NCHRP
REPORT 488

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Additional Investigations on Driver Information Overload



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Various Westat staff made important contributions to the work. Richard Huey developed the instrumentation for the laboratory and on-road experiments and Carina Tornow programmed control software. Dr. Paul Zador provided statistical advice. The conduct of the experiments and analyses was supported by Jerimiah Singer, Molly Fogash, Adele Bensur, Carolyn Kalinowski.

FOREWORD

By Charles W. Niessner, Staff Officer Transportation Research Board

This report presents the findings of a research project to investigate the information load imposed on drivers from freeway signs and to develop a model to predict driver information load. The model has been incorporated into a software tool to help practitioners identify driver information overload problems and evaluate alternatives for sign locations. The report will be of particular interest to traffic engineers with responsibility for freeway sign legends and installations.

"Driver information overload" results from providing too much information, through devices or conditions, for a driver to perceive and respond properly. Therefore, the information load on a driver is a property not only of the specific sign they are encountering, but also of the roadway context in which the sign occurs, the information context in which the sign occurs, the behavior characteristics of the driver, and the particular navigational task. Where drivers are confronted with more information than they can process, they may decelerate severely or drive unduly slowly, make late or erratic maneuvers, take an improper route alternative, ignore critical information, fail to monitor other traffic, or have excessive eyes-off-the-road episodes. These behaviors have obvious safety and operational consequences.

Under NCHRP Projects 3-50 and 3-50(2), "Driver Information Overload" and "Additional Investigations on Driver Information Overload," respectively, Westat, Inc. developed and validated a driver information overload model for freeways and translated the model into a practical tool for traffic and safety professionals to use in analyzing driver information loadings.

Based on a literature review and analysis of alternate approaches, NCHRP Project 3-50 made substantial progress in understanding the problem and developed a general model that captured the primary aspects of the problem. Two research experiments conducted under Project 3-50 provided some empirical basis for certain aspects of the model. However, at the conclusion of the project, the model remained primarily conceptual rather than empirical.

Project 3-50(2) expanded on the previous work by conducting additional laboratory and on-road experiments. The laboratory experiments attempted to bracket the range of information loads associated with each sign type and the manner in which individual signs of a sign array combine to determine the overall information load associated with processing the sign array. The on-road experiments used a unique procedure in which the drivers continuously operated a thumbwheel dial, mounted on the steering wheel, in order to reflect moment-to-moment changes in the subjective difficulty of taking in all of the information with which they were dealing. The experiments also recorded vehicle speed, navigational errors, and other overt driver problems. Taken together, the experiments provided an empirical basis for refining the general conceptual model.

The model and the associated empirical base still has some limitations. Among these, there was not a sufficient empirical basis for defining a "red line" level that indicates information overload. The model output is quantitative, but relative at this point. Thus, alternate sign treatments can be compared as better or worse, but more research or experience with the model will be required before a given information load rating can be taken to be good, questionable, or bad (overload).

The model can be used to evaluate a given system of signs or to seek improvements using a "what if" approach. In addition to the software tool, the project also provided a set of guidelines and recommendations for dealing with sign information overload problems.

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ADDITIONAL INVESTIGATIONS ON DRIVER INFORMATION OVERLOAD

SUMMARY

NCHRP Project 3-50(2), "Additional Investigations on Driver Information Overload," investigated the problems motorists face when confronted with a multitude of complex sign displays as they drive and navigate. It extends work begun under a predecessor project, NCHRP Project 3-50, "Driver Information Overload." Together, these projects involved research that developed a model that predicts the peak information demand experienced by drivers when encountering arrays of signs on freeways. The model was then adapted as a software tool to help practitioners identify problems related to driver information load and evaluate alternatives for locating signage.

"Driver information overload" is defined as providing a motorist with too much information, through a series of devices or conditions, for a driver to have adequate time to perceive and respond properly. Therefore, the information load on a driver is a property not only of the specific sign he or she is encountering, but also of the roadway context in which the sign occurs, the information context in which the sign occurs, characteristics of the driver, and the particular navigational task. Where drivers are confronted with more information than they can process, they may decelerate severely or drive unduly slowly, make late or erratic maneuvers, take an improper route alternative, ignore critical information, fail to monitor other traffic, or have excessive eyes-off-the-road time episodes. These behaviors have obvious safety and operational consequences.

On the basis of a literature review and analysis of alternative approaches, an initial model of the driver information load process was developed. The model was related to the concept of the "information load profile" of the Positive Guidance model. As developed here, the Driver Information Load model viewed two general sources of demand as drawing on driver attention resources. One source, termed Information Search Demand, comes from dealing with the information displays confronting the driver. The two components of the Information Search Demand are the characteristics of the specific sign array and the characteristics of the general information environment in which that display occurs. The other general source of demand on the driver, termed Driving Task Demand, comes from dealing with the roadway and traffic while simultaneously trying to navigate. The model treated two components of Driving Task Demand: (1) one concerns the general features of the roadway and (2) the other recognizes that attentional demand increases in some manner as a key navigational choice point is approached. This

model was further developed and refined through a series of four experiments, two in the laboratory and two on the road. The four experiments established the reasonableness of this simple model for predicting the information demand on the driver and generated a quantitative implementation of the model.

The first experiment dealt with the information load imposed by individual freeway signs. A "universe" of navigation-related freeway signs was defined based on the *Manual on Uniform Traffic Control Devices* (*MUTCD*), and the study attempted to bracket the range of information loads associated with each sign type. Participants in a laboratory study had to attempt to extract relevant information from the signs during brief views similar in duration to a single glance at a sign while driving. Based on this work, a look-up table was devised, so that an analyst could assign a reasonable information load value to any typical freeway sign. The second laboratory experiment then dealt with the manner in which individual signs of a sign array combine to determine the overall information load associated with processing the sign array. Photoediting techniques were used to manipulate scenes so that sign panels could be "added" or "subtracted" from roadway scenes, with a viewing procedure similar to the first experiment. Various "rules" were investigated as predictors of the information demand of a sign array, based on the use of individual sign ratings taken from the look-up tables of the previous experiment. On the basis of the findings of this experiment, an analyst could then use the look-up table for individual signs and apply a summation rule to determine the information load associated with a set of signs co-located with one another on a freeway. The remaining two experiments were the preliminary and primary on-road experiments, which addressed other aspects of the driver information load model. These included roadway factors, spatio-temporal aspects of information load, and overt indices of driving problems. The on-road experiments used a unique procedure in which the driver continuously operated a thumbwheel dial, mounted on the steering wheel, in order to reflect moment-to-moment changes in the subjective difficulty of taking in all of the information with which they were dealing. The experiments also recorded vehicle speed, navigational errors, and other overt driver problems. Taken together, the set of experiments provided an empirical basis for refining the general conceptual model.

The set of experiments produced the following conclusions:

- "Information load ratings" for individual signs, as operationalized in this study, were reliable and replicable. Ratings for a common subset of signs used in the two laboratory studies correlated at $r = 0.86$, despite a number of methodological differences between the experiments.
- The look-up tables developed in the initial experiment accurately predicted the empirically derived information load ratings of individual signs. When the tables were used to predict the information load of new signs in the second laboratory experiment, the correlation between the table-derived values and the laboratory findings was $r = 0.84$.
- The information demand of an *array* of signs could be well-predicted based on knowledge of the individual signs, using the lookup table. The multiple-R correlation was 0.95.
- The information load imposed by a sign array, as actually measured on the road, could be well-predicted by the four-factor model (described below). The group load ratings for mean peak information for drivers in the on-road experiment correlated at $R = 0.81$ with the model prediction. This means that even though the model is quite simple, it is still able to account for approximately two-thirds of the variance in the on-road ratings.

The model, and the associated empirical base, still suffer from a number of limitations, discussed in the report. Among these, there was not a sufficient empirical basis for defining a "red line" level that indicates "information overload." The model output is quantitative, but relative at this point. Thus, alternative sign treatments can be compared as better or worse, but more research or experience with the model will be required before a given information load rating can be taken to be good, questionable, or bad (overload).

