Information Deficiencies on Low-Volume Rural Roads

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A description is provided of portions of a Federal Highway Administration study. The objectives of the study were to identify driver information needs on two-lane rural highways; identify potential driver problems that can be alleviated by way of low-cost information treatments; and develop a simple procedure that can be used by state and local personnel to identify information deficiencies on low-volume roadways for which adequate accident data are not available. As part of this study a 5,000-mi, 15-state sample of roadway and informational characteristics was obtained by use of a microprocessor-based, instrumented vehicle. The data base provided insights into the nature of existing informational problems and, by way of extrapolation, an estimate of the magnitude of informational deficiencies. Estimates are presented of the nationwide scope of informational problems at horizontal curves, narrow bridges, and intersections, which are the three primary features of the two-lane rural roadway system that are associated with higher accident rates. The field data collection and problem identification activities provided the basis for the development of a simple, in-vehicle procedure that can be used by state and county engineers, road supervisors, and others to identify problem sites and determine the appropriate remedial informational treatments. The procedure involves the consideration of driver expectancies; a form of commentary driving to identify problem sites; and the application of situation-specific information deficiency checklists to determine the appropriate remedial treatment.

Two-lane rural highways comprise the bulk of the nation's total roadway system. They represent about 80 percent of all roadways, both paved and unpaved, and nearly all (97 percent) of the total rural highway mileage. About 80 percent of these roads have low traffic volumes, with an average daily traffic (ADT) of less than 400 vehicles per day (vpd).

A recently completed FHWA study by Smith et al. indicated that approximately 34 million motor vehicle accidents can be expected to occur over the next 20 years on two-lane rural highways unless positive action is taken to correct the problems responsible for many of these accidents (*1*). The study also indicated that the likelihood of an accident on two-lane rural highways is greatest at horizontal curves, bridges, and intersections. Low-cost safety improvements such as signing and delineation were found to offer the greatest potential for cost-effective countermeasures on the two-lane rural road system.

The motor vehicle accident estimate of 34 million must be of concern to all those responsible for operating and maintaining this system because each accident represents a potential tort action. As was stated in a study by Oliver:

> ...the state is not an insurer of the highway, but it must provide a reasonably safe driving environment for a reasonably prudent driver. Inspection, advance notice, and correction of discovered defects all are within the zone of reasonable program activities. Ignorance of a defect or a dangerous situation—or knowledge of such a situation without warning the motorist to its presence—will expose the state to a liability judgement. A dangerous situation that remains extant for a prolonged period of time will leave the state in an indefensible situation (*2*).

A recent study of tort liability in the Pennsylvania Department of Transportation by Gittings indicated that signing deficiencies, such as missing, obscured, or inadequate signs, were the contributing factors that most frequently occurred in tort claims (*3*). These were the very types of problems that were found by the FHWA study to offer the greatest potential for cost-effective solutions.

This study is based on the results of a study by Hostetter et al. (*4*). It was designed to complement the efforts of the previously cited work by Smith et al. The three specific objectives of the study were to identify driver information needs on two-lane rural highways; identify potential driver problems that can be alleviated by way of low-cost information treatments; and develop an inexpensive procedure that can be used by state and county engineers, road supervisors, and others to identify information deficiencies.

The field survey portion of the study was intended to provide a basis for estimating the existing types and magnitude of information deficiencies. It was also intended to provide a detailed sample of the physical and informational characteristics of the two-lane rural roadway system. The latter objective was considered to be of extreme importance because relatively little was known about the existing roadway characteristics of the two-lane rural road system, particularly that part of the system that is under local control.

ROADWAY AND INFORMATIONAL CHARACTERISTICS

The field data collection effort employed the use of a vehicle that was equipped with sensors that provided information on distance, steering wheel position, accelerator position, and brake pressure. Sensor output was automatically recorded each second by a microprocessor and stored on disk. The system also enabled the manual input of codes that detailed specific roadway and informational characteristics.

Roadway characteristics and driver information systems were sampled on nearly 5,000 mi of open road sections of the two-lane rural road system in 15 states throughout the country. These data served as the basis for estimating information deficiencies on the nation's two-lane rural road system. They also provided descriptive data regarding roadway and informational characteristics.

