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# DRIVER NEEDS ON TWO-LANE RURAL HIGHWAYS

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Final Report

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## EXECUTIVE SUMMARY

### Project Scope and Approach

Two lane rural highways compromise the bulk of the nations 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 ADT's of less than 400 vehicles per day.

A recently completed FHWA study by Smith, et al.(1983) indicates 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 problems responsible for many of these accidents. The study also indicated that the probability of an accident on two-lane rural highways is greatest at horizontal curves, bridges, and intersections. Frequency and severity of horizontal curve accidents increases both with increasing degree of curvature and with driver unfamiliarity with the roadway. Bridges exhibit approximately twice the accident rate as that of the overall two-lane rural roadway system. Intersections, the third roadway location identified as having a higher than expected probability of accident experience, are estimated to be involved in nearly one in five of all two-lane rural highway accidents. The FHWA study also found that low-cost safety improvements such as signing and delineation offer the greatest potential for cost-effective solutions on the two-lane rural road system.

This study is designed to complement the efforts of the previously cited FHWA study. It had as its objectives: to identify driver information needs on two-lane rural highways; to identify potential driver problems that can be alleviated via low cost information treatment(s); and to develop an inexpensive procedure for identifying information deficiencies that can be used by State and county engineers, road supervisors, etc.

Driver needs were initially addressed by performing a series of task analyses. This analytic method resulted in the identification of the

actions and decisions required of the driver and provided the basis for identification of information needs. To ensure that all of the driver decisions had been identified and to satisfy the other requirements of the study an extensive field effort was designed. The purpose of the field efforts were: to identify driver decisions missed in the analytic effort; to provide a basis for estimating the existing types and magnitude of information deficiencies; to provide a detailed sample of the physical and informational characteristics of the two-lane rural roadway system.

The field work employed a vehicle instrumented with a microcomputer system interfaced with sensors that recorded distance, steering wheel position, accelerator position, and brake pressure. The system automatically sampled and stored the sensor data and allowed for manual input of codes detailing roadway and information system characteristics.

Using this system, a staff of senior project personnel sampled nearly 5,000 miles of the two-lane rural road system in 15 States throughout the country. Useful data for 553 sections, with an average section length of approximately 9 miles, were obtained. These data were the basis for estimating information deficiencies on the nation's two-lane rural system and also provided descriptive data regarding roadway and informational characteristics.

### Findings

The primary findings resulted from the analysis of information deficiencies identified in the 5,000 mile sample. The focus of the information deficiency analysis was on horizontal curves, narrow bridges, and stop/signal controlled intersections; the three primary situations on the rural two-lane system associated with higher accident rates.

Horizontal curves accounted for about half of the identified information deficiencies. The curve information deficiency analysis was based on curves

greater than 6 degrees that were preceded by a tangent section of at least 1,000 feet, i.e., moderate to sharp isolated curves. Approximately 11 percent of the 12,000 plus horizontal curves in the data base met these conditions. A potential information deficiency was considered to exist if a driver was not given advance warning of one of these curves. Nearly 57 percent of the moderate to sharp isolated curves had no advance warning signs. Analyzing these curves in terms of the difference between tangent approach speed and curve speed (assuming average superelevation and friction values) it was found that nearly 27 percent represented information deficiencies i.e. almost certainly required a curve warning sign. This averages to one information deficient curve for every 30 miles of paved roadway. Applying this value to the approximately 1.6 million miles of paved two-lane rural roads in the United States, the total number of information deficient curves is estimated to be on the order of 53,000.

The next most frequent type of information deficiency was associated with narrow bridges. Of the approximately 700 narrow bridges identified 74 percent were sight restricted i.e. were preceded by a vertical or horizontal curve within a specified (speed-dependent) distance in advance of the bridge. Nearly 86 percent of the sight restricted narrow bridges had no advance warning. This does not imply that all such bridges constitute an information deficiency. Existing traffic volumes may be sufficiently low that advance warning is not considered necessary if hazard panels are used to mark the bridge. However, until more is known about the causes of narrow bridge accidents, the combination of sight restriction and lack of advance warning is a condition that must be considered a potential contributor at least for multiple vehicle accidents. Considering the fact that narrow bridges appear to have a greater influence on single vehicle accidents (Smith et al. 1983) an information deficiency that is more likely to be associated with accidents is one related to the presence or absence of hazard panels which show the extent of the constriction.

Anytime the on-bridge roadway cross section is reduced relative to the approach roadway cross section, i.e., shoulder decrease or loss or pavement width reduction, there is likely to be an increased danger associated with

not providing at-bridge hazard panels. Approximately 18 percent of the restricted sight distance narrow bridges had neither advance warning nor at-bridge hazard panels. This translates into an estimated 30,000 narrow bridge related problems on the nation's paved two-lane rural road system.

While the total number of stop/signal controlled problem intersections encountered was not great, the potential severity of accidents at intersections is significant for those intersections where the driver is more likely to fail to stop on the controlled approach. Approximately 27 percent of the stop/signal controlled intersections were found to have some sort of sight restriction i.e. had approach configurations that did not provide the driver with safe stopping distance in advance of the intersection after the control device was observed. Of these sight-restricted intersections, 57 percent had no advance warning of the control. There are estimated to be a total of about 20,000 stop/signal controlled intersections that are sight restricted and have no advance warning of the control.

Overall there were approximately 66 deficiencies per 1,000 miles in the base data. Extrapolating to the 1.6 million miles of paved rural two-lane roadway there are estimated to be about 106,000 potential information deficiencies associated with horizontal curves, narrow bridges and stop/signal controlled intersections.

### Products

A major product of the study is a simple field-based procedure to aid State and local agencies in identifying information deficiencies. The need for such a procedure is based on the fact that the degree of hazard associated with a given type of deficiency was found to be highly dependent upon the context within which it occurs. Because of this, decisions as to whether a deficiency is severe enough that it should be alleviated must be made at a local level on the basis of a field evaluation and consideration of factors such as traffic volume, percentage of unfamiliar drivers, accidents, etc. The fact that correcting information deficiencies

has been judged to be the most cost-effective means of reducing accidents on the two-lane rural system suggests that systematizing procedures for local identification of informational problems would make a significant contribution to enhancing overall safety on the rural two-lane system.

The first step in aiding local agencies in the identification of and solution to information problems has been the procedure and the associated information deficiency checklists (reference, volume II- Simplified Location of Information Deficiencies [SLIDE] - a Procedure) developed as part of the current study. The procedure was presented and demonstrated at two regional workshops and was deemed useful by potential users. Local agencies were generally more enthusiastic than State representatives. State representatives appeared to be reflecting their agencies greater capability to use accident record systems to identify hazardous locations.

A second major product is an extensive catalog of rural two-lane roadway and associated information characteristics with an emphasis on the lower volume roads; a portion of the overall system for which relatively little roadway characteristics data has existed until now. The roadway characteristics include: pavement width, shoulder width, type and condition, curves per mile (and approximate degree of curvature), intersections per mile, narrow bridges per mile, and sight restrictions (horizontal and vertical curves). The associated informational characteristics include striping type and condition, warning signs, regulatory signs, along with the relationship of the signs and markings to geometric features.

A third product is a series of highly detailed task analyses for each situation of interest i.e. curves, narrow bridges, intersections, etc. These task analyses include all necessary driver actions and decisions and a specification of the alternative sources of information. These task analyses, can be used to develop special purpose information checklists, to identify alternative driver performance measures for various situations, etc.

## Recommendations

Before the SLIDE procedure can be offered to local agencies some study effort should be devoted to determining the type of training that is most cost effective and the minimum time required for various types of training. This could be handled in much the same fashion as the demonstration programs for Positive Guidance.

Because the bulk of the problems are in local jurisdictions the use of existing technology transfer programs aimed at such jurisdictions, e.g., the Rural Technical Assistance Program (RTAP), would appear to be the most likely way to introduce the SLIDE procedure to the field.

The second major recommendation involves a longer range research effort. Prior to this study there was relatively little data available which describes the roadway or informational characteristics of the two-lane rural system (particularly the lower design end of the system that comprises a great deal of the total mileage). There is also relatively little accident information available for roadways in this class. This study has produced an accurate 5,000-mile data base of roadway and information characteristics. It would appear illogical to not use this data base to broaden our knowledge of the two-lane rural system. For example, the data base could be used to aid in selecting a number of sites and sections for long-term collection of accident data that can be analytically tied to known informational and roadway characteristics.

Such information would, in time, provide a sound safety related basis for assignment of priorities to programs for upgrading both the physical and informational components of the two-lane rural roadway system. Accurate correlational data between accidents and roadway and informational characteristics could aid in identifying where to direct efforts in research and/or implementation to obtain the greatest possible reduction in the predicted number of accidents that might otherwise occur.

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## I. INTRODUCTION AND TECHNICAL APPROACH

Two lane rural highways compromise the bulk of the nations 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. Two lane rural highways exist primarily to provide land service, i.e., access to abutting land uses. This is reflected by the low traffic volumes observed. It is estimated that about 38 percent of all two-lane rural highways have average daily traffic (ADT) volumes of less than 50 vehicles per day. Only about 20 percent of the total two-lane rural highways have ADT's of more than 400 vehicles per day. These higher volume roads are for the most part arterials and major collectors; routes whose function is primarily to serve traffic moving through an area.

A recently completed FHWA study by Smith, et al.(1983) indicates 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 problems responsible for many of these accidents. The study also indicated that the probability of an accident on two-lane rural highways is greatest at horizontal curves, bridges, and intersections. The rate of horizontal curve accidents was found to increase both with increasing degree of curvature and with driver unfamiliarity with the roadway. As the number of curves per mile goes up, accident rate goes down. Based on the findings it can be inferred that the combination of isolated curves and unfamiliar drivers may present particular safety problems. Bridges exhibit approximately twice the accident rate as that of the overall two-lane rural roadway system. It appears that any constrictions on the highway, such as a bridge where shoulder width may be reduced or eliminated or where pavement width may even be reduced, are potentially much more hazardous locations. Intersections, the third roadway location identified as having a higher than expected probability of accident experience, are estimated to be involved in nearly one in five of all two-lane rural highway accidents. The implications of the higher intersection related accident rate are not as apparent as in the case with horizontal curves or bridges. Nevertheless, the very magnitude of the accident experience dictates that attention be given to

identifying solutions to two-lane rural road intersection problems as well.

A major finding of the FHWA study was that low-cost safety improvements such as signing and delineation offer the greatest potential for cost-effective solutions on the two-lane rural road system. Low cost improvements of the type identified generally represent responses to missing, inadequate, or confusing driver information presentations. Providing safe roadways requires that drivers be given needed information in the proper format at the appropriate point(s) along the roadway. The fundamental questions that must be answered then are what is needed and where is it needed? That, in essence, was the charge given to the Institute For Research (IFR) when it was awarded contract DTFH61-81-C-00096, "Driver Needs on Two-Lane Rural Highways." This study, performed under the aegis of FCP 1M, "Operational Safety Improvements for Two-Lane Rural Highways," is designed to complement the efforts of the previously cited FHWA study, had three specific objectives: they were:

- o To identify driver information needs on two-lane rural highways.
- o To identify potential driver problems that can be alleviated via informational treatment(s).
- o To develop an inexpensive procedure that can be used by State and county engineers, road supervisors, etc., to identify information deficiencies.

Driver information needs were addressed initially via task analysis, a procedure which involves, for each of the geometric/operational situations of interest, consideration of at least the following questions:

- o What action(s) must the driver take?
- o What decisions must the driver make in order to choose an appropriate action?

- o What information does the driver need to make an appropriate decision?

The determination of information needs considers first, the required information or cues available from the roadway and environment; and next, the circumstances under which supplemental signs and markings are beneficial (i.e., where natural cues are lacking and/or provide conflicting information).

The task-analytic approach to the determination of information needs provided a logical framework and point of departure for a deficiency analysis. Although a necessary effort, task analysis alone was not considered sufficient to adequately identify driver information needs. To ensure that all of the driver decisions had been identified, this project also entailed an extensive field effort designed to satisfy the following study purposes:

- o Identify driver decisions missed in the analytic effort.
- o Provide a basis for estimating the types and magnitude of information deficiencies.
- o Provide a detailed sample of the roadway characteristics of the two-lane rural roadway system.

The research prospectus associated with this effort stated that the purpose of the study was, in the broadest sense, to "...examine how drivers utilize two-lane rural highways and traffic control systems, signs, markings, and devices used thereon..." and to "...identify safety problems from a human factors perspective." However, there was the realization on the part of FHWA that relatively little was known about existing roadway characteristics of a large portion of the two-lane rural system, particularly that extensive segment of the system under local control. Therefore, a prime objective of the study was to determine the characteristics of two-lane roadways and their associated driver information systems. In as much as the two-lane rural roadway system has evolved over an extended period of

time rather than being designed to any explicit set of standards as is the case with the several Federal Aid Systems, one can expect a great deal of variety in physical and informational characteristics. These differences are magnified because of the differential upgrading/improvement resulting from the fact that while some of these two-lane rural roads come under State control, much of the system is the responsibility of local jurisdictions. This suggested that a substantial sample of roadway mileage would be required to provide adequate descriptive data on existing roadway characteristics and information systems.

The other principal issue in the study was the identification of information deficiencies; hence, a critical task that had to be faced in planning was one of operationally defining an information deficiency. Ideally, a deficiency would have been defined in analytic terms followed by empirical verification (by showing that drivers, in fact, had problems with those information systems judged deficient and not with those judged adequate). For a number of reasons this approach was not feasible. The large number of specific situations that were of concern, the range of roadway design configurations, and the variety of ways in which information needs might be met for those situations made it economically impossible to use subject drivers to identify deficiencies. Further, the low volumes of most of the two-lane rural system, along with the fact that a large proportion of the drivers were likely to be familiar local drivers who did not need supplemental information, argued against observing naturally occurring traffic. Finally, the literature review provided numerous examples of studies that involved comparisons of signs and markings that were analytically judged to be different but where no differences in actual driver response was shown. All of these factors argued economically and/or technically against large scale use of test subject drivers or naturalistic observation for the primary data collection effort.

What was required, then, was a research approach which accommodated both the large scale sampling of roadway characteristics and information systems and also produced a credible means of identifying informational problems, both theoretically and from a driver performance standpoint. The approach

adopted was one which provided a group of senior human factors/traffic engineering personnel with in-depth exposure to the two-lane rural roadway system by utilizing them as part of the data collection team. Conceptually, this technique is not unlike that used by field anthropologists, i.e., to "live" in and experience a situation for a long enough period of time so that those things measured and observed can be adequately interpreted and will provide useful information. A basic assumption in choosing the approach was that for most of the low volume two-lane rural roadway system it is not possible to sign for the worst case, i.e., the unfamiliar and unalerted driver. Rather, attention should be given to satisfying the information needs of the unfamiliar but reasonably alerted driver. Owing to the large scale sample taken in the study, the staff drivers qualified as being unfamiliar with the specific roadways in the sample. Further, because the actual driving was conducted over 6- to 10-hour segments each day, a reasonable case could be made that the staff drivers were not likely to remain excessively alerted during the entire day's data collection. At the very least they were less alerted than a "test" subject driver would have been after driving a strange vehicle for an hour or so. Thus, the general approach, while somewhat atypical provided the best way of accommodating the diverse needs of the study.

The field effort employed a vehicle instrumented with a completely self-contained microcomputer system interfaced with sensors that recorded distance, steering wheel position, accelerator position, and brake pressure. Each second the buffer was polled and the status of the sensors determined. These time based measures were used subsequently to compute cumulative distance and speed. The system automatically sampled and stored the sensor data and allowed for manual input via a conventional keyboard. The manual entries, codes detailing roadway and information system characteristics, were stored, using a common time base, along with sensor data.

During the course of a session, the driver engaged in and recorded a driving "commentary" and identified sites at which information deficiencies caused uncertainty and/or driving problems. An analysis of the commentary tapes in conjunction with analytically derived decision data provided an

identification of the types of problems encountered. A simplified variation of the procedure used by the staff was also used as a basis for the development of a field procedure that could be used by State and local jurisdictions to identify potential informational problem sites, analyze the specific problem, and identify alternative informational solutions. This procedure entitled "Simplified Location of Information Deficiencies (SLIDE) is presented in Volume II.

