Sign Advisory System for Low-Volume Roads

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Development of a prototype expert system for signing low-volume roads is described. The system consists of the following four modules: (a) basic sign training and overview, (b) determining the need for signs, (c) determining the size of guide signs, and (d) sign placement. The system is intended to be used as a training tool for personnel with limited traffic control device design or placement experience. It is also intended to be used as one resource to aid in the selection, procurement, placement, and installation of appropriate road traffic control devices. The system was evaluated by the Forest Service field units with favorable response. It was also felt that the system may be useful to other federal and county agencies. Therefore, the system was submitted and subsequently approved as a Coordinated Federal Lands Highways Technology Improving Program (CTIP) project. The Forest Service is currently working with the CTIP agencies and National Association of County Engineers in the system development effort.

This paper describes the development of a prototype expert system for signing low-volume roads. The prototype system was developed for demonstration purposes and is not ready for implementation. The system consists of four modules: basic sign training and overview, determining the need for signs, determining the size of guide signs, and sign placement.

Many government agencies do not have traffic engineering expertise available wherever and whenever needed because of personnel and budget limitations. At times, the planning, design, and installation of traffic control devices are the responsibilities of personnel who are not trained or experienced in traffic engineering or the application of the *Manual on Uniform Traffic Control Devices* (MUTCD) (*1*). This situation increases the potential for incorrect installation of traffic control devices and other signs, and may lead to unsafe conditions and other undesirable results, including increased costs.

In the Forest Service, many experienced personnel with technical sign expertise are approaching retirement. To retain their expertise, the Forest Service decided to develop a road sign advisory expert system for use as a training tool for personnel with limited traffic control device knowledge and experience. The system may also be used to aid in the selection, procurement, placement, and installation of appropriate traffic control devices.

The developed prototype system contains a first-stage module for personal computers using artificial intelligence. This module addresses warning signs pertaining to horizontal alignment. The artificial intelligence system queries the user about site and traffic conditions and interactively provides written and visual guidance for proper sign selection, sizing, and installation on the basis of published standards.

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The module was evaluated by Forest Service field units. Responses were favorable and supportive of further module development. Initial indications were that the system could provide needed training and also serve as a user-friendly signing information resource for those not skilled in traffic engineering. In May 1990, the Road Sign Advisory Expert System was selected as a Coordinated Federal Highways Technology Improvement Program (CTIP) project. The Forest Service is working with the CTIP agencies and National Association of County Engineers (NACE) to expand the prototype system to cover the whole spectrum of warning signs and selected regulatory signs (i.e., Stop, Yield, and Speed Limit) for conventional and special purpose roads. Other sign categories will be included following completion of this work. The CTIP agencies include Federal Highway Administration, Bureau of Land Management, National Park Service, Forest Service, and Bureau of Indian Affairs. This development work is expected to be completed by the end of 1991.

THE MAKEUP OF THE EXPERT SYSTEM

An expert system is a computer program that performs at the level of a human expert in a complex but narrow field and uses human traits such as logic to solve problems. It is composed of a knowledge base and an inference engine. The knowledge base is made up of data and rules by which conclusions are reached. The data may be either factual, heuristic, or empirical. The inference engine is the problem-solving component of the expert system. It includes a collection of processing procedures for examining data-using rules.

Software and Hardware

IBIS (*2*), a commercial system shell for developing expert systems, was used for this sign advisory system. It provides the framework for building expert systems in the same manner as templates are built for accounting spreadsheet programs. Hardware requirements for IBIS are IBM-compatible MS–DOS machines with 512K ram memory and printer. A DOS version 2.0 or higher is required. Printer may be either HP Laserjet or Epson compatible.

Knowledge Base

Two different types of knowledge used in engineering practice are deterministic and heuristic. Deterministic knowledge is

preserved in references, manuals, handbooks, and textbooks. Heuristic knowledge is the subject matter knowledge possessed by individuals, characterized by beliefs, opinions, experience, and rules of thumb.

Most of the knowledge base data used for this system is deterministic knowledge obtained from MUTCD (*1*), *Manual of Traffic Engineering Studies* (*3*), and Forest Service handbooks (*4*). Heuristic knowledge was obtained from several Forest Service engineers and technicians with road signing experience. Much of the heuristic knowledge was related to determining the need for signs.

