Geometric Inconsistencies and Accident Experience on Two-Lane Rural Highways

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The relationship between geometric inconsistencies and accident experience on two-lane rural highways is discussed. Inconsistent geometric features pose operational and safety problems because of disparities between the expected and actual driver workload and attention level requirements of the features. U.S. design policy, which is based on the design-speed concept, does not provide a systematic basis for preventing geometric inconsistencies. Several European countries and Australia, however, have recognized this limitation and have supplemented the design-speed concept with consideration of operating speeds along alignments. The two basic approaches for identifying and quantifying geometric inconsistencies are discussed: one is based on operating speeds and the other, on driver workload. Procedures based on operating speeds are used in Europe and Australia, and two such procedures have been developed in the United States. These procedures use the change in operating speeds to quantify the severity of geometric inconsistencies. Their application is limited to evaluation of horizontal alignment, however. Driver workload has the advantage of being applicable to most types of inconsistencies but the disadvantage of not being directly measurable. The results of a preliminary study of the statistical relationship between geometric inconsistencies (quantified in terms of driver workload values using a procedure developed by Messer et al.) suggest that driver workload values are good predictors of accident experience on two-lane rural highways.

In the United States, horizontal and vertical alignment design policy is based on the design-speed concept, as detailed in the AASHTO document *A Policy on Geometric Design of Highways and Streets* (1). Leisch and Leisch (2) suggested that "the design-speed concept, as presently applied, does not preclude inconsistencies in highway alignment." Glennon and Harwood (3) agreed that "the AASHTO design policies have often led to inconsistently designed highways."

Geometric inconsistencies violate driver expectancy and, therefore, may degrade traffic operations and safety. They have higher workload requirements than drivers expect, and they often require abrupt changes in speed, path, or both. Such changes have been identified as surrogate measures for accident experience on two-lane rural highways (4–6).

This paper focuses on the relationship between accident experience and the severity of geometric inconsistencies. First, the nature and effects of geometric inconsistencies are discussed. Next, current U.S. and foreign practices for promoting geometric design consistency are summarized, and two approaches for evaluating geometric design consistency are

described. Finally, pilot study results are presented on the statistical relationship between the severity of geometric inconsistencies [measured using the procedure based on driver workload developed by Messer et al. (7)] and accident experience on five two-lane rural highways in Texas.

NATURE AND EFFECTS OF GEOMETRIC INCONSISTENCIES

The inconsistency of geometric features is best explained in terms of the interaction among driver, vehicle, and roadway. The roadway geometry and other factors (including the roadside environment, weather, traffic control devices, and traffic conditions) are the primary inputs to the driving task and determine the workload requirements imposed upon the driver. The driver's expectancy and attention level influence how quickly those inputs are processed and how well the driving tasks are performed. The driver's performance translates into vehicle operations—such as operating speed and lateral placement—that can be observed and measured.

Driver workload is defined as "the time rate at which drivers must perform a given amount of work or driving tasks" (7). Driver workload increases with increasing geometric complexity. Workload increases as the time available to perform a given amount of work decreases because of increases in speed or reductions in sight distance. Workload is higher for unfamiliar drivers than for familiar drivers (7).

Expectancy influences both the driver's workload requirements and attention level and, consequently, the driver's level of performance. Lunenfeld and Alexander (8) describe two basic forms of driver expectancy: a priori and ad hoc. A priori expectancies are long-term and widely held expectancies, based on collective previous experience, that drivers bring to the driving task. Unusual geometric features (e.g., a one-lane bridge), features with unusual dimensions (e.g., a very long or very sharp horizontal curve), and features combined in unusual ways (e.g., an intersection hidden beyond a crest vertical curve) may violate a priori expectancies. Ad hoc expectancies, on the other hand, are short-term expectations that drivers formulate during a particular trip; they are based on site-specific practices and situations encountered in transit. Geometric features whose dimensions differ significantly from upstream features (e.g., a horizontal curve significantly sharper than upstream curves) may violate ad hoc expectancies.

A driver's attention level also influences the successful performance of driving tasks. "Drivers allocate sufficient atten-

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tion to maintain a perceived level of driving safety" (7). Most rural highways require relatively low attention levels. Geometric inconsistencies, however, demand more attention than normally required and, therefore, than drivers expect. If sight distance to an inconsistent feature is adequate, drivers should have sufficient time to increase their attention levels and perform the necessary vehicle control actions; if sight distance is not adequate, some drivers may not have time to react properly, and accidents may result.

