Presenting Descriptive Information in Variable Message Signing

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In a study of driving simulators the effects on route choice and driving behavior of presenting descriptive types of information on variable message (route guidance) signs were evaluated. Subjects had to choose between a normal route to a fixed destination, which could suffer from congestion of varying severity, and an alternative route. Three modes of variable information presentation were compared: (a) length of congestion, in kilometers; (b) delays relative to normal travel times, in minutes; and (c) travel times, in minutes. The reliability of the information was also varied and could be high, intermediate, or low. Thirty-six men participated in the experiment, and every subject made 123 runs in the simulator. By presenting descriptive information, divergence levels were found that varied widely over the range from 0 to 100 percent, as a function of the actual information given. This is to be compared with the inflexibility of conventional (prescriptive) signing. User optimum was most often reached by presenting travel time information. Such information also proved to be most resistant against degradations in reliability. There was an overall increase in driving speed when descriptive information was given, and this may be interpreted as anticipatory behavior from the side of the driver to compensate for the expected delay upon finding the normal route to be congested.

Certain parts of a road network may suffer from congestion while other sections still have spare capacity. In those cases variable message signing (VMS) may be a means for diverging traffic from an originally intended, or normal, route toward a reasonable alternative.

A driver's inclination to diverge and the driver's capability to find a user-optimal decision strategy will depend on what information is presented and how it is presented. An important choice for the signing authority in this respect is whether to present prescriptive messages that indicate the alternative that one would want the driver to follow or to present descriptive messages that inform the driver of relevant conditions on the alternatives without providing an explicit recommendation.

The potential gain of descriptive VMS messages is that driver acceptance could be high because drivers would appreciate the freedom to make their own choices. And because information could be given in a fine-grained form, so that it could reflect prevailing conditions on the alternatives with high accuracy, descriptive messages could achieve a level of fine-tuning of traffic streams to capacities that would be unattainable with prescriptive messages.

It is in this latter respect, however, that descriptive modes of information provision may be vulnerable—that is, the presented information had better be sufficiently reliable, or drivers might start disregarding it to such a degree that the road-signing authority wishes it had stuck to a purely prescriptive mode of signing. Empirical evidence on some aspects of descriptive information modes was gathered in questionnaire studies by Heathington et al. (*1*) and Dudek et al. (*2*). These studies were directed at discovering motorists' preferred forms of descriptive information when encountering congestion. The pattern of the results in both studies appeared to be that information on congestion length and travel speed was clearly preferred to descriptions of travel time or delays in travel time. For several reasons, however, this pattern may not be directly applicable to the present issue. First, both studies asked only about preferred information on a single (habitual) route, without actually posing a choice problem. Second, situations displayed were hypothetical and did not involve actual behavior. Third, the issue of reliability was not raised, that is, it was not investigated whether preferences would have been maintained after experiencing possible fluctuations in the degree of reliability of the information.

Heathington et al. subsequently did put their subjects in a (hypothetical) choice situation in which they could indicate whether they would diverge to avoid some specified delay at a certain monetary cost (*3*). Results showed that probability of diversion was a function of the magnitude of the delay (or saved travel time) as well as of the implicated cost. Like the earlier authors, however, Heathington et al. did not consider how the inherent unreliability of the displayed information could affect behavior.

The recent literature on VMS, motivated by the increasing congestion levels on the world's roads, contains modeling efforts of diversion behavior in which a central role is assigned to motorists' apprehension of the state of affairs on the alternative routes (*4,5*). However, these models appear to lack realism because they must pose levels of user knowledge—and conditionalize model outputs on these—that are arbitrary because it is not known what these depend on (e.g., the type of information and the way it is displayed and the inherent unreliability that this information might possess).

The present study sought to determine the effects on drivers' inclinations to diverge from their normal routes when descriptive VMS messages of different reliability are encountered. Reliability here is defined in terms of the degree of correlation between the information provided on the VMS sign and the driver's subsequent experience on the chosen alternative, that is, the actual arrival time.

DESIGN OF STUDY

Subjects were presented with route-choice decisions while driving in the TNO Institute for Perception's driving simu-

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lator. Driver behavior was measured at the decision locations so that the experiment would yield results not only in terms of route choices but also on the relation between route choice and actual driving behavior (*6*).

General

Subjects were first shown a stylized layout of the configuration of highways around Amsterdam (Figure 1). They were asked to imagine themselves as having to arrive in Zaanstad each day at 9:00 a.m. at the latest, finding themselves at Diemen at 8:30 a.m. and having to choose to circumvent Amsterdam clockwise or counterclockwise from the entrance of the beltway. An experimental run consisted of the subjects driving from Diemen to the decision point at the entrance of the beltway and then farther, for a total of about 4 km. The simulator then stopped and subjects were told of their arrival times. No other simulated traffic was present.