A series of independent computer analyses of the signing and geometric characteristics that were encoded provided estimates of the nature and magnitude of a number of information deficiencies such as the percentage of sharp isolated curves with no warning; percentage of narrow bridges with sight distance restrictions and no warning; the percentage of stop-controlled intersections with inadequate warning, etc.

Using this system, a staff of drivers sampled approximately 5,000 miles of the two-lane rural road system in 15 different States spanning all sections of the country. In all, useful data on 553 sections, with an average section length of approximately 9 miles, were generated.

The analytic potential of the combined automatic and manual input data base is enormous indeed, and it is doubtful whether anyone would have sufficient resources to exploit all there is to exploit. Consider, for example, that the keyboard operator coded all roadway characteristics, including intersections, narrow bridges, etc., and all signs encountered. Consider also that the steering wheel position sensor provided sufficient data to identify the direction and severity of all but the gentlest of curves or short curves where manual code input overrode sensor information. Thus, for each section, a complete coordinated catalog of the horizontal curvature of the roadway segment and its information system was obtained (along with a record of vehicle performance) and is available for analysis.

A large body of information is presented in the chapters that follow. For the most part the technical discussions are based on analyses selected for their direct relevance to the study's goals.

## II. ROADWAY AND INFORMATIONAL CHARACTERISTICS

### A. THE SAMPLE

Roadway characteristics and driver information systems were sampled in 15 States; the field data sample encompassed 4946 miles and 553 roadway sections, each section averaging nearly 9 miles in length. The sampling plan was developed to ensure representation of a broad range of geographic and terrain effects. States were sampled in all but two of the 9 FHWA Field Regions in the Continental United States (reference table 1). Data collection driving loops were developed to ensure that a number of the states within which samples were obtained were among those known to have better than average accident record keeping capabilities. Within each state, a number of roadway samples were obtained. It is apparent from tables 1 and 2, which show the mileage and number of sections sampled in each State, and the terrain by pavement type respectively, that the sampling plan was biased toward rolling and mountainous terrain. The rationale for the sampling bias was that the intentionally underrepresented unpaved roadways account for a very low percentage of the vehicle miles travelled; and further, a large percentage of such travel is by familiar drivers.

Rolling and mountainous terrain was emphasized because of the relative difficulty of the guidance level driving task in these areas and the probability of encountering a greater variety of geometric situations likely to produce driving problems. The richer mix of problems exhibited in these areas broadens the research community's understanding of the nature and extent of driver information problems.

The majority of the field data were collected under clear weather conditions; however data collection was not terminated during the infrequent periods of rain encountered. With regard to night data collection, only a small portion of the effort was devoted to night collection. Early in the study night data were collected on 15 sections. These same sections were also driven and cataloged during daylight conditions. In all cases the night data on each section were collected before the daylight data. The

Table 1. Samples by State.

<u>FHWA</u> <u>Field Region</u>	<u>STATE</u>	<u>MILES</u>	<u># SECTIONS</u>	<u>MI/SEC</u>
1	NY	295.9	35	8.5
	VT	147.4	16	9.2
3	MD	175.8	24	7.3
	PA	466.8	64	7.3
	VA	304.8	39	7.8
	WV	29.0	3	9.7
4	NC	468.5	53	8.8
	TN	726.7	72	10.1
5	OH	235.0	34	6.9
6	OK	166.1	18	9.2
	TX	430.8	42	10.3
8	CO	665.9	72	9.3
	UT	229.8	24	9.6
10	ID	92.7	6	15.5
	WA	510.6	51	10.0

Table 2. Surface type by terrain type for total sample (number of sections/mileage).

TERRAIN	SURFACE TYPE						
	UNPAVED		PAVED		TOTALS		
	Section	Miles	Section	Miles	Section	Miles	Percent
Flat	3	28.6	54	467.6	57	496.3	(10%)
Rolling	15	103.6	361	3161.8	376	3265.3	(66%)
Mountainous	9	56.7	111	1127.7	120	1184.4	(24%)
TOTALS	27	188.9	526	4757.0	553	4945.9	(100%)

purpose of the day/night collection was to determine the extent to which night driving information requirements and/or problems differed from daylight. The initial data indicated an insufficient difference in day/night information requirements to justify the efforts involved in obtaining significant additional amounts of night data.

Finally, the sampling approach was intended to complement the study by Smith et al. (1983) by providing more detailed support in mountainous terrain. As shown in table 2, flat terrain represented 10 percent of the mileage sampled, with mountainous terrain representing 24 percent and rolling representing 66 percent. By contrast the percent of two-lane rural mileage for terrain type reported by Smith et al. was 31.5 percent flat, 9.6 percent mountainous, and 58.9 percent rolling.

Another general characteristic of the sample that deserves mention is its relationship to the roadway classification system developed by Smith et al. for identifying, quantifying, and structuring two-lane rural highway safety problems. This classification system was designed to divide the heterogeneous two-lane system into groupings which have common characteristics or problems. Since safety, i.e., accident rate, was the main focus of the study, the stratification was based upon the relationship between sectional characteristics and accident rate. The sectional characteristics that were recommended for the roadway classification system are: volume, lane width, curves/mile, and intersections/mile.

Table 3 shows the total paved roadway sample classified into three of the four categories identified above. Where Smith et al. used lane widths of < 10 feet, 10 feet, and > 10 feet, this study uses the functionally equivalent values for pavement (roadway) width of < 20 feet, 20 feet, and > 20 feet respectively. The other three classifications are essentially unchanged from those recommended. It should be noted that the Smith et al. system includes a third grouping for sections having more than five intersections per mile; however, most of the sections encompassed in this category would occur within towns. The more than 5 intersections/mile category was excluded from table 3 since signing and geometric characteristics of

towns were not included in the sample reported herein (i.e., coding was terminated while traveling through towns). Traffic volume data, the fourth category recommended for the classification, was obtained for approximately 80 percent of the sections and 78.8 percent of the mileage coded for this study. Table 4 relates those ADT estimates received from States to the variables in the recommended classification system. Table 5 shows the mileage and percent of the sample in each ADT category.

Table 3. 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			

Table 4. Sample breakdown for recommended classification.

ADT	ROAD 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	
		MI*	%**	MI	%	MI	%	MI	%	MI	%	MI	%	MI	%	MI	%
0-399	< 20	46	4.6	79	7.8	192	19.0	171	17.0	-	---	--	---	--	---	5	0.5
	20	53	6.2	114	11.3	50	5.0	14	1.4	-	---	--	---	2	0.2	-	---
	> 20	78	7.8	78	7.8	64	6.4	46	4.5	-	---	--	---	--	---	5	0.5
400-999	< 20	40	3.9	73	7.2	153	15.1	106	10.5	-	---	--	---	5	0.5	-	---
	20	9	0.9	73	7.2	56	5.5	39	3.8	-	---	2	0.2	--	---	-	---
	> 20	174	17.2	141	13.8	78	7.7	48	4.7	8	0.8	--	---	--	---	-	---
1000-1999	< 20	--	---	27	3.2	30	3.5	28	3.3	-	---	---	---	--	---	-	---
	20	30	3.5	79	9.2	9	1.1	27	3.2	-	---	--	---	8	0.9	-	---
	> 20	281	32.9	182	21.3	108	12.6	40	4.6	8	0.9	--	---	11	1.1	-	---
2000-4999	< 20	--	---	10	1.0	15	1.6	--	---	-	---	3	0.3	--	---	-	---
	20	7	0.7	50	5.4	9	0.9	--	---	-	---	--	---	--	---	-	---
	> 20	309	33.6	349	38.0	109	10.9	24	2.6	7	0.7	19	2.1	20	2.1	-	---
5000-9999	< 20	--	---	--	---	--	---	--	---	-	---	--	---	--	---	-	---
	20	7	5.2	--	---	--	---	--	---	-	---	--	---	--	---	-	---
	> 20	41	29.1	54	38.2	9	6.5	--	---	8	5.9	14	9.8	7	5.2	-	---
>10,000	< 20	--	---	--	---	--	---	--	---	-	---	--	---	--	---	-	---
	20	--	---	--	---	--	---	--	---	-	---	--	---	--	---	-	---
	> 20	--	---	25	100.0	--	---	--	---	-	---	--	---	--	---	-	---

\* Rounded

\*\* % within ADT Category

Table 5. Mileage by volume category.

<u>ADT</u>	<u>Miles</u>	<u>Percentage</u>
0 - 399	1008	25.4
400 - 999	1005	25.3
1000 - 1999	867	21.9
2000 - 4999	920	23.2
5000 - 9999	141	3.6
<u>≥ 10,000</u>	25	0.6
TOTALS	3966	100.0

#### B. ROADWAY CHARACTERISTICS AND FEATURES

The information on roadway characteristics and features was obtained using the vehicle instrumentation and computer data acquisition system described in detail in section I, volume III. At the beginning of each roadway section, pavement width was measured and all roadway characteristics were coded and stored. Changes in roadway characteristics and features (e.g., intersections, bridges, etc.) were entered as they were encountered. Figure 1 presents the roadway characteristics and features that could be coded for each section. As can be seen from a review of the descriptors used, certain evaluative characterizations involved judgments of the type that a driver is likely to make; as such, these characterizations reflect the overall perceptual environment within which the driver operates on the two-lane rural system.

#### Surface Characteristics

The sample was nearly evenly split between roadways of 20 feet or less and those greater than 20 feet. Table 6 shows the number of sections and mileage of the sample in various pavement width categories. Paved roadways were predominately asphalt surface, only 5 percent being concrete. This generally reflects published statistics.

ROADWAY CHARACTERISTIC/FEATURE	DESCRIPTORS
SURFACE WIDTH*	Measured Value Narrower Wider
SURFACE TYPE	Unpaved Asphalt Concrete
SURFACE CONDITION	Poor Fair Good
SHOULDER TYPE	None Unpaved Paved
SHOULDER CONDITION	Not Driveable Questionable Driveable
SHOULDER WIDTH	Two Wheels Four Wheels
INTERSECTION	Number of Legs (3-way, 4-way, other) Cross Road Surface (unpaved, asphalt, concrete)
BRIDGE	Type Hazard Panel (type III, other, none) Width (full, shoulder decrease, shoulder loss, pavement decrease)
RR CROSSING	Type Protection (passive, beacon, gate)
VERTICAL CREST	Location Coded
NUMBER LANES	Lane Add Lane Drop

\* Surface width was measured at start of section. Changes in width were coded as part of run.

Figure 1. Roadway characteristics and features coded.

Table 6. Mileage by pavement width (paved roads only).

<u>Pavement Width</u>	<u># Section</u>	<u>Miles</u>	<u>% Miles</u>
<15	8	63.2	1.3
15 - 16	29	216.7	4.6
17 - 18	80	598.9	12.6
19 - 20	147	1289.8	27.1
21 - 22	114	1109.2	23.3
23 - 24	99	948.4	19.9
>24	49	530.9	11.2
TOTALS	526	4757.1	100.0

The judgment involving the characterization of surface condition was based primarily on the effect of the surface upon driving; more specifically, the effect it had on being able to comfortably maintain a speed near the speed limit on tangent sections or extremely gentle curves where horizontal alignment did not control the speed. The condition judgment was made and encoded after the initial 1 to 3 miles of the section had been driven. If within the section conditions were found to be poorer or better, the condition code was modified when the change persisted for more than one-half mile.

Nearly 85 percent of the sections were judged to have good surface conditions according to the above criteria, and less than 1 percent were judged to be in poor condition. Considering only asphalt surfaces, which constituted the bulk of the sample, 86 percent were judged to be good, with 12 percent rated fair and 2 percent poor.

#### Shoulder Characteristics

Approximately 36 percent of the paved roadway mileage sampled involved roads with no shoulder of any kind. Of the 3100 miles of paved roadway in the sample with shoulders, 64 percent of the shoulder miles were unpaved and 36 percent were paved. Shoulder width was not measured directly but was categorized with regard to the driver's perception as to whether a vehicle could get fully out of the travel lane. Shoulders were coded as either

two-wheel or four-wheel, a four-wheel shoulder being one that was wide enough to get the car completely out of the travel lane. Nearly 66 percent of the roadways with shoulders had shoulders of "two-wheel" width.

Table 7 shows the breakdown of shoulder width for paved and unpaved shoulders.

Table 7. Shoulder width/shoulder type (paved roads only).

SHOULDER TYPE	SHOULDER WIDTH					
	2-wheel		4-wheel		Total	
	Miles	%	Miles	%	Miles	%
Unpaved	1590	80.2	393	19.8	1983	100
Paved	538	48.2	578	51.8	1116	100
TOTALS	2128	----	971	----	3099	---

Shoulder condition was also characterized by the driver as being "not driveable," "questionable," and "driveable." A shoulder classified as not driveable was one for which the shoulder condition appeared to make it unsafe for the driver to leave the roadway over most of the section. A shoulder classified as questionable represented a condition in which the driver would have to slow down considerably and search for a specific location that appeared to be stable enough and flat enough to use. A driveable shoulder was one that appeared to provide frequent opportunities for use.

Although shoulder condition and shoulder width were each generally characterized by a single code representative of the section, there was not a great deal of constancy in these attributes. Shoulder condition and, to a lesser extent, width were highly variable within most sections. That is, there were frequent short segments within most sections where apparent width and condition was different from the initial code assigned to the overall

section. Recall, however, that the classification code was changed (updated) only if a change in width or condition prevailed for at least one-half mile. Most of the changes, while frequent, prevailed on segments shorter than one-half mile in length.

Less than 1 percent of the shoulder mileage was coded as not driveable. As might be expected, the narrower shoulders were viewed much more frequently as being of questionable driveability. For the two-wheel shoulders, approximately 61 percent of the mileage was classified as questionable, whereas only 30 percent of the mileage of four-wheel shoulders was so classified.

### Roadway Features

The roadway features of primary interest on the basis of highest accident probabilities (Smith et al., 1983) are horizontal curves, narrow bridges, and intersections. The frequency of occurrence of these features is shown on table 8 for various terrain types. As might be expected, the primary difference among various terrain types is the frequency with which curves occur.

### C. INFORMATIONAL CHARACTERISTICS

The material presented in this section covers the general informational characteristics of the two-lane rural roadway system. It does not deal specifically with information deficiencies; deficiencies are described and discussed in chapter IV.

### Pavement Striping Characteristics

The striping characteristics coded were presence/absence of centerlines and/or edgelines and a judgment as to the visibility (or quality) of the lines. The visibility judgments identified lines as faded or bright, and were related to the utility of the lines for the driver in identifying the path ahead. For example, on a section with edgelines and centerlines where

Table 8. Roadway characteristics by terrain type  
(paved only).

TERRAIN	# SEC	MILES	CUR /MI	NARBR /MI	INT /MI
Flat	54	467.6	1.37	0.15	1.10
Rolling	361	3161.8	2.10	0.16	1.24
Mountainous	111	1127.7	4.30	0.11	0.99
All Terrain	526	4757.1	2.55	0.15	1.17

the path of the roadway curved and the curvature was obvious before the lines could be detected, the line was coded as "faded." On a long tangent section, if the line(s) ahead of the vehicle were not continuous, i.e., if they exhibited "break-up," the faded code was also used.

Approximately 17 percent of the paved mileage sampled had no edgelines or centerlines, and 31 percent had centerlines only. The paved mileage containing both centerlines and edgelines constituted 52 percent of the sample.

As pavement width increased, the percentage of roadways with either centerlines or centerlines and edgelines also increased. This is reasonable as 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 markings.

Table 9 summarizes the data with regard to delineation of the edge of the paved roadway. Approximately 52 percent (2462 miles) of the paved roadway mileage had edgelines. Nearly 22 percent (491 miles) of the remaining 2261 miles without edgelines was characterized as "unclear edge," i.e., provided poor definition of the actual edge of the roadway. Thus, slightly more than 10 percent of the overall sample could be characterized as problematic with respect to adequate path definition for the driver.

Table 9. Roadway edge condition.