CURRENT PRACTICES FOR PROMOTING GEOMETRIC DESIGN CONSISTENCY

U.S. Practice

AASHTO (1) provides specific, quantitative guidelines on individual design elements (e.g., horizontal and vertical curves). It provides only general, qualitative statements, however, on ways to combine those elements into an alignment and to coordinate horizontal and vertical alignments. The design-speed concept is the mechanism for achieving consistency among the individual elements of an alignment. Design speed is the "maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern" (1). Implementing the design-speed concept involves two steps. First, a design speed is selected "consistent with the speed a driver is likely to expect," on the basis of the functional classification of the highway, development environment, and topography. Then, "all of the pertinent features of the highway should be related to the design speed to obtain a balanced design" (1).

The design-speed concept presumes that a design will be consistent if the individual geometric features share the same design speed. Unfortunately, the concept, as implemented in the United States, cannot guarantee consistent design. A fundamental limitation is that the design speed applies only to horizontal and vertical curves, not to the tangents that connect those curves. Design speed has no practical meaning on horizontal tangents. It provides no basis for establishing maximum tangent lengths to promote consistency by controlling the maximum operating speeds that can be attained. As a result, the maximum safe operating speed on a tangent, especially a long one, often exceeds the design speed of the horizontal curves at either end of the tangent.

The design-speed concept does not provide sufficient coordination among individual geometric features to insure consistency. It controls only the minimum value of the maximum safe speeds for the individual features along an alignment. For example, a highway with a 50-mph design speed could have only one curve with a maximum safe speed of 50 mph and all other features with maximum safe speeds of 70 mph or greater. As a result, operating speeds approaching the critical curve are likely to exceed the 50-mph design speed. Such an alignment would comply with a 50-mph design speed, but it might violate a driver's ad hoc expectancy and exhibit undesirable operating-speed profiles.

Theoretically, the only way the design-speed concept could systematically prevent inconsistent operating-speed patterns is if one presumes that drivers know the design speed of the roadway and choose an operating speed less than or equal to that design speed, even though it may be safe to operate at higher speeds along most of the alignment. Clearly, that presumption is unreasonable. Therefore, the design-speed concept does not provide a systematic mechanism for preventing geometric inconsistencies.

Foreign Practice

Several European countries and Australia, recognizing the limited ability of the design-speed concept to promote consistent designs, have adopted design procedures that incorporate explicit consideration of operating speeds. As a result, their practices to promote geometric design consistency appear to be more advanced than those in the United States.

European Practice

A 1985 survey of European geometric design practices suggests that several European countries "place much greater emphasis on achieving consistency among design elements than is called for in the U.S. practice. . . . The effect which individual design elements have on operating speed is the mechanism for determining design consistency" (9). The Germans have guidelines on minimum and maximum tangent lengths and the maximum change in degree of curvature between successive horizontal curves (6). The Swiss also have guidelines on minimum and maximum tangent lengths and employ a speed-profile technique to estimate changes in operating speeds between successive features in horizontal alignments (6). Swedish design practice includes predicting speed profiles from horizontal and vertical alignments in order to evaluate alternative alignments for speed consistency (9). French design policy also suggests maximum tangent lengths to avoid driver fatigue (10). It is also common practice to base super-elevation and sight-distance design on the higher of the selected design speed and the predicted operating speed.

Australian Practice

In 1980, Australia's geometric design policy for low-speed alignments—that is, 90 km/hr (56 mph) or less—was revised to incorporate greater attention to horizontal alignment consistency by placing more emphasis on actual operating speeds (11). A 1988 review of that policy recommended that the approach based on operating speed be retained (12). Australian policy was based on research by McLean (13–15) of driver speed behavior on horizontal curves. McLean (14) found that speeds on horizontal curves depended not only on the radius of curvature but also on the "speed environment," which is defined as the "85th-percentile speed on level tangent sections"; it reflects "the driver's perception of the overall speed standard of a road."

Summary

Several foreign countries' geometric design procedures supplement the design-speed concept with consideration of

operating-speed profiles in order to promote consistency along an alignment. Such consideration is not a formal part of U.S. geometric design practice. An evaluation of the appropriateness and feasibility of adopting similar practices in the United States is, however, clearly warranted.

GEOMETRIC DESIGN CONSISTENCY EVALUATION PROCEDURES

Several procedures for evaluating the consistency of geometric design have been developed in the United States, but their applications have been limited. The two basic approaches have been the procedures developed by Leisch and Leisch (2) and Lamm et al. (16) and the procedure developed by Messer et al. (7). These procedures are reviewed in the following paragraphs. Several other researchers have suggested conceptual approaches to evaluating design consistency, including Polus and Dagan (17), who propose an approach based on spectral analysis; Hirsh et al. (18–20), who propose a probabilistic approach; and Oglesby (21), who proposes an approach based on positive guidance. These concepts have not been fully developed and, therefore, will not be discussed herein.

