-399	o	o	o	o	o	o	o	o
	400-749	**	27	**	**	**	**	**	**
	750-999	*	*	*	*	*	*	*	*
	1000-1999	**	**	**	**	**	**	**	**
	2000-2999	19	13	**	26	**	21	**	**

*40 ft. pavement has higher accident rate than 34 ft.
**40 ft. pavement has lower accident rate than 34 ft., but cost break doesn't occur within 30 years.
oThe group of study sections representing this category didn't contain any sections in one or both width classes.

TABLE 23

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 4 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 44 FT. VS. 40 FT. WIDE PAVEMENT

ALL TERRAIN TYPES COMBINED

Assigned Cost of Accident Involving Injury or Fatality is $10,000

Construction Year ADT	$12,000/Mi. Initial Cost Difference				$18,000/Mi. Initial Cost Difference			
Annual Interest	6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
0-249	o	o	o	o	o	o	o	o
250-399	o	o	o	o	o	o	o	o
400-749	*	*	*	*	*	*	*	*
750-999	o	o	o	o	o	o	o	o
1000-1999	*	*	*	*	*	*	*	*
2000-2999	*	*	*	*	*	*	*	*

*44 Ft. pavement has higher accident rate than 40 ft.

oThe group of study sections representing this category didn't contain any sections in one or both width classes.

TABLE 24

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 4 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 24 FT. VS. 20 FT. WIDE PAVEMENT

ALL TERRAIN TYPES COMBINED

Assigned Cost of Accident Involving Injury or Fatality is $20,000

		$12,000/Mi. Initial Cost Difference				$18,000/Mi. Initial Cost Difference			
	Annual Interest	6%		12%		6%		12%	
	Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT	0-249	**	**	**	**	**	**	**	**
	250-399	12	10	**	15	24	15	**	**
	400-749	*	*	*	*	*	*	*	*
	750-999	25	15	**	**	**	25	**	**
	1000-1999	7	6	8	7	10	9	19	12
	2000-2999	*	*	*	*	*	*	*	*

*24 ft. pavement has higher accident rate than 20 ft.
**24 ft. pavement has lower accident rate than 20 ft., but cost break doesn't occur within 30 years.

TABLE 25

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 6 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 34 FT. VS. 28 FT. WIDE PAVEMENT

ALL TERRAIN TYPES COMBINED

Assigned Cost of Accident Involving Injury or Fatality is $20,000

	$18,000/Mi. Initial Cost Difference				$27,000/Mi. Initial Cost Difference			
Annual Interest	6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT 0-249	*	*	*	*	*	*	*	*
250-399	*	*	*	*	*	*	*	*
400-749	*	*	*	*	*	*	*	*
750-999	13	11	**	19	27	17	**	**
1000-1999	6	6	8	7	10	8	15	11
2000-2999	5	4	5	5	7	6	9	8

*34 ft. pavement has higher accident rate than 28 ft.
**34 ft. pavement has lower accident rate than 28 ft., but cost break doesn't occur within 30 years.

TABLE 26

COMPARISON BETWEEN EXISTING IDH MINIMUM PAVEMENT WIDTHS AND SUGGESTED MINIMUMS

Range of Current ADT	Avg. 20 yr. ADT of Sample Sections in the Given Range of Current ADT (2% growth)	DHV (assume 13% of 20 yr. ADT)	Suggested Minimum Width (ft.)	IDH min. Width Primary Highway (ft.)	IDH min. Width Secondary Highway (ft.)
0-249	246		20	26-28	26-28
250-399	467		20	34	28
400-749	851	111	24	34	34
750-999	1294	168	28	34	34
1000-1999	2124	276	34	40	40
2000-2999	3643	474*	40	44	44

*IDH design standard calls for 4-lane design when DHV exceeds 400.

TABLE 27

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 8 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 28 FT. VS. 20 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $10,000

	$24,000/Mi. Initial Cost Difference				$36,000/Mi. Initial Cost Difference			
Annual Interest	6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT								
0-249	**	**	**	**	**	**	**	**
250-399	**	27	**	**	**	**	**	**
400-749	*	*	*	*	*	*	*	*
750-999	**	**	**	**	**	**	**	**
1000-1999	**	**	**	**	**	**	**	**
2000-2999	*	*	*	*	*	*	*	*

*28 ft. pavement has higher accident rate than 20 ft.
**28 ft. pavement has lower accident rate than 20 ft., but cost break doesn't occur within 30 years.

TABLE 28

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 14 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 34 FT. VS. 20 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $10,000

	$42,000/Mi. Initial Cost Difference				$63,000/Mi. Initial Cost Difference			
Annual Interest	6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT 0-249	*	*	*	*	*	*	*	*
250-399	**	**	**	**	**	**	**	**
400-749	*	*	*	*	*	*	*	*
750-999	**	28	**	**	**	**	**	**
1000-1999	25	16	**	**	**	26	**	**
2000-2999	**	**	**	**	**	**	**	**

*34 ft. pavement has higher accident rate than 20ft.
**34 ft. pavement has lower accident rate than 20ft., but cost break doesn't occur within 30 years.

TABLE 29

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 10 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 34 FT. VS. 24 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $10,000

	$30,000/Mi. Initial Cost Difference				$45,000/Mi. Initial Cost Difference			
Annual Interest	6%		12%		6%		12%	
Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT 0-249	*	*	*	*	*	*	*	*
250-399	*	*	*	*	*	*	*	*
400-749	**	**	**	**	**	**	**	**
750-999	**	28	**	**	**	**	**	**
1000-1999	**	21	**	**	**	**	**	**
2000-2999	26	16	**	**	**	27	**	**

*34 ft. pavement has higher accident rate than 24 ft.
**34 ft. pavement has lower accident rate than 24 ft., but cost break doesn't occur within 30 years.

TABLE 30

NO. OF YEARS REQUIRED TO PAY BACK INVESTMENT IN 8 FT. WIDER PAVEMENT BASED ON ACCIDENT COST SAVINGS - 20 FT. VS. 20 FT. WIDE PAVEMENT

Assigned Cost of Accident Involving Injury or Fatality is $20,000

		$24,000/Mi. Initial Cost Difference				$36,000/Mi. Initial Cost Difference			
	Annual Interest	6%		12%		6%		12%	
	Annual Traffic Growth	2%	5%	2%	5%	2%	5%	2%	5%
Construction Year ADT	0-249	27	17	**	**	**	28	**	**
	250-399	15	12	**	21	29	19	**	**
	400-749	*	*	*	*	*	*	*	*
	750-999	25	16	**	**	26	**	**	**
	1000-1999	20	14	**	**	**	23	**	**
	2000-2999	*	*	*	*	*	*	*	*

*28 ft. pavement has higher accident rate than 20 ft.

**28 ft. pavement has lower accident rate than 20 ft., but cost break doesn't occur within 30 years.