SYSTEM DEVELOPMENT

The long-term objective is to develop an expert system that will eventually include the following sign categories and other traffic control devices:

1. Regulatory signs,
2. Warning signs,
3. Guide signs,
4. Construction and maintenance signs,
5. Motorist services signs,
6. Recreation and cultural interest area signs,
7. Tourist-oriented directional signs, and
8. Markings.

Initial development was limited to those warning signs related to changes in horizontal alignment.

The system's four modules are (a) basic sign training and overview, (b) determining the need for signs, (c) determining the size of guide signs, and (d) sign placement (Figure 1).

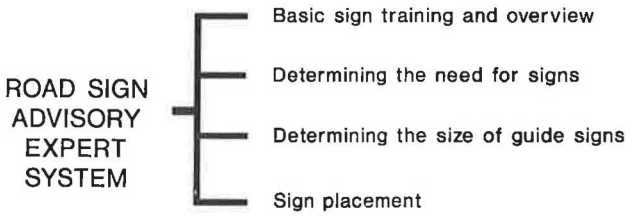

FIGURE 1 Structure of the road sign advisory expert system.

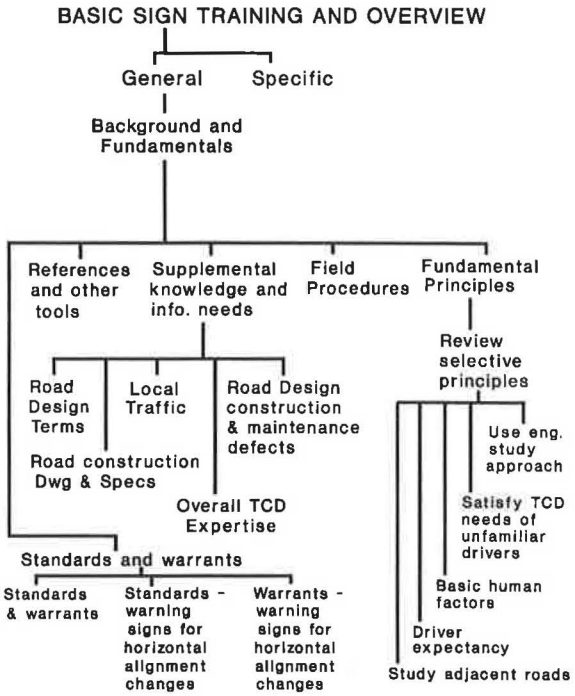

FIGURE 2 General information of basic sign training and overview.

Module 1—Basic Sign Training and Overview

Information included in this module is both general and specific. General information includes: background and fundamentals of sign engineering; basic concepts of signing described in MUTCD, the Traffic Control Device Handbook, and other traffic sign directives; the definition of traffic control devices; and so forth. Figure 2 shows a sample of general information contained in Module 1.

Specific information describes the use and detailed characteristics of individual warning signs. As shown in Figure 3, warning signs were classified into eight categories:

- Advisory speed plate,
- Hazard markings,
- Changes in horizontal alignment,

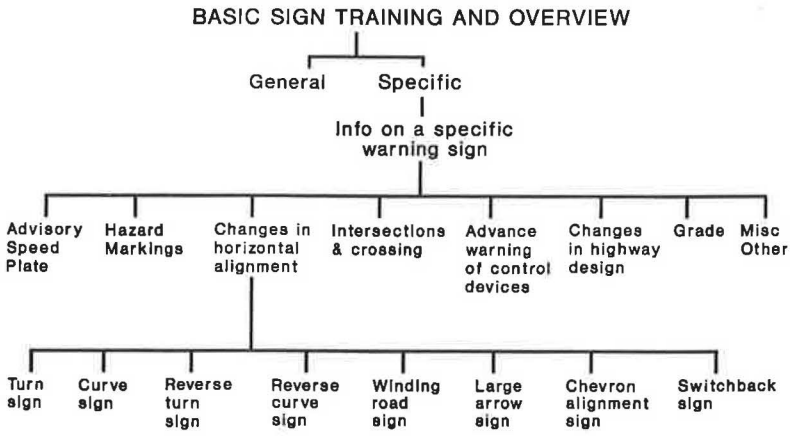

FIGURE 3 Specific information of basic sign training and overview.