<u>Road Edge Demarcation</u>	<u>Miles</u>	<u>Percent</u>
No Edgeline - Unclear Edge	491	10.4
No Edgeline - Clear Edge	1770	37.5
Edgeline - Faded	257	5.4
Edgeline - Bright	2205	46.7
	<hr/>	<hr/>
TOTALS	4723	100.0

## General Signing Characteristics

Specific advance warning and regulatory signs coded for the sample are shown in figure 2. It should be noted that 11 warning signs considered to be less important to the requirements of the study were coded "other." An example of this "other" class is the "Divided Highway" sign. "Slippery When Wet" and "Bridge Freezes Before Roadway" signs were not coded at all as their presence or absence is a matter of agency policy and does not necessarily relate to actual driver need. For any advance warning sign which included an advisory speed plate, the speed advisory value was also coded.

<u>Advance Warning Signs</u>	<u>Regulatory Signs</u>
Curve	SPEED LIMIT (Value)
Turn	REDUCED SPEED AHEAD (Value)
Reverse Curve	STOP
Reverse Turn	YIELD
Winding Road	
Intersection	
Stop Ahead	
Yield Ahead	
Signal Ahead	
Narrow Bridge	
One Lane Bridge	
Railroad	
Other	

Figure 2. Signs coded.

Table 10 shows the rate at which various classes of signs are encountered by a driver on various types of terrain. As might be expected mountainous terrain requires the greatest number of signs and flat terrain the fewest. Exclusive of the two signs not coded, a sign of some type is encountered, on the average, approximately every 3600 feet. Note that this represents only one direction of travel. For purposes of estimating a total sign inventory there are nearly three signs per mile on the open road sections of the paved two-lane rural system.

It should be noted that additional descriptive data for each terrain type are provided in section II, volume III.

Table 10. Sign summary by terrain type.  
(Paved roads only)

<u>Terrain</u>	<u># Sec</u>	<u>Miles</u>	<u>All Warning Signs/ Mile</u>	<u>Speed Signs/ Mile</u>	<u>Speed Reduction Signs/ Mile</u>	<u>STOP/ YIELD Signs/ Mile</u>	<u>Total Signs/ Mile</u>
Flat	54	467.6	.72	.25	.04	.10	1.12
Rolling	361	3161.8	1.05	.32	.03	.07	1.49
Mountainous	111	1127.7	1.22	.34	.04	.02	1.63
All Terrain	526	4757.0	1.06	.32	.03	.07	1.49

### III. DRIVER NEEDS

#### A. DRIVER DECISIONS

One of the specific objectives and one of the first tasks accomplished in the study was the identification of the driver decision universe. It is primarily from knowledge of the driver decisions that information needs and the alternative means of meeting those needs are identified.

The identification of the decision universe was begun by conducting a task analysis for each roadway situation of interest. Six specific situations were analyzed. They are:

- o Horizontal curve
- o Vertical curve
- o Narrow bridge
- o Stop sign controlled intersection
- o Railroad grade crossing
- o Lane width reduction

In addition a seventh generalized task analysis was developed to cover those geometric features not included above. The task analysis data were subsequently supplemented by reviewing the driver commentary tapes to determine whether drivers were faced with decisions other than those identified via the analytic procedure.

The approach used encompasses parts of several previously applied approaches/procedures to the analysis and specification of information requirements, namely, the Information-Decision-Action (IDA) task analysis procedure with supplemental support via elements of the Positive Guidance procedure (Post, T. et. al. 1981).

One of the primary advantages of the IDA procedure is that it does not lock one in to one specific level of detail as do some of the other task analysis procedures. Simple or complex systems may be analyzed and the

degree of thoroughness may be selected for maximum usefulness. Further, and more important, the IDA approach lends itself readily to field verification of information requirements. That is, in a field procedure such as the one used in this study, the commentary driving provides input as to the driver decisions associated with various situations. Those data can then be checked against the analytically derived decision and the IDA models can be supplemented where necessary. The IDA begins with the specification of required actions (maneuvers) and involves a "back-solving" approach to the specification of information requirements. To appreciate the value of backward solutions, one need only consider an oversimplified analogy to test-taking. If a student knows the precise questions that will be included on a final exam, then the areas requiring preparation are precisely defined. Furthermore, there is a complete appreciation of what information will not help achieve satisfactory results. Thus, the goal-orientation carries with it a healthy measure of efficiency inasmuch as it focuses on necessary and sufficient conditions.

In effect, the IDA approach begins by reversing its own sequence (IDA = ADI). That is, the necessary action (A) is determined, e.g., speed reduction; next the decision (D) that must be made by the driver is identified, e.g., take foot off gas and touch brake; finally the information (I) necessary to alert the driver to the need to take an action is identified, e.g., curve warning sign with advisory speed plate. By completely specifying these relationships, it is possible to anchor the input both to and from the driver-vehicle unit in such a way as to permit specification of the necessary and sufficient stimuli for negotiating a given roadway segment. This specification, furthermore, permits the development of the requisite time-distance relationships that in turn provide specific objective reference points in the physical situation for the subjective and unobservable phenomena of driver perception and decision-making.

Generally speaking, the driver commentary data did not result in identifying driver decisions that were different from those derived analytically. The primary finding from the driver commentary was the relatively high frequency with which the commentary reflected a change in response readiness.

That is, where the driver recognized the potential need to respond, e.g., to decelerate or modify path, but decided to maintain the status quo until additional information was obtained. For example, in a curve situation the additional information may be visual cues related to curve sharpness, kinesthetic cues, or in the case of narrower roadways, an oncoming vehicle. In other words the driver realizes that a response may be required but chooses to await the acquisition of information that provides greater certainty about the situation. This, of course, should be expected because signs, particularly warning signs, are not specific to driver, vehicle, or roadway characteristics. For example, the same curve warning sign will have a different effect on the driver of a high center of gravity van than it will on the driver of the sports car. The van driver may always begin to decelerate when a curve warning sign is seen while the sports car driver may not slow down at all until a real need to do so is perceived. Therefore, a driver with some experience will realize that a behavioral response may or may not be required on the basis of warnings.

The detailed task analyses for the seven situations specified earlier are presented in section III, volume III. It should be noted that the output of the task analysis effort has been restructured for presentation and for greater ease of use by others. First, the driving commentary data was used to identify driver reactions which are totally cognitive and cannot be observed. Those are specified along with those behavioral responses that can be observed and measured. Secondly, the first decision listed for each situation is not actually a decision but the perceptual identification of the situation. This initial perception was included as a "decision" because it generates an information requirement and the purpose of the entire exercise of identifying driver decisions is to use the information as a basis for ultimately identifying information deficiencies.

It will be noted that the detailed task analyses were developed for use by project personnel and were not necessarily intended for publication. However, because they were done for each situation and are unavailable in that specific form elsewhere, it was decided that they may be of use to other researchers. The material in each of the analyses could, for example, be used to develop driver information need checklists for special purpose field evaluations. Other uses might be: identification of the most appropriate driver behavior measures for each situation or the development of driver behavior flow diagrams or time-line diagrams. Since the potential

uses are highly varied the analyses are presented in their most detailed form so that the widest range of use might be possible.

## B. DRIVER EXPECTANCY

The concept of driver expectancy has been used and written about frequently in the literature on driver behavior. It is assumed that when driver expectancy is violated the driver will either fail to respond, respond inappropriately, or exhibit a longer response time than normal (Post, T, et. al, 1981). There is much support in the basic psychological literature for this assumption with regard to information processing and decision tasks. However, with respect to the overall driving task, expectancy has remained more or less conceptual in that we have little knowledge as to what roadway factors generate the expectancies that are likely to influence performance. While it was not one of the primary objectives of the study to operationalize expectancy, it was deemed potentially useful; and measures of expectancy were therefore integrated into the study data collection. Initially it was hoped to not only operationalize the concept, but to develop an expectancy-based roadway classification system as a basis on which to differentiate information needs among various classes of roadway.

The ideal way to study driver expectancy would be to take a large number of subjects on a large variety of roadway designs and thereby to determine what sort of expectancies were formed and to determine the relationship of these expectancies to various roadway characteristics experienced. This sort of an approach was not within the resources of the study; thus the plan for collection of expectancy data was designed to be consistent with other study needs. That is, since a large number of roadways had to be sampled in order to identify the characteristics of the two-lane rural system and to identify the driver decision universe, drivers associated with the research team were used to provide the expectancy data. This satisfied the objective of having expectancy data from unfamiliar drivers for a wide range of two-lane roadway characteristics and permitted the correlation of expectancies with those characteristics. The potential criticism of this approach is that expectancies stated by study personnel may not be the same expectancies stated by the average driver. In order to counteract this sort of criticism (and for purposes of consistency), the expectancies were structured, and the resulting expectancy items were rated on each roadway to encompass a range

of expectations from general to specific. It was felt that the range was sufficiently broad that most types of expectancies that would be mentioned by drivers were included in the set.

Each of nine expectancies was rated on a five-point scale for each roadway section cataloged. The expectancy ratings were given by the driver after 1 to 3 miles of the section had been driven. Figure 3 shows the sectional expectancy rating scales used. As can be seen, the expectancy statements involve some grouping. That is, expectancy items 1 and 9 are general; items 5 and 7 are related to the information system; items 2, 3, 6, and 8 relate primarily to the control task; and item 4 relates to general sight distance characteristics. The rationale behind using such a large number of expectancy ratings was to provide a means of assessing the relationship of each to various roadway characteristics, and a means of determining the extent to which various specific expectancies are intercorrelated with more general expectancies and with each other.

Table 11 shows the intercorrelations among expectancies. Intercorrelations were computed using the Pearson product-moment method via the SAS package. As can be seen, with the exception of the two expectancies related to signing, the correlations are, in general, quite high. The lower sign related correlations may represent the internal biases of different drivers. That is, depending on where one does most of his or her driving, a fairly strong roadway geometry/sign expectancy has been developed. Since expectancy is typically dealt with in the literature in a general sense, i.e., as something encompassing a variety of roadway and traffic factors, it is of interest to note that the two most general expectancy items (Comfort Level and Overall Attention) correlate highly with the other factors. This finding is noteworthy in that it provides support for the idea that driver expectancy can be treated as a broad nonspecific assessment of the roadway situation, and that future research aimed at operationalizing expectancy can safely use fewer more general items.

1. Comfort Level

- A. Very Comfortable
- B. Comfortable
- C. Moderate
- D. Uncomfortable
- E. Very Uncomfortable

6. Speed Changes

- A. Very Few
- B. Few
- C. Moderate
- D. Many
- E. Very Many

2. Attention to Speed

- A. Very Casual
- B. Casual
- C. Moderate
- D. Watchful
- E. Very Watchful

7. Safe Speed Information

- A. Almost Always Provided
- B. Usually Provided
- C. Provided a Moderate No. of Times
- D. Seldom Provided
- E. Almost Never Provided

3. Attention to Steering

- A. Very Casual
- B. Casual
- C. Moderate
- D. Watchful
- E. Very Watchful

8. Oncoming Traffic

- A. Very Small Effect
- B. Small Effect
- C. Moderate Effect
- D. Large Effect
- E. Very Large Effect

4. View of the Road Ahead

- A. Almost Never Limited
- B. Seldom Limited
- C. Moderately Limited
- D. Usually Limited
- E. Almost Always Limited

9. Overall Attention

- A. Very Casual
- B. Casual
- C. Moderate
- D. Watchful
- E. Very Watchful

5. Traffic Signs

- A. Almost Always Provided
- B. Usually Provided
- C. Provided a Moderate No. of Times
- D. Seldom Provided
- E. Almost Never Provided

Figure 3. Sectional expectancy ratings.

Table 11. Expectancy intercorrelations.

EXPECTANCY ITEM	COMFORT LEVEL	ATTEN TO SPEED	ATTEN TO STEER	VIEW AHEAD	TRAFFIC SIGNS	SPEED CHANGES	SPEED INFO	ONCOMING TRAFFIC	OVERALL ATTEN
Comfort Level	1.0000								
Attention to Speed	0.8358	1.0000							
Attention to Steering	0.8248	0.8565	1.0000						
View of Road Ahead	0.6919	0.7335	0.7276	1.0000					
Traffic Signs	0.6233	0.5783	0.5614	0.4771	1.0000				
Speed Changes	0.7472	0.8009	0.7724	0.7049	0.5221	1.0000			
Safe Speed Information	0.6320	0.5956	0.5884	0.4928	0.9263	0.5526	1.0000		
Oncoming Traffic	0.7490	0.7335	0.7701	0.5888	0.5874	0.6955	0.6131	1.0000	
Overall Attention	0.8423	0.8799	0.8740	0.7403	0.6240	0.8012	0.6577	0.7855	1.0000

## Expectancies and Roadway Characteristics

It will be recalled that, with the exception of roadway width, the roadway features cataloged were characterized in terms of what is seen by the driver. Since the assumption underlying the generation of driver expectancy is that expectancies are formulated on the basis of both long and short term experience, it was felt that it would be useful to assess the relationship between the expectancies and roadway characteristics to determine the extent to which the roadway characteristics encountered on a given section related to the stated expectancies.

This analysis involved a regression of each expectancy item on the roadway characteristics cataloged, i.e., surface width, type and condition, shoulder width, type and condition, and terrain. The assumption that driver expectancy reflects a great deal more than the influence of the visually obvious roadway characteristics encountered is supported by the results of the regression analyses. Table 12 shows the  $R^2$ 's associated with the regression analysis conducted for each expectancy item. These were derived using the SAS RSQUARE procedure. It will be noted that the  $R^2$ 's shown represent the variance accounted for by the combination of all seven roadway variables. As shown, the maximum amount of variance accounted for is less than 40 percent for the expectancy item related to overall attention requirements. This is not meant to imply that roadway/environmental characteristics encountered can never account for a greater percentage of the variance in expectancy than is accounted for here. Rather, the results may indicate that other, less obvious, visual attributes of the roadway or environment must be accounted for if the relationship between these factors and expectancy is to be discovered.

It is instructive to review the single roadway characteristic which accounted for the greatest amount of variance for each expectancy item. Table 13 presents these data. Of interest here is the fact that for each expectancy item either shoulder condition or width accounted for the greatest amount of the variance. Bearing in mind that these two roadway characteristics are highly correlated in the sample obtained ( $R=.82$ ), this

Table 12. Expectancy x roadway characteristics regression analysis.

EXPECTANCY ITEM	R <sup>2</sup> *
Comfort Level	.3102
Attention to Speed	.3402
Attention to Steering	.3303
View Ahead	.1818
Traffic Signs	.3423
Speed Changes	.3287
Safe Speed Information	.3637
Overall Attention	.3659

\* From each separate regression with all roadway characteristics.

Table 13. Roadway characteristics accounting for maximum variance in expectancies.

EXPECTANCY ITEM	ROADWAY CHARACTERISTIC	R <sup>2</sup>
Comfort Level	Shoulder Condition	.228
Attention to Speed	Shoulder Width	.263
Attention to Steering	Shoulder Condition	.237
View Ahead	Shoulder Width	.161
Traffic Signs	Shoulder Condition	.220
Speed Changes	Shoulder Width	.245
Safe Speed Information	Shoulder Width	.238
Overall Attention	Shoulder Width	.261

suggests that perhaps some factor related to "openness" or "clear zone" may be a factor which is important in determining driver expectancy.

In addition to the expectancy analyses involving individual expectancy items, several analyses were conducted using an expectancy index, i.e., the mean of the sum of the expectancy values for each sample. While it was not anticipated that additional information would be uncovered by using the index, it did facilitate some analyses in that there were fewer values to manipulate. In other words, the use of the index was a means of more economically investigating a number of relationships of potential interest. While the analyses performed using the expectancy index revealed, as anticipated, nothing more than those using the individual expectancy analysis, two of those done only with the index deserve mention. Both were aimed at examining the issue of whether the perceptions and judgments reflected in the expectancy data were related to general physical features which, in turn, related to actual performance. The first analysis was a regression of the expectancy index with the observable physical features used previously but with the number of curves per mile (CPM) added as an independent variable. This measure was added to the other physical features because it was one of the classification variables in the system recommended by Smith et al. (1983) in their study of safety on two-lane rural highways. This analysis showed that CPM accounted for a greater percentage of the variance in expectancy index than did those observable physical features on which the individual expectancy items were based. The correlation between CPM and the expectancy index was  $R = .71$ . The next highest correlation of a physical feature with expectancy index was  $R = .56$  for shoulder width. Thus, if one had to choose a single physical characteristic of a roadway section to predict driver expectancy, curves per mile would, on the basis of current evidence, be the most appropriate choice. It should be noted that the addition of all other roadway characteristics to the regression model only increases the correlation with expectancy index to  $R = .78$ .