The model that emerged from this work was a four-factor multiple regression that included the following factors:

1. **Sign array information demand**: based on a method of summing individual sign values derived from a set of look-up tables.
2. **Maneuver proximity**: based on a ramping function that takes into account the distance of the sign array from the maneuver point. The function begins to ramp up 6,000 ft from the maneuver point and peaks 1,500 ft from the maneuver point, before ramping down from there to the maneuver point.
3. **Local information density**: based on the information demand and distance of the other sign arrays surrounding the target sign array.
4. **Roadway demand**: based on the geometric features of the roadway over the 11,000 ft preceding the maneuver point. The features include the number of lanes, curves, merges, exits, weaving sections, and lane drops.

The model does not include driver or traffic variables because it is based on the worst-case conditions. The driver is assumed to be either elderly or inexperienced, unfamiliar with the route, and navigating to an approaching destination. However, the driver is also assumed to be non-impaired and English-literate. Information load appears to be worst under conditions of moderately heavy but flowing traffic. When congestion is heavy and speeds are slow, the difficulty is not in acquiring the information but in accomplishing the maneuver. When traffic is light, there is less demand on the driver and there is more opportunity to slow down and to make maneuvers.

The model was implemented as a Driver Information Load software tool, designed for IBM compatible PCs with a Windows Operating System (Windows 95 or later). It uses Microsoft Access Runtime and Excel programs simultaneously. The program takes the analyst through the data entry process and use of the look-up tables for individual signs. Model output is in both tabular and graphic formats, and shows the contribution of the various model component elements to the overall information load. The model can be used to evaluate a given system of signs or to seek improvements using a "what if" approach. In addition to the software tool, the project also provided a set of guidelines and recommendations for dealing with sign information overload problems.

CHAPTER **1**

INTRODUCTION AND OVERVIEW

THE PROBLEM OF DRIVER INFORMATION OVERLOAD

Drivers are frequently confronted with a multitude of information displays, which they must perceive, comprehend, and evaluate while they are simultaneously controlling their vehicles, monitoring other traffic, dealing with distractions, and navigating to a destination. In most metropolitan areas, one can readily find examples of freeway sites where within a few minutes of driving time there are dozens of elements of route guidance information, in addition to other information sources and distractions. The need for signing is frequently associated with complex traffic operations, geometrics, or potentially hazardous situations, so that the information load confronting the driver is often greatest when the demands of vehicle control, guidance, and crash avoidance also impose their greatest workload. When drivers are confronted with more information than they can process, they may decelerate severely or drive too slowly, make late or erratic maneuvers, take an improper route alternative, ignore critical information, fail to monitor other traffic, or have excessive episodes of eyes-off-the-road time. These behaviors have obvious safety and operational consequences. Current standards permit rather high densities of destination signing, and current guidance is lacking in terms of helping the traffic engineer determine when there is too much information and what can be done to address it. The purpose of NCHRP Project 3-50 (*2*), "Additional Investigations on Driver Information Overload," was to address these issues. It sought to define the problem, provide a means for estimating information load, and provide guidance for dealing with potential driver overload. The "*Additional Investigations*" in the project title reflects the fact that this project extended work begun under an initial project, NCHRP 3-50, "Driver Information Overload" (*1*).

Driver information overload (DIO), as used in this project, is defined as providing a motorist with too much information, through a series of devices or conditions, for a driver to have adequate time to perceive and respond properly. Thus the definition is not based simply on the content of the relevant signs. Rather, it must include the content of all relevant signs, the time and distance available to view them, the simultaneous demands on the driver, and the cognitive demands of interpreting the information in the signs. "Information overload" is not a simple property of a particular sign array, but rather a more complex interaction of the sign, its context, and the driver's knowledge and task.

Gordon's (*2*) insightful work on the information load of highway signs emphasized this key point: "The naïve view that overload is simply accounted for by the amount of displayed information is erroneous. Information load is largely determined by what the driver does with the displayed information." In other words, the drivers of two vehicles travelling through the same site may have very different information loads imposed upon them by the existing environment. A driver who is familiar with the roadway and simply wants to stay on the current route does not have a particularly burdensome task. Even if there is extensive signing, he/she does not have to fully attend to all the information. In contrast, a driver who is lacking in perceptual/cognitive capabilities or driving experience, unfamiliar with the route, traveling when traffic is heavy, and looking for the appropriate route to an unfamiliar destination, has a very different demand for dealing with sign displays. What this means is that the information "content" of traffic control devices is not equivalent to the information "load" on the driver.

Because information overload is a complex and driver-specific process, there is a challenge in representing this process in a manner that is useful for the traffic engineer. Complex human information processing models, of the sort used to design advanced cockpit displays or process control consoles, might have the sophistication to represent the mental demands, given sufficiently detailed information cast in terms of psychological constructs. However, a practical traffic engineering aid should not require this level of effort or force the engineer to deal with psychological variables rather than traffic engineering variables.

OBJECTIVES AND SCOPE OF THE PROJECT

The objectives of the project were to develop a model of driver information load for freeway applications and to translate that model into a practical tool so traffic and safety professionals could analyze driver information load. The specific focus on freeway signing applications provided a reasonable scope for the effort because this was felt to be the primary locus of current traffic engineering concern. Ultimately, it

would be useful to broaden the scope of guidance to include other types of roadways (e.g., arterials) and other modes of communication (e.g., intelligent transportation systems, highway advisory radio). However, absent any existing model of DIO and the lack of empirical data upon which to develop a model, it would be unrealistic to address such diverse applications under an initial project of limited scale. The goal of developing guidelines for the range of freeway applications was itself an ambitious target of real practical significance.

In order to achieve this final objective, the project incorporated a number of intermediate goals. These included identifying driver information-processing needs and problems related to freeway guide signing; understanding current traffic engineering concerns and practice related to information overload; incorporating driver and roadway factors into a useful conceptual model of driver information load; refining the model through research experiments; and developing a practical tool for traffic and safety professionals based on the model.

It should be noted that this project dealt specifically with the problem of *information overload*, and not with other issues related to signing practice. A number of important signing problems can, like information overload, lead to driver confusion, operational problems, and safety concerns. However, these are beyond the scope of the present project, and should be explicitly distinguished from information overload. These issues include information deficiencies, confusing sign content, use of route names or numbers for guidance, selection of destinations to show on signs, sign placement to avoid obstruction, and detailed design aspects for variable message signs. While all of these are worthy issues, this project focused on DIO, which concerns the ability of drivers to handle information within time/distance constraints.

OVERVIEW OF PROJECT TASKS AND RELATION TO NCHRP PROJECT 3-50

A series of tasks were undertaken to accomplish the project objectives. These efforts represent an extension of the work begun under NCHRP Project 3-50. In the earlier project, there was a review of the technical literature pertinent to DIO. This included research on sign perception, visual search, information processing, models of driver behavior, and general models of human information processing. A preliminary conceptual model of DIO was then developed. Two experiments (one laboratory and one on-road) were conducted to begin refinement and quantification of the conceptual model. This preliminary work essentially was completed in 1997 (an interim report was delivered in 1998). Based on the promise of the initial findings, the present project began in late 1999 to continue development of this line of work. Project NCHRP 3-50(2) included the following major tasks:

- Update the literature review of NCHRP Project 3-50 and determine if any recent research has implications for the information load model or the planned research experiments.
- Conduct new experiments to provide an empirical basis for the proposed information load model.
- Revise and refine the model based on the research findings.
- Implement the model in computerized form; exercise and evaluate the model.
- Formulate the model into a practical user tool for traffic and safety applications.
- Provide guidelines for freeway sign use that would address DIO.

The sections that follow describe these project efforts and their findings. Key activities and findings from the earlier project (NCHRP Project 3-50) are incorporated into the discussion, where appropriate.

CHAPTER **2**

LITERATURE REVIEW

A detailed literature review was conducted to summarize the current understanding of how drivers handle roadway information, particularly when there are constraints on the time or distance available for a decision. The full literature review was conducted under NCHRP Project 3-50. It was presented as an interim project report under that project (*3*) and was updated for the present project.

INITIAL REVIEW OF LITERATURE

The initial review of literature took place under NCHRP 3-50 and was conducted in 1995. This literature review first considered the findings related to how people notice and attend to signs. A sign or other traffic control device (TCD) will not impose any information load on a driver if it is not "noticed" or attended to. However, this is not an all-or-none process. Rather, highway information sources can be processed to varying degrees and have varying amounts of attention directed at them. The information load is, therefore, not a direct function of the amount of information in the sign, but of the degree to which the driver processes that information. Most of the research on the ability of signs to capture attention and force information processing ("conspicuity") comes from research on warning or regulatory signs, rather than guide signing. Attributes of the sign, its location in the visual field, legibility, background complexity, competing information elements (relation to "noise" elements), and driver expectancy have all been shown to be important determinants of whether, when, and to what degree signs will be processed. Because this literature primarily dealt with warning or regulatory signing, it was of limited use for quantifying driver behavior related to freeway guide sign use.