VMS Implementations

VMS signs were positioned 300 m from the entrance of the beltway. VMS descriptive information was presented in three ways:

1. Length of congestion on the alternatives, in kilometers (Figure 2);
2. Expected delays relative to normal travel times on the alternatives, in minutes (Figure 3).
3. Expected travel times on the alternatives, in minutes (Figure 4).

A standard (prescriptive) decision sign was, moreover, positioned exactly at the entrance of the beltway, that is, at the end of the sequence of signs that subjects encountered. Under normal conditions (no congestion on either of the alternatives) the expected travel time was taken to be 7 min in the clockwise direction (A10-W) and 12 min in the counterclockwise direction (A10-O). These were based on an average travel speed of 100 km/hr. Under critical conditions congestion was assumed on the clockwise route (A10-W), and it could vary in length between 1 and 6 km. Corresponding travel speed under congestion was taken to be 23 km/hr, with resulting expected travel times on the normal (clockwise) routes varying between 9 and 19 min, and with consequent expected delays ranging from 2 to 12 min. The alternative (counterclockwise) direction

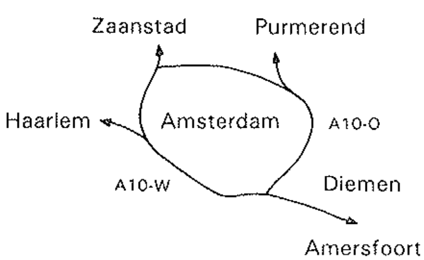

FIGURE 1 Configuration of Amsterdam Beltway as used in experiment.

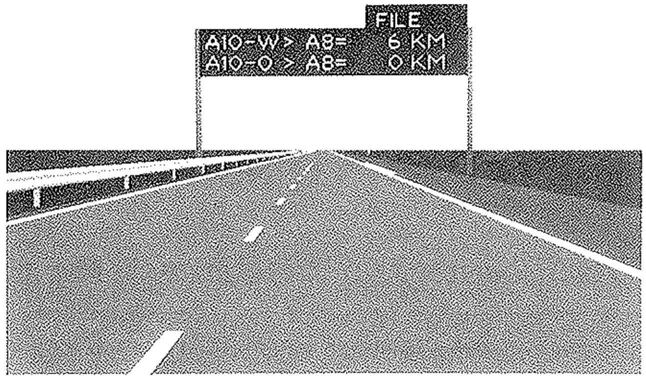

FIGURE 2 Indication of congestion lengths; sign says there is 6 km congestion (FILE) on normal route (A10-West), and none on alternative (A10-East) to A8 interchange (for Zaanstad destination).

was always assumed to be congestion-free, so the expected travel time on this route was always 12 min.

Reliability of Information and Arrival Times

The reliability of the information presented to subjects was experimentally manipulated by varying the degree to which actual travel times fluctuated about their expected values, which are the values given in the previous section. For example, if there was an assumed 3-km-long congestion on the normal route, resulting in a 6-min expected delay on that route, the real delay as experienced by subjects would always be close—on either side—to 6 min in the most reliable condition, whereas it would fluctuate considerably about that value in the least reliable condition.

Reliability conditions were thus defined in terms of the standard deviation of travel times (or, equivalently, delays) about their expected values. In the most reliable condition the standard deviation was 1.4 min; in the moderately reliable condition, 2.5 min; and in the least reliable condition, 3.0 min.

The manipulation of reliability levels was done only for the normal (clockwise) route. In the counterclockwise direction,

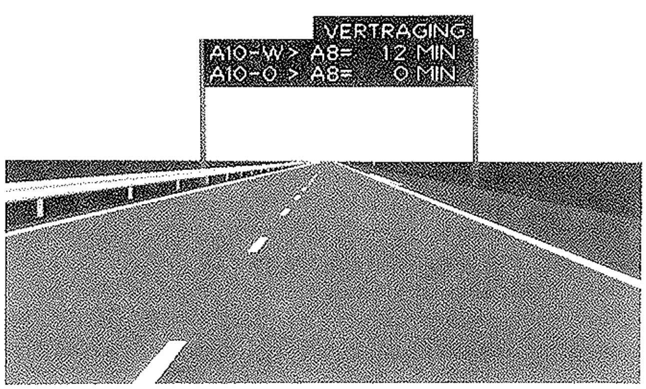

FIGURE 3 Indication of delays (VERTRAGING) relative to normal travel times.