The final question with regard to the expectancy index is its relationship to driver performance. Since speed is the global performance measure that relates most logically to hazard and information need in various situa-

tions, a correlational analysis of average speed and expectancy was conducted. The thinking here is that, if a driver is driving on a lower design roadway and the expectancies are that the driving task will be difficult, will entail a lot of speed changes, etc., the overall speed will be lower because of the combined effects of geometrics and expectancies. To the extent that this is the case the driver will approach each uncertain situation more carefully and will have more time to respond to natural cues in the absence of supplemental information. For a situation of any given level of hazard, the actual risk is reduced because the lower speeds give the driver more time to assess the situation and respond. This is why a curve, for example, of a given level of severity may absolutely require a warning sign on a higher design roadway, whereas the same curve on a lower design roadway may operate relatively safely without signing.

In order to obtain some additional data on expectancies and the relationship between expectancy and average speed, a small group of test subjects drove an instrumented vehicle on a 42-mile test circuit in the vicinity of State College, PA composed of seven sections representing a range of designs. The subjects drove approximately 5 miles previous to starting the test circuit so as to become familiar with the vehicle. The test subjects were simply told that we were interested in driving patterns on various types of two-lane rural roadways and in what drivers expected when various types of roadways were traversed. Previous to the start of the test circuit each subject reviewed operational definitions of each expectancy and the scaled responses. Figure 4 presents the operational definitions for the five expectancies used. After the drivers had driven approximately 1 mile on each of the seven sections, they were asked to provide verbal responses to the structured expectancy questions. This exercise used twelve test subjects - seven male, five female - ranging in age from 22 to 62 years. None of the subjects was familiar with the sections in the test circuit. The results of the correlational analysis confirmed the findings of the staff drivers, with the correlation between expectancy index and speed on various sections being  $R = .71$ .

The correlation of expectancy index with speed produced a reasonably high value of  $R = .69$  for the staff drivers.

A. Overall Attention Required

Depending on things such as pavement condition, traffic, number of curves, and width of the road, some two-lane roads require you to be watchful, whereas others can be driven casually. Do you feel the overall attention required by this road will be: (1) Very casual; (2) casual; (3) Moderate; (4) Watchful, (5) Very watchful.

B. View of the Road Ahead

Some two-lane roads have so many curves and hills that your view ahead is frequently limited, whereas others have long straight and level stretches that allow you to see far ahead. On this road do you think that the view of the road ahead will be: (1) Almost never limited; (2) Seldom limited; (3) Moderately limited; (4) Usually limited; (5) Almost always limited.

C. Attention to Speed

Things such as sharp curves, abrupt hill crests, and intersections may require you to frequently adjust your speed. That is, you may have to watch your speed closely on some roads, but you can drive others casually. On this roadway, do you think your attention to speed will be: (1) Very casual; (2) Casual; (3) Moderate; (4) Watchful, (5) Very watchful.

D. Presence of Traffic Signs

Some two-lane rural roads provide a lot of traffic signs to warn you about things such as curves, intersections, and narrow bridges, while others provide few or none. Do you think traffic signs on this road will be: (1) Almost always provided; (2) Usually provided; (3) Moderately provided; (4) Seldom provided; (5) Almost never provided.

E. Overall Comfort Level

Because of roadway conditions noted before, driving a road may be comfortable or uncomfortable for you. On this roadway do you think you are going to be: (1) Very comfortable; (2) Comfortable; (3) Moderately comfortable; (4) Uncomfortable; (5) Very uncomfortable.

Figure 4. Driver expectancy ratings.

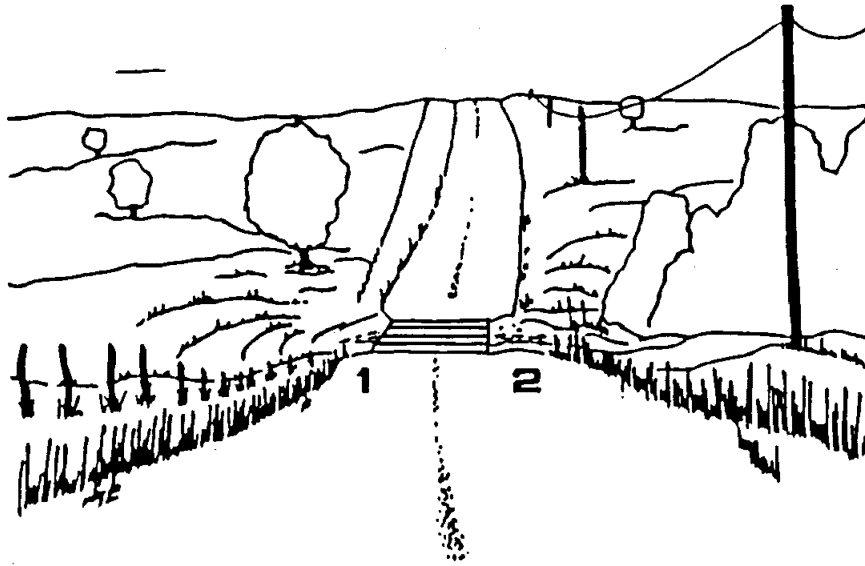
#### IV. INFORMATION DEFICIENCIES

Individuals need information to be able to perform their driving task safely, conveniently, efficiently, and comfortably. For example, areas of information need involve horizontal and vertical alignment, surface condition, surface width, maximum safe speed, speed of oncoming traffic, and available motorist services, just to name a few.

Drivers receive information visually from the highway environment and in-vehicle displays, audibly, and from their kinesthetic and tactile senses. The majority of information is received visually from the driver's perception of the highway environment. The environment includes formal information, i.e., signs and markings provided by a government jurisdiction, treated natural information, and natural information. The latter two refer to all other elements of the highway environment that assist the driver in making correct alignment and speed control decisions, e.g., tree or brush lines

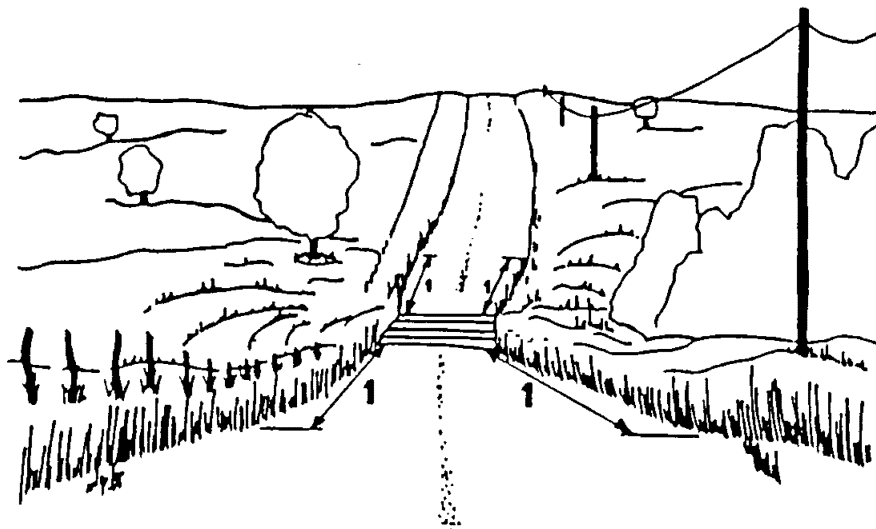
The distinction between treated natural and natural information is illustrated in figures 5 and 6. Figure 5 depicts the natural information available on the approach to a narrow bridge. Figure 6 illustrates how the roadside vegetation can be "tapered," i.e., modified, in such a way as to provide treated natural information to aid in indicating the narrowness of the bridge.

When drivers do not receive information necessary to traverse a roadway section safely and expeditiously, regardless of where it comes from, an information deficiency exists. A principal problem then is to define just what constitutes an information deficiency. A review of NCHRP Report 123, Development of Information Requirements and Transmission Techniques for Highway Users (1971), indicates that 120 different information needs were identified. Further, the authors state, "... it must be emphasized that this inventory does not represent the universe of needs ...." Examination of the large number of needs identified indicated that many are not directly relevant to the requirements of this project. Even so, the sizable



1. Roadway wider than culvert.
2. Roadway edge leads driver into culvert ditch instead of onto culvert.

Figure 5. Example of natural information.



1. Tapered section - roadway edge leads to culvert ends.

Figure 6. Example of treated natural information.

number of potential information deficiencies associated with not satisfying those remaining was considered too large to serve as a basis for evaluating those problem sites expected to be discovered during the field survey phase of the study. Rather it was concluded that the most efficient approach, in the absence of any specific information about the nature and magnitude of the information deficiency problem on two-lane rural roads, would be to develop a set of information deficiency categories after completing the field data phase of the study. This approach was used, and the results are reported in the last section of this chapter.

This chapter addresses the subject of information deficiencies from three different aspects. First is a presentation of the magnitude and nature of the potential information deficiency problem developed from the approximately 5000 miles of field survey data. Horizontal curves, narrow, i.e. width restricted, bridges, and stop/signal controlled intersections are addressed as being the three features offering the most potential for information deficiency related problems. The second section presents examples of a number of different situations identified with some frequency during the field survey phase as being information deficient. The reasons why information deficiencies exist in these situations is discussed in some detail. The third and final section of this chapter presents brief descriptions of the ten categories of information deficiency identified as a result of both the literature review and the field survey efforts.

#### A. AN OVERVIEW OF THE INFORMATION DEFICIENCY PROBLEM

An information deficiency is considered to exist whenever drivers require specific knowledge about the road ahead and the same is not provided. The need for any form of specific information usually results from some change in alignment or geometry that is not visible to the driver in time for the appropriate maneuver to take place safely, be it speed change, alteration in lateral placement, or a stop.

Low-volume, two-lane rural road sight restrictions that generate a need for information, typically signing, are primarily associated with horizontal

and vertical curves. Besides the problem horizontal curves may present to drivers, i.e., how should the curve be negotiated and at what speed, they, along with crest vertical curves, act to prevent the driver from catching sight of some other physical feature, e.g., narrow bridge, railroad crossing, stop-or signal-controlled intersections, etc., in time to execute an appropriate maneuver.

In the nearly 5,000 miles of rural two-lane roads sampled, horizontal curves are the most prevalent physical feature (over 12,000), and present, at the isolated sharper curves, the greatest need for information. Narrow (width restricted) bridges, with only about 700 of all types in the data base, represent a distant second. Controlled intersections, with a total of slightly more than 300, are next in frequency of occurrence. Railroad crossings occurred so infrequently that they do not merit separate attention.

The remainder of this section addresses each of the three geometric features, i.e., horizontal curves, narrow bridges, and stop or signal controlled intersections, in terms of the magnitude of potential information deficiencies associated with each. It is important to understand that it is not possible to identify if any given geometry is or is not information deficient. So much of what determines that is site specific. What is possible, however, is to characterize those locations that might be information deficient, thus providing some idea of a "worst case" specification of the driver's information needs on the total two-lane rural road system.

## B. CURVE-RELATED INFORMATION DEFICIENCIES

Curves are without doubt the most frequent physical feature of concern in terms of potential information deficiencies. The accident data for curves indicates that both degree of curvature and frequency of curves have an influence on accident rate. With regard to degree of curvature, an early study by Raff (1953) states that the increase in accidents per million vehicle miles (MVM) is about 0.15 per degree of curve. The accident rate values cited in the AASHO "Red Book" (1966) regarding degree of curvature

are: < 3 degrees = 1.37 accidents/MVM; 3-5 degrees = 2.48 accidents/MVM; and 5 degrees = 3.86 accidents/MVM. Accident rate/curvature relationships do not appear to be that simple, however. In his 1953 study Raff also indicated that accident frequency relates to both degree of curvature and frequency of curves. In general, accident rates are higher when there are more curves per mile except for isolated sharp (>10 degree) curves. In that case, accident rates go up. Finally, Smith, et al. (1983) cite a Georgia study which showed a trend of increasing fatal accident frequency associated with degree of curvature. This study showed that in comparison with tangents: (a) curves greater than 6 degrees have approximately five times the fatal accident rate; (b) curves of 1-3 degrees have at most 1.5 times the fatal rate; and (c) curves of 4-6 degrees have 2.0-2.5 times the fatal rate. With regard to severity Smith et al. (1983) appropriately highlight the situation by pointing out that while an estimated 25 percent of the two lane rural highway mileage is curved, almost 40 percent of the fatal accidents occur on curves. In summary, past accident studies indicate that degree of curvature and curve frequency influence accident frequency and also accident severity. These factors were therefore the focus of the analysis of curve-related information deficiencies. The curve data base for the present study contained slightly more than 12,000 curves. This is an underestimate of the actual total number of curves in the total roadway sample. As indicated earlier the automated data collection system is such that gentle curves may not always be identified as being curves. However, sharper curves, e.g. greater than 3 degrees are accurately represented in the data base.

Table 14 indicates how the total sample of 12295 curves recorded in the data base is distributed by curve category and advance tangent length. Three curve categories are provided: <6 degrees, 6<sup>+</sup> to 10 degrees, >10 degrees. Six degrees corresponds roughly with a maximum design speed of about 55 mi/h, while 10 degrees corresponds with a design speed of about 45 mi/h. Two different advance tangent lengths are used: <1,000 feet and ≥ 1,000 feet. This latter categorization implies curve isolation. That is, a curve preceded by a tangent of at least 1,000 feet can be considered isolated,

i.e., drivers approaching it are essentially free of speed-reducing influences of other, earlier curves.

Table 14. Distribution of all curves by degree of curve and length of preceding tangent.

PRECEDING TANGENT LENGTH	DEGREE OF CURVE			TOTALS	
	$\leq 6^\circ$	$6^+ - 10$	$> 10^\circ$	N	(%)
$< 1000'$	3184 (25.9)	2455 (20.0)	3486 (28.3)	9125	(74.2)
$\geq 1000'$	1784 (14.5)	746 (6.1)	640 (5.2)	3170	(25.8)
TOTALS N (%)	4968 (40.4)	3201 (26.1)	4126 (33.5)	12295	(100)

Reviewing table 14 one sees that about 26 percent of all curves may be considered isolated. From the standpoint of curve-related information deficiencies it is the isolated curve which is of the greatest concern. The long advance tangent of an isolated curve encourages travel at or above the roadway speed limit. If this tangent speed is higher than the safe speed around the curve and no curve warning is provided, an unsafe situation can exist. The sharper the curve, the more speed differential between the tangent and the curve is likely to occur and the more necessary some form of advance warning information becomes.

For the purpose of this analysis, information deficiencies are only considered for isolated curves with moderate ( $6^+$  to 10 degrees) and sharp ( $>10$  degrees) horizontal alignments. Curves with gentle ( $\leq 6$  degrees)

alignments are generally not a problem as a driver can traverse those curves at speeds up to the 55 mi/h National Maximum Speed Limit (NMSL). Clearly, some of these curves could present problems under higher speed limit conditions such as those in existence prior to enactment of the NMSL. Non-isolated curves, such as those with advance tangents of less than 1,000 feet, are not considered significant in terms of information deficiency problems, as a driver is more likely to be cautious when entering a curve if it is closely preceded by one or more curves rather than by a long tangent section.

There are a total of 1,386 curves in the data base which meet the joint criteria of being isolated, i.e., a preceding tangent of at least 1,000 feet length and a degree of curvature of at least 6 degrees. This represents slightly more than 11 percent of the total curve data base. Table 15 presents the number of isolated moderate to sharp curves in the data base and whether or not they had advance curve warning signs.

Table 15. Distribution of moderate to sharp isolated curves by presence of advance curve warning sign.

ADVANCE WARNING PROVIDED		DEGREE OF CURVE		TOTALS
		6 <sup>+</sup> - 10	> 10°	
YES	N (%)	302 (40.5)	298 (46.6)	600 (43.3)
NO	N (%)	444 (59.5)	342 (53.4)	786 (56.7)
TOTALS		746	640	1386

Reviewing Table 15 one sees that about 43 percent of all isolated moderate to sharp curves have advance warning signing of some type. About two-thirds of the advance warning signs are either a curve or turn sign while the remaining one-third are reverse curve, reverse turn or winding road signs. As might be expected, the percentage of isolated curves with advance warning signs increases with increased degree of curvature. Contrast this with the fact that only about 5 percent of the gentle non-isolated curves (Degree  $\leq 6$  and tangent  $< 1,000$  feet) have advance warning signs and it is clear that those individuals responsible for operating the low-volume, two-lane rural road system from which the total sample was drawn recognize that moderate and sharp isolated curves have the potential of creating difficulties for the driver. The relatively high percentage of curves in these categories with curve warning signing attests to that.

Further evidence that many of the responsible authorities do recognize the potential difficulties that drivers may experience in traversing horizontal curves on two-lane rural highways is found in the extent of information provided. Table 16 indicates for all isolated moderate to sharp curves with advance warning signs, the frequency with which a supplemental advisory speed plate was provided.

Table 16. Distribution of moderate to sharp isolated curves with advance warning signs by degree of curve and presence of supplemental advisory speed plate

SPEED PLATE PROVIDED		DEGREE OF CURVE		TOTALS
		6 <sup>+</sup> - 10	> 10°	
YES	N (%)	161 (53.3)	199 (66.8)	360 (60)
NO	N (%)	141 (46.7)	99 (33.2)	240 (40)
TOTALS		302	298	600

Table 16 indicates that as curve sharpness increases the likelihood of having supplemental advisory curve speed information also increases. Two-thirds of the curves of more than 10 degrees that have advance curve warning information also have advisory speed information to provide drivers with the most assistance possible.

For the purpose of this discussion, all of the isolated curves of more than 6 degrees without any form of advance warning are considered to be locations with potential information deficiencies. Seven hundred and eighty-six curves in the data base satisfy the joint conditions of being isolated of more than 6 degrees with no advance warning of any kind. While this represents only about 6 percent of all curves identified in the data base, it does account for some 57 percent of all isolated moderate and sharp curves, a not inconsiderable percentage.

This does not mean that more than half of all moderate and sharp isolated curves are information deficient. Whether or not a curve with no advance warning may be considered potentially information deficient depends on whether the approach speed on the tangent is consistent with 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 isolated moderate to sharp curves not having advance warning signs. Approach speeds were aggregated into three categories; less than 45 mi/h, 45 mi/h to 54 mi/h, and 55 mi/h. Assuming average superelevation and friction values, it is assumed that the design speed for a 6 degree curve is about 55 mi/h and the design speed for a 10 degree-curve is about 45 mi/h. A distribution of the 786 isolated curves without advance warning signing by approach speed and curve category is presented below.

<u>Tangent Approach Speed (mph)</u>	<u>6<sup>+</sup> - 10°</u>	<u>&gt; 10°</u>	<u>TOTALS</u>
< 45	216	208	424
45 to 54	169	110	279
55	<u>59</u>	<u>24</u>	<u>83</u>
TOTALS	444	342	786

Of the 786 curves, 424 have tangent approach speeds of less than 45 mi/h. Thus 54 percent of the total non-signed isolated curve sample, in general, is not likely to require signing as approach speeds are less than design speed of the curve. This is not meant to imply that curve warnings are never needed when approach speeds are less than 45 mi/h. Clearly, if the curve is sufficiently sharp, even 35 to 40 mi/h approach speeds will be too high. That level of specificity, however, lies outside the framework of this discussion. In as much as roads with very sharp curves tend to have lower speed limits and fewer isolated curves, it is reasonable, in attempting to characterize the problem on a more macroscopic level, to assume that none of these 424 sites is likely to require advance signing and, thus, they do not represent potential information deficiencies.

What of the remaining 362 isolated unsigned curves? There are 83 moderate and sharp curves with tangent approach speeds of 55 mi/h. All of these are potentially information-deficient locations as curves of more than 6 degrees cannot be safely negotiated at 55 mi/h. Similarly the 110 curves of more than 10 degrees with tangent approach speeds of at least 45 mi/h are also potential information-deficient locations. Thus  $83 + 110 = 193$  of the 786 isolated unsigned curves are clearly worthy of consideration as potentially information-deficient locations. Less readily definable are the 169 curves of 6<sup>+</sup> to 10 percent with approach speeds of 45 to 54 mi/h. Clearly, the sharper curves (8 to 10 degrees) associated with higher speeds (50 mi/h or more) also can be considered as being potentially information deficient. In that speeds which tend to be biased toward lower values and low-degree curves are far more prevalent than sharper curves, it will be assumed that only 10 percent of these 169 curves are potentially information deficient. Therefore, a total of 210 of the 786 isolated unsigned curves can be considered information-deficient. This represents nearly 27 percent of all unsigned, isolated moderate and sharp curves in the total field data sample, which averages out to about one potential information-deficient curve situation for every 23 miles of paved roadway in the data sample. If this estimate were to be applied to all 3 million plus miles of two-lane rural roads in the United States paved and unpaved, the total number of potential information deficient-curve sites would be on the order of 130,000 plus.

It is important to remember that this analysis cannot and does not attempt to identify specific problem locations. Rather one can only indicate the potential magnitude of the situations that might be likely candidates for study by the specific local jurisdiction to determine if true information deficiencies exist.

### C. NARROW BRIDGE RELATED INFORMATION DEFICIENCIES

Before proceeding into the discussion of information deficiencies related to narrow bridges it should be noted that any constriction that included a vertical structure was considered to be a narrow bridge. While most of the structures so identified were at least 20 feet in length (the standard definition of a bridge), some of the structures would be more accurately identified as culverts. However, because in each case, there was a narrowing of cross section and a vertical structure with which the driver could collide, it was felt that the safety problem was similar in both cases and could benefit from the same informational treatment.

Using this definition of a narrow bridge (and the associated potential safety hazard), the number of such constrictions is much greater than the 60,000 reported by Ivey (1979). Based upon the number of narrow bridges/constrictions found in the 5,000 mile sample of roadways, the 701 narrow bridges identified calculates to one every 7 miles. Using an estimate of 1.6 million miles of paved rural two-lane roadway based on values provided in Smith et al. (1983), the number of narrow bridges/constrictions would be estimated to be in excess of 200,000 rather than 60,000.

As pointed out by Smith et al. (1983) less accident information exists for bridge and culvert sites than for curves, intersections, etc. However, based upon their review they estimated that there are approximately 20,000 reported collisions at such constrictions annually. In a review of the data from a study by Kihlberg and Tharp (1968), these authors also suggest that the accident rate on a 0.3 mile section with a narrow bridge is 1.5 times greater than on a similar section without a narrow bridge. However, with

regard to this estimate they point out that it is doubtful whether a structure has a longitudinal effect on safety of more than 0.1 mile. Taking this into consideration they estimate that a bridge probably increases the probability of an accident by 2.5 to 3 times the base rate on a vehicle exposure basis.

While there is, as mentioned, relatively little direct and generalizable evidence of the safety problem at narrow bridges, Ivey (1979) reports on a Texas improvement project aimed at reducing accident problems at narrow bridges. This project was conducted on a section of roadway that contained a large number of narrow bridges and on which the fatal accident rate was 56 percent higher than the statewide average; with a large proportion of the problem attributed to the narrow bridges. While there is limited data regarding the severity of accidents at narrow bridges, the data reported by Perchonok et al. (1978) indicates that more than 50 percent of the accidents at constrictions are fatal accidents. This high percentage of fatalities merits, at the very least, adequate informational treatments at narrow bridges regardless of volume. The use and non-use of hazard panels, advance warning (when needed due to a sight distance restriction), and advisory speed signs is 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 where travel way width is reduced (pavement decrease) are considered to be the most serious. Total shoulder loss, although generally less hazardous than an actual pavement decrease, can indicate potential problem conditions, particularly when the total pavement width is minimal, e.g., 20 feet or less, and inadequate information is provided. The shoulder decrease category represents the least potentially serious of the three narrow bridge groupings. It is included, however, as any reduction in the total width of pavement plus shoulders can present a problem particularly where sight distance is restricted and the necessary advance or at-bridge warning information is not available.

Of the approximately 700 narrow bridges, a total of 517 (74 percent) were identified as being sight restricted, i.e., a horizontal or vertical

curve existed within a specified (speed-dependent) distance in advance of the narrow bridge. For each narrow bridge location the observer recorded whether or not an advance warning sign existed within 1,000 feet of the bridge, the type of sign, and presence of a speed advisory plate if one existed. Table 17 indicates the number of narrow bridges by type of advance signing observed and by form of sight restriction. The bulk of the sight restrictions observed (79.3 percent) were due to crest vertical curves in advance of the narrow bridge. Only 14.3 percent of the sight-restricted bridges had any form of advance warning regardless of the reason for the sight restriction. It should be noted that one quarter of the locations with some form of advance warning sign also included a speed advisory. This represents less than 4 percent of the total sample of sight-restricted narrow bridges and indicates the perceived unimportance of this form of supplemental information, at least in terms of a width-constrained situation.

Table 17. Distribution of sight-restricted narrow bridges by advance warning sign type and sight restriction type.

ADVANCE SIGNING	CREST	CURVES		TOTALS	
		Medium (6-10°)	Sharp (>10°)	N	(%)
Narrow Bridge with Speed Advisory	3	0	3	6	(1.1)
Narrow Bridge w/out Speed Advisory	25	1	7	33	(6.4)
1-Lane Bridge with Speed Advisory	14	0	0	14	(2.7)
1-Lane Bridge w/out Speed Advisory	18	1	2	21	(4.1)
No Advance Warning	350	52	41	443	(85.7)
TOTALS	N (%)	410 (79.3)	54 (10.4)	53 (10.3)	517 (100)

What does it mean that over 85 percent of the narrow bridges in the data base have no advance warning signs? It would be rash to conclude from table 17 that the overwhelming majority of narrow bridges on the two-lane rural road system have information deficiencies. Clearly this is not the case. Conversely, it would be equally inappropriate to assume that because such a large number of sight-distance restricted narrow bridges were observed without advance signing that no information deficiencies exist at such locations.

How then can one better bound the magnitude of the potential information deficiency problem? It is important to recognize that ADT is low on a large proportion of the rural roads surveyed, significantly reducing the probability that opposing vehicles will come into conflict at the narrow bridge. If advance warning signing is not generally required in low ADT situations, what is necessary? Clearly there is a need to identify to the oncoming driver the existence and location of any lateral obstruction created by the narrow bridge, e.g., raised curbs or bridge rail. This is accomplished by the use of object markers. Three types of object marker are described in section 3C-1 of the MUTCD with type III being preferred for use by FHWA.

Table 18 presents a breakdown of the sight-restricted narrow bridge sample by type of width restriction, i.e. shoulder decrease, shoulder loss, or pavement decrease, and object marker type, segregated by locations with some form of advance warning signing and without any form of signing. The small total number of locations with some form of advance signing shown in table 17 suggests that an aggregation of the type presented in table 18 is appropriate.

If one considers that the two-lane rural road system tends to be composed of roads with comparatively narrow travelways (e.g., 46 percent of all paved roads in the approximately 5,000-mile sample had travelways of 20 feet or less), a total loss of shoulder and certainly an actual pavement width decrease pose potential problems for drivers. It is important to note that whereas 49 percent of the shoulder loss type of narrow bridge occurs on roads with travelways of 20 feet or less (near the sample average), 75 per-

Table 18. Distribution of sight-restricted narrow bridges by type of width restriction, type of object marker, and presence/absence of advance warning signing

ADVANCE SIGNING	SHOULDER DECREASE			SHOULDER LOSS			PAVEMENT DECREASE		
	OBJECT MARKER TYPE			OBJECT MARKER TYPE			OBJECT MARKER TYPE		
	III	I or II	None	III	I or II	None	III	I or II	None
YES	7	0	1	19	1	1	26	3	16
NO	84	48	45	130	62	37	18	7	12
TOTALS BY COLUMN	91	48	46	149	63	38	44	10	28
TOTALS BY WIDTH RESTRICTION	N 185 (%) (35.7)			250 (48.4)			82 (15.9)		

cent of all pavement-decrease narrow bridges (regardless of sight restrictions) occur where pavement widths are 20 feet or less! Thus, an already narrow roadway condition is made even worse at the narrow bridge. Reviewing Table 18 one sees 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. This total absence of information about an actual narrow roadway pavement decrease and where it occurs would be of concern regardless of whether or not a sight restriction occurs. Where it does occur, it has the potential for serious safety problems.

Although the absolute number of such "worst case" problem locations in the data sample is small (12 in 4,757 miles of paved roads) it may be indicative of a significant national problem. If one accepts the data sample as being reasonably representative of the two-lane rural road system, the 12 cases in 5,000 miles translates into nearly 5,000 such locations on the national two-lane rural road system: a not inconsiderable number. While this may be potentially the most serious one, it is not the only problem associated with narrow bridges in the data sample. For example, besides the 12 pavement-decrease type of narrow bridges that have neither advance warnings nor object markers, there are another 16 pavement-decrease sites with advance warning signs that have no at-bridge object markers. While the lack of object markers may not be too significant a problem in daylight hours due to the presence of advance warning signing, it is of great potential concern at night when a driver does not get needed information about actual lateral clearance at the narrow bridge. Similarly the 38 instances of sight-restricted bridges with complete shoulder loss with neither advance warning nor object marking pose additional safety hazards to drivers. Thus, nearly 13 percent (66/517) of the sight-restricted narrow bridges in the 5000 mile roadway sample lack either advance warning signs, at-bridge object markers, or both. Although sufficient accident data is not available for these sites to make any definitive statements, it appears reasonable to assume that the absence of such warning devices at sight restricted narrow bridges could be expected to create potential safety hazards for drivers. If this is the case, having better than one in ten of all sight restricted narrow bridges

on the nations two-lane rural road system information deficient in such a way could represent no little problem.

Potential safety problems related to the absence of any form of object marking on narrow two-lane roadways subject to an actual pavement decrease or a total shoulder loss are not limited to sight restricted locations. Rather, the total absence of any form of object marking where a pavement decrease or total shoulder loss is involved may well exhibit safety problems at all narrow bridges, particularly at night.

Specifically, it would appear that all narrow bridges should have some type of object markers installed to aid oncoming drivers in positioning themselves in lane to avoid bridge-related obstructions. Use of the advance warning sign would appear to be more directly associated with higher ADT's, where the probability of meeting an oncoming driver on or adjacent to the narrow bridge increases significantly, or where a sight restriction is sufficiently close to the bridge that use of object markers alone is not sufficient.

Certainly, any sight restricted narrow bridge having neither advance warning signs nor at-bridge object markers would seem to possess the potential for a safety hazard. Ninety-four of the 517 sight restricted narrow bridges in the data sample were information deficient in that no signs or markers of any type was presented. Expanding the data sample to the estimated 1.6 million miles of paved two-lane rural roads, indicates that there are in the order of 32,000 information deficient sight restricted narrow bridges on the two-lane rural road system.

#### D. STOP-OR-SIGNAL CONTROLLED INTERSECTION INFORMATION DEFICIENCIES

In their review of intersection accident data Smith et al. (1983) point out that most of the research and analysis of intersection accidents has concentrated on urban intersections, with only limited data available for two lane rural highways. However, based upon the quantification of

accidents from the Kihlberg and Tharp (1968) study they estimate that the accident experience for roadway sections with intersections is two to three times greater than sections without intersections. They go on to point out that because the above numbers are based upon comparisons of 0.3 mile sections, a correction for the area of influence of the intersection would suggest that the actual difference is likely to be three times greater than that noted above on a per vehicle mile of travel basis i.e. the accident rate would be six to nine times greater for intersections.

It should be noted however, that these data are more applicable to intersections serving ADT's of 1,000-5,000 and would not therefore be adequate estimates for many of the low volume intersections sampled in the present study. As the above authors point out, while one would expect intersection accident rate to increase with increasing volume, the increase may be masked for low volume intersections because of the inferior intersection design characteristics of such intersections. While other data on accident frequency are reported in the literature, the results are not consistent from study to study.

The type of accident which is of primary concern with regard to the potential for implementing a successful informational remedy is the multiple vehicle accident in which a driver fails to stop. According to Smith et al. (1983) angle accidents are the predominant multiple vehicle type and constitute 60 percent of all fatal two-lane rural intersection accidents and 80 percent of all such multiple vehicle accidents. Essentially these accidents are caused by a driver on the controlled approach proceeding onto the crossing roadway without appropriate clearance. Such an incident may be due to the available sight distance or to the failure of the driver on the controlled approach to heed the control. While the restricted sight distance problem cannot be solved via an informational treatment, the failure to stop can be reduced if the failure is due primarily to inadequate warning of a sight-restricted approach rather than due to a willful act. Thus the focus of the intersection-related information deficiency analysis is on sight-restricted approaches to STOP sign controlled intersections and the existence or non-existence of advance warning of the traffic control

ahead. Given that 50 percent of the rural intersection accidents are reported by Smith et al. (1983) to occur at STOP sign controlled interesections, the identification of these kinds of deficiencies focuses on the most significant intersection problem that has been identified on the rural two-lane system.

The total data base contained approximately 5,600 intersections. It is important to recall that these intersections are all on roadway sections outside any kind of urbanized area, e.g, village, town, or city. As such, the incidence of any form of intersection control of traffic on these roadways is quite small. A total of only 321 stop-controlled intersections and 64 signal-controlled intersections were recorded by observers. This represents about 7 percent of the total number of intersections traversed. Of these 385 intersections only 105 were sight-restricted, i.e., had approach configurations such that after observing the control, oncoming drivers did not have adequate stopping sight distance in advance of the intersection for the given approach speed. Although these sight-restricted intersections represent only 27 percent of all observed stop and signal-controlled intersections and less than 2 percent of all intersections observed they do merit attention as the potential for accident is great in these situations. Consider that the traffic control device, stop sign or signal, was initially introduced because crossroad traffic volumes were sufficiently great to justify the installation. Thus, if a sight restriction prevents an oncoming driver from stopping in advance of the intersection when necessary, any resulting right-angle accident that might occur would have the potential for being extremely serious.

Table 19 indicates the distribution of stop and signal control intersections observed, by the presence/absence of advance warning and the type of geometry causing the sight restriction.

The figures in table 19 indicate that 57 percent of the sight-restricted stop and signal-controlled intersections (60/105) had no advance warning signing and that these are split between crest vertical curves (24) and sharp horizontal curves (30).

Table 19. Distribution of stop and signal controlled intersections by presence/absence of advance warning sign and sight restriction type.

ADVANCE WARNING	CREST	CURVES		TOTALS	
		MEDIUM (6-10°)	SHARP (> 10°)	N	(%)
With Advance Warning	13	5	27	45	(42.9)
Without Advance Warning	24	6	30	60	(57.1)
TOTALS	N (%)	37 (35.2)	11 (10.5)	57 (54.3)	105 (100)

Although 60 intersections, with the potential for being information deficient, out of a total of some 5,600 observed intersections appears to be an insignificant number (slightly over 1 percent), it is important to note that in nearly 60 percent of those cases where stop or signal control was deemed necessary and a sight restriction occurred, no advance warning sign was provided. Although few in absolute numbers, the large percentage of potential safety problem locations does indicate that jurisdictions do need to look carefully at their rural road stop and signal-controlled intersections, however few in number they may be, to ensure that adequate advance warning is being provided where necessary. Omission of this inexpensive but necessary corrective action can result in accidents with the possibility of tort liability action being initiated against the responsible governmental agency.

#### E. NATIONAL IMPLICATIONS OF THE FINDINGS

A variety of potential information deficiencies were identified as existing in the nearly 5,000 miles of paved two-lane rural roadway observed. If the roadway sample can be considered representative of the paved portion of the 3 million plus miles of two-lane rural roads in the United States, it is possible to provide at least order of magnitude estimates of the total

potential information deficiency problem. A word of caution is in order. The 5,000-mile data sample case is biased toward rolling and mountainous terrain. As such 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 (flat = 31.5 percent, rolling = 58.9 percent, Mountainous = 9.6 percent) with the data sample collected as part of this study (flat = 9.8 percent, rolling = 66.5 percent, mountainous = 23.7 percent), and the average curves per mile by terrain type obtained suggests that the estimated frequency of potential horizontal curve problems might be more in the order of 1 per 30 miles rather than the 1 per 23 miles observed in the field data.

From a review of the frequency of potential information deficiencies observed, by physical feature, the following appears relevant:

<u>Feature</u>	<u>Estimated Average Frequency</u>
Isolated horizontal moderate to sharp curves with no advance warning	1 per 30 miles
Sight restricted narrow bridges without object markers and advance warning	1 per 51 miles
Sight restricted stop/signal controlled intersections without advance warning sign	1 per 79 miles

If the three estimates are grouped, the 5,000 mile data sample contains slightly more than 66 potential information deficiencies, irrespective of type, per 1000 miles of paved roadway. If one accepts the reasonableness of this estimate and assumes a value of about 1.6 million miles of surfaced two-lane rural roads, there may be slightly less than 106,000 potential information deficiencies associated with horizontal curves, narrow bridges, and stop/ signal-controlled intersections on this system. The greatest contributor to the total is horizontal curves, which account for slightly more than half of all potential problem locations.

Although the magnitude of the potential nationwide information deficiency problem is large, it resides primarily on systems under the jurisdic-

tion of local agencies. As such, it is not amenable to direct Federal action. Rather, it is a problem that must be addressed indirectly through technology transfer to (a) sensitize those responsible to recognizing the existence of the problem and (b) provide simple and effective techniques that can be used to identify information-deficient locations and suggest simple, inexpensive solutions.

#### F. INFORMATION DEFICIENT SITUATIONS

During the driving and cataloging of the approximately 5,000 miles of two-lane rural roads, a number of specific situations were identified as being information-deficient. It should be noted that the situational descriptions presented below have been derived from the identification and analysis of the problem sites encountered during the field exercise. As such they represent situations in which one of the staff drivers encountered a guidance level driving problem. Given that the staff drivers were experienced drivers and were alert, even though they were unfamiliar with the sections being driven, it can safely be assumed that these situations are truly hazardous for unalerted, unfamiliar, and perhaps inexperienced drivers. These included the following:

- o Stop-controlled intersections.
- o One-lane bridge.
- o Horizontal curves.
- o Tangential intersections.
- o Intersections with poor navigational signing.
- o Uncontrolled Y-intersections.
- o Railroad grade crossings with rough surface.
- o Weight-restricted bridges.
- o Low-overhead clearances.

The remainder of this section presents brief discussions concerning each of these situations and the common causes that contributed to making them information-deficient. Short of undertaking detailed studies at each location, it is not possible to suggest meaningful solutions to these specific problems, nor is it considered appropriate to do so.

## Stop-Controlled Intersections

During the field survey, a number of stop-controlled intersections were identified as information-deficient. For a majority of them, the view of the stop sign was obstructed by foliage, structures, or alignment but no formally aided information about the STOP sign was provided. An unfamiliar driver, relying totally on the available information, may not be able to stop in time if the STOP sign cannot be seen from a sufficient distance ahead of the intersection.

Even if the STOP sign is visible from a sufficient distance, the stop-controlled intersection can still be information-deficient. Other factors affect the degree to which drivers' needs are adequately satisfied. These factors include the conspicuity of the STOP sign, the visibility conditions, the unaided information present, the informational cues provided by other vehicles, and even the distance from the last STOP sign. A driver, after travelling many miles on roads without STOP signs, may develop an expectancy that STOP signs will not be encountered on that road. When one is encountered, this expectancy may be violated and it may take the driver longer to depress the brake pedal than is normal. In some cases, other vehicles may provide misleading information. For example, on the approach to a T-intersection with foliage obstructing the right leg, a vehicle proceeding left on the left leg prompted the study driver to think the situation ahead was a left curve rather than a stop-controlled T-intersection.

STOP signs also compete with other information sources. Even in rural areas, many objects attract the driver's attention, including grazing farm animals, natural features, and structures. STOP signs must be sufficiently conspicuous to attract the driver's attention and convey their intended meaning when the driver needs it.

Stop-controlled intersections can be information-deficient even if a STOP AHEAD warning sign is provided. Warning signs, in and of themselves, may not adequately satisfy drivers' information needs. If there is nothing to confirm the presence of an intersection or a STOP sign, drivers may

simply choose to disregard or even forget the warning. In other words, drivers tend to believe what they see, rather than what they are told via signs, signals, markings, and other traffic control devices. As an example, on the approach to a stop-controlled intersection was an oversized symbolic STOP AHEAD warning sign with a supplementary advance street name plaque 600 feet from the intersection. Over the next 500 feet, however, there were no other forms of information or visual cues suggesting that an intersection, let alone a STOP sign, was ahead. The approach was tree-lined with foliage creating virtual tunnel vision for the driver, as can be seen in Figure 7. At a distance of only 80 feet, the STOP sign became clearly visible.



Figure 7. Information-deficient approach to a stop controlled intersection.

## Narrow/One-Lane Bridges

During the field survey, many one-lane/narrow bridges were also identified as information-deficient. Most of them were situated on or near horizontal curves. Because of the curvature, the reduced width of the bridges was not easy to perceive.

Even if a ONE-LANE BRIDGE sign is provided in advance, bridges can still be information-deficient. For example, on the approach to a bridge, a ONE-LANE BRIDGE warning sign was encountered approximately 750 feet upstream of the bridge. However, after the driver travelled approximately 600 feet, the bridge was not yet visible. Figure 8 shows the driver's perspective of the roadway scene at a distance of only 150 feet from the bridge. At 50 feet, the entire bridge could be seen, as shown in figure 9. Even at this distance, a driver may not be able to estimate the bridge width because it is distorted by the horizontal curvature. The width of this bridge was only 12 feet! Thus, for this situation, the available information, which included the ONE-LANE BRIDGE warning sign was insufficient.

Other one-lane/narrow bridges were identified as information deficient for a variety of reasons, including use of the wrong warning sign or use of the right warning sign in the wrong place. For example, a location was found where a NARROW BRIDGE warning sign was used in advance of a 15-foot-wide bridge on an 18-foot-wide roadway. At another bridge, a ONE-LANE BRIDGE warning sign was used but it was placed only 100 feet from a 16-foot-wide bridge.

Another common cause contributing to making one-lane bridges information-deficient was the location of type III object markers relative to the bridge abutment/railings. Sometimes, the object markers were displaced to the outside of the abutments, indicating that the bridge was wider than it was. One bridge was found where the object markers were properly located and the unmarked pavement surface was tapered, but where the shoulders actually flared out. At this location, because of the shoulders, formal information about the reduced width of the bridge was weakened by contrary information provided by the road surface.



Figure 8. Information-deficient approach to a 12-foot-wide bridge.



Figure 9. View of the 12-foot-wide bridge from a distance of 50 feet.

Sometimes the need for information about one-lane bridges competes with the need for information about horizontal curves. One situation was encountered which involved a sharp curve followed by a one-lane bridge. The upstream section of roadway consisted of three sharp horizontal curves separated by tangent sections. In advance of the three horizontal curves were symbolic turn warning signs with 15 mi/h advisory speed plates. On the approach to the sharp curve preceding the downstream one-lane bridge, the roadway appeared to curve gradually to the left as can be seen from the photograph shown in figure 10, which was taken 225 feet from the point of curvature. A warning sign with the nonstandard legend 2 ONE-LANE BRIDGE and a supplemental 15 mi/h advisory speed plate was located slightly upstream of the curve. While there was formal information about the one-lane bridge, there was no formal information about the curve. The unaided information provided by the roadway environment did not indicate the sharp degree of curvature. Because the information was inconsistent and incomplete, trouble was experienced negotiating the curve. (The number 2 in the 2 ONE LANE BRIDGE sign referred to a second bridge 500 feet around the curve and downstream of the first bridge.)



Figure 10. Information-deficient approach to a sharp curve followed by a one-lane bridge.

## Horizontal Curves

Numerous horizontal curves were identified as information-deficient. To a great extent, design inconsistency, which causes driver expectancy violations, contributed to the information deficiencies. On a rural road with many curves, it was common to find one curve that was much sharper or longer than the other curves. If all the curves were designed similarly, then drivers, after traversing the first few curves, would expect the remaining curves to be similar. However, when one curve is not similar in its geometric characteristics (e.g., degree of curvature, length, superelevation, etc.), then driver's expectancies are violated. During the field survey, many curves that were inconsistent with upstream curves did not have any formal information. Consequently, these were identified as information-deficient.

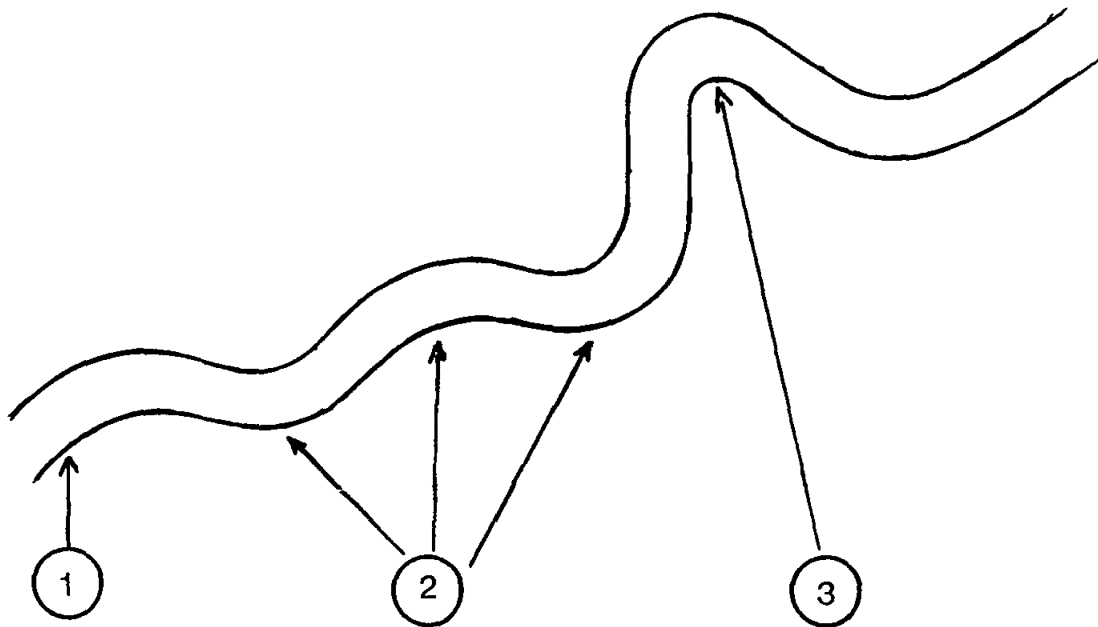
Inconsistency of information was another factor that contributed to information deficiencies at curves. Currently, many different informational treatments are used at curves. These include symbolic advance warning signs with and without advisory speed plates, series of post-mounted delineators, chevron alignment signs, series of raised or recessed pavement markers, large arrow signs, and combinations thereof. During the field survey, curves with similar geometric characteristics were found which had different informational treatments. Even within the same geographic areas, some curves had chevron signs, but other similar curves with similar approach alignments did not. Some curves had advance warning signs with advisories, other similar curves had advance warning signs without advisory speed plates, and some similar curves did not even have any advance warning signs.

These inconsistent informational treatments contributed to making the consequences of missing information more severe. For example, if drivers expect advisory speed plates on curve warning signs, then they may expect that a curve without an advisory speed plate does not require a reduction in speed. If the curve does indeed require a significant speed reduction, then a driver may be totally surprised, respond late, incorrectly, or not at all, and possibly run off the road.

There is great potential to provide supplementary (coded) information to drivers through consistent informational treatments. For example, if large arrow warning signs were always used at the apex of short sharp curves and chevrons were always used for long sharp curves, then drivers would learn vis-a-vis their experience that these signs transmit different information as to length and sharpness of horizontal curves.

Another point to make about information-deficient curves is that the need to provide information about curves often competes with the need to provide information about other geometric features including intersections, one-lane/narrow bridges, and railroad grade crossings. During the field survey, many intersections and bridges were located on or near horizontal curves. Several of these situations were identified as being information-deficient because one or both information needs were not completely satisfied. Depending on the available natural information provided by the roadway environment, there may be a need to provide formal information about both the curves (and if necessary, the safe curve speed) and the intersection or one-lane/narrow bridge.