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The sampling plan was developed to ensure that a broad range of geographic and terrain effects was represented. States were sampled in seven of the nine FHWA field regions in the continental United States. Approximately 58 and 42 percent of the sample mileage came from east and west of the Mississippi, respectively. Paved roadway in rolling and mountainous terrain was deliberately emphasized in the sample roadway mileage breakdown shown in Table 1. Unpaved roadways were not sampled extensively because they account for a very low percentage of total vehicle miles traveled. Furthermore, a large percentage of that travel is by familiar drivers; consideration of information deficiencies was therefore of a lower priority. Rolling and mountainous terrain were emphasized because of the relative difficulty of driving in these regions and the increased probability of encountering a variety of geometric situations that are likely to create driving problems.

The total paved roadway sample was classified in a manner consistent with that of the Smith et al. study, as shown in Table 2 (*1*). As expected, a general relationship exists between pavement width and curves/mi; wider pavements are more likely to be associated with fewer curves/mi, which is an indication of an overall higher design, and vice versa.

Roadway Characteristics and Features

Surface and Shoulder Characteristics

The sample was almost evenly split between roadways of 20 ft or less (46 percent) and those greater than 20 feet (54 percent). Ninety-five percent of the roadways were asphalt. This generally reflects published statistics.

The surface of nearly 85 percent of the road mileage sampled was in good condition as judged by the ability to comfortably maintain a speed near the speed limit on tangent sections or curves where horizontal alignment did not control the speed. Less than 1 percent of the road surfaces were judged to be in poor condition.

Roads with no shoulder of any kind accounted for about 36 percent of the paved roadway mileage sampled. Of the remaining 3,100 mi of paved roadway in the sample, 64 percent had unpaved shoulders and 36 percent had paved shoulders. Shoulders were coded as either two-wheel or four-wheel. A four-wheel shoulder was one that was wide enough to get a car completely out of the travelway. Nearly 66 percent of the roadways with shoulders had shoulders of a two-wheel width.

TABLE 1 SURFACE TYPE BY TERRAIN TYPE FOR TOTAL SAMPLE MILEAGE

	Surface Type		Total	
Terrain	Unpaved (mi)	Paved (mi)	Miles	Percent
Flat	28	468	496	10
Rolling	104	3,161	3,265	66
Mountainous	57	1,128	1,185	24
Total	189	4,757	4,946	100

TABLE 2 PAVED ROADWAY MILEAGE IN PAVEMENT WIDTH, INTERSECTIONS/MILE, AND CURVES/MILE CATEGORIES

PAVEMENT WIDTH	INTERSECTIONS/MILE							
	0-2.5				2.5-5.0			
	CURVES/MILE				CURVES/MILE			
	0-1.0	1.0-2.5	2.5-4.5	>4.5	0-1.0	1.0-2.5	2.5-4.5	>4.5
< 20	119	351	547	344	0	3	15	4
20	106	353	178	126	0	9	10	0
> 20	890	905	427	244	31	33	52	6
Subtotals	1115	1609	1152	714	31	45	77	10
TOTALS	4590				163			

Roadway Features

The roadway features of primary interest on the basis of highest accident probabilities are horizontal curves, narrow bridges, and intersections. The frequency of occurrence of these features is shown in Table 3 for three terrain types. The primary difference between the terrain types is the frequency at which curves occur.

Informational Characteristics

Pavement Striping Characteristics

Slightly more than half of the paved mileage had both centerlines and edgelines. Another 31 percent had only centerlines. Seventeen percent of the paved mileage sampled had neither edgelines nor centerlines.

As pavement width increased, the percentage of roadways with either centerlines or centerlines and edgelines also increased. This is reasonable because wider pavements generally imply a higher type of geometric design to serve greater traffic volumes, which in turn suggests the likelihood of a higher standard of marking.

General Signing Characteristics

A variety of specific regulatory and warning signs was coded in the data sample. The regulatory signs were SPEED LIMIT, REDUCED SPEED AHEAD, STOP, and YIELD. All major curve, intersection, and narrow bridge warning signs were identified, such as REVERSE CURVE and STOP AHEAD. A variety of warning signs that were considered to be less important to the requirements of the study, such as "Divided Highway," were simply coded "other." The SLIPPERY WHEN WET and BRIDGE FREEZES BEFORE ROADWAY signs were not coded at all because their presence or absence is a matter of agency policy. If an advance warning sign included an advisory speed plate, the speed advisory value was also coded in the data base.

The rate at which signs were encountered on various types of terrain is shown in Table 4. It was estimated that three regulatory or warning signs of some type could be found on each mile of the open road sections of the paved two-lane rural system, not including the two signs that were not coded.