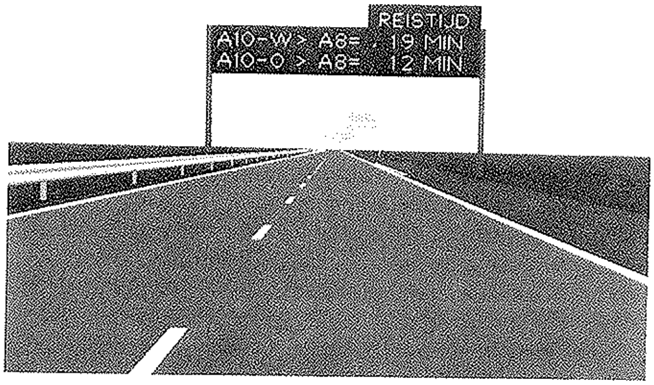

FIGURE 4 Indication of absolute travel times (REISTIJD).

travel times always had a standard deviation of 1.4 min about their expected values.

Arrival times were predetermined and did not depend on the subjects' actual speeds on the 4-km stretch that they drove. Thus, arrival times were only a function of the information shown on the VMS, of the prevailing (and predetermined) level of reliability of the messages, and of a subject's route choice.

The distributions of arrival times were composed in such a way that there was always a user optimum to diverge at a congestion length above 2 km (i.e., an expected travel time on the normal route above 12 min or a delay above 4 min), irrespective of reliability conditions.

The deadline for arrival at the Zaanstad destination was 9:00 a.m. A penalty applied of Fl 2.00 per minute late (Fl 1.81 = $1.00 U.S.). The total penalty earned was subtracted from an initial sum, which left most subjects with a reasonable award for taking part in the experiment.

Measurements

The TNO Institute for Perception's simulator has a MEGATEK 944 CGI-system that generates real-time images displayed by means of a high-resolution projector (BARCOGRAPHICS 800) (7).

Each subject conducted 123 runs in the simulator, 33 of which contained congestion on the normal route. In the first part of the series subjects were familiarized with the routes so that they could recognize the normal route. Besides the route choice decisions, the following measures of driving performance were taken at the decision point:

1. Vehicle speed on the last 200 m of the approach to the decision sign.
2. The position of the vehicle, measured in the longitudinal direction, on the off-ramp when the subjects diverged from the normal route.

Experimental Design and Subjects

The independent variables of information presentation mode (three levels) and reliability (three levels) were manipulated between subjects, so that there were 3 × 3 = 9 groups of four subjects each. Each subject thus drove for the complete series of 123 simulator trials under a fixed combination of "information presentation mode" and "reliability." The subjects were 36 men between 23 and 51 years old (average 34), with a minimum of 10 000 km/year traveled over the most recent 5-year period.

RESULTS

Diversions from Normal Route

Figure 5 shows the percentage of runs in which subjects diverged from the normal route. The reliability of the presented information appears to have a considerable effect on the inclination to diverge when information is in terms of congestion length. In this information mode it may happen, with less reliable information, that divergence does not even approach 100 percent under the most extreme conditions of congestion on the normal route.

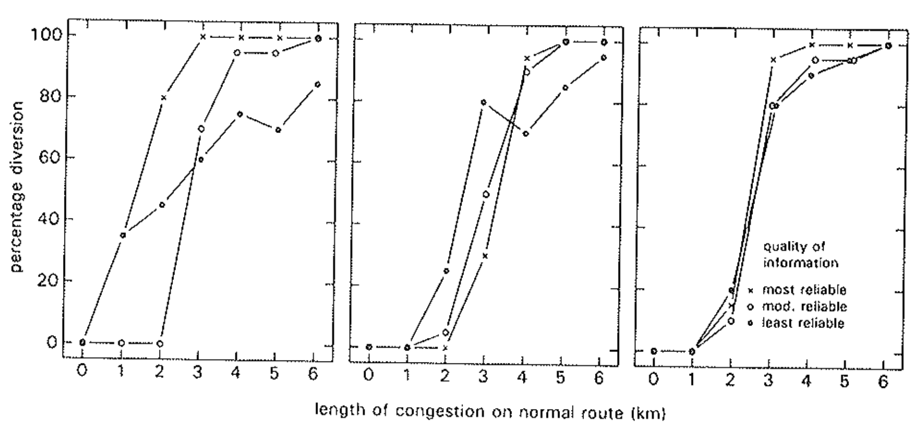

FIGURE 5 Rate of diversion as a function of informative mode, reliability of information, and extent of congestion (and associated travel time or delay: 1 km congestion is equivalent to 2 min delay): *left*, length of congestion; *middle*, delay; *right*, travel time.

When information is in terms of travel times or delays, divergence is much less affected by the reliability of the information, although there is the tendency that diversion levels only slowly approach 100 percent under the less reliable conditions.

Application of User-Optimal Strategy

The diversion data as shown in Figure 5 may also be analyzed in terms of whether subjects applied the user-optimal strategy—to diverge at congestion lengths (or their time equivalents) of more than 2 km. The following table gives the results:

	Reliability		
Information Mode	*High*	*Medium*	*Low*
Congestion length	81	93	68
Delay	81	89	84
Travel time	97	93	91

A χ^2-test on the data in this table yielded 4.68, which is significant at level $p < .05$ for 4 degrees of freedom. The pattern in the interaction is as follows. When information is given in the form of expected travel times, the user-optimal choice is made in most cases; this is not affected by the reliability of the information itself. Information on delays, relative to normal travel times, shows a lower overall percentage user-optimal choice, which also does not appear to be affected by the information's reliability. However, presenting the information in the form of an expected length of congestion is a mode that breaks down, in terms of user-optimal choice, at the least reliable condition.

Driving Behavior at Decision Point

An average increase in driving speed of 1.05 m/sec was observed on the last 200 m of approach to the decision sign when the preceding VMS sign contained information indicating a deviation from the normal (i.e., congestion-free) situation. As Figure 6 shows the exact magnitude of the increase depended on the indicated length of congestion (or its equivalent travel time or delay); the effect was statistically significant at $p = .002$ as tested by analysis of variance [$F(5.135) = 4.17$].

No relation was found between the off-ramp longitudinal position at which the vehicle left the normal route in case of divergence and either the VMS congestion message or the inclination to diverge itself, as measured by the relevant percentages for all subjects taken together.

DISCUSSION OF RESULTS

Effects of Decision To Diverge When There Is Descriptive Information

The results of this experiment show that the form in which descriptive information is given, the reliability of the information, as well as the content of the information determine whether a driver will diverge from the normal route. Not surprisingly, there is an overall increasing tendency to diverge when signing indicates worsening conditions on the normal route. However, a driver's inclination to diverge is also sensitive to certain conditions in which a particular type of information comes in conjunction with a particular level of reliability. Thus, although inherent reliability is of little effect in the travel time mode, reliability matters a lot when information is given as length of congestion.

The reason for this presumably is that the user optimum is easier to find when information is in the form of expected travel times, or delays relative to normal travel times, than when it is in the form of kilometers of congestion. That is, despite the deviations occurring between expected and actual arrival times, a driver is more capable of discerning the statistical relationship between these variables than when he or she must work on the basis of expected kilometers of congestion (with performance nevertheless being judged in temporal terms, i.e., having to arrive at the destination in time). The latter process thus simply appears to break down when sufficient unreliability is added.

Descriptive Information and Driving Behavior

The analysis of driving speed on the approach section to the decision point showed that the display of information indicating congestion on the normal route caused a slight increase in speed (3.8 km/hr). This may be interpreted as an anticipatory action in the face of an expected time loss, irrespective of the actual choice made at the decision point. The finding that the increase in speed tended to rise with the indicated severity of the congestion (Figure 6) is in line with this interpretation. Thus, there appears to be a link between the displayed descriptive information and the driving behavior on the approach to the decision point.

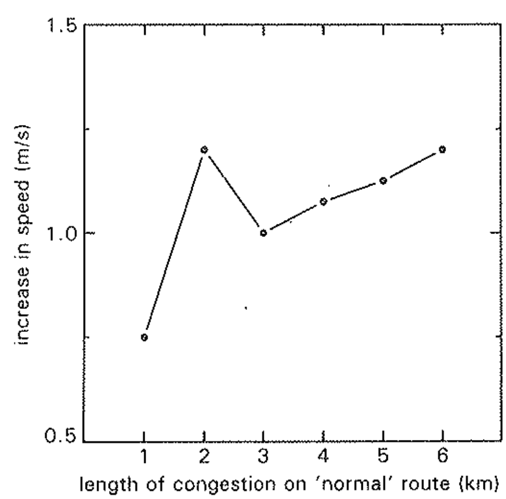

FIGURE 6 Relation between extent of congestion [length in kilometers, or equivalent travel time (delay)] and increase in speed relative to noncongested condition.

CONCLUSIONS

The experiment described in this paper permits the following conclusions:

1. Providing descriptive information on VMSs results in diversion rates that are sharply differentiated according to prevailing conditions, so that they offer a high potential for the fine-tuning of traffic streams to capacities in more or less critical route choice configurations.
2. Supplying descriptive information in the form of expected travel times is relatively insensitive to degradation in the reliability of the information.
3. Offering descriptive information in the form of congestion length in kilometers is relatively sensitive to degradations in reliability.
4. Driving speed toward the decision point increases slightly when VMS indicates congestion on the normal route.

ACKNOWLEDGMENT

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