Leisch and Leisch

Leisch and Leisch (2) evaluate geometric design consistency using an operating-speed profile used to identify undesirable large speed differentials. Their procedure estimates average running speeds for passenger cars and trucks on horizontal curves and tangents. Truck speeds on vertical grades are also estimated. The speed-estimating procedures are derived from AASHTO design policies of 1965 and 1973 (22,23).

Leisch and Leisch (2) recommended a three-part, 10-mph rule:

1. Average automobile speeds along an alignment should vary by no more than 10 mph,
2. Design speed reductions should not exceed 10 mph, and
3. Average truck speeds should differ from average automobile speeds by no more than 10 mph.

Lamm et al.

Lamm et al. (16) recommended a simplified version of the German procedure. They estimate the change in 85th-percentile speed from a tangent to a horizontal curve or between successive horizontal curves on two-lane rural highways, depending on whether the tangent is independent or nonindependent. Their speed estimates are based on a regression analysis of data from 261 horizontal curves in New York State (24). The determination of whether a tangent is independent or not is based on the length of the tangent: a tangent is independent if it is long enough for traffic to accelerate over some part of its length (10). Lamm et al. rate horizontal alignment design consistency in terms of the change in degree of curvature (ΔDC) and corresponding change in 85th-percentile

operating speeds ($\Delta V85$) between successive horizontal elements, as follows:

- Good: $\Delta DC \le 5$ degrees   or $\Delta V85 \le 6$ mph
- Fair: 5 degrees $\Delta DC \le 10$ degrees   or 6 mph $< \Delta V85 \le 12$ mph
- Poor: $\Delta DC > 10$ degrees   or $\Delta V85 > 12$ mph

Messer et al. (7) use driver workload to evaluate geometric design consistency. Workload is estimated based on (a) the criticality of and sight distance to the individual geometric feature, and (b) the consistency and spacing between successive features. Criticality ratings were developed for 10 geometric features: horizontal curves, crest vertical curves, bridges, divided highway transitions, lane drops, intersections, railroad grade crossings, shoulder-width changes, lane-width reductions, and crossroad overpasses.

The workload for a feature is calculated as follows:

$$WL_n = R_f \times S \times E \times U + C \times WL_{n-1} \tag{1}$$

where

$$
\begin{aligned}
WL_n &= \text{workload value for feature } n, \\
R_f &= \text{workload potential rating for feature } n, \\
S &= \text{sight-distance factor,} \\
E &= \text{feature expectation factor,} \\
U &= \text{driver unfamiliarity factor,} \\
C &= \text{feature carryover factor, and} \\
WL_{n-1} &= \text{workload value for the preceding feature,} \\
&\quad n - 1.
\end{aligned}
$$

The workload potential rating (R_f) represents the criticality of the individual feature. The rating was based upon evaluations of features by design, traffic, and human factors engineers on a seven-point scale (0 = no problem and 6 = critical problem). Feature criticality depends on the feature type and its relative frequency of occurrence, basic operational complexity, and overall accident experience. The sight-distance factor (S) increases from 0.6 to 1.8 as the sight distance to the feature decreases from approximately 1,400 to 400 ft. The feature carryover factor (C) increases from 0 to 1 as the separation distance between features decreases from approximately 2,000 to 0 ft. The feature expectation factor (E) equals 1 if feature n is not similar to the preceding feature, $n - 1$, and equals $(1 - C)$ if feature n is similar to feature $n - 1$. The driver unfamiliarity factor (U) increases with the percentage of drivers unfamiliar with the roadway from 0.4 for a rural local road that has mostly familiar drivers to 1.0 for a rural principal arterial that has many unfamiliar drivers.

The first term of the equation suggests that the workload value for a particular feature (n) is a function of (a) the criticality of the feature itself; (b) the sight distance to the feature; (c) the similarity between feature n and the preceding feature, $n - 1$; and (d) the familiarity of drivers with the roadway. For a feature with a given criticality, the workload value decreases as the sight distance to the feature increases; that is, the shorter the sight distance, the less time is available for drivers to adjust their attention level, process the information presented, and initiate the necessary control actions to traverse the feature and, therefore, the higher the workload. If the preceding feature ($n - 1$) is similar, it creates an ad hoc

expectancy that reduces the workload for feature n. The workload value increases with the percentage of unfamiliar drivers.

The second term of the equation accounts for the effect of preceding features on the workload value for feature n. The contribution of preceding features to the workload value for feature n increases as the separation distance between the features decreases; that is, the more closely spaced the features, the less time is available to process the information presented by the feature and to initiate the required control actions associated with the feature—and, therefore, the higher the workload.

Messer et al. provide level of consistency criteria that are similar in concept and application to the level of service criteria used in highway capacity analysis. The levels are defined in Table 1.

Summary

The severity of geometric inconsistencies has been quantified in terms of changes in operating speed and in driver workload. Both measures have advantages and disadvantages. Operating speed can be directly measurable in the field, whereas driver workload cannot be. Operating speed is limited in application to horizontal curves and vertical grades, whereas driver workload provides a common frame of reference for a wide range of geometric features and feature combinations. Conceptually, workload is a more appealing basis for quantifying inconsistencies, because it represents the demands placed on the driver by the roadway; operating speed is only one of the observable outputs of the driving task.

RELATING DRIVER WORKLOAD VALUES AND ACCIDENT EXPERIENCE

The most important criterion for evaluating measures of geometric inconsistency is their correlation to accident experience. Several researchers have identified speed change as a good surrogate for accident experience at horizontal curves on two-lane highways (4–6). To date, however, there has been no attempt to correlate driver workload values and accident experience. This section reports the results of a pilot study (25) of the statistical relationship between workload measures [based on the Messer, et al. procedure (7)] and accident experience on five two-lane rural highways in Texas.

Motivation for Study

This study was motivated by the belief that (a) the application of geometric design consistency principles could significantly improve design; (b) part of the reason available procedures are not being applied in the United States is the time required to use them; (c) the use of the procedures could be facilitated by incorporating them into any of the computer-aided roadway design packages used by state highway agencies; (d) to generate interest in the procedures, it would be necessary to demonstrate their benefits; and (e) the most important benefit would be the ability to explain the effect of geometrics on accident experience better than previous analyses that focused on isolated geometric elements.

Scope of Study

This study was unfunded and, therefore, limited in scope. The goal was to develop workload-based statistical measures and techniques for explaining accident experience on rural highways. The intent was to pursue a larger study if the results of the pilot study were promising. In order to evaluate the measures and techniques, consistency evaluations were performed and accident data were collected for five two-lane rural highways near the Texas A&M University campus. Accident data for January 1987 through June 1990 (3½ years) were extracted from the Texas master accident file for these roadways. The analyses were limited to total accidents; no attempt was made to analyze accidents by type, severity, contributing factors, or such.

Effective Workload Value

One enhancement to the Messer et al. procedure (7) was necessary in order to perform statistical analyses. The problem was that a workload value is estimated for each feature; as a result, sections of roadway on which features overlap have multiple workload values (one for each feature). For statistical analyses, it was necessary to associate a unique workload value and an accident rate or frequency with each uniform section of roadway. The unique workload value that was selected for each uniform roadway section i with length l_i was the highest of the workload values for the features that overlapped; this value was named the effective workload value (EWL_i). EWL_i satisfies the statistical definition of a random variable and is therefore suitable for statistical analyses.

TABLE 1 Driver-Workload–Based Level of Consistency Criteria

Level of Consistency	Workload Value (WL_n)	Likely Driver Response
A	≤1	No Problem Expected
B	≤2	
C	≤3	Small Surprises Possible
D	≤4	
E	≤6	
F	>6	Big Problems Possible

Study Sites

Five farm-to-market (FM) highways, classified functionally as rural collectors, were selected on the basis of their geometry in an attempt to cover the full range of workload values. All of the highways are in gently rolling terrain. Table 2 summarizes the characteristics of the highways. The highways are old by Texas standards (30–40 years) and have relatively low traffic volumes (330 to 1,450 vpd). The number of features with workload ratings (primarily horizontal and vertical curves but also at-grade intersections and bridges) varies from 30 to 98 (3.7 to 7.9 features per mile).

Sample Consistency Evaluation

Consistency evaluations were performed separately for each direction of the five highways. Figure 1 provides an example of the results: an EWL_i profile for one of the highways studied, FM-1179. The workload for combination or closely spaced features increases in the direction of travel because of the carryover effect. The high EWL_i value at Station $120 + 00$ was for a pair of 12-degree horizontal curves separated by a short tangent. It should also be noted that tangents have an EWL_i value of 0, which implies not that tangents impose no workload on drivers but rather that the workload in tangents is taken as the baseline value.