One of the most important findings of the field survey was that drivers' informational needs are not being satisfied by the winding road advance warning signs, and in some cases, the reverse curve advance warning sign where an internal curve of the winding road section or the second curve of the reverse curve is sharper than the first curve. A sketch of this situation is shown in Figure 11. Reverse curves and winding road sections that fit this description were frequently identified as information deficient. The differences in the degrees of curvature between the first curve and the second or internal curve for these information-deficient reverse curves and winding road sections were substantial. Even if advisory speed plates were attached to the advance warning signs, difficulty was still experienced in negotiating the sections with second curves or internal curves much sharper than the first. Because of the current inconsistency in signing curves in many parts of the country, it is hypothesized that drivers, after traversing the first curve (which is less sharp than the downstream curves), expect that they can take the subsequent curves at speeds higher than what would be considered the safe curve speed.



1. Winding Road Warning Sign With Speed Advisory
2. Gentle Curves Not Requiring Speed Reduction
3. Sharp Curve Requiring Speed Reduction

Figure 11. Example of information-deficient winding road section.

Curves which were much longer than upstream curves and compound curves were also frequently identified as being deficient because needed information was not present or provided. Several sharp horizontal curves following crest vertical curves were also identified as being information deficient. On the approaches to the crest vertical curves of these information deficient situations, the treelines and/or telephone lines often appeared as though the roadway was tangent beyond the hillcrest. Moreover, formal information about the downstream curve was not provided. Consequently, there was considerable surprise when the horizontal curve was encountered after the hillcrest. In a few cases, a curve warning sign was provided but it was located after the crest such that it was not visible on the approach to the crest.

### Tangential Intersections

Another information-deficient situation, encountered frequently, was a horizontal curve with a side road or driveway that tangentially intersects the curve, as shown in plan view in figure 12. For a majority of these information-deficient situations, the tangentially intersecting side road/driveway was of a lower design than the approach. Figure 13 provides an example of an information-deficient horizontal curve with a tangentially intersecting side road. The road actually curves left, despite the fact that the telephone poles and lines provide misleading information that the road continues straight ahead.

At other information-deficient tangential intersections, the telephone lines, tree lines, and foliage along the outside edge of the road transmit natural information that the road goes straight. Even if appropriately placed and appropriately presented information is provided via signing, the natural information is so strong that it conflicts with or even overpowers the formal information. Except for a few counties and States, the use of a modified curve warning sign, as shown in figure 14, is extremely limited. If formal information is provided it is usually a standard turn or curve advance warning sign or a large arrow sign. These devices do not adequately satisfy the driver's information needs in advance of these

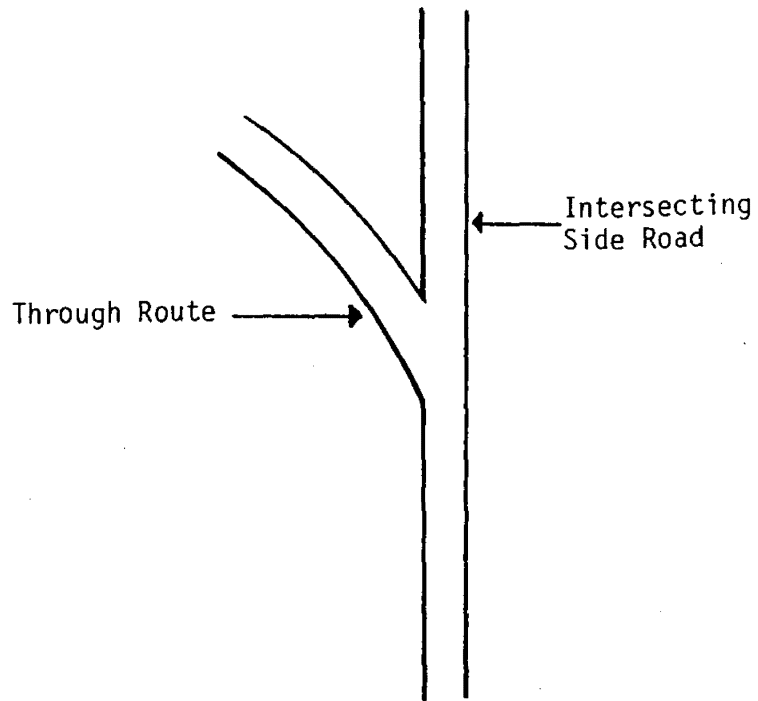


Figure 12. Plan view of tangential intersection.



Figure 13. Information-deficient horizontal curve with a tangentially intersecting side road.

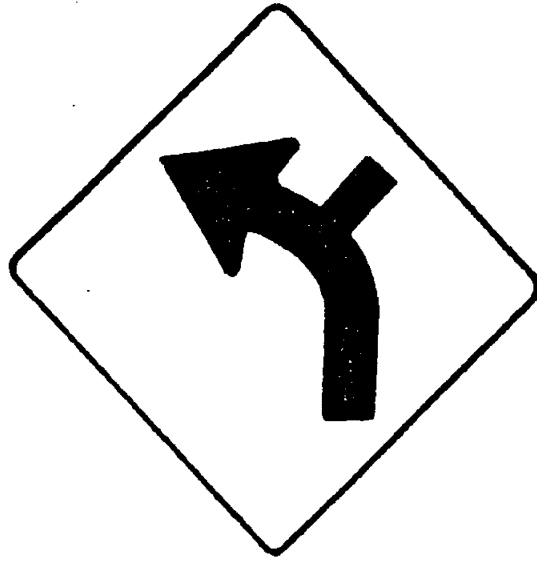


Figure 14. Modified curve warning signs.

situations. Quite often, the staff drivers were surprised by the presence of the intersecting side road when these tangential intersections were encountered despite the presence of a standard curve or turn warning sign. This was especially true when a vehicle was on the side road approaching the intersection.

In several instances, the tangentially intersecting leg was actually a driveway. However, on the approach, the driveways appeared to be a continuation of the through route. It was not until one was extremely close to the intersection that it was possible to determine that they were driveways. An example of such an information-deficient situation is illustrated in figure 15, which shows the driver's perspective from a point 265 feet upstream of the point of curvature for a left horizontal curve. At approximately this distance, the staff driver, based on an interpretation of information provided by the roadway environment, expected the road to curve up the hill. In reality, this is a driveway and the road curves left. To the left of the driver's direct line of sight is a large left arrow warning sign. This sign is located beyond the point of curvature and beyond the apex of the curve.



Figure 15. Information-deficient curve with a tangentially intersecting driveway.

For many of these information-deficient tangential intersections, the sight distance to the roadway surface of the curved continuation leg was slightly obscured by either a small crest vertical curve or by roadside foliage. These sight distance restrictions did not allow the driver a clear preview of the main roadway.

During the field survey it was frequently observed that both the curve geometrics and the intersection geometry were substandard at these tangential intersections. In addition, the consequences of driver error at right curves with tangentially intersecting roads is more severe than the consequences of driver error at left curves with tangentially intersecting roads.

On a right curve with tangentially intersecting side road, the driver continuing straight must cross traffic. This exposes the driver to possible head-on, side-swipe/opposite direction, and angle collisions.

## Intersections with Poor Navigational Signing

Another geometric situation which was frequently found to be information-deficient was an intersection that requires the driver to turn in order to continue on the signed/designated route. Figure 16 presents a sketch of this type of intersection. Although the focus of this research was on information needs related to the guidance level of the driving task, guidance performance problems were encountered at these intersections due to the lack of navigational information. In the absence of adequate navigational information prior to the intersection, the unfamiliar driver is likely to expect that the designated route continues straight ahead through the intersection. This is especially true when the two roads are of similar design.

An example of this type of information-deficient situation is illustrated in figure 17, which shows the driver's perspective at a distance of 75 feet from the intersection. Although there is a county route designation sign present it has such low conspicuity that it would not attract the driver's attention. An unfamiliar driver approaching this intersection may believe, on the basis of the information available, that the correct maneuver is to go straight ahead. If this path was followed the driver would be on a different route than intended.

When navigational information was present at these information-deficient types of intersections, it was often inadequate. Sometimes, home-made signs were put up by local residents who were tired of giving directions. At other locations, the highway signs were small or improperly placed.

There is a greater need to provide formal navigational information when the natural information transmitted by the roadway is misleading. The resulting driver performance problems were also worse when the continuation leg of the designated route was of a different design (e.g., surface width, surface type, presence/absence of centerline) than the approach while the non-continuation roadway with a different route designation was of the same design as the approach. An example of such an intersection is shown in figure 18. A driver must turn left at this intersection to stay on Route 611.

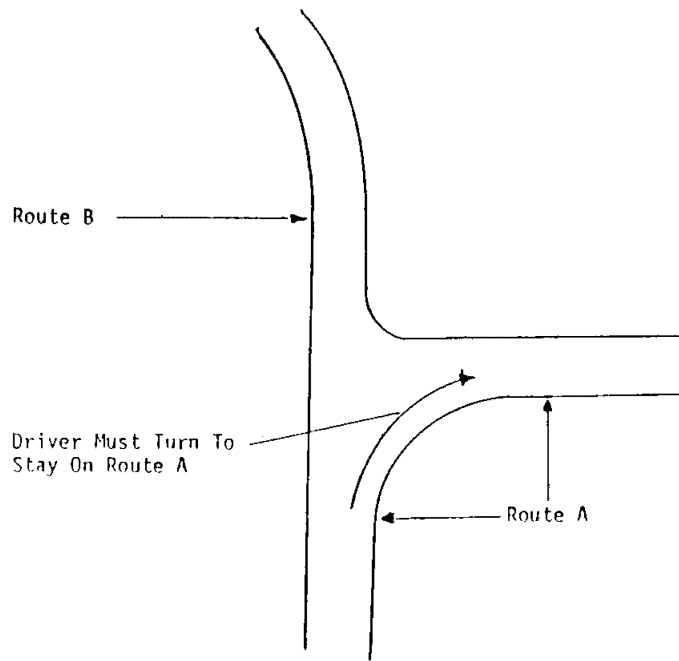


Figure 16. Plan view of intersection with poor navigational signing.



Figure 17. Driver's perspective of information-deficient intersection from 75 ft.



Figure 18. Intersection with misleading natural information.

### Uncontrolled Y-Intersections

Another geometric situation frequently identified as information-deficient is the uncontrolled Y-intersection. At a majority of these situations, there was insufficient navigational information which, in turn, caused guidance performance problems for the staff drivers during the field survey. Quite often a driver approaching a Y-intersection is not able to discern which route to take. Sometimes this will require slowing down or even stopping to check a map or directions, provided a proper route decision could be made. During deceleration or while the vehicle is stopped, there is a greater probability of being rear-ended by another vehicle, especially if the driver of that vehicle is familiar with the local road system. There is also a greater probability of drivers getting lost, resulting in wasted travel and fuel.

An excellent example of an information-deficient Y-intersection is contained in figure 19, which shows the driver perspective of the Y-intersection from a distance of 125 feet. Because there is no formal navigational information present, an unfamiliar driver may not know which way to go, especially since the two legs look almost identical. Figures 20 and 21 show views of the left and right legs, respectively, of this intersection.

Most of the uncontrolled Y-intersections identified as being information-deficient had legs which were very similar in pavement type, pavement surface quality/texture, and pavement width, but did not have any navigational information present. Even if a standard symbolic Y-intersection advance warning sign was present, difficulty was experienced in selecting the proper route where the surfaces of the two legs were of similar quality. In fact, at these types of intersections, formal guidance information alone does not adequately satisfy the driver's need for information. Formal navigational information is required, but frequently not provided, in any format. For this situation treated natural information may be sufficient to satisfy the driver's need. For example, the textures or surface qualities of the two legs could be differentiated so as



Figure 19. Information-deficient, uncontrolled Y-intersection.



Figure 20. Left leg of information-deficient Y-intersection.



Figure 21. Right leg information-deficient Y-intersection.

to provide information that one of the two legs is the continuation leg for the through route. In considering this type of treatment, care should be taken to ensure that the information available during nighttime conditions also adequately satisfies the unfamiliar driver's needs.

### Railroad Grade Crossings with Rough Surfaces

Another situation encountered in the field and identified as being information-deficient was a railroad-highway grade crossing with a rough crossing surface. In the survey, over 5,000 miles of two-lane rural roads, including a number of rough crossings, were encountered that provided no formal information concerning the crossing surface or the safe crossing speed. Data from the U.S. D.O.T/A.A.R National Rail-Highway Crossing Inventory indicates that approximately 29,000 grade crossings have unconsolidated surfaces (e.g., ballast or other unconsolidated material placed above the tops of crossties, with or without planks on one or both sides of the running rails). An example of an information-deficient railroad-highway grade crossing is illustrated in figure 22. This slide, taken at a distance of only 30 feet from the crossing, clearly shows the roughness of this crossing.

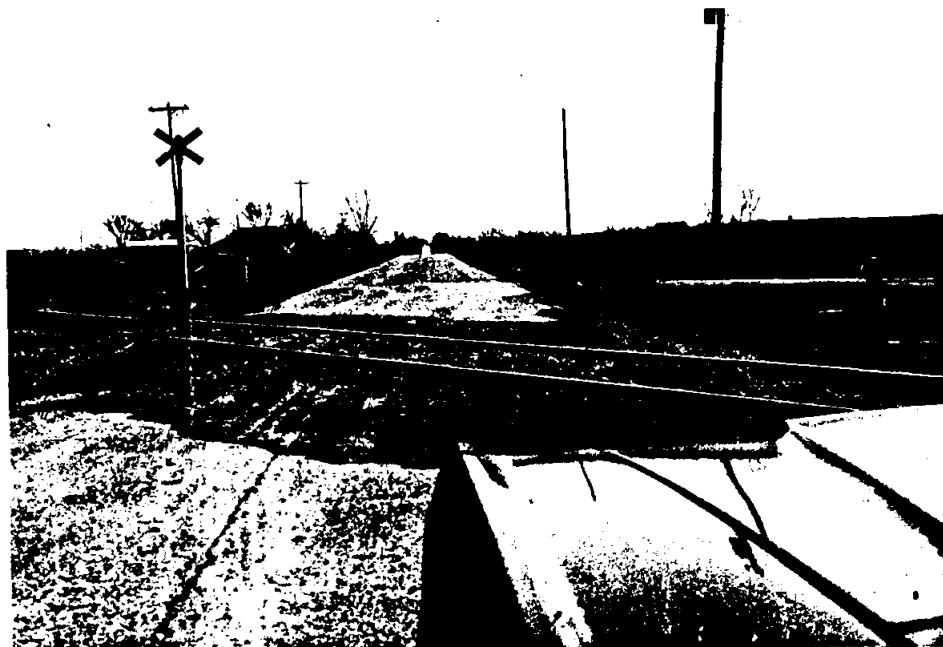


Figure 22. Information-deficient railroad-highway grade crossing

## Weight-Restricted Bridges/Overhead Restrictions

Although the staff drivers had few difficulties with weight-restricted bridges and overhead restricted clearances, formal interviews with several truck drivers indicated that these situations are frequently deficient in information for truck drivers. The truck drivers indicated that there is often no advance information about the weight limit or the clearance restriction; or, if it is provided, it is located too close to the situation to make selection of an alternate route possible. Truck drivers have to backup or turn their rigs around on narrow roads when these situations are encountered. Some truck drivers have been known to cross bridges with loads exceeding the restricted limits because the proper information was not received in the proper location and the driver did not want to turn around. Even when adequate advance information is provided, the detour or bypass routes are not adequately signed for truck drivers to easily navigate back to the original route. In addition to drivers of trucks, drivers of recreational vehicles and buses also have problems with these situations when inadequate information is provided.

### G. INFORMATION-DEFICIENCY CATEGORIES

Analysis of the various specific information deficient situations identified in the field enables identification of ten distinct types of information deficiencies. A deficiency was considered to exist if the information was:

- o Missing.
- o Incomplete.
- o Too Much.
- o Unnecessary.
- o Misleading.
- o Confusing/Conflicting.
- o Inappropriately Located.
- o Inappropriately Presented.
- o Externally Obstructed.
- o Inconsistent.