INFORMATION DEFICIENCIES

Individuals need information to be able to drive safely, conveniently, efficiently, and comfortably. Most of the needed information is received visually from the driver's perception of the highway environment. The environment includes such formal information as signs and markings provided by a government jurisdiction, and natural information. Natural information refers to all other elements of the highway environment that assist the driver in making correct alignment and speed control decisions, such as tree or brush lines. Natural

TABLE 3 PAVED ROADWAY FEATURES BY TERRAIN TYPE

Terrain	Miles	Curves/ Mile	Narrow Bridges/ Mile	Intersections/ Mile
Flat	468	1.37	0.15	1.10
Rolling	3,161	2.10	0.16	1.24
Mountainous	1,128	4.30	0.11	0.99
All Terrain	4,757	2.55	0.15	1.17

TABLE 4 SIGN SUMMARY BY TERRAIN TYPE ON SAMPLE OF PAVED ROADS ONLY

TERRAIN	MILES	All Warning Signs/ Mile	Speed Signs/ Mile	Speed Reduction Signs/ Mile	STOP/ YIELD Signs/ Mile	Total Signs/ Mile
Flat	468	.72	.25	.04	.10	1.12
Rolling	3161	1.05	.32	.03	.07	1.49
Mountainous	1128	1.22	.34	.04	.02	1.63
All Terrain	4757	1.06	.32	.03	.07	1.49

information can be treated to enhance the visual cues in given situations. For example, roadside vegetation can be tapered to improve the way in which the natural information indicates the narrowness of a bridge.

Problem Overview

An information deficiency is considered to exist whenever specific information necessary to drivers about the road ahead is not provided. The need for any form of specific information usually results from a change in alignment or geometry that is not visible in the time needed for the driver to take appropriate action safely, such as a change in speed, an alteration in lateral placement, or a stop.

A number of distinct types of information deficiencies were observed in the field. They range from situations in which necessary information was not available to the driver because it was obscured, missing, or incomplete, to situations in which the information presented was misleading, confusing, or inconsistent.

Of all the types of information deficiencies that were identified, misleading information may be the most difficult to immediately identify because it can occur in a variety of ways. Misleading information occurs not only when the formal information available is incorrect or incomplete, but also when available natural information misleads the driver. An example of misleading information transmitted by signs is a location in which advance work zone warning signs are placed when construction has already been completed. An example of misleading natural information is a sight-restricting crest-vertical-curve in which trees or telephone poles beyond the crest appear to indicate that the road is straight when, in fact, a horizontal curve exists immediately after the crest.

An excellent example of a situation with misleading information that was observed in the field was a narrow bridge that had a centerline painted through it. The centerline provided an associative cue from past experience that the bridge was sufficiently wide for two vehicles to safely pass each other. However, the width from bridge rail to bridge rail was only 15 ft. This situation was further compounded because the reduced width could not be easily perceived by the driver because the bridge was situated on a slight reverse curve. The distance between Manual of Uniform Traffic Control Devices Type 3 object markers could lead an approaching driver to believe that the bridge is much wider than it actually is. If a driver does not perceive the reduced width and an oncoming vehicle attempts to cross the bridge, the driver might have to brake sharply before the bridge or, even worse, crash into the bridge abutment or the oncoming vehicle.

Horizontal curves were the most prevalent physical feature (over 12,000) in the nearly 5,000 mi of rural two-lane roads that were sampled. The most information is needed on horizontal curves, particularly isolated sharper curves. Narrow, width-restricted bridges, which represent only about 700 of all types in the data base, are a distant second. Stop- or signal-controlled intersections, which total slightly more than 300, are next in frequency of occurrence. Railroad crossings occurred so infrequently in the sample that they do not merit separate attention. Each of these three geometric features is discussed in terms of the magnitude of potential information deficiencies that was estimated from the sample.

Information Deficiencies Related to Curves

The accident data for curves indicate that both degree of curvature and frequency of curves influence accident frequency and severity. This provided the focus of the analysis of curve-related information deficiencies.