Since EWL_i is a random variable, it was possible to develop a relative frequency distribution to characterize each highway. The distribution of EWL_i values for FM-1179 is illustrated in Figure 2. The relative frequency is the proportion of the total length of roadway with a given EWL_i value. The class intervals correspond to the levels of consistency summarized in Table 1. It was also possible to compute the mean and variance of EWL_i values for each highway (by direction).

Levels of Analysis

Two levels of analysis were developed. A microscopic analysis evaluated the statistical relationship between the accident frequency and the EWL_i value for individual geometric features. A macroscopic analysis evaluated the statistical relationship between the accident rate and mean EWL_i value for each highway direction.

Microscopic Analysis

The microscopic analysis involved constructing Table 3, a two-way contingency table of the distribution of features by accident frequency and level of consistency, and performing a χ^2-test of independence. The null hypothesis of the test is that the accident frequency and EWL_i value of a feature are independent. To satisfy the requirement of the χ^2-test that the expected frequency in each cell be greater than or equal to 5, it was necessary to collapse the last three columns of the table.

The calculated χ^2-value is 31.65; therefore, the hypothesis that the accident frequency and EWL_i value for a geometric feature is independent is rejected at a 0.01 significance level. Table 3 suggests that accidents are more likely to occur on highway segments with high EWL_i values than on segments with low values.

Exposure rates (in terms of vehicle miles traveled) vary among the levels of consistency, which somewhat masks the relationship between accident experience and workload. For example, Level-of-Consistency $A(EWL_i \leq 1)$ represents 58 percent of the features (463 out of 804) but approximately 75 percent of the total length of roadway studied. In an effort to control for the different exposure rates, the average accident rate for the geometric features in each level of consistency was computed. Figure 3 illustrates the results and suggests a strong relationship between accident rate and level of consistency.

An analysis was also conducted to determine whether it was necessary to control for the effect of annual average daily traffic (AADT) on accident rates. The results indicated no variation in accident rates by AADT. This result is probably due to the small range of AADTs at the study sites and is not likely to be generalizable to a larger sample of sites.

Macroscopic Analysis

The macroscopic analysis consisted of regression analyses of the overall accident rate and mean EWL_i value for extended highway sections. This mean value quantifies both the criticality of the individual geometric features of the roadway and the consistency among features along the alignment. The mean EWL_i value for each direction of the highway was computed as follows:

$$\mu_{EWL} = \frac{\sum (l_i)(EWL_i)}{\sum l_i}$$

TABLE 2   Characteristics of Study Sites

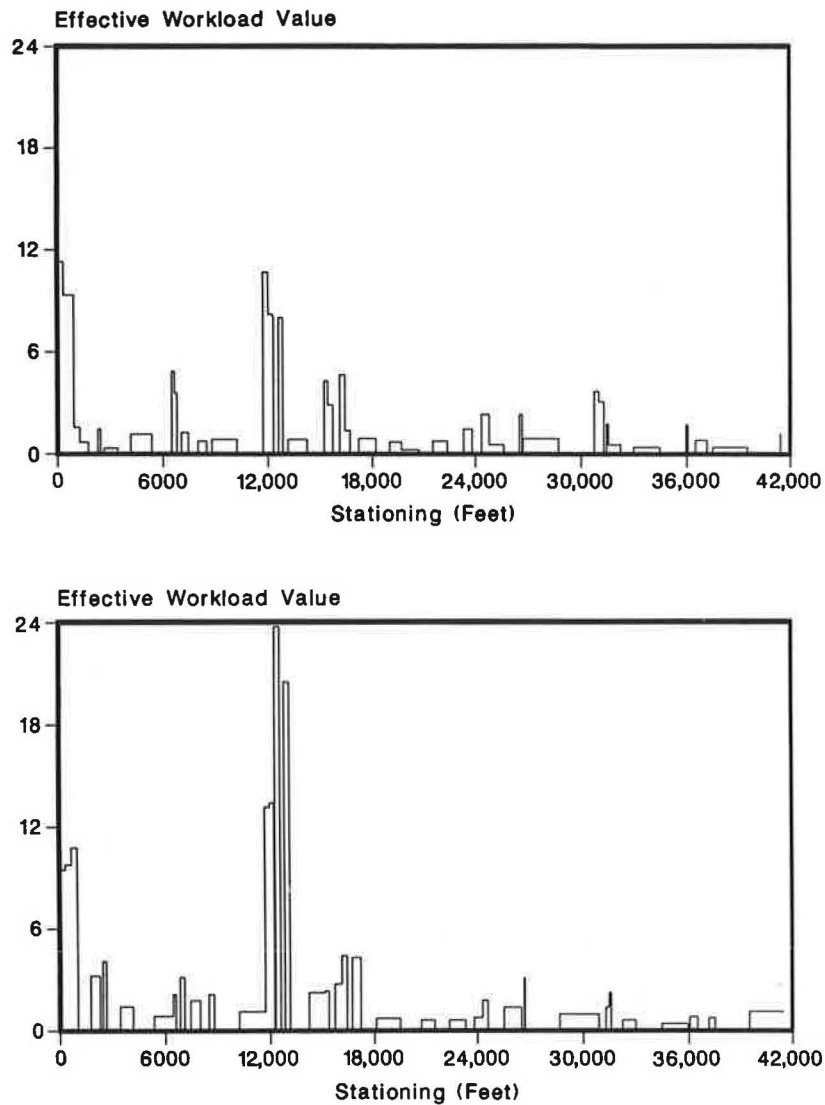| Route	Lane Width (ft)	Shoulder Type	Length (mi)	Number of Features	Average AADT (vpd)	Number of Accidents
FM 1179	10	Aggregate	7.89	40	1450	28
FM 2154	11	Aggregate	8.07	30	1330	28
FM 391	10	None	12.41	98	1020	33
FM 1362	10	Turf	7.44	41	330	6
FM 3058	10	Turf	8.40	38	670	4

FIGURE 1 Effective workload profile for FM-1179: southbound (*top*) and northbound (*bottom*).

where

μ_{EWL} = mean effective workload value for the extended highway section,
l_i = length of feature i, and
EWL_i = effective workload value for feature i.

A scatter plot of the average accident rate versus μ_{EWL} is presented in Figure 4. The 10 data points represent values for two directions of five highways.

Linear, quadratic, and logarithmic forms of the relationship between average accident rate and μ_{EWL} were evaluated. The best-fitting model was a quadratic function of the form

$$y = \beta_0 + \beta_1 x + \beta_2 x^2$$

where

y = average accident rate for one direction of an extended highway section,

x = μ_{EWL} for one direction of an extended highway section, and
$\beta_0, \beta_1, \beta_2$ = regression coefficients.

Table 4 summarizes the estimated regression coefficients. The model, which is plotted in Figure 4, had an F-value of 26.42 (significant at a 0.0005 level) and an R^2-value of .88.

Caution should be exercised in interpreting the results because of the small data set. The high R^2 probably resulted in part from the small sample size; one would not expect geometrics alone to explain such a high proportion of the variability in accident experience. Nonetheless, the results are promising, and the relationship is intuitively appealing.

The results indicate considerable variability among the accident rates for sections with low μ_{EWL} values. The accident rate is smaller on sections with moderate workload than on sections with either low workloads (which may result in driver inattentiveness) or high workloads (which may overload drivers). Another possible interpretation is that there is a thresh-
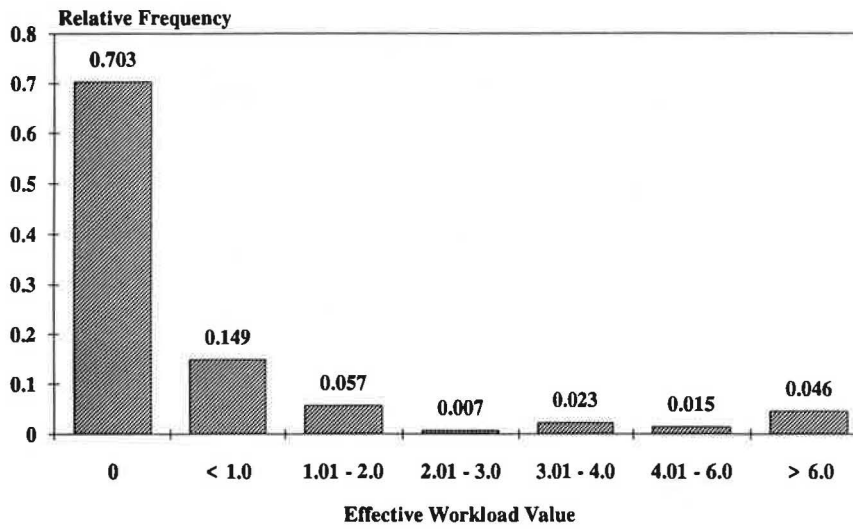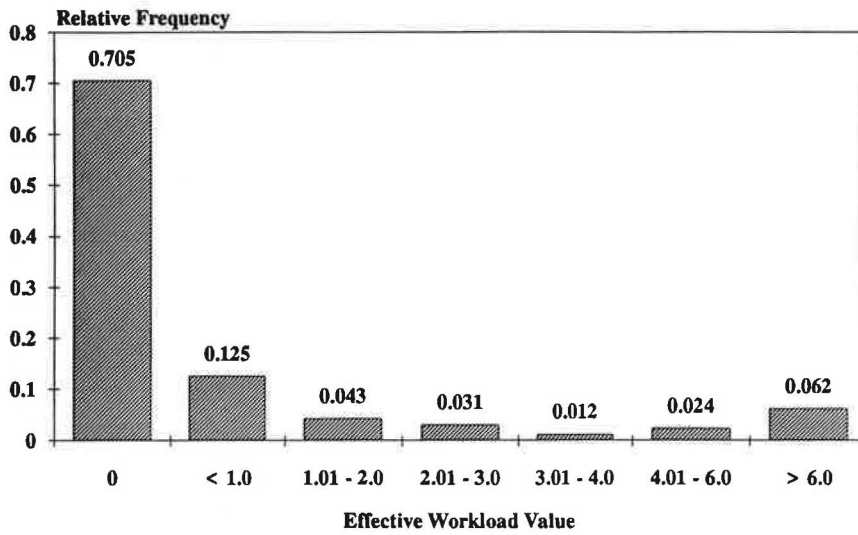
FIGURE 2 Relative frequency distribution of effective workload values on FM-1179: southbound (*top*) and northbound (*bottom*).

TABLE 3 Two-Way Contingency Table of Accident Frequency Versus Level of Consistency

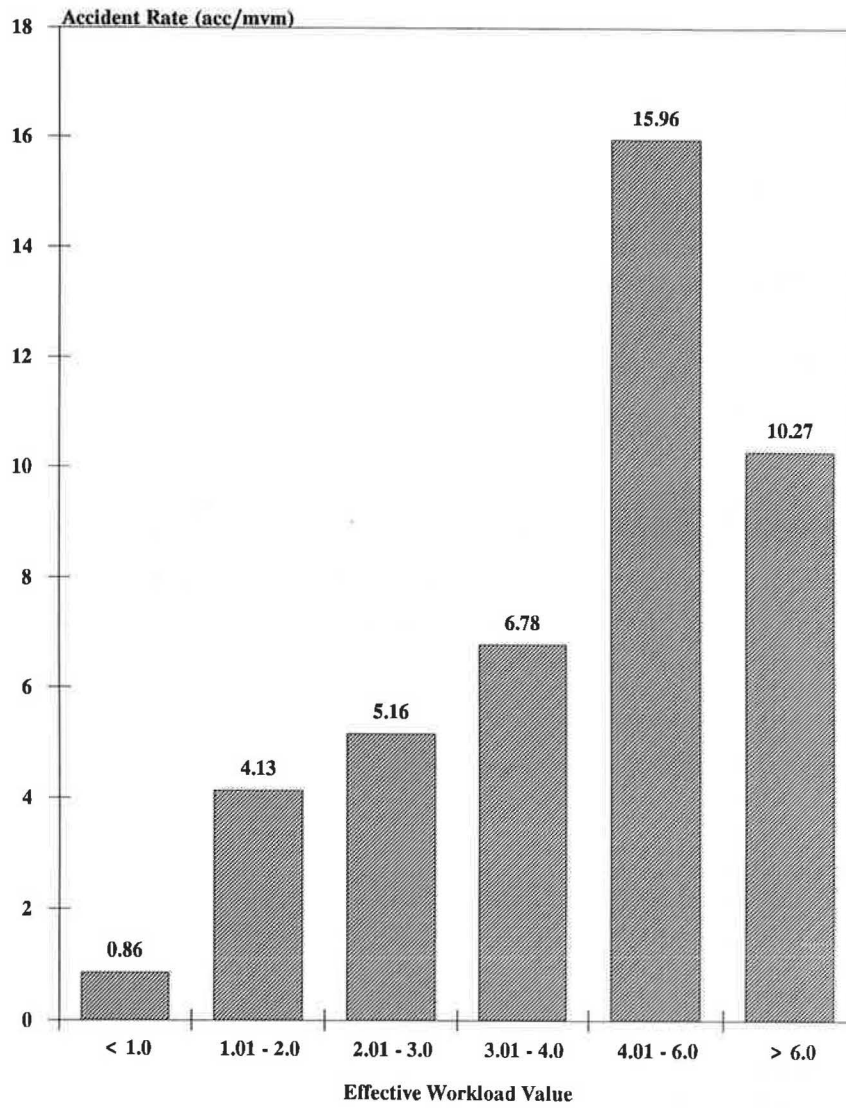| Accident Frequency	Level of Consistency						Total
	A	B	C	D	E	F	
0	442	117	77	44	30	26	736
1 or more	21	14	8	6	5	14	68
Total	463	131	85	50	35	40	804

FIGURE 3 Average accident rates by level of consistency.
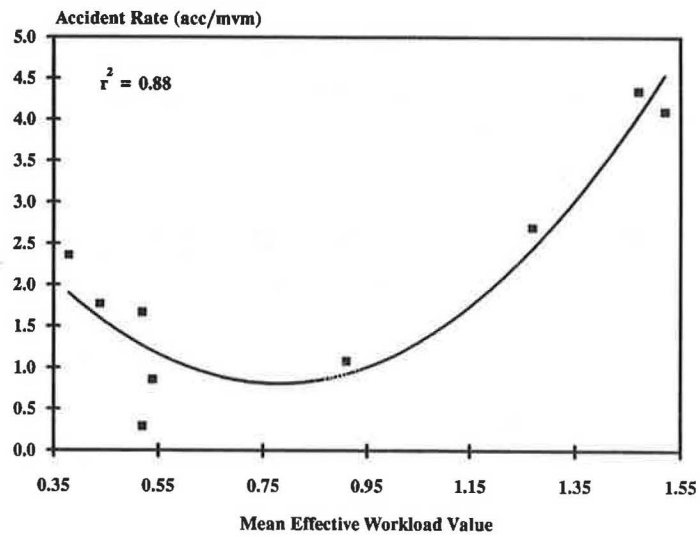

FIGURE 4 Accident rate versus mean effective workload value.

TABLE 4   Summary of Regression Coefficient Estimates

Regression Coefficient	Coefficient Estimate	t-Value for Ho: $\beta=0$	p-Value	Std. Error of Estimate
β_0	4.9500	4.12	0.0045	1.20
β_1	-10.6179	-3.32	0.0127	3.19
β_2	6.8088	4.06	0.0048	1.68

old workload value below which accident rates are insensitive to workload and above which a relationship exists.

Summary

The pilot study results suggest that driver workload measures, based on the Messer et al. procedure (7), may be good indicators of accident experience on two-lane rural highways. The workload value, which quantifies the criticality of individual features and the interacting effects of combinations of features along an alignment, could be a mechanism for improving our ability to explain, predict, and quantify accident likelihood on rural highways. The μ_{EWL} value may be useful as a safety index for priority-ranking highway sections for geometric improvements. The variance in EWL_i values is another possible measure of the level of geometric inconsistency along an alignment and merits additional study. The EWL_i profile is a useful, graphical tool for highlighting potential problem areas. The EWL_i values of individual features may be a reliable quantitative basis for evaluating the need for and effectiveness of specific geometric improvements.

CONCLUSIONS AND RECOMMENDATIONS

Geometric inconsistencies pose operational and safety problems because they require more attention and greater workload than drivers expect. U.S. design policy, which is based on the design-speed concept, does not provide a systematic basis for preventing geometric inconsistencies. Several European countries and Australia have recognized this limitation and have supplemented the design-speed concept with consideration of operating speeds.

Two basic approaches for identifying and quantifying geometric consistencies have been developed in the United States: one based on operating speeds and the other on driver workload. The procedures based on operating speeds that were developed by Leisch and Leisch (2) and Lamm et al. (16) are similar to European and Australian practices. They use the change in operating speeds (which has proved to be a good surrogate for accident experience at horizontal curves) to quantify the severity of horizontal geometric inconsistencies.

Messer et al. (7) quantify geometric inconsistencies using driver workload values, which apply to most types of inconsistencies but are not directly measurable. The statistical analysis results reported herein suggest that driver workload values may be good predictors of accident experience on two-lane rural highways.

The promising results from this pilot study suggest that a more comprehensive study is warranted. The safety effectiveness of European and Australian design procedures should be reviewed. The statistical relationships among driver workload values, changes in operating speed, and accident experience should be tested on a larger sample of highways. Techniques for more direct measurement of workload—such as occluded vision tests—should be evaluated. If these results continue to show strong correlations between accident experience and the severity of geometric inconsistency, actions should be taken to facilitate and encourage the evaluation of the geometric design consistency of existing and new rural highways.

ACKNOWLEDGMENTS

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