To some degree, several of these types overlap. For example, inappropriately located information may contribute to the creation of confusing information. Inconsistent information may result from the providing of unnecessary information along with certain missing information. A later section of this chapter briefly describes these types of information deficiencies.

It should be noted that it is not necessary to accurately identify the specific type of deficiency as part of the suggested procedure developed to assist jurisdictions in detecting information deficiencies (reference volume II). Rather, what is important to understand is that there are a variety of ways in which a specific situation can be information-deficient.

The remainder of this section presents each of the ten types of information deficiencies and briefly discusses how it might occur.

Missing Information occurs when the needed information is not provided. Consider, for example, a sight-restrictive crest-vertical-curve followed by a sharp horizontal curve that requires a speed reduction. Because the driver's view of the road prevents a perception of the need for a speed reduction, formal information about the curve is necessary. If this information is not provided through signing, then an information deficiency would exist.

Incomplete Information occurs when the information provided does not completely satisfy all of the driver's needs. In other words, the driver does not get enough information to be certain of driving task requirements of the situation. Examples of incomplete information include warning signs with the legends SLOW, CAUTION, and DANGER. An example of incomplete information is illustrated in figure 23, which shows a warning sign with the legend SLOW and a 25 mi/h advisory speed plate. The diamond shape of the sign and yellow background transmit warning information to the driver. However, the legend SLOW, does not convey to what the warning applies (e.g., narrow bridge, deer crossing, stop ahead). Consequently, the driver does not receive the needed information as to why a speed reduction should take place.

Too Much Information occurs when too much information is presented for the driver to process in the time available for the given operating speed. The attention demands brought about by the particular location and associated task loadings and subtask interactions are such that the driver does not have the load-shedding or information-processing capacity to handle all requisite demands. As a result, the driver may miss needed signals or make errors because of exceeded capacity. Examples of too much information include situations where too many signs are placed in close proximity to each other or where there is too much legend on one sign. A specific example of too much information is illustrated in figure 24, which shows a warning sign with the legend DIP DANGER FLASH FLOODING DO NOT ENTER IF FLOWING.

Unnecessary Information occurs when the information displayed is not needed. The consequences of this type of information-deficiency are not as severe as the other types of information deficiencies. However, the practice of providing information when it is unwarranted or redundant may intensify the problems at other locations where needed information is missing. The practice of oversigning may raise drivers' expectations regarding signing. A common example of this type of deficiency would be a very gentle curve, say 2 to 3 degrees, with an advance curve warning sign. Another might be a curve with many more post-mounted delineators and/or chevron signs than are needed. It is emphasized that redundant information may be desirable in some locations where it has to fight for the driver's attention along with many other visual stimuli. At other locations, however, it may be unnecessary and wasteful of resources.

Misleading Information occurs when the information available is not only incorrect or incomplete but is such that it misleads the driver. Specific information transmitted from the highway scene can be misleading as well as information transmitted by traffic signs. An example of misleading information transmitted by signs would be a location with advance work zone warning signs where the reconstruction has been completed. An example of misleading information transmitted by the highway scene would be a sight-



Figure 23. Example of incomplete information.



Figure 24. Example of too much information.

restrictive crest-vertical-curve with trees beyond the crest providing information that the road goes straight when, in actuality, the road curves immediately after the crest.

An example of a situation with misleading information is given in figure 25, which shows a narrow bridge with a centerline across it. The centerline provides information (via implication from past association) that there is enough width for two vehicles to safely pass each other on the bridge. However, the width from bridge rail to bridge rail is only 15 feet! This situation is further compounded by the fact that the reduced width is not easily perceived by the driver because the bridge is situated on a slight reverse curve. In fact, on the approach, the distance between the type III object markers may lead the driver to believe that the bridge is much wider than is actually the case. If a driver does not perceive the reduced width and an oncoming vehicle attempts to cross, the driver may have to brake sharply before the bridge or, even worse, may crash into the bridge abutment or the oncoming vehicle.

Confusing Information occurs when the information displayed is ambiguous or conflicts with the information provided by the roadway environment. Examples include locations with multiple sets of pavement markings and locations where warning signs with speed advisories are followed by regulatory speed limit signs.

An example of confusing information is illustrated in figure 26. In actuality, there were a series of horizontal curves between the tangent approach in the foreground and the tangent section in the background. However, from the driver's perspective, it appears that the road curves sharply to the right and that the tangent section in the distance may be on an intersecting road. Even though the sign correctly warned of the situation ahead, the visual scene provided strong information suggesting a different situation ahead. The result is that the driver may be confused by the apparently conflicting information. This figure also exemplifies another type of informational deficiency related to the location of signs. As can



Figure 25. Example of misleading information.



Figure 26. Example of confusing information.

be seen, the winding road warning sign is located too close to the point of curvature of the first curve to provide adequate response time to the drivers.

Inappropriately Located Information occurs when the information displayed is not in its optimum location. For displayed information to be effectively conveyed, the driver must have sufficient time to process the information and respond to it. For example, warning signs placed very close to the hazard to which they apply do not provide information at the location where the driver needs it most. On the other hand, if the warning sign is placed too far upstream, drivers may forget it because of intervening events or else assume it is erroneous. Inappropriately located signs present particular problems at night when the driver relies more heavily on the information provided by signs and marking than on the view of the road ahead.

Inappropriately Presented Information occurs when the information displayed is not in its optimum form. Examples of inappropriately presented information include markings and signs that do not conform to the uniformity principles of the Manual on Uniform Traffic Control Devices (MUTCD), signs with word legends when standard symbols would be more quickly recognizable, and delineation which could be more effective if transmitted by means of another device. An example of a sign with an inappropriate presentation of information would be a diamond-shaped sign with the legend "SLOW DANGER ONE LANE BRIDGE" in white letters on a red background. Although this is a unique sign that may attract a driver's attention, it violates the MUTCD color code and at night could be mistaken for a STOP sign. Moreover, regardless of its possible effectiveness, a sign of this type would be considered in violation of accepted practice (MUTCD) in a tort liability case. The appropriate presentation would be a ONE LANE BRIDGE legend in black letters on yellow background with a black borderline, along with the use of a speed advisory plate if a speed reduction was warranted.

Externally Obstructed Information occurs when the needed information is obstructed by foliage and/or roadside objects (e.g., telephone poles, light poles, other signs, bridge abutments, etc.). The most common cause of this

type of information deficiency is foliage. Examples would include locations where a sign is partially or even totally obscured by foliage and locations where the edgeline is covered by sand.

Inconsistent Information occurs whenever the content, manner, or location of information varies from place to place along a section of roadway. As such, it has a broader definition than do the other nine defined types discussed earlier. Although it is difficult to illustrate this type of information deficiency, an example would be a section of road for which some curves have curve warning signs with advisory speed plates and other almost identical curves have curve warning signs without advisory speed plates. This type of deficiency causes particular problems for the driver when the first curve or group of curves encountered have advisory speed plates and later curves do not have advisory speed plates. Other examples of inconsistent information include the inconsistent use of chevrons, large arrow signs and post-mounted delineators on curves and inconsistent signing in advance of speed zones.

## V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A large number of information deficiencies were shown to exist on the two-lane rural roadway system, particularly in the lower design, lower volume roadways sampled in this study. This finding coupled with the findings of previous studies indicating that accident rates are considerably higher for certain situations on the two-lane rural system i.e. curves, intersections, narrow bridges, suggests that something must be done to begin to alleviate these problems. While economic considerations preclude making all of the physical changes necessary to prevent a large proportion of the 34 million accidents that could occur on the rural two-lane system over the next 20 years (Smith et al. 1983), nearly all of the information problems can be corrected by the use of conventional traffic control device. Even this minimal treatment can be expected to have a positive effect on accident reduction.

The informational elements of concern were pavement striping and signing. With regard to pavement striping it was found that 48 percent of the paved roadways sampled had no pavement edge markings. Of the roadway mileage with no edge striping nearly 38 percent had a sufficiently clear definition of the roadway edge that a driver could differentiate between the road edge and the shoulder. However, slightly more than 10 percent of the total paved mileage in the sample was characterized by unclear roadway edges, thus providing poor path definition for the driver. While some of this mileage was on roadways with insufficient pavement width to warrant edgelines, it would seem that shoulder maintenance, at least to the extent of providing clear differentiation between the road edge and the shoulder, would be warranted.

With regard to signing, the analysis of deficiencies focused upon more specific geometric situations i.e. curves, narrow bridges, and stop/signal-controlled intersections. Of these situations, curves accounted for the greatest number of deficiencies. Based upon a sample of slightly more than 12,000 curves it was found that approximately 26 percent of the curves were isolated i.e. preceded by a tangent section of 1,000 feet or greater.

From the standpoint of curve-related information deficiencies it is the sharper (i.e., 6 degrees or greater) isolated curve which is of greatest concern because of the potential difference between tangent approach speed and safe curve speed. About 11 percent of the total curves in the sample met the joint criteria of degree of curvature and isolation. Of these moderate or sharp isolated curves nearly 57 percent had no advance warning signs. An analysis of these curves, using the measured tangent approach speeds and assuming average superelevation and friction values, showed that nearly 27 percent represented information deficiencies. Adjusting for the overrepresentation of mountainous and rolling terrain in the sample this averages to one information deficient curve for every 30 miles of paved roadway in the sample. Applying this estimate to the 1.6 million plus miles of paved two-lane rural roads in the United States, the total number of information deficient curves would be on the order of 53,000.

The next most frequent type of deficiency was associated with narrow bridges. Of the approximately 700 narrow bridges identified 74 percent were sight restricted i.e. were preceded by a vertical or horizontal curve within a specified (speed-dependent) distance in advance of the bridge. Of the sight restricted narrow bridges nearly 86 percent had no advance warning. The statement of this fact is not meant to imply that all such bridges constitute an information deficiency. That is, the traffic volumes (and the associated probability of meeting an oncoming vehicle) may be such that advance warning is not necessary if hazard panels are used to mark the bridge. However, until more is known about the causes of narrow bridge accidents, the combination of sight restriction and lack of advance warning is a condition that must be considered a potential contributor at least for multiple vehicle accidents. Considering the fact that narrow bridges appear to have a greater influence on single vehicle accidents (Smith et al. 1983) an information deficiency that is more likely to be associated with accidents is one related to the presence or absence of hazard panels which show the extent of the constriction. Further as bridges become narrower relative to the approach pavement i.e. pavement decreases as opposed to shoulder decreases, the hazard of not providing hazard panels in all

likelihood increases. It was found that 75 percent of all of the narrow bridges that involved a pavement decrease occurred where pavement widths are 20 feet or less. Thus an already narrow roadway condition is frequently made even worse at a narrow bridge. Further almost 16 percent of the sight restricted narrow bridges involve pavement decreases and nearly 15 percent of these have neither advance warning nor any form of at-site object marker. Although the absolute number of such problem locations is small, if one accepts the study sample as being representative of the two-lane rural road system, the findings translate into nearly 5,000 of the worst case problem locations. However, considering all narrow bridges i.e. bridges with any degree of restriction, that have neither advance warning or object marker/hazard panels, there are slightly more than 30,000 estimated problem locations.

While the total number of stop/signal controlled problem intersections encountered was not great, the potential severity of accidents at intersections is significant for those intersections at which there is an increase in the probability that a driver may fail to stop on the controlled approach. Approximately 27 percent of the stop/signal controlled intersections were found to have some sort of sight restriction i.e. had approach configurations such that after observing the control device the approaching driver did not, at the approach speed, have stopping sight distance in advance of the intersection. Of these sight-restricted intersections, 57 percent had no advance warning of the control. There are estimated to be slightly more than 20,000 stop/signal controlled intersections that are sight restrictive but have no advance warning of the control.

Translating the various types of information deficiencies to a per mile basis, it was found that there are approximately 66 deficiencies per 1,000 miles. Using the value of 1.6 million miles of paved rural two-lane roadway there are estimated to be about 106,000 potential information deficiencies associated with horizontal curves, narrow bridges and stop/signal controlled intersections. The greatest contributor to the total is horizontal curves, which account for approximately half of all potential problem locations.

What is not known with any degree of accuracy is the extent to which any given information deficiency is likely to produce accidents. It was found that the severity of a given type of deficiency is highly dependent upon the context within which it occurs. Because of this fact, decisions as to whether a deficiency is severe enough that it should be alleviated must be made at a local level on the basis of a field evaluation and in terms of local funds available. That is, the severity and cost effectiveness of correcting the deficiencies must be judged by the local jurisdiction on the basis of factors such as traffic volume, percentage of unfamiliar drivers, accidents, etc. The fact that we cannot recommend Federal guidelines for assigning priorities to eliminating a given type of deficiency is irrelevant at this point. The most significant and real problem in the field is the vast number of local jurisdictions that control a large proportion of the two-lane rural system without formal procedures or programs to identify accident problems that might be remediated via informational treatments. The fact that correcting information deficiencies has been judged to be the most cost-effective means of reducing accidents on the two-lane rural system suggests that systematizing procedures for local identification of informational problems would make a significant contribution to enhancing overall safety on the rural two-lane system.

The first step in aiding local agencies in the identification of and solution to information problems has been the procedure and the associated information deficiency checklists (reference, volume II- Simplified Location of Information Deficiencies [SLIDE] - a Procedure) developed under the current contract. In order to obtain an indication of the technical acceptability in the potential user community, the procedure was presented and demonstrated at two regional workshops.

The majority of the State and local agency participants attending the workshops were positive about the procedure. State representatives generally indicated, however, that their agencies already have programs to identify deficient locations (e.g., hazardous locations) via accident

records, thus they would not be as likely to adopt the entire procedure. Local jurisdiction representatives, on the other hand, indicated that they did not have such programs and thought the SLIDE procedure would be very useful to them. All workshop participants thought that the procedure, based on the exposure they experienced in the workshops, would heighten the sensitivity and awareness of the driver/investigator making it possible to better judge information deficient locations. Further, many felt that the procedure could be exercised in conjunction with other tasks that are currently done. Several indicated they would attempt to implement the procedure but felt the need for better training-oriented documentation and/or direct training.

Before the SLIDE procedure can be offered to local agencies it is recommended that some study effort be devoted to determining the type of training that is most cost effective and the minimum time required for various types of training. A study effort of this sort could be handled in much the same fashion as the demonstration programs for Positive Guidance. That is, different local agencies would be provided with various types of training and their ability to identify informational problems would then be assessed. The training programs could conceivably vary from video/film oriented presentations to intensive one-on-one, "on-the-road" training.

The conduct of such a series of demonstration program/training research sessions would also provide valuable suggestions from field personnel as to desirable procedural modifications necessary to more adequately accommodate variations in local conditions.

Once the most cost effective training requirements and procedures are determined, the next step would be to identify the best means to introduce the SLIDE procedure to the field. Because the bulk of the problems are in local jurisdictions the use of existing technology transfer programs such as the Rural Technical Assistance Program (RTAP) would appear to be the most likely dissemination mechanism. Since RTAP currently makes specialists in transportation available to local communities and agencies and arranges conferences and seminars the sort of effort recommended here would appear to

be possible within the existing framework. Note that regional FHWA training seminars could be held to train RTAP personnel to, in turn, provide training for local agencies.

The second major recommendation is a longer range research effort. To date there has been relatively little data available which describes the roadway or informational characteristics of the two-lane rural system (particularly the lower design end of the system that comprises a great deal of the total mileage). There is also relatively little accident information available for roadways in this class. This contract has produced an accurate 5,000-mile data base of roadway and information characteristics. It would be wasteful if this data base were not used to broaden our knowledge of the two-lane rural system. It would seem that the information in the data base could be used as a basis for selecting a number of sites and sections for long-term collection of accident data that can be analytically tied to known informational and roadway characteristics.

Such information would eventually provide a sound safety related basis for assignment of priorities to programs for upgrading both the physical and informational characteristics of the two-lane rural roadway system. In other words, accurate correlational data between accidents and roadway and informational characteristics could act to identify more specifically where the focus of both upgrading and research should be in order to ultimately reduce the predicted number of accidents that might otherwise occur. Further, by continuing the collection of accident information beyond the periods in which upgrading changes are implemented, it would be possible to accurately assess accident reduction benefits of the changes.

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