- Intersections and crossings,
- Advance warning of control devices,
- Changes in highway design,
- Grade, and
- Miscellaneous.

Individual signs included in the changes in horizontal alignment category are as follows:

- Turn sign,
- Curve sign,
- Reverse turn sign,
- Reverse curve sign,
- Winding road sign,
- Large arrow sign,
- Chevron alignment sign, and
- Switchback sign.

The definition, warrant, and graphic display of each sign may be queried by the user.

Module 2—Determining the Need for Signs

The criteria used for determining the need for signs varies from one sign to another. Factors considered in the selection of a warning sign for changes in horizontal alignment include the vehicle approach speed (V'), the recommended vehicle speed through the change in horizontal alignment (V), the speed differential between the approach and recommended speeds ($\bar{v} = V' - V$), sight distance, driver expectancy, accident history, and the characteristics of road geometry.

The approaching speed denotes the average vehicle operating speed (85th percentile) on a road segment immediately before a change in horizontal alignment. The recommended vehicle speed is defined as the maximum safe speed at which a vehicle can negotiate a change in horizontal alignment. Curve characteristics such as radius, superelevation, and side friction are some factors that affect this value. The recommended vehicle speed may be determined by either mathematical computation or by field test.

The formula for computing the recommended speed is (*5*)

$$V^2 = 15R(e + f)$$

where

V = recommended speed (mph),
R = radius of curve (ft),
e = rate of superelevation (ft/ft), and
f = safe coefficient of side friction.

The recommended speed can also be determined by field test using a ball-bank indicator (*5*). A ball-bank indicator consists of a steel ball in a sealed curved tube. It is mounted on a test vehicle. When the test vehicle is driven around the curve at various speeds, the ball-bank readings provide a measure of the centrifugal force acting on the vehicle.

The prototype program uses the following logic to determine the need for specific signs.

Turn Sign (W1–1)

The recommended speed is 30 mph or less.

Other factors influencing the selection are considered as follows:

1. If the speed differential is 10 mph or greater, a sign is recommended;
2. If the speed differential is equal to or greater than the speed differential used by other local (within a 3-mi range from the road segment under study) road management agencies to determine the need for a turn or curve sign, a sign is recommended;
3. If the sight distance is obstructed from clear view and the speed differential is equal to or greater than 5 mph, a sign is recommended;
4. If the approach grade is equal to or greater than −6 percent and the speed differential is equal to or greater than 5 mph, a sign is recommended; and
5. If the site of interest has a history of previous accidents, a sign should be considered.

Curve Sign (W1–2)

The recommended speed is greater than 30 mph.

The logic for determining the need for curve signs is similar to that used for turn signs.

Reverse Turn Sign (W1–3)

A Reverse Turn sign is recommended for marking two turns or a turn and a curve in opposite directions, as defined in the warrants for turn and curve signs, that are separated by a tangent of less than 600 ft.

Reverse Curve Sign (W1–4)

A Reverse Curve sign is recommended for marking two curves in opposite directions, as defined in the warrants for curve signs, that are separated by a tangent of less than 600 ft.

Winding Road Sign (W1–5)

A Winding Road sign is recommended for marking three or more turns or curves, as defined in the warrants for turn and curve signs, that are separated by tangents of less than 600 ft. If continuous winding road conditions extend over 1 mi, a supplemental distance plaque is recommended. Repeating the distance plaque at two increments is recommended when the average vehicle speed exceeds 35 mph or the winding road conditions exceed 5 mi in length.

Large Arrow Sign (W1–6, W1–7)

A Large Arrow sign is recommended for marking sharp changes in road alignment in the direction of travel.

Chevron Alignment Sign (W1–8)

A Chevron Alignment sign is recommended for marking those sharp changes in road alignment in the direction of travel that require additional emphasis and guidance in addition to that provided by the Large Arrow sign or standard delineators.

Switchback Sign (FW1–U)

A Switchback sign is recommended when (*4*)

1. The vehicle approach speed is 30 mph or less,
2. The deflection angle between the tangents to the curve equals or exceeds 120 degrees, or
3. The speed differential meets the requirements for a Turn sign.

Advisory Speed Plate (W13–1)

The use of the advisory speed plates is recommended under the following conditions:

1. The speed differential is 10 mph or greater and the approach grade is less than −6 percent.
2. The speed differential is 5 mph or greater and the approach grade is greater than −6 percent.

Module 3–Determining the Size of Guide Signs

This module was designed to calculate guide sign panel length and height from the user's input of letter height, number of lines on the sign, and content of each line. It also calculates the area of the sign panel. The criteria used for this module are as follows:

1. Letter, numeral, and spacing widths are based on Series C of the *Standard Alphabets for Highway Signs* (*6*);
2. The spacing for top, bottom, and end margins equals ¾ of the capital letter height;
3. The spacing between lines equals ½ of the capital letter height;
4. The spacing between words and characters equals 4 times the letter stroke width;
5. The fraction length equals 1½ times the capital letter height; and
6. The horizontal arrow length equals 1¼ times the letter height and the vertical arrow length equals the letter height.

Module 4—Sign Placement

This module has not yet been developed. The MUTCD (*1*) and other related references will be used as the major sources of information when it is developed.

SYSTEM OPERATION

System operation starts with a main menu from which the user may select one of the four modules. As shown in Figure 4, the operation algorithm allows the user to repeatedly acquire the information stored in the same level of the data tree or to return to the main menu.

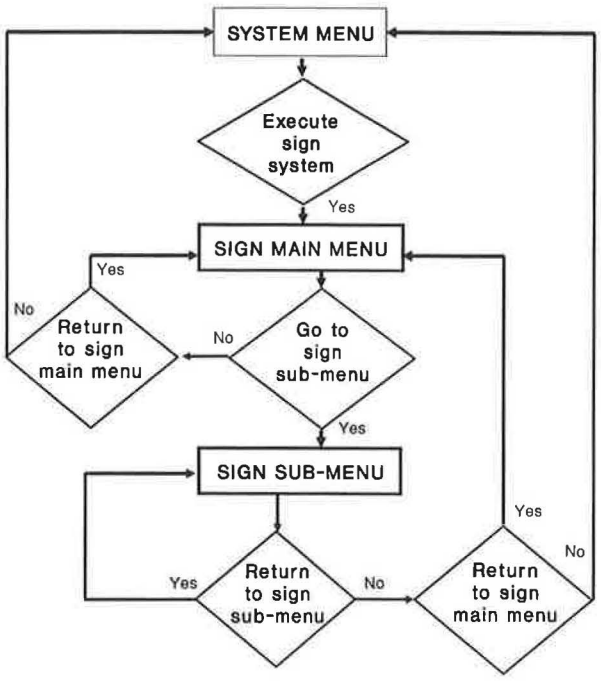

FIGURE 4 Operation algorithm of training and overview.

Module 1—Basic Sign Training and Overview

If a user selects Module 1, "Basic Sign Training and Overview," from the main menu, the system will display a submenu on the lower half of the screen with a question asking, "Which type of information do you wish to review?" There are three choices: general information, specific information, and return to main menu. If the user selects general information, another submenu will be shown on the screen identifying the types of information available for review. If the user selects specific information, the system will display a submenu of individual signs. After the user selects a specific sign, the system will display text describing the sign and its usage along with a graphic display of the sign. If the user selects return to main menu, the user is returned to main menu to select either general information or specific information.

Module 2—Determining the Need for Signs

In order to determine the need for signs for a specific situation, the user first selects Module 2, "Determining the Need for Signs," from the main menu. The user must then select the appropriate sign category from the first submenu and the appropriate sign type from the second level submenu. The user is then led through a series of questions pertaining to

- The number of turns and curves being evaluated,
- The length of tangent between each turn or curve,

- The approaching speed,
- The recommended speed,
- The speed differential,
- The approaching grade,
- Any site obstructions,
- Any accident records for the site under investigation,
- Local agency practice for signing similar situations, and
- Driver expectancy.

On the basis of the user's answers to these questions, the system will make specific signing recommendations.

The system provides four options for the user to display the program output:

- Display;
- Display and print;
- Display and file; and
- Display, print, and file.

For other than the Display option, the user must provide information to identify the location evaluated. This information includes road number, milepost, intersection, sign number, date, region, national forest, and ranger district.

The output report includes location identification information, the conditions on which the recommendation is based, and the recommended alternative. It also provides space for comments and signature. A sample report format is shown in Figure 5 (*left*); a sample graphic display of the recommended signs is shown in Figure 5 (*right*).

Module 3—Determining the Size of Guide Signs

The user may determine the size of individual guide signs by selecting Module 3. On the basis of the user's answers to a series of queries, the sign size will be determined and displayed on the screen. If desired, the user may invoke an EDIT

RECOMMENDED ROAD SIGN

Road No.: 1234
Milepost: 5.2
Intersection:
Sign No.: 100

Date: 3/4/90
Region: R05
National Forest: F10
District: D5

BASE CONDITIONS:

- The approaching speed is 35 mph
- The recommended speed is 25 mph
- The speed differential is 10 mph
- The speed differential used to determine the need for the sign for road segments near the study site is unknown
- The sight distance is obstructed
- The negative grade is less than 6%
- The curve is sharper and less obvious than the normal situation, that is, the change in alignment violates the driver's expectancy
- The I–angle is less than 120 degrees
- No accidents have been reported

The selected alternative: A TURN SIGN WITH CHEVRON ALIGNMENT SIGN AND SPEED PLATE IS RECOMMENDED

Comments – Rationale for not adopting the system recommendation or for selecting another alternative:

Recommended: _____ (signature) (date)

Approved: _____ (signature) (date)

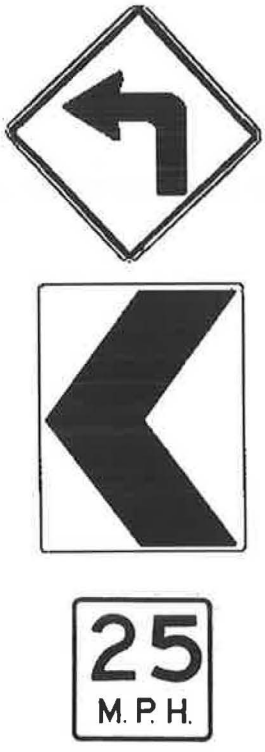

FIGURE 5 (*left*) **Report of sign evaluation and** (*right*) **recommended signs.**

command to adjust the text of the sign by inserting new text, by deleting text, or by rearranging the text or sign layout, or both. Modifications of this type require that the user rerun the program to recalculate the line lengths and sign panel dimensions. At this time, the user may also add information (road number, station, etc.) to identify sign location. When the sign design has been completed, the user may either PRINT or SAVE the output. Note that neither the screen display nor the printed output are to scale.

System queries and user responses for a typical situation are as follows:

System Queries	*Responses*
Please enter letter height in inches	5
Please enter number of lines on the sign	2
Please enter text of line #1	ALBUQUERQUE 5 >
Please enter text of line #2	PECOS 51 >
Do you want line totals? (Y/N)	Y
Do you want the area of the sign panel? (Y/N)	Y

For these responses, the output shown in Figure 6 will be displayed on the screen.

SYSTEM EVALUATION

In May 1989, the prototype of the Road Sign Advisory Expert System and a questionnaire (Figure 7) were mailed to the nine Forest Service regional offices for evaluation. All regions responded, with six of the nine favoring additional developmental effort. Some regions expressed concern that traffic control device decisions required professional judgment that could not be recognized or applied by expert systems.

Most of the users who tested the system indicated that it was easy to use. Some suggestions were made to improve the system to make it more understandable and user friendly. The majority of the respondents indicated that the system is a useful tool for training personnel with limited signing experience. On a 1-to-10 scale, where 1 represents little usefulness and 10 denotes great usefulness, the rating for using the system as a training tool ranged from 5 to 9, with an average of 7.5. The rating for using the system to determine the need for signs ranged from 1 to 10, with an average of 6.6. The majority of respondents would like the system expanded to include signing for other situations such as recreational developments, trails, forest entrance, and administrative sites.

Many respondents agreed that the system could save time; however, they could not determine exactly how much time would be saved.

CONCLUSION

The prototype Road Sign Advisory Expert System presented in this paper demonstrates the feasibility of using expert systems as one tool for managing road signing programs. The system may also be useful as a training aid.

ACKNOWLEDGMENT

The authors thank other project team members—Margaret Bro, Dave Neeley, Doc Morrison, and Milt Taylor—for their contributions to the development of the knowledge base. Special thanks go to Ted Zealley and Jerry Bowser for their intellectual support. We also acknowledge that the program for calculating the size of guide signs was written by B. Wahl and Earl Williams.

This material was developed, written, and prepared by employees of the U.S. government; therefore, it is in the

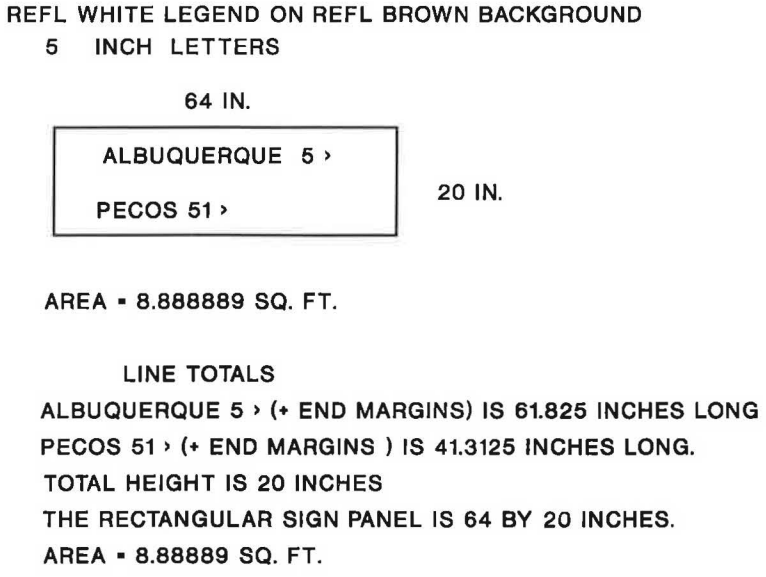

FIGURE 6 Report of calculating a guide sign.

Region _____ Forest _____ District _____

Job Title _____

Level of Sign Expertise: No( ) Low( ) Medium( ) High( )

We Need Your Help!

An "expert" sign model for road signs is proposed for microcomputer use (or DG when the DG version of IBIS, the expert system shell, is available). It would have two purposes: (1) as a training tool for the new or untrained sign coordinators on a District or Forest; and (2) to provide "expert" guidance to journeyman signs persons when deciding whether signs are needed and, where needed, what signs to use.

This prototype model is being developed only for the standard road warning signs relating to changes in horizontal alignment. To become a fully functional system for all road signs, the remaining warning signs and all of the regulatory and guide signs would need to be added.

By answering the following questions, you can help determine the future of this effort:

1. Was the model easy to use? Yes ( ) No ( ) If not, why?

2. What would improve it for the ease of the user?

3. Was the model understandable? Yes ( ) No ( ) If not, why?

4. What would make it more understandable?

5. Did you learn about the change in horizontal alignment signs from it? Yes ( ) No ( ) Explain please.

6. Would this "expert" model be useful for the purposes stated if it were complete with all road warning, regulatory, and guide signs? (select a number)

	Little Usefulness							Great Usefulness	
Training	1( )	2( )	3( )	4( )	5( )	6( )	7( )	8( )	9( )	10( )
Evaluation	1( )	2( )	3( )	4( )	5( )	6( )	7( )	8( )	9( )	10( )

7. Should it include recreational, trail, Forest entrance, and administrative signs? Yes ( ) No ( )

8. Should we continue this effort, including changes as per your comments above? Yes ( ) No ( )

9. Would the system save you time? Yes ( ) No ( )

If yes, please estimate, with explanation, the amount of time that could be saved.

Thank You for Your Help!

General Comments (optional):

FIGURE 7 Questionnaire.

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The information contained in this paper reflects the views, opinions, and conclusions of the authors and does not necessarily represent those of the Forest Service.