The total sample of curves recorded in the data base was distributed by curve category and advance tangent length. Three curve categories were defined: gentle ($\leq 6°$); moderate (6° to 10°); and sharp ($>10°$). A 6° curve roughly corresponds with a maximum design speed of about 55 mph, whereas a 10° curve corresponds with a design speed of about 45 mph. Two different advance tangent categories also were defined: nonisolated ($<1{,}000$ ft) and isolated ($\geq 1{,}000$ ft). The isolated category indicates that drivers approaching a curve are essentially free of any speed-reducing influences of immediately preceding curves.

Approximately 26 percent of all the curves in the sample were characterized as isolated. An isolated curve is of the greatest concern from the standpoint of curve-related information deficiencies. The long advance tangent of an isolated curve encourages travel at or above the roadway speed limit. The sharper the curve, the more a speed differential between the tangent and the curve is likely to occur and the more necessary it becomes to provide some form of advance warning information.

Information deficiencies are only presented for isolated curves with moderate and sharp horizontal alignments. Non-isolated curves, such as those with advance tangents of less than 1,000 ft, are considered less critical in terms of information deficiency problems. This is because a driver is more likely to be cautious or drive more slowly when entering a curve if it has been closely preceded by one or more curves instead of a long tangent section.

A total of 1,386 curves in the data base met the joint criteria of being isolated and sharp; in other words, they had a degree of curvature of at least 6°. This represents slightly more than 11 percent of the total curve data base. Information on the number of isolated sharp curves in the data base and whether or not they had advance curve warning signs can be found in Table 5. Approximately 43 percent of all such curves have an advance warning sign of some type. As might be expected, the percentage of isolated curves with advance warning signs increased with an increase in the degree of curvature, which demonstrated that the need to warn drivers under these conditions was clearly recognized.

Recognition of the potential difficulty of driving on horizontal

TABLE 5 DISTRIBUTION OF MODERATE TO SHARP ISOLATED CURVES BY PRESENCE OR ABSENCE OF ADVANCE CURVE WARNING SIGN

	Degree of Curve		
	6°-10°	>10°	Total
Advance Warning Provided			
Number	302	298	600
Percent	(40.5)	(46.6)	(43.3)
No Advance Warning Provided			
Number	444	342	786
Percent	(59.5)	(53.4)	(56.7)
Total	746	640	1,386

curves on two-lane rural highways was evidenced by the extent of information that was provided. Two-thirds of the sharp curves that had advance curve warning information also had advisory speed information.

All of the isolated moderate or sharp curves that had no form of advance warning were considered to be locations with potential information deficiencies. According to that criterion, 786 curves in the data base could be considered deficient. Although this number represents only about 6 percent of all curves identified in the data base, it represents more than half of all isolated moderate and sharp curves.

One cannot conclude from this that more than half of all moderate and sharp isolated curves are information-deficient. Whether or not a curve with no advance warning can be considered potentially information-deficient depends on the approach speed on the tangent and the speed that can be safely maintained around the curve. Tangent approach speeds available in the data base were examined for each of the 786 unsigned, isolated, moderate to sharp curves.

There are 193 curves in the data base for which the relationship between approach speed and degree of curvature indicates a potential information deficiency. Less readily definable are another 169 moderate (6 to 10°) curves with approach speeds of 45 to 54 mph. Some of these curves may also have approach speed and degree of curvature relationships that could create a potential information deficiency. Because of the manner in which speeds and curve degree were distributed in the data base, it was assumed that 90 percent of these 169 curves did not require specific curve-related information. Therefore, 210 of the 786 isolated unsigned curves in the data base were assumed to be information-deficient. This represents slightly more than one out of every four of the unsigned, isolated, moderate to sharp curves in the total field data sample. This translates to about one potentially information-deficient curve for every 23 mi of paved roadway in the data sample.

Information Deficiencies Related to Narrow Bridges

For the purposes of this study, any constriction that included a vertical structure was considered to be a narrow bridge. Although most of the structures so identified were at least 20 ft in length (the standard definition of a bridge), some could be more accurately identified as culverts. In either case, however, a narrowing of cross-section and a vertical structure with which the driver could collide were present. Regardless of the terminology used, similar safety problems are likely to benefit from similar informational treatments.

According to this definition of a narrow bridge, the number of such constrictions was much greater than the 60,000 reported by Ivey et al. (*5*). Of the 701 narrow bridges and constrictions found in the 5,000-mi sample of roadways, it was estimated that one such site existed every 7 mi. When only the estimated 1.6 million mi of paved rural two-lane roadway are considered, the total number of narrow bridges and constrictions is estimated to be greater than 200,000, which is over three times that reported by Ivey et al.