The literature review next considered models of the visual search process. Visual search processes can be defined in terms of three elements: (1) target characteristics, (2) search field characteristics, and (3) search strategies. Strategies are often classified in terms of how the eye covers the search field. The broad distinction is between visual search schemes that are controlled by the features of the objects in the visual field and schemes that are controlled by the knowledge and beliefs that the viewer brings to the situation. In some situations, the manner in which the visual field is scanned is largely determined by what is in that field: salient objects and their spatial relationships influence the way the eye scans the field. This is referred to as an "exogenous" search strategy. In other situations, the manner in which the visual field is scanned is largely determined by a systematic plan, or "cognitive strategy." This is referred to as an "endogenous" search strategy, and researchers in this field have distinguished a variety of types of endogenous search strategies. In many real world situations, a combination of strategies may be used. Research on visual search in highway driving, particularly the work of Theeuwes (*4*), has highlighted the importance of endogenous strategies that are specifically related to people's expectancies about roadways and signs. In other words, drivers will scan a roadway scene differently than they would scan a similarly structured scene that was not a driven roadway. The way the eye scans is based on people's knowledge of what typically occurs. This is an efficient search strategy when the expectancies are accurate. However, when signs occur in locations that violate driver expectations, there can be considerable delays in detecting those signs.

The literature review next covered the findings related to how people process the information in signs, given they have directed sufficient attention to the signs. Eye movement studies found that most signs receive at least some glances, even when the situation is complex. Although most signs were "read" (if not fully comprehended), this proportion drops when vehicle interactions become more demanding. Much of the pioneering work concerning where and when drivers look for information has been done by Rockwell and Bhise (*5*), although important advancement in modeling this process has been disappointingly limited since that time. Also, much of the work on sign processing has involved warning or regulatory signs, rather than freeway guide signing. Rockwell's work has defined a number of important factors that influence when the initial glance to a sign occurs, how much attention the sign receives, what portion of the available viewing time it draws, and how attention gets distributed among competing features. One finding of note is that when drivers are unfamiliar with the road and confused about the path, they often begin sign-reading late, use a low proportion of the available legibility distance, concentrate their attention on signs during critical periods, and continue reading as late as possible. Drivers who are more familiar with the route and less stressed do not exhibit these characteristics.

The research on noticing signs, directing attention, and processing sign information emphasizes the notion that the human information processor is not a passive receiver of

information. He/she has various strategies for seeking or ignoring different sources of information. When information load is high, the driver does not simply accept the overload, but invokes strategies for dealing with it.

The literature review also addressed models of the driver related to information use. These included the positive guidance model (*6*), DHESS Design and Evaluation of Highway Signing Model (*7*), and work by the Texas Transportation Institute on guidance related to real-time (changeable message sign) information display (*8*). None of these models was directly usable for determining driver information load, but all were useful for approaching the topic. Positive guidance, in particular, provided a simple model that was adaptable to the problem. In addition to these models of driver behavior, the literature review also described the general development of information processing models from academic theory and other domains of application.

In summary, the literature review indicated that there has been a considerable amount of research on how drivers may perceive or respond to signs and other TCDs, but relatively little study has directly addressed the specific issue of driver information overload (DIO). There are many aspects to how a driver handles roadway information, but the literature is very fragmented. For example, most of the research on how a sign gets noticed has been based on studies of warning signs, while other research on message formats may be specific to guide signs or variable message signs. The literature does not provide a coherent basis for integrating detailed knowledge about all of the component perceptual and cognitive processes that together determine how much effort is needed to process information in a given situation.

Several key themes emerge from the literature reviewed here, and should be noted:

1. The information load imposed by a given array of information is not simply a function of the total number of "bits" of information contained within the array. The tasks the driver is engaged in, the roadway situation, and the attributes of the driver are essential, interacting factors. A specific sign will impose a load dependent upon its meaning to the driver, driver expectancy, driver experience, driver familiarity with the roadway, and individual differences in performance capabilities. The presence of interacting traffic, roadway geometry and navigational choice points, and other TCD and information sources are critical. The ability of the driver to "shed" irrelevant or lower priority information is an important attribute, as are the perceptual search and processing strategies used to organize and analyze a scene. Because sign processing is not simply mechanistic, it is not sufficient to simply assign a given sign some fixed value in terms of the load it imposes on a driver. If a meaningful model of driver information load is to be developed, it apparently will have to incorporate explicit assumptions about a particular driving scenario: the driver, the task, familiarity and expectancy, environment, and so forth.
2. There is little common ground between current, applied models of driver information handling and basic models and applications for processing cognitive information. Models used for traffic engineering applications have the advantages of being relatively simple and of directly incorporating traffic engineering concepts and variables. However, their simplicity and mechanistic nature make them questionable as reasonable models of driver information processing. Current theoretical and empirical work in human information processing provides more sophisticated models, but they are complex and difficult to work with, and do not deal very directly with highway concepts. Such theories have been incorporated into network models for military design applications (e.g., helicopter displays), but the level of analysis, effort, and expertise involved in applying these models is likely prohibitive for normal traffic engineering applications.
3. Previous research on highway signs has focused predominantly on individual elements of information displays, rather than on the influence of broader arrays of information incorporating multiple TCD and spatio-temporal aspects of information distribution. There is substantial information, for example, on when a given sign may become legible or on how the perception-reaction time may be characterized. There is much less information on how driver performance will be influenced by sequences and arrays of signs of various types, in various locations, competing with one another for attention.
4. Existing research has revealed a variety of important concepts and relationships, but often these are at a qualitative level. There may not be a solid empirical basis for incorporating these factors into a sophisticated, quantitative model of information load, driver performance, or other higher-order description.

In summary then, as of 1995 the literature showed many factors related to driver information load and clearly indicated that a method or model for computing this load cannot be simply a mechanistic addition of the number of information elements in a display. At the same time, there were serious limitations of empirical data and current models that restricted the ability to quantify DIO.

LITERATURE UPDATE

As an initial step in the continuation of this line of research, the literature review was updated. This limited search was sharply focused on work that had been published or conducted since the initial review, and that had direct relevance for modeling DIO or for the methodology of researching the problem. The search specifically covered the time period 1994 to 1999 and was conducted in October to November 1999. The search effort included published, unpublished, and ongoing research, including foreign and domestic sources.

A variety of search activities were undertaken, including the following:

- Primary database automated keyword search;
- Key journal/proceedings scans;
- Internet search;
- Contacts with key experts; and
- Contract with technical committees and professional societies.

Although a great many articles were initially targeted by the keyword searches and other techniques, a subsequent scan of abstracts limited this set to about 36 titles requiring direct consideration. Upon obtaining these documents, each was scanned for actual relevance. Most turned out not to be directly related to the issue of DIO as related to highway signage. Even several major research efforts of which we were aware, and which sounded superficially as though they would be relevant, turned out to offer little of real benefit.

The general impression that emerged from all of this review was that there has been very little recent activity in related areas, with the exception of research on driver workload related to in-vehicle information systems (IVIS). This focus on in-vehicle technologies is part of the broader effort that has been directed at intelligent transportation systems (ITS). The types of ITS tasks investigated included things such as moving map displays, cellular phone use, or on-board display of information on points of interest.

While the present project is focused on roadway signing, it would seem that research on parallel issues for in-vehicle displays might provide some useful insights. However, this was rarely the case because this ITS work provides very little in terms of theory or models that we can draw on. Rather, there are very specific empirical evaluations regarding the ability of a driver to engage in a certain information-intensive task while driving. There are minimal means to generalize these findings. Typical questions might be whether a given item is more effectively presented as an auditory or a visual message, or whether a particular visual message works best as a text, chart, or icon display, or whether using a cellular phone disrupts vehicle control. None of this was very useful for extension to external roadway sign practices.

Another line of research that was not pursued in this search had to do with improvements to the legibility of highway sign alphabets. To the extent that legibility distances can be improved, drivers may derive a benefit in having more time to process that information. For example, Garvey and Pietrucha (*9*) describe a new type font called "Clearview," which they report resulted in a 22% increase in legibility distance for older drivers at night. The researchers did not find font legibility research to be directly relevant to model development, except to highlight the fact that, to the extent that sign legibility distance is used in any design tool built around a model, the analyst should be cognizant of any unique fonts that might significantly modify the estimated legibility distances.

While none of the more recent research had major implications for the continuation of the driver information load project, several studies were of some interest and raised various points worth noting. The research programs or research articles considered in detail included the following:

- An FHWA project on *In-Vehicle Information Systems Behavioral Model and Design Support* (*10*);
- An NHTSA project on *Heavy Vehicle Driver Workload Assessment* (*11*);
- A laboratory study of time-of-day effects on processing sign information (*12*);
- Ontario Ministry of Transport research on tourist sign information (*13*);
- Texas Transportation Institute research on workload effects associated with aspects of highway design (*14, 15*);
- An "in situ" study of driving workload during extended commuting trips (*16*); and
- A minimum required legibility distance model of sign placement for rural two-lane roads (*17*).

Detailed discussion of each of these sources, and the implications for DIO research or modeling, are provided in Appendix A.

While there are items of interest in the above sources, nothing in the recent technical literature directly affected the basic approach to the driver information load model as initially developed under NCHRP Project 3-50 and discussed in Chapter 3. There are some interesting alternative or complementary approaches to dealing with the problem, but they are not very mature and offer no obvious advantages to the current approach. There is little in the way of either empirical data or conceptual approaches that may be of immediate use for the current application.

A number of approaches seen in other work share a general conception of the problem with the present approach as outlined in Chapter 3. That is, they assume an attention-sharing model with limited attentional resources, competing demands from informational tasks and transient factors as well as general driving/vehicle control tasks, and additive processes for integrating these demands (e.g., Hankey [*10*]; Woolridge [*14*]; Kiger et al. [*11*]; Zeitlin [*16*]).

There were some methodological points raised by some of the reviewed literature, and these influenced some details of the on-road research conducted in this project. However, these are in the manner of methodological refinements, rather than basic changes, as follows:

- The use of brake activations as a supplemental performance measure of driver workload;
- The need to control for time-of-day effects in experimental design; and
- Consideration of potential driver expectancy violations in the interpretation of findings.

CHAPTER **3**

GENERAL APPROACH TO MODELING DRIVER INFORMATION LOAD

The motivation for developing a model of driver information load was to derive a basis for a practical tool for analyzing potential overload situations and to provide improved engineering guidance for freeway signing practice. The eventual users of this model and its associated products are seen to be traffic engineers and safety professionals. This objective helped guide the selection of a general approach to a model, the assumptions that underlie the model, and the conceptual model that ultimately was carried forward into the research phase. The model needs to be able to (a) rely on sign and roadway factors as the primary input, and (b) produce some sort of quantitative index of problem magnitude as output. The model is not an attempt to describe or replicate the complex perceptual and cognitive processes taking place within the driver.

CHOICE OF GENERAL APPROACH

A variety of approaches to modeling driver information load are possible as options. The literature review provided in Chapter 2 revealed a number of these. Broadly, these might be categorized as rather simplistic driver behavior models based on traffic engineering variables, more complex models of driver eye movement, and visual sampling based on the structure of the visual scene and the driving task, or complex cognitive models of human information processing in multitask environments. Originally, it was felt that the optimal approach might be a hybrid of several types of models. However, it soon became apparent that the type of information required for realistic cognitive modeling would place undue demands on the analyst for a traffic engineering application. In order to be a useful tool, the model should require mainly traffic engineering variables as inputs, with the complex underlying perceptual and cognitive processes transparent to the user. Many of the complexities could be dealt with by means of worst-case assumptions or the use of look-up tables rather than computations.

The general approach selected took advantage of the Positive Guidance model (*6*, *18*) as a convenient starting point. The Positive Guidance model is a systematized means of incorporating driver capabilities and behavior into the design or evaluation of highways, integrating human factors and highway engineering. It has the virtue of being an established and familiar resource in traffic engineering. The information load profile is a key part of the Positive Guidance approach that possesses a number of parallels with the modeling requirements of this project. It provided a useful conceptual approach for constructing a means of incorporating a range of information-processing demands on the driver. However, the information load profile technique also has a number of limitations or unrealistic assumptions for the present application, and so serves only as a conceptual starting point.

The Positive Guidance model, in common with a variety of other models of driver behavior, views the demands of the driving task as composed of three levels of task requirements. In Positive Guidance, these are viewed as a pyramid of three interrelated levels of performance: control, guidance, and navigation, with each level representing increasing complexity and a decreasing scale of priority, or "primacy." *Control tasks* are related to the driver interaction with the vehicle, controlling speed, path, and direction. Information at this level is provided by feedback from movement of the vehicle and from vehicle displays. The *guidance level of performance* is defined as those tasks related to a driver's selection and maintenance of safe speed and path. Guidance tasks require a driver to make decisions using judgments, estimates, and predictions. Information at this level is provided by highway characteristics, traffic, and traffic control devices. *Navigation tasks* involve the planning and execution of a trip from beginning to end. Decisions such as lane choice or speed are made at choice points along the route. Information sources may include prior experience, maps, signs, and landmarks. As one progresses through the levels of the Positive Guidance Pyramid, the tasks have less primacy and become more complex; drivers require more time to acquire information from signs and process information. When information sources compete for attention, lower primacy information tends to be discarded or delayed from consideration. The important implication of this conceptualization for the purposes of modeling driver information load from freeway signage is that the model must incorporate the demands of other aspects of the driving task as well as just the information present within a sign array. The ability to deal with sign information must be viewed in the context of the current driving task.

An important component of the Positive Guidance approach is the "information load profile." The information load profile schematizes the demands placed on the driver as a function of

the number of significant roadway items competing for a driver's attention. Schematically, each item is represented by a horizontal bar along an axis that corresponds to its location on the road. Each bar begins at the point in the road where the item first becomes visible or legible and continues until the item is passed. The bars for the various items are "stacked" as they overlap on these schematic diagrams. The information load at any point is determined by the height of the stack at that point. Excessive loading at a given point is seen as increasing the probability of a crash. While the present project attempts to model the problem of coping with sign information, rather than specifically with crash effects, the concept of using some additive model to integrate all of the demands on the driver at a particular location is appealing. However, while the information load profile technique from Positive Guidance provides an interesting analogy, it has a number of limitations for application to the present problem. Briefly, these include:

- All roadway items, from lane lines to geometric features to signage, have identical contributions to total load;
- The impact of a given element is mapped on the basis of the section of the roadway over which it is viewable; this may not be the same as the region over which it is likely to influence the driver;
- The summation of multiple elements to achieve a total information load is based on simple addition, but actual rules may be more complex;
- Applications of Positive Guidance have focused mainly on safety issues relating geometric design and traffic control devices to driver performance demands; there has not been as much consideration of navigation-related tasks. As a result,
  - The approach provides a more "micro" approach to roadway geometry and roadside features than may be desirable for the present application, and
  - The approach does not distinguish well among complex navigational sign messages and arrays of signs.

Thus, something conceptually analogous to the information load profile provides a useful general framework from which to develop a model of driver information overload (DIO) for freeway guide signing, but it is only a starting point. A number of changes or refinements are required in order to achieve a useful quantitative model.

ASSUMPTIONS INCORPORATED IN THE MODEL

A set of assumptions related to the general modeling approach was explicitly set forth before conducting the research experiments and more detailed modeling efforts. These assumptions included the following items.

Driver and Task

One of the complicating factors in modeling information load is that the load is not simply a function of the sign content, but also the driver's knowledge, abilities, and task. A different information load could be computed for every driver encountering a sign array. To simplify this situation, the model is assumed to involve a "design driver," who typifies those most likely to experience problems dealing with the information load, within reasonable limits. The following design driver characteristics are assumed:

- **Familiarity.** The driver is assumed not to be familiar with the particular site.
- **Navigation Task.** It is assumed the driver needs to actively navigate in order to reach his destination, and that the signing contains information relevant to that decision.
- **Age and Experience.** The design driver is assumed to be an older driver or an inexperienced driver. These represent groups most likely to experience difficulty. Older drivers are less able to perceive and rapidly process sign information. Inexperienced drivers devote relatively more of their attention to the lower-level driving tasks (control and guidance levels) and are less effective in their attention-sharing strategies.
- **Impairment.** It is assumed that the design driver is *not* impaired by alcohol, drugs, or excessive fatigue.
- **Literacy.** It is assumed that the design driver is English-literate.

Roadway Type and Traffic

The model is confined to freeway and expressway signing. Within these categories of roadway, there are still meaningful differences in the demand that the roadway will place on the motorist, exclusive of the navigational signing issues. The model should therefore include some means of reflecting a range of roadway demand. However, the degree of traffic congestion (level of service) is not a variable that needs to be incorporated into the modeling. Based on analyses done under NCHRP Project 3-50, the problem of DIO did not appear to be experienced during the stop-and-go conditions of peak periods because there was more time to process the information. The sense of information overload was greatest during moderately heavy but rapidly moving traffic. Therefore, this is the condition for which navigational signing systems must be designed and evaluated. The model need not be complicated by incorporating the level of service because the interest is not in the range of conditions at a site but rather with the design condition of moderately heavy but at-speed traffic.

Sign Type

The focus of interest is on signing relevant to the navigation task. This includes guide signing, motorist service signing, and recreational and cultural interest signing. For purposes of determining DIO situations, it is assumed that warning and regulatory signing can be ignored in this model. This assumption is based on the literature on driver eye movement, which suggests that where an unfamiliar driver is in an undecided navigational situation, the information from other sources can be "shed." This assumption may not be appropriate for arterial roadways, where control and guidance tasks require closer attention to traffic control devices at many points. However, because the interest here is specifically with freeways and expressways, the model can reasonably exclude traffic control devices other than guide signing, motorist service signing, and recreational and cultural interest signing.

Sign Set

Interest is specific to normal freeway signing, as typified by the signs defined in Sections 2E, 2F, and 2H of the *Manual on Uniform Traffic Control Devices* (*19*). This reasonable assumption provides a very important advantage for the model. It allows us to assume a fairly large, but finite, universe of possible signs. This means that the "information load" of a given sign can be directly determined from a look-up table, rather than needing to be computed based on a set of general characteristics of the sign (size, color, contrast, font, wording, diagrams, complexity, organization, message length, expectancies regarding content, etc.). It would take considerable research and development effort to develop a reasonable algorithm for translating general sign characteristics into an estimate of information load, and the resulting estimate would likely not be as accurate as one could achieve through a direct evaluation of the sign itself. Therefore, the information load model is not based around component sign physical characteristics, but is based upon matching a given sign to an exemplar from a structured universe of freeway signs.

GENERAL CONCEPTUAL MODEL

A general conceptual model of driver information load, consistent with the points of previous sections, was developed under NCHRP Project 3-50 and provided a starting point for the present project. This model is described as "conceptual" because it defines the various component elements of the model but is not formalized or quantitative in dealing with them. The research described in Chapter 4 was intended to provide a basis for a more refined and quantitative implementation of this general model.

The primary objective of the model is to define the information load associated with a given sign array within its roadway context. The term "sign array" is intended to refer to a set of individual sign panels that are co-located with one another at a given point on the roadway. Thus for example, three individual sign panels located on an overhead mast would constitute a single sign array. The model of driver information load is based on a process of determining the demand placed on the driver by sign arrays and by the driving task, and then summing these in an appropriate manner to derive a total demand placed on the driver's information-processing capabilities. In considering the demand on the driver in dealing with the information present in a given sign array, the model needs to incorporate: (a) the information content and format of the signs of interest; (b) the local information context in which those signs are placed; and (c) the demands of the driving task concurrent with the sign information processing task.

Figure 1 presents a high-level overview of the model. The model breaks the driving task into two major categories, Information Search Demand (ISD) and Driving Task Demand (DTD). Together these categories draw on the attention of the driver. The driver's ability to devote attention to these demands is dependent in part upon various characteristics of the driver, as shown in the illustration. As discussed above, the model uses a "design driver" concept so that individual driver characteristics do not need to be considered. The design driver assumes a locally unfamiliar driver involved in navigating at an approaching choice point. The driver is assumed to be older (e.g., age 65 or older) or inexperienced, English-literate, and not impaired.

The two categories of the driving task, ISD and DTD, are related to the three levels of driver performance of the Positive Guidance model. The lower-level demands of the guidance and control tasks are combined into a single category, DTD, encompassing the general characteristics of the roadway segment and choice points. ISD is analogous to the navigation task as defined by Positive Guidance. Both of these demands, as defined within the DIO framework, compete for available attention resources of the target driver. For purposes of this model, additional demands on driver attention from in-vehicle sources and tasks are not a consideration. Information sources are primarily visual and external to the vehicle.

The driver information load is determined by computing the DTD and the ISD and summing these to derive a total demand, in the same manner as information elements are "stacked" in the Positive Guidance information load profile. DTD and ISD are themselves each composed of component factors that are also summed to determine the overall DTD or ISD values. The DTD is conceptualized in the model as having two components, a demand associated with the roadway segment and a demand associated with the interchange and its proximity. The ISD is conceptualized as having a specific sign array component and a local information density component. Thus the overall information load on the driver represents some additive process of four general sources of

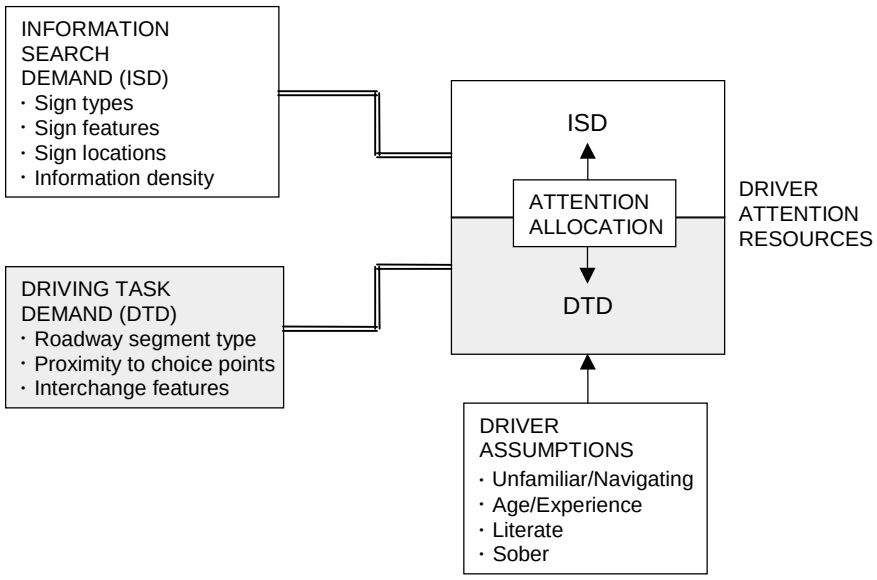


Figure 1. Driver information load model components.

demand for attentional resources: the general roadway, the proximity to maneuver points, the particular array of sign panels at a given location, and the more extended set of informational sources in the general vicinity around the particular sign array. The model presumes that as the total information load approaches higher levels, the driver begins to experience more difficulty in dealing with the information. At some point, the difficulty is severe enough to generate safety or operational problems, defining an "information overload" level. The sections that follow first discuss the DTD portion of the model, then the ISD portion, and finally the combination of all elements to derive the total demand.

Components of Driving Task Demand

The DTD is presumed to be a function of two factors: the roadway baseline requirement and the proximity to the navigation choice point.

The roadway baseline requirement is a general level of attentional demand requirement that is viewed as being more or less uniform over a section of freeway. It is determined by the nature of the roadway and its features. The initial means of addressing this factor was to simply categorize freeways in terms of a three-factor scheme: (1) distance between exits; (2) ADT/lanes each direction; and (3) level of service. However, this categorization scheme did not work particularly well for the on-road experiment of the present project. The preferred means of determining a value for the roadway baseline requirement was based on the set of particular geometric features present (as will be discussed further in Chapter 4). However operationalized, conceptually this factor should be viewed as the general demand imposed upon the driver over an extended segment of freeway based on the geometric, operational, and environmental characteristics of the roadway.

Although the baseline demand of a given freeway is treated as constant over an extended section of roadway, it is necessary for the model to recognize an increased demand as the vehicle approaches a navigational choice point that requires a driving maneuver. Models of driver behavior, including Positive Guidance, typically recognize features such as exit areas as imposing additional load, and the empirical findings of the initial (NCHRP Project 3-50) on-road rating experiment (and confirmed in the subsequent research of this project) identified a factor that clearly "ramped up" as the choice area was approached. The reasons for this increased load may have to do with the perceptual and control demands required to monitor conflicting traffic, find gaps, determine the appropriate lane, determine the appropriate speed, execute lane changes, and adjust speed. It might also be related to increasingly urgent cognitive or emotional factors associated with resolving uncertainty. The precise form of this maneuver proximity ramping function is an issue for model development, and it is dealt with further in Chapter 4.

Figure 2 illustrates the conceptual load diagram for DTD. The X-axis represents distance along the roadway, from some point upstream of the exit maneuver point to the gore point for the freeway exit. The information load imposed upon the driver by the roadway is shown on the Y-axis. Part of the DTD is due to the characteristics of the section of the roadway and is treated as fixed over the course of the road segment. This is labeled "Roadway Baseline." Superimposed on this baseline is the "Maneuver Proximity" function, which begins to ramp up at some distance from the exit point and reaches a peak

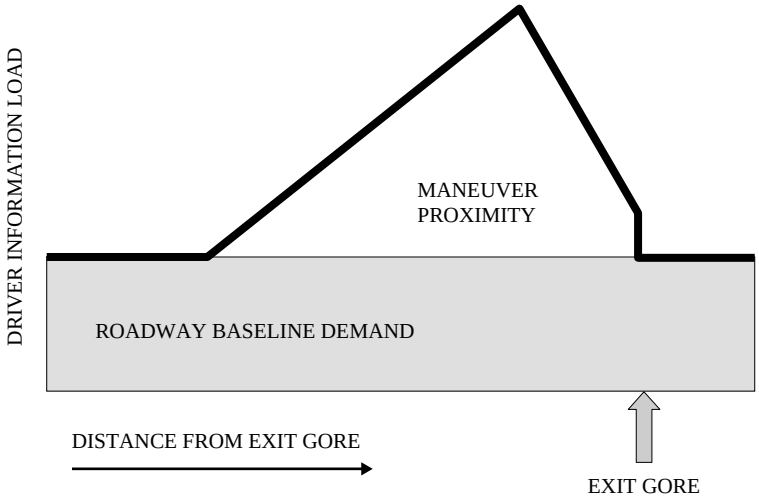


Figure 2. Information load conceptual diagram for driving task demand.

somewhere near the exit point. Taken together, these factors define a DTD profile, upon which the ISD profile is stacked.

Components of Information Search Demand

Conceptually, ISD is the demand imposed upon the driver by the effort of searching the formal information sources provided on the roadway and processing the information so as to support navigational decision-making. There are several aspects to this. First, each sign panel that the driver encounters has to be dealt with to some degree. However, the demand associated with a given sign panel depends in part on the information context in which that sign occurs. One aspect of this context is the other sign panels with which the sign may be co-located, that is, the sign *array*. There is no *a priori* reason to assume that the degree to which a given sign contributes to the overall information demand is identical whether that sign occurs in isolation or together with other signs. For example, consider three individual signs, A, B, and C. If presented alone, each of these signs may have some information demand level associated with processing it. Does this mean that if the motorist now encounters a sign array comprised of three sign panels, A, B, and C, the associated information demand for dealing with the array simply will be equivalent to summing the demands for the individual signs? This appears unlikely for a variety of reasons (search strategies, temporal constraints). Because the modeling approach selected here begins with determining the information demand associated with specific freeway sign types, some rule must be found for combining the associated demands for individual signs that comprise a sign array.

A given sign array will exert its effect over some span of distance and time, so that successive sign arrays may influence one another if they are in close enough proximity. Obviously, the demand on a driver would be greater if two complex sign arrays occurred in close succession as opposed to being spaced far apart. Therefore, the demands of dealing with the information in one particular sign array is influenced by the presence of other signs in the area. This is what is referred to in the model as the local information context. Somehow the model must be able to reflect the interaction of successive sign arrays. The initial modeling efforts under NCHRP Project 3-50 attempted to do this through defining an "envelope" of information demand in the region surrounding a given sign array, and then summing the overlapping portions of the envelopes for successive sign arrays. Figure 3, taken from the NCHRP Project 3-50 report (1) illustrates this concept. The upper panel of the figure (labeled "individual sign loads") shows information load envelopes for six sign arrays located along a roadway. The height of each function at a given point reflects the demand on the driver related to the sign array. The second panel of the figure (labeled "local sign effects") shows how the overlapping functions for individual sign arrays are summed to generate a total information load at each point, one that takes into account all of the sign arrays that may be influencing the driver at that point. However, there were problems with this approach. First, it was difficult to define the appropriate envelope shape, either through the empirical findings or theoretical treatments. Second, in order to yield meaningful results, an additional factor had to be added to the model, one that looked at the density of sign information over the full extent of a roadway site. This factor is shown as the "information density component" load in the bottom portion of the figure. The inclusion of this factor reflected the fact that motorists seemed to be responding to the effects of information that was located beyond the envelope

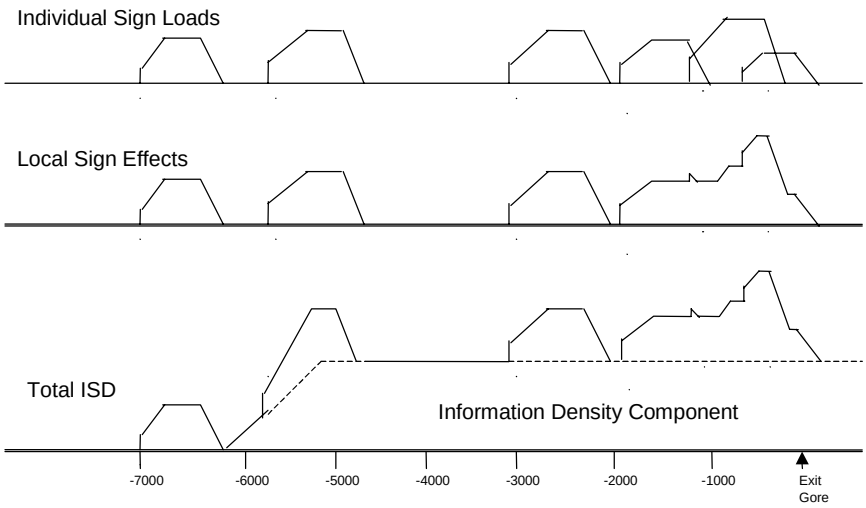


Figure 3. Components of information search demand.

of the sign, based on theoretically assumed envelope shapes. Based on the findings of the research reported in Chapter 4, another approach is provided in the model described later. However treated, it is essential to recognize that a particular sign array occurs in the context of other signage distributed along the site and that this additional signage provides a local information context in which the particular sign array must be dealt with by the motorist.

In summary, the major points with regard to the ISD are as follows: (a) there is some demand associated with a given sign; (b) some rule governs the summation of individual sign loads to determine the demand associated with a given sign array; and (c) other signage in the vicinity of a particular sign array provides a local information context that also contributes to the difficulty of dealing with the target sign array. Figure 4 illustrates this conception of ISD. In contrast to Figure 3, this figure does not attempt to illustrate any particular region over which the information load of a given sign array is experienced; a single point of information load is shown. The need and ability to describe the spatiotemporal aspects of information demand are dealt with further in subsequent sections.

Total Information Load

The total information load represents the ISD value overlaid upon the DTD value. Figure 5 illustrates this conceptualization. The figure shows the summing of the two factors, each composed of its subfactors. The overall height of the function represents the total demand associated with coping with the navigation-related sign information. Some level of this demand defines an "information overload" region. The research and modeling efforts described in the subsequent sections of this report represent an effort to formalize this conceptual scheme and develop a useful engineering tool based around this model.

Although the conceptual model was illustrated diagrammatically in order to illustrate the process of summing component aspects of information load, this does not imply that the ultimate model or related engineering tool needs to be diagrammatic rather than in some other form. Formalization of the conceptual model will be dealt with in subsequent sections of this report. It should also be recognized that this initial effort at modeling is limited in that it does not include all possible factors contributing to information load nor does it attempt to treat each component factor to the greatest level of

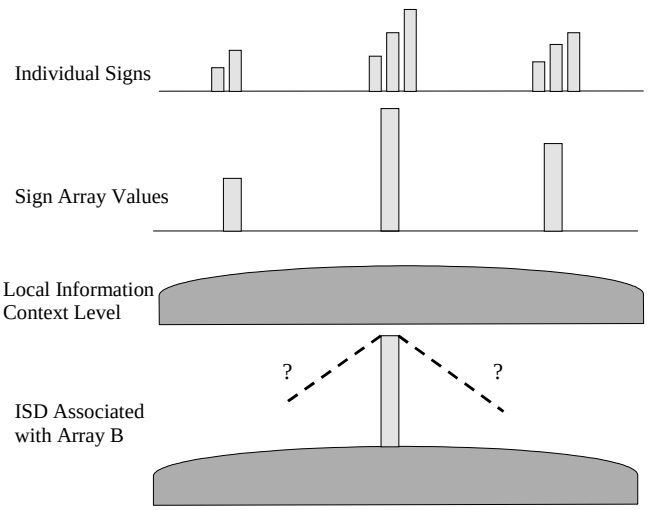


Figure 4. Conceptual scheme for information search demand.

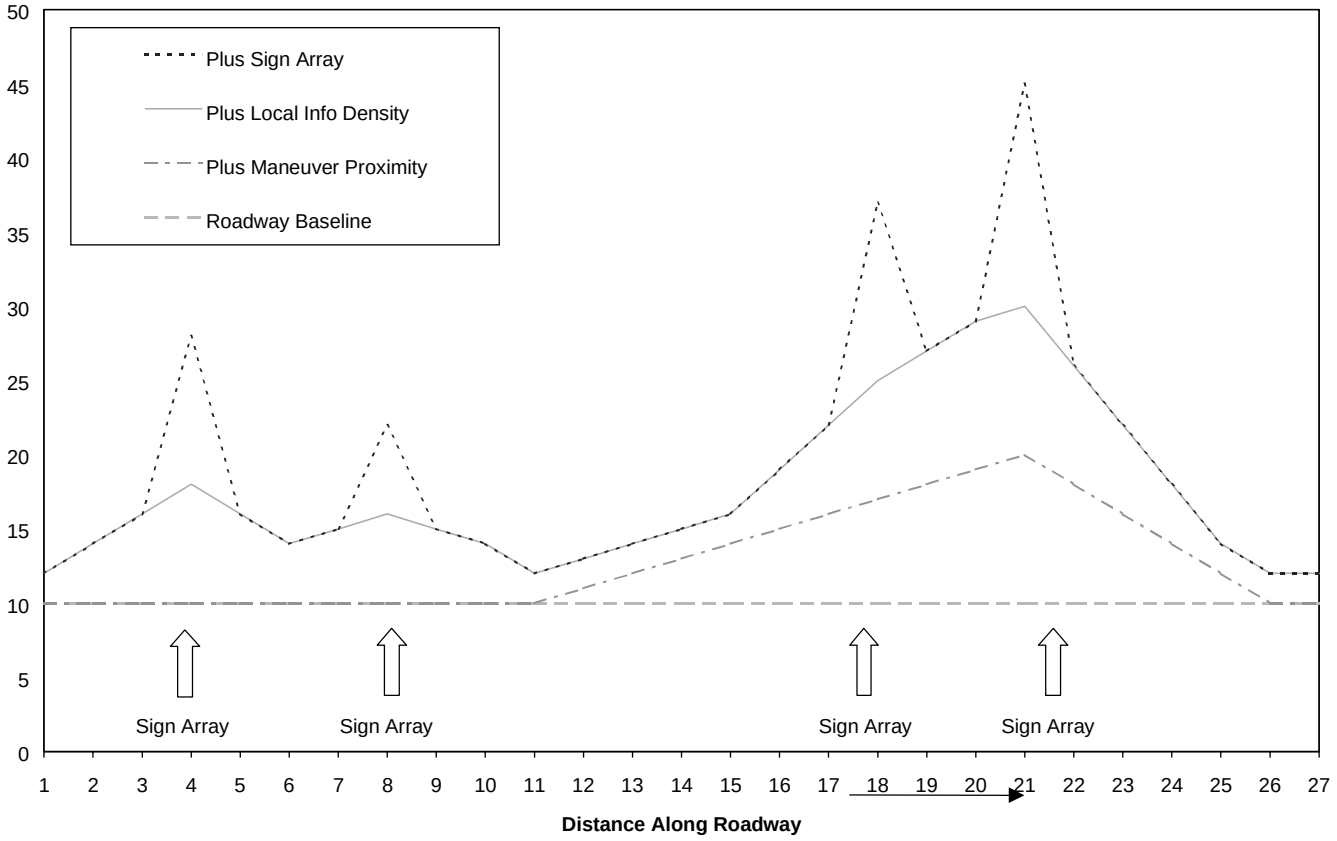


Figure 5. Conceptual scheme for total information load.

detail. For example, off-road signing and distractions are not explicitly treated, nor are transient factors such as obscuration of signs by trucks in the traffic stream. Roadway driving demands could be treated at a much more micro level of analysis (e.g., point-by-point consideration of every roadway element). The model does not address qualitative aspects of the sign message (e.g., is the message ambiguous, are the destination names appropriate?) or fundamental traffic engineering principles (e.g., appropriate legibility and sight distances). Nonetheless, the scope of the problem that is addressed is substantial and provides an opportunity to significantly improve current practice.

CHAPTER **4**

RESEARCH EXPERIMENTS

OVERVIEW OF SET OF EXPERIMENTS

Two experiments, one laboratory-based and one on-road, were conducted as part of this project. These two experiments were related to two previous experiments carried out under NCHRP Project 3-50. Because this set of experiments formed a series of related findings, all four are included here. One experiment carried out under NCHRP Project 3-50, the Preliminary On-Road Experiment, essentially served as a pilot study for the later Primary On-Road Experiment, so it is discussed in less detail.

The first experiment dealt with the information load imposed by individual freeway signs. A "universe" of navigation-related freeway signs was defined based on the *Manual on Uniform Traffic Control Devices* (*MUTCD*), and the study attempted to bracket the range of information loads associated with each sign type. Based on this work, a look-up table was devised, so that an analyst could assign a reasonable information load value to any typical freeway sign. The second experiment then dealt with the manner in which individual signs that make up a sign array combine to determine the overall information load associated with processing the sign array. Based on the findings of this experiment, an analyst could then use the look-up table for individual signs and apply a summation rule to determine the information load associated with a set of signs co-located with one another on a freeway. The preliminary and primary on-road experiments then addressed other aspects of the driver information load model. These included roadway factors, spatiotemporal aspects of information load, and overt indices of driving problems. Taken together, the set of experiments provided an empirical basis for refining the general conceptual modeling approach described in Chapter 3.

INDIVIDUAL FREEWAY SIGN INFORMATION LOAD

Overview and Objective

The objective of this experiment was to define a relative measure of information load for any navigation-related signing likely to appear on a freeway. This was accomplished by first defining the set of likely signs and specifying each one in a manner keyed to the relevant *MUTCD* section or figure. This research was conducted prior to the completion of the Millennium Edition of the *MUTCD* (*19*), so the 1988 version of the *MUTCD* (*21*) served as the reference document. For each specific sign type identified, the permissible range of elements allowed by the *MUTCD* was determined. Based on this, two specific versions of the sign were developed: a lower-complexity version and an upper-complexity version. For example, Sign E1-1a in Figure 2-9 of the 1988 *MUTCD* (and Figure 2E-13 of the 2000 *MUTCD*) shows an advance major guide sign with a separate exit panel marker. This sign is illustrated in Figure 6a. A lower-complexity version of this sign would contain one short destination name, in addition to the route marker, while an upper-complexity version would contain two long destination names in addition to the route marker. Figure 6b illustrates low- and high-complexity examples for this sign type. In the experiment, lower- and upper-complexity versions of each possible sign type were assessed. As a result, the findings could be presented as a look-up table. An analyst using the table could directly look up the type of sign, see the range of information load between the lower- and upper-complexity versions, and determine where in this range the specific example under consideration was likely to fall (i.e., was it analogous to the lower-complexity example, the higher-complexity example, or somewhere in between?).

In addition to bracketing lower- and upper-complexity examples as permitted by the *MUTCD*, the set of signs tested also included some that went beyond the *MUTCD*'s recommendations. For example, a version of the advance major guide sign with a separate exit panel marker could be developed with three destination names. This allows the analyst to consider the "penalty" in information load for stretching any of the recommendations for a specific sign type. The data were also analyzed in a manner that permitted some estimate of the general effects of various factors, such as word length, additional destinations, and so forth.

The primary use of the findings of this experiment is to provide a means of adjusting for the contributions of signs of varying complexities in the driver information load model. However, the look-up tables may also be useful in themselves as a means of getting a sense of the relative complexities of very different types of signs.



Figure 6a. Example sign from MUTCD.



Figure 6b. Examples of low-complexity and high-complexity versions.

Method

Sign Stimuli

A set of 275 different signs was used in the experiment. These signs represented variants of 54 basic sign formats. Table 1 lists the 54 specific sign formats (right-most column), broken out under headings of sign type/color (e.g., guide signs, motorist services signs) and subheadings of sign categories (e.g., advance guide signs, exit direction). The signs were taken from Sections 2E through 2I of the 1988 *MUTCD* (*20*). Section 2E in the 1988 *MUTCD* was "Guide Signs—Expressway" and Section 2F was "Guide Signs—Freeways;" these now correspond to Section 2E, "Guide Signs—Freeways and Expressways" of the 2000 *MUTCD*. Section 2G, "Motorist Service Signing," of the 1988 *MUTCD* corresponds to Section 2F, "Specific Service Signs," of the 2000 *MUTCD*. Section 2H, "Recreational and Cultural Interest Area Signs," of the 1988 *MUTCD* corresponds to Section 2H of the 2000 *MUTCD*, with the same chapter title. Section 2I, "Tourist-Oriented Directional Signs (TODS)," of the 1988 *MUTCD* corresponds to Section 2G, "Tourist-Oriented Directional Signs (TODS)," of the 2000 *MUTCD*. Versions of each sign were developed using a computerized drawing package and were representative in terms of font, color, format, and information content. The relative size of the sign images was consistent with typical practice and *MUTCD* guidance.

All signs fell into one of three sets. These included a "bracket" set, a "stretch" set, and a "format" set. They are defined as follows:

- **Bracket Set.** This set represented the broad range of signs as defined in the *MUTCD*. The specific sign examples "bracketed" the normal *MUTCD* cases by presenting a high- and low-information version of each sign type. Half of these signs displayed the minimum amount of information prescribed by the *MUTCD*, while half displayed the maximum amount of information that the *MUTCD* prescribes.
- **Stretch Set.** This set contained signs that exceeded the *MUTCD*'s recommendations for amount of information. This was accomplished by increasing the number of destinations, the number of route markers, the number of cardinal directions, and the number of lane indicators.

TABLE 1 MUTCD sign categories and format bases for stimuli

Sign type & color	Sign categories	Specific sign format (reference *MUTCD*, 1988)
Guide Signs or Recreation & Cultural Area (large) Signs (Green)	Advance Guide	- Fig. 2-9 - Sign E1-1 - Major with separate Exit Number Panel (E1-5) - Sign E1-1a - Major integrated - Sign E1-2 - Minor with text - Sign E1-3 - Minor w/o route
	Exit Direction	- Fig. 2-13 - Dest., Route & Diag. Arrow
	Lane Drop	- Fig. 2-33 - Sign E11-1 - Major with arrow - Sign E11-1a - Major - Sign E11-1b - Split minor - Sign E11-1c - Minor
	Gore	- Fig. 2-14 - Signs E5-1 & E5-2 (separate) - Sign E5-1a (integrated)
	Pull Thru	- Fig. 2-15 - Sign E6-2 - Small shield - Sign E6-2a - Large shield
	Supplemental Guide	- Fig. 2-11 Multiple-Destination Exits with suffix - Multiple-Destination Exits with NEXT RIGHT or SECOND RIGHT (no figure) - Fig. 2-26 - PARK & RIDE
	Interchange Sequence	- Fig. 2-18 - Sign E8-1
	Community Interchange Identification	- Fig. 2-19 - Sign E8-2
	"Next-Exits" Supplemental	- Fig. 2-10 - Sign E2-1 (horizontal) - Sign E2-1A (vertical)
	Next (X) Exits Area	- Fig. 2-20 (Sign E9)
	Post-Interchange Distance	- Fig. 2-17 (Sign E7)
	Diagrammatic	- Fig. 2-32
	Mileposts	
Motorist Services Signs (Blue)	General	- Fig. 2-43 - with "NEXT SERVICES" - without
	Specific	- Fig. 2-47 - Single-exit interchange - Double-exit interchange - Fig. 2-48 - Gas - Food - Lodging - Camping
	Rest Area & Scenic Area	- Fig. 2-44 - Rest Area Gore

(*continues on next page*)

TABLE 1 ***(Continued)***

Sign type & color	Sign categories	Specific sign format (reference *MUTCD*, 1988)
	Tourist Information & Welcome Centers	- Advance Guide (no figure) - REST AREA, TOURIST INFO CENTER, ___ MILES - REST AREA, STATE (opt.), WELCOME CENTER ___ MILES - Exit Direction (no figure) - REST AREA, TOURIST INFO, arrow or NEXT RIGHT - REST AREA, STATE, WELCOME CENTER, arrow or NEXT RIGHT
	Radio Information	- Sign D12-1 - WEATHER INFO - Sign D12-3 - CB CHANNEL 9 - TRAFFIC INFO (no figure)
	Carpool Information	- Sign D12-2 - CAR POOL - COMMUTER INFO (no figure) - VAN POOL (no figure)
Recreation & Cultural Area Signs (Brown)	General Guide	- Fig. 2-52 - Integrated multi-symbol - Separate multi-symbol - Water Symbol - Winter Symbol - Major Destination w/ Distance - Major Destination w/ Direction
Other	VMS	
	Boundary and Orientation	
	Weigh Station	
	Route Markers & Trailblazers	- Fig. 2-45 - Fig. 2-46

- **Format Set.** This set altered the format of the information presented in the sign. Conventional advance guide signs and exit signs in the "minimum information" bracket set were used as a basis for format changes. Changes included interchanging the location of a destination with a route marker, interchanging the location of a destination with exit information, moving a diagram from the right to the left side of a diagrammatic sign, and presenting destinations in capital letters. Variable message sign formats were also varied by altering the word order and number of lines.

Research Participants

A total of 23 people participated in the study. The group consisted of five females under the age of 20, six males under the age of 20, six females over the age of 65, and six males over the age of 65. The mean age for each age/gender group was as follows: young females, 17.7 years old; young males, 16.9 years old; older females, 73.4 years old; and older males, 72.8 years old. Selection of these age groups reflects the assumption of the information overload model that the target driver groups are either young novice drivers or older drivers. Participants were all English-literate, licensed to drive, and had normal or corrected-to-normal vision.

Procedure

Research participants viewed the signs in groups of up to five people, in a laboratory setting. Each computerized sign image was projected on a screen using a computer projection monitor. Participants rated each sign on a seven-point scale using a hand-held key pad. The sequence and timing of stimuli, as well as the collection of response ratings, was computer

controlled. Each sign appeared for a period of 1.75 sec; this value was selected because it is approximately equivalent to the duration of a single glance during highway driving (Bhise and Rockwell [*7*]). The participants were asked to evaluate the signs as drivers who must gather certain information crucial to driving and navigation. Specifically, they rated "How easy or difficult was it to obtain the information from the sign?" on a scale from 1 ("Very Easy") to 7 ("Very Difficult"). To ensure participants were attending to the signs and drawing information from them, comprehension questions also appeared at random times after participants had made their ratings. These were multiple choice questions, answered by means of the keypad. An example comprehension question is "Which lane should you be in if you want to go south on Route 94? 1. the left lane; 2. the right lane; 3. either the left or the right lane; 4. none of the above." The specific question asked was appropriate to the sign that it followed. These comprehension questions were used simply to require the participants to concentrate on extracting sign information, and were not treated as part of the analysis of sign load. Several practice trials were given, with an opportunity for the participants to ask any questions. Following this, data collection was begun, with a different random sