Special Traffic Control To Meet Motorist Information Needs on Long, Steep Grades

JOSEPH L. HENDERSON, EUGENE M. WILSON, GEORGE A. DALE, AND CLAUDIA L. SCRIVANICH

A new concept in traffic control devices is evaluated. The subject of the study is a special message information sign on US-14A near Burgess Junction, Wyoming. The sign presents motorists with percent and length of grade information in response to a long sustained 10 percent downgrade. This diagramatic sign is located in a turnout. Vehicles such as tractor semitrailers, single-unit trucks, motor homes, and vehicles pulling trailers are required to turn out and read the sign. This method for presenting complex information to motorists is effective and the compliance with the required turnout is high.

Informing motorists of roadway conditions can normally be accomplished by using traditional methods of traffic control. Quite often, warning signs must be used to alert motorists to geometric and alignment conditions that may violate driver expectancy or create a confusing situation. Presented in the following sections is a case study describing a new concept in the use of traffic control devices. The study was conducted on a mountainous section of US-14A in northern Wyoming. A special information warning sign located at a turnout requires certain motorists to turn out and stop. Motorist compliance with this requirement and message comprehension were the focus of this study.

PREVIOUS RESEARCH

The state of the art in driver message signing has been advancing in the areas of directional and guide signing, variable message signs, and positive guidance. Driver responses to the message content, response time, and route choice have been analyzed by many researchers.

Previous studies have covered subjects such as motorist route selection criteria (1), diversionary signing and driver behavior (2), tourist information systems (3), positive guidance (4), and traffic operations, safety, and positive guidance projects (5). Studies related to guide signs are directed toward new applications of directional and guide signs (6-9). Research concerning driver systems addresses the need for coordinating signs, maps, and tourist information to reduce user costs and traffic congestion (10, 11). These studies are designed to evaluate specific route and grade information that is provided to selected motorists.

A method for providing grade and length of grade information to truck drivers is now being researched. A grade severity rating system (12) has been designed to designate a specific speed for a tractor semitrailer driver to use when driving on a downgrade. As the results were first envisioned, each downgrade on every road would be rated by using this system, and drivers would be expected to reference previous driving experiences to take advantage of the system. This idea gave way to a weight-specific speed sign that would show a specific speed for different weight classes. The Colorado Department of Highways (13), and highway departments from nine other states participated in a program to test this signing concept. The results have been inconclusive to date, and observations have shown that a high percentage of drivers do not recognize the intent of the signs.

In the following section the study is discussed including a description of the study site and the traffic control used.

THE STUDY

Turnout signing is a unique concept because motorists stop to read these signs, whereas the information on other signs is conveyed to drivers as they travel along the road. Two signs located at turnout areas were designed to alert drivers to a long, steep downgrade that exists on US-14A between Burgess Junction and Lovell, Wyoming. Drivers who turn out are separated from through traffic and have an unlimited amount of time to study these signs. The primary study objectives were to determine the ability of the sign to convey grade data, the motorists' comprehension of this information, motorists' compliance with the required turnouts, and driver expectancy of grades.

The locations of the study sites are shown in Figure 1. Highways of interest are US-14 and US-14A between Burgess Junction and Cody, Wyoming. These are both two-line primary highways with a similar type design and are located in rugged mountainous terrain. US-14A contains a section of road located 20 mi west of Burgess Junction that has a great deal of 10 percent grade. Most motorists have never experienced a long sustained 10 percent grade. The grades are deceptive because of the high quality of the road. A driver who is unaware of or unfamiliar with such grades may tend to be accelerating more than he perceives. Also, some of these motorists are driving...
some type of recreational vehicle or a vehicle with a trailer. More traditional grades of 5 to 7 percent exist on US-14. Special attention has been given to these highways because they are major routes to the east entrance of Yellowstone National Park and are traveled by nonresidents of Wyoming. The majority of westbound traffic at Burgess Junction uses US-14. During the study period, 62 percent of the westbound traffic used US-14. Out-of-state vehicles accounted for 86 percent of the traffic on US-14 and 57 percent on US-14A.

An information sign (Figure 2) is located on US-14A about 1 mi west of Burgess Junction. This sign, which measures about 10 ft by 30 ft, has been designed to show that the distance from Burgess Junction to Cody is approximately the same by way of US-14A or US-14, but that the grades are much more severe on US-14A. Advance signing requires all semitrailer trucks, buses, recreational vehicles, and vehicles pulling trailers to stop and read the information sign (Figure 3).

Another turnout warning sign is located about 25 mi west of Burgess Junction on US-14A at a brake check safety area. This sign, shown in Figure 4, provides more detailed information about the 10 percent downgrade, including the location of a brake cooling turnout and the three truck runaway ramps. The same vehicle classifications are required to turn out.

 Signing associated with the uphill travel direction is shown in Figure 5. This sign is located just east of Lovell, Wyoming, approximately 20 mi before the steep upgrade section. This is the only grade signing in the uphill direction.

DATA COLLECTION

Data were collected manually and by using driver interviews during the summers of 1984 and 1985. The interview sites were located at the Burgess Junction information sign turnout west of Burgess Junction on both US-14 and on US-14A at the bottom of the grade and on US-14A at the top of the grade (see Figure 1). Sample sizes for the various surveys are given in Table 1. The surveys were designed to gather information concerning comprehension of the information signs, driver's understanding of percent and length of grade, and route selection criteria. Also of interest were any problems encountered on the grades in the study area and whether drivers diverted to US-14 after stopping at the Burgess Junction information sign. Vehicle classification, origin of license, and stopped time were obtained.

Major findings of this study are presented in the following sections. The major findings discussed in this paper are only those that were statistically significant at the 0.05 level. Topics of discussion are turnout signing, downgrade analysis, and upgrade analysis.

TURNOUT SIGNING

Compliance with the required turnout was essential for this signing technique to be effective. Of all the vehicles observed at the sign, only about 32 percent stopped. However, the rate of compliance for vehicles required to stop was quite high. More than 62 percent of the vehicles required to stop did stop. Vehicles required to stop are trucks, recreational vehicles, and vehicles with trailers. Out-of-state motorist compliance with the required turnout was almost 80 percent, whereas only about 20 percent of local Wyoming motorists complied. More first-time users of US-14A stopped at the sign than any other group (80 percent). The overall rate of compliance was slightly higher in 1985 and local Wyoming compliance decreased slightly.
driver behavior was observed for vehicles that stopped at the sign. The amount of time that drivers took to read the sign was recorded. Wyoming motorists generally stopped for less than 30 sec, whereas out-of-state drivers generally stopped for more than 30 sec. Drivers of vehicles required to stop viewed the sign longer than drivers of other vehicles. Average times were 37 sec and 29 sec, respectively. The vehicles that stopped at the sign and then diverted to US-14 were also observed. During the data collection period, 110 vehicles were observed that diverted to US-14. Of this number, 80 percent were from out of state and 67 percent were required to turn out. Of the 4,558 vehicles observed, 7.6 percent of the total vehicles using the turnout diverted to US-14. This was 2.4 percent of the total US-14A traffic observed. No route diversion signing existed before the turnout signing. This additional signing was incorporated into the design because of the reopening of US-14A on a new steeper alignment.

Driver behavior at the brake check sign turnout was also examined. Less than 50 percent of the vehicles required to turn out at the sign did so; however, 56 percent of the out-of-state vehicles stopped that were required to do so. Fifty-nine percent of the drivers who stopped at the Burgess Junction information sign also stopped at the brake check sign.

Drivers' actions at the brake check sign, including stopped time, were observed. Of the vehicles that stopped at the sign, average viewing time for vehicles required to stop was longer than for vehicles not required to stop (53 sec versus 28 sec). This difference was attributed to the message content of the sign, which is targeted toward vehicles required to turn out. The sign provides more specific information than does the Burgess Junction information sign concerning the percent grade, overall length of grade, location of three truck escape ramps, and location of the brake cooling area. The difference in average viewing times indicated that motorists were spending the additional time necessary to assimilate this detailed information on the brake check sign.

**DOWNGRADE ANALYSIS**

The downgrade of US-14A was examined to determine the driver expectancy of the length and percent of grade and to

**TABLE 1 NUMBERS OF SURVEYS AND OBSERVATIONS BY LOCATION AND YEAR**

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Driver Surveys</th>
<th>No. of Driver Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>US-14A</td>
<td>US-14</td>
</tr>
<tr>
<td></td>
<td>Downhill</td>
<td>Downhill</td>
</tr>
<tr>
<td>1984</td>
<td>186</td>
<td>204</td>
</tr>
<tr>
<td>1985</td>
<td>573</td>
<td>198</td>
</tr>
<tr>
<td>Total</td>
<td>759</td>
<td>402</td>
</tr>
</tbody>
</table>
determine whether operational problems existed. Driver expectation of percent of grade on US-14A was affected by driver's domicile and frequency of travel on this road. The local Wyoming motorists and regular users of the road felt more comfortable driving on the road than other motorists. Only about 40 percent of the motorists interviewed indicated that they had used a lower gear to descend the grade. In many cases, not using a lower gear resulted in brakes on vehicles descending the grade becoming extremely hot. This not only occurred on vehicles required to stop at the signs, but also on some passenger vehicles. One passenger vehicle lost its brakes during the study period in 1985. This vehicle, with a heavily loaded trailer, used the middle truck escape ramp. Quite a few motorists stopped while descending the grade on US-14A. Some of the motorists who stopped did so more than once. A few motorists even stopped at truck escape ramps, which creates a hazard in the event that the ramp is needed by a vehicle that has lost its brakes.

Results of the downgrade driver interviews indicated that most motorists did not understand the concept of percent grade. After the 1984 study three additional signs with the text All Vehicles Use Lower Gear were added. This substantially reduced the problem of hot smoking brakes. In 1985, 573 interviews were conducted below the 10 percent grade. There were 51 vehicles (8.9 percent) that had noticeably hot brakes. Additional signing, Save Your Brakes, Use Lower Gear, has been recommended.

A comparison was made between the motorists' perception of the downgrade on US-14A and that on US-14 by surveying motorists on both routes. Most motorists thought that the
grades on US-14A were steeper than expected and that the grades on US-14 were not as steep as expected. This result depended on the domicile of the driver. In general, Wyoming motorists responded that the grades were as expected. Out-of-state motorists generally responded that the grades were steeper than expected, particularly on US-14A.

**UPGRADE ANALYSIS**

The upgrade on US-14A was analyzed to determine characteristics of the uphill motorist and to learn what problems these motorists may have experienced driving up the mountain. More than 80 percent of the vehicles observed traveling upgrade were passenger vehicles: very few heavy vehicles such as tractor-semi trailers, single-unit trucks, and motor homes were observed. Only one of the heavy vehicles observed was a local Wyoming vehicle. This indicated local awareness to the difference in grade severity between US-14A and US-14. Many vehicles stopped on their way up the mountain. Some overheating problems were observed, but most motorists stopped to take advantage of the scenic vistas. Uphill travel problems were observed for bicyclists, older vehicles, and heavily loaded vehicles. A number of bicyclists were observed in 1985 attempting to ride up the steep portion of US-14A. Two cross-country cyclists spent an entire day attempting to ascend the grade before they received motorist assistance. The rest that were observed turned around.

Motorists indicated that the uphill advance warning sign, located about 1 mi east of Lovell, was understandable (see Figure 5). This sign is located on a relatively flat tangent section about 20 mi before the steep uphill section. Some motorists thought that the sign should indicate more detail concerning the grade on US-14A. This sign is the only one that provides information to the motorist about the grade before or during their trip up the mountain. Quite a few vehicles were observed traveling part of the way up the mountain and then turning around. This was probably because the drivers did not know how long the grade was.

The foregoing discussion contains the major results of the study conducted in 1984 and 1985. On the basis of these major study findings, the following conclusions are made:

1. The use of turnout signing is an effective method of traffic control. Motorists will comply with the requirement to turn out and stop.
2. Signing in a turnout should be considered when information content is long or complex or when messages are appropriate for only a select group of motorists.
3. Motorist comprehension of percentage of grade is poor. Diagrammatic signing or word messages explaining this concept are necessary to help motorists when grades are severe.
4. Providing uphill and downhill turnout areas on long, steep grades is necessary to help lessen the effects of brake and vehicle overheating.
5. Special uphill signing is necessary to inform motorists of length and percentage of long, steep grades.
6. Consideration should be given to prohibiting bicycle traffic on long, steep grades unless special provisions have been made for this type of traffic.

**RECOMMENDATIONS**

The use of turnout signing has been shown in this study to be an effective method. It should only be considered in situations where low traffic volumes exist.

Most of the drivers who were interviewed at the Burgess Junction information sign did not understand percentage of grade, and some suggested that the sign should also attempt to educate about it. To do so, diagrammatic signs could be used to show a comparison between a possible known or alternative grade and the one about to be traversed. Another possible solution would be to design a sign that would be placed in a turnout or rest area that explains grade.

Quite a few motorists stopped while descending the grade on US-14A. An adequate number of brake-cooling areas should be provided so that drivers can stop as often as desired. Operational reviews should be conducted periodically to determine whether the number of brake-cooling areas is adequate and whether they are being used.

Many motorists were observed traveling part of the way up the mountain and then turning around. This behavior could be a result of not knowing actually how steep the road was or how much farther they had to drive before reaching the summit. Signing showing distance to turnout areas as well as to the summit is important on long steep grades. Of most benefit to the driver would be information on percentage and length of grade (14).

Special warning signs alerting bicyclists to long steep upgrades could be beneficial to this group. Consideration should also be given to prohibiting bicycle traffic on grades of this severity.

**ACKNOWLEDGMENTS**

The authors wish to express sincere thanks to the University of Wyoming, Wyoming Highway Department, and the Federal Highway Administration. Two of the authors, Joe Henderson and Claudia Scrivanich, were graduate students at the University of Wyoming when this research project was conducted. The funding of this project through the Highway Research Program is greatly appreciated.

**REFERENCES**

First, I argue against the principle of compelling drivers to turn out. If the sign is legally enforceable, would all noncomplying drivers be equally culpable? Or would enforcement be concentrated on drivers of vehicles bearing out-of-state license plates? Whether the sign is legally enforceable or not, it is likely to be disregarded by a significant proportion of drivers. The erection of traffic signs that are habitually ignored by many drivers is likely to bring traffic laws (and their makers) into disrepute.

I appreciate the difficulty in conveying complex information to drivers, but believe that compulsory turnouts do not provide a satisfactory solution. Somehow, drivers should receive all the information they need without being compelled to turn out and stop.

Creative intersection design at Burgess Junction and destination signing may be effective in diverting out-of-state drivers away from US-14A to the less steep US-14.

Second, I note that the purpose of the research described by the authors was the evaluation of a new concept in traffic control devices for motorists on long, steep grades. The authors' sixth conclusion ("Consideration should be given to prohibiting bicycle traffic on long, steep grades unless special provisions have been made for this type of traffic") and a similar recommendation would appear to fall outside the scope of the study. This conclusion and recommendation, I believe, are inappropriate and unnecessarily discriminatory. None of the authors' research described here has shown the need for (or legality of) such a measure.

The further recommendation that "special warning signs alerting bicyclists to long, steep upgrades could be beneficial to this group," although still outside the research objective, may be quite adequate for the authors' purposes of discouraging cyclists, but any stronger conclusions should in my opinion be based on specific research.

AUTHORS' CLOSURE

Mr. Macbeth's discussion was interesting, and in total considers two points. The first was his argument against a required turnout and the enforcement of the requirement to turn out. In his discussion, he indicates that turnout signing may be of benefit. The study showed that this was in fact the case. In a state with an economy of many cities and that is largely dependent on tourist traffic, it is not feasible to sign a route to create a competitive advantage for one city. Creating a motorist who is informed of the uniqueness of this long, steep grade was the goal of the turnout design. Enforcement is not really at issue. Local motorist behavior did not create a follow-the-leader effect. With an average daily traffic of 400 vehicles per day, this is not a problem.

The second comment concerning bicycle travel was due in part to our omission. The research study itself did not investigate both uphill and downhill travel behavior. Although bicycle travel uphill was not specifically detailed in this paper, we wanted to include this finding in the hope that it might be useful for designers in the future.