Less accident information exists for bridge and culvert sites than for curves, intersections, and other road situations. However, based on a review, Smith et al. estimated that approximately 20,000 reported collisions occur annually at such constrictions (*1*). Study results from Kihlberg and Tharp suggest that the presence of a narrow bridge may increase the probability of an accident by up to 2.5 to 3 times the base rate on a vehicle exposure basis (*6*).

Although limited data exist regarding the severity of accidents at narrow bridges, Perchonok indicated that more than 50 percent of the accidents at constrictions involved fatalities (*7*). This high percentage of fatalities merits, at the very least, adequate informational treatments at narrow bridges regardless of traffic volume. The use of hazard panels, advance warning (when needed as a result of a sight distance restriction), and advisory speed signs formed the focus of the deficiency analysis.

Bridges were defined as being narrow if a shoulder width decrease, shoulder loss, or pavement width decrease was observed. In terms of driver safety, locations that were characterized by a pavement decrease were considered to be the most serious. Total shoulder loss, although generally less hazardous than an actual pavement decrease, can indicate potential problems, particularly when the pavement width is minimal, such as 20 ft or less. The shoulder width decrease category represents the least potentially serious of the three narrow bridge groups. It is included, however, because any reduction in the total width of pavement and shoulders could present a problem, particularly when sight distance is restricted and the necessary advance or at-bridge warning information is not available.

Nearly three-quarters of the 701 narrow bridges in the data sample were identified as being sight-restricted; for example, a horizontal or vertical curve existed within a specified (speed-dependent) distance in advance of the narrow bridge. Approximately 85 percent of the sight-restricted bridges had no advance warning. Only about one in four locations in which an advance warning existed had an associated speed advisory. This represents less than 4 percent of the total sample of sight-restricted narrow bridges, which indicates that this form of supplemental information was perceived as unimportant, at least in terms of a width-constrained situation.

The fact that over 85 percent of the sight-restricted narrow bridges had no advance warning signs is not meant to suggest that the overwhelming majority of narrow bridges on the two-lane rural road system have information deficiencies. It would be equally erroneous, however, to assume that all of these locations are free of any information deficiencies. How then can one reasonably estimate the magnitude of the potential information deficiency problem? It is important to recognize that ADT was low on a large proportion of the rural roads surveyed. This significantly reduces the probability that opposing vehicles will come into conflict at the narrow bridge, and reduces the need for advance warning signing.

It is necessary, however, to identify to the oncoming driver the existence and location of any lateral obstruction created by the narrow bridge, such as raised curbs or a bridge rail. This can be accomplished through the use of object markers. Nearly 80 percent of the sight-restricted bridges had some form of object marker.

The sight-restricted narrow bridge sample is broken down in Table 6 by type of width restriction, presence or absence of some form of object marker, and presence or absence of some form of advance warning signing.

Because the two-lane rural road system tends to be composed of roads with comparatively narrow travelways, a total loss of shoulder and certainly an actual travelway decrease pose potential problems for drivers. It is important to note that although 49 percent of the shoulder-loss type of narrow bridges were located on roads with travelways of 20 ft or less (near the

TABLE 6 DISTRIBUTION OF SIGHT-RESTRICTED NARROW BRIDGES BY TYPE OF WIDTH RESTRICTION, PRESENCE/ABSENCE OF OBJECT MARKER, AND PRESENCE/ABSENCE OF ADVANCE WARNING SIGN

	SHOULDER DECREASE		SHOULDER LOSS		PAVEMENT DECREASE	
	OBJECT MARKER		OBJECT MARKER		OBJECT MARKER	
ADVANCE SIGNING	YES	NO	YES	NO	YES	NO
YES	7	1	20	1	29	16
NO	132	45	192	37	25	12
TOTALS BY COLUMN	139	46	212	38	54	28
TOTALS BY RESTRICTION N (%)	185 (35.7)		250 (48.4)		82 (15.9)	

sample average), 75 percent of all the pavement-decrease type of narrow bridges were located on roads in which the pavement widths were 20 ft or less. Therefore, an already narrow roadway condition is exacerbated at the narrow bridge.

It is indicated in Table 6 that almost 16 percent of the sight-restricted narrow bridges are of the pavement-decrease type. Nearly 15 percent of these were observed to have neither advanced warning nor any form of at-site object marker. The total absence of information on a narrow roadway with a further travelway decrease is a reason for concern regardless of whether or not a sight restriction occurs. When a sight restriction does exist, the potential for serious safety problems also exists.

Although the absolute number of such worst-case problem locations is small (12 in 4,757 mi of paved roads), an extrapolation to the entire two-lane rural road system suggests the possible existence of over 4,000 such locations. Although the total absence of warning information is potentially the most serious problem, it is not the only one associated with narrow bridges. Besides the 12 pavement-decrease type of narrow bridges that have neither advance warnings nor object markers, another 16 pavement-decrease sites exist with advance warning signs that have no at-bridge object markers. Although the lack of object markers may not be a significant problem in daylight hours, it is a matter of great potential concern at night, when drivers get little advance visual information about lateral clearance at the narrow bridge. The 37 instances of sight-restricted bridges with complete shoulder loss and with no advance warning or object marking can similarly pose additional safety hazards to drivers.

In all, 18 percent of the sight-restricted narrow bridges in the data sample, regardless of degree of constriction, were information-deficient in that both signs and object markers were missing. Potential safety problems related to the absence of object marking on narrow bridges are not limited to sight-restricted locations. The absence of object marking on narrow bridges in which a pavement decrease or total shoulder loss exists could pose safety problems, particularly at night.

State and local agencies may be leaving themselves open for tort claims in the event of accidents, because the courts may well hold that a reasonably safe driving environment was not provided. It appears that some type of object markers should be installed on all narrow bridges to help oncoming drivers position themselves in the lane to avoid bridge-related obstructions. Use of an advance warning sign appears to be more directly associated with higher ADTs, in cases in which the probability of meeting an oncoming driver on or adjacent to the narrow bridge increases significantly, or in cases in which a sight restriction is close enough to the bridge that use of object markers alone is insufficient.

Information Deficiencies Related to Stop - or Signal-Controlled Intersections

The multiple-vehicle intersection accident in which a driver fails to stop is of primary concern when one considers information deficiencies. According to Smith et al., angle accidents are the predominant multiple-vehicle type; they constitute 60 percent of all fatal, two-lane rural intersection accidents and 80 percent of all such multiple-vehicle accidents (*1*). These accidents are essentially caused by a driver on the controlled approach proceeding into the crossing roadway without appropriate clearance. When the failure to stop primarily results from inadequate warning of a sight-restricted approach, as opposed to a willful act, the intersection is amenable to information-related correction. The focus of this intersection-related information deficiency analysis was on sight-restricted approaches to intersections that are controlled by stop signs, where 50 percent of the rural intersection accidents are reported to occur (*1*). The analysis also considered whether or not advance warning was provided in these situations.

The total data base contained approximately 5,600 intersections all of which were on roadway sections outside any type of urban area, such as a village, town, or city. Only 321 stop-controlled intersections and 64 signal-controlled intersections were identified. This represents about 7 percent of the total number of intersections traversed. Slightly more than 25 percent of these 385 intersections were sight-restricted; in other words, they did not have an adequate stopping sight distance. Although these sight-restricted intersections represent less than 2 percent of all intersections observed, they merit attention because the potential for accidents is great in these situations. If a sight restriction causes a driver to enter an intersection improperly, any right-angle accident that results could be extremely serious.

Fifty-seven percent of the sight-restricted, stop- and signal-controlled intersections had no advance warning signs. The sight restrictions were about evenly split between crest vertical curves and sharp ($>10°$) horizontal curves.

In nearly 60 percent of the cases in which stop or signal control was deemed necessary and a sight restriction occurred, no advance warning sign was provided. The potential severity of accidents at such problem locations indicates that jurisdictions need to carefully examine their rural stop- and signal-controlled intersections, however few in number they may be, to ensure that adequate advance warning is being provided and adequately maintained. Omission of this inexpensive but necessary corrective action could result in serious accidents, and tort liability action could be initiated against the responsible governmental agency.

NATIONAL IMPLICATIONS OF THE FINDINGS

A variety of potential information deficiencies was identified in the nearly 5,000 mi of two-lane rural roadway that were sampled. Extrapolation of the sample results to the 1.6-million-mile paved portion of the two-lane rural roads in the United States yields an order of magnitude estimate of the total potential information deficiency problems. The estimated average frequency of each of the deficiencies is shown as follows.

Feature or Deficiency	*Estimated Average Frequency*
Isolated, horizontal, moderate to sharp curves with no advance warning	One every 30 mi
Sight-restricted narrow bridges with no object markers or advance warning	One every 51 mi
Sight-restricted, stop- and signal-controlled intersections with no advance warning sign	One every 79 mi

Because the 5,000-mi data sample emphasized rolling and mountainous terrain, it almost certainly contains more curves than would be the case if a more representative sample had been obtained. A comparison of the total rural mileage by terrain (31.5 percent flat, 58.9 percent rolling, and 9.6 percent mountainous) with the data sample collected as part of this study (9.8 percent flat, 66.5 percent rolling, and 23.7 percent mountainous), and the average curves/mi by terrain type obtained, suggests that the estimated overall frequency of potential horizontal curve problems might be more on the order of 1 every 30 mi, as was shown earlier, as opposed to the rate of 1 every 23 mi that was reported in the field data.

If the three estimates are grouped, one might expect about 66 potential information deficiencies, irrespective of type, every 1,000 mi of paved roadway. Use of this estimate and an assumed 1.6 million miles of surfaced, two-lane rural roads indicates that over 100,000 potential information deficiencies may exist. Horizontal curves account for approximately 53,000 of the locations; sight-restricted narrow bridges account for another 31,000; and sight-restricted, stop- and signal-controlled intersections account for the remaining 20,000 locations.

Although the potential problem nationwide is great, information deficiencies exist mostly on systems that are under the jurisdiction of a myriad of local agencies, each of which may have comparatively few specific problems. This situation is not amenable to direct federal action. It is a problem that must be addressed indirectly through technology transfer to sensitize responsible local agencies and governments to the existence of the problem, provide simple, effective techniques to identify information-deficient locations, and suggest simple, inexpensive solutions. An example of such a procedure is briefly described in the following paragraphs.

A simple procedure that can be used by state and local agencies to identify information deficiencies was developed as part of this study (*8*). It essentially consists of a windshield survey that requires no equipment other than a tape recorder. The procedure is largely based on the concept of identifying driver expectancy violations and uses a commentary driving process to identify potential problem sites. It also includes situational problem checklists that can be used in a more detailed analysis of the identified potential problem sites. The checklists aid in the development and specification of the most appropriate countermeasures. An example of one of the checklists is shown in Figure 1. The procedure is described in a study by Hostetter et al. (*8*).

Although a relatively simple survey technique is employed, its use in a programmatic manner can materially simplify problem identification. As such, it should enable local jurisdictions to identify and correct high-risk locations and thus reduce the likelihood of being sued. Such a program may also be of value in cases in which tort claims are instituted. In a study that was cited earlier, Oliver provided an example of a case in which the programmatic use of a similar type of windshield survey resulted in the reversal of a decision in a case that a state agency had initially lost in a lower court (*2*).

REFERENCES

1. S. A. Smith, J. Purdy, H. W. McGee, Sr., D. W. Harwood, A. D. St. John, and J. C. Glennon. *Identification, Quantification, and Structuring of Two-Lane Rural Highway Safety Problems and Solutions.* Reports FHWA/RD-83/022 and 83/021. FHWA, U.S. Department of Transportation, June 1983.

INFORMATION DEFICIENCY EVALUATION
NARROW/ONE-LANE BRIDGES

PART I

LOCATION: ______________________ MILES FROM
ROUTE ID ______________________ REFERENCE POINT ______________________
APPROACH DIRECTION N S E W (circle)

DATE __________ TIME __________ AM PM INSPECTORS ______________________
APPROACH SPEED DURING SURVEY __________ MPH
SPEED LIMIT: a) Posted __________ MPH or b) Estimated __________ MPH (one entry)
DECISION SIGHT DISTANCE (circle one set)

SPEED (max of above)	30	35	40	45	50	55	60
DSD (feet)	230	290	355	430	510	590	680

PART II

(1) Is the bridge clearly visible from decision sight distance?
______ Yes ______ No

If no, go to (3)

(2) From decision sight distance, can you perceive the reduced roadway width at the bridge?
______ Yes ______ No

If yes, go to (5)

(3) Is there a NARROW BRIDGE or ONE-LANE BRIDGE warning sign present?
______ Yes ______ No

If no, go to (5)

(4a) Is the warning sign accurate? (i.e., the ONE-LANE BRIDGE is applicable to bridges with usable roadway widths less than 16 ft or 18 ft if a significant number of wide vehicles cross the bridge or if the approach alignment is winding)
______ Yes ______ No

(4b) Is the warning sign clearly visible on the approach?
______ Yes ______ No

(4c) Is the warning sign properly designed according to the specifications in the MUTCD?
______ Yes ______ No

(4d) Is the warning sign properly located? (i.e., neither too far upstream such that you would "forget" it or too close to the bridge such that you still would not have sufficient time to select a safe speed and decelerate to it) (Check Table of Placement Distance for Advance Warning Signs in MUTCD)
______ Yes ______ No

(4e) Is there a supplemental speed advisory plate attached to the warning sign?
______ Yes ______ No

(5) Do other informational sources (i.e., hazard panels, guardrails, edgelines, roadway edges, bridge abutments, etc.) provide information suggesting 1) that the situation ahead is **not** a narrow/one-lane bridge, 2) that usable roadway width across the bridge is wider than it actually is, or 3) that a narrow/one-lane bridge is located further downstream?
______ Yes ______ No

If yes, then identify those sources and describe how they provide confusing, conflicting or misleading information:
____
____
____
____

(6) Is the sight distance to opposing vehicles sufficient for you to make a safe decision on whether you can safely cross the bridge and to safely execute the selected maneuver?
______ Yes ______ No

(7) Is the presently available information sufficient for you to recognize the narrow/one-lane bridge at a distance such that you can decelerate safely to a safe and comfortable crossing speed?
______ Yes ______ No

(8) Would the presently available information be sufficient for you to recognize that a narrow/one-lane bridge is downstream:
- during nighttime conditions? ______ Yes ______ No
- when the roadside vegetation is at its densest growth? ______ Yes ______ No

FIGURE 1 Sample problem location checklist.

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4. R. S. Hostetter, K. W. Crowley, H. W. McGee, Sr., and W. E. Hughes. *Driver Needs on Two-Lane Rural Highways*. Vol. I—Technical Report. FHWA, U.S. Department of Transportation, April 1985.
5. D. L. Ivey, R. M. Olson, N. E. Walton, G. D. Weaver, and L. W. Furr. *NCHRP Report 203: Safety at Narrow Bridge Sites*. TRB, National Research Council, Washington, D.C., June 1979.
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8. R. S. Hostetter, K. W. Crowley, H. W. McGee, Sr., and W. E. Hughes. *Driver Needs on Two-Lane Rural Highways*. Vol. II—Simplified Location of Information Deficiencies. FHWA, U.S. Department of Transportation, April 1985.

Development of Geometric Design Standards for Low-Volume Roads in Canada

D. Bews, G. Smith, and G. Tencha

Approximately 76 percent of the road system in Canada has been classified as rural local roads that carry low traffic volumes. In the past, a uniform set of geometric design standards for roads was not available in Canada. The lack of national standards for low-volume roads resulted in agencies developing their own. These standards may not have been compatible with the required function of the road and also had the effect of nonuniform treatment of roads between road jurisdictions. Transportation planners and designers were faced with the problem of reducing national standards, which were originally developed for a higher classification of roads, to meet economic constraints. It became evident that there was a need to find ways to construct these roads more economically and to maintain their safety and effectiveness. As a result, the Roads and Transportation Association of Canada initiated a project to develop a national set of geometric design standards for low-volume roads. A separate chapter for low-volume roads is now included in the *Manual of Geometric Design Standards for Canadian Roads*. A discussion is presented of the approach used to develop the geometric design standards for low-volume roads, the results and findings, and future research that should be performed to further refine the standards.

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The Canadian Road Network consists of over 800 000 km of roads that serve a population of approximately 25.6 million. Approximately 610 000 km, or 76 percent, of these roads can be classified as rural local roads that carry low traffic volumes. In addition, 490 000 km of these rural local roads have either earth or gravel surfaces.

In the past, geometric design standards for these types of roads were not specifically addressed in Canada. Both road planners and designers were faced with either using national standards that were developed for a higher classification of roads, which resulted in roads being built at a great cost that was unrelated to their function, or reducing these higher classification standards to meet economic constraints, usually without a logical basis for doing so.

In many instances, the lack of national design standards for these roads and the pressure to reduce costs resulted in agencies developing their own design standards or, in certain instances, in constructing roads without regard for any design standards. This has resulted in the creation of standards that are not compatible with the road function, nonuniformity of standards between jurisdictions, arbitrary selection of standards, and in many cases an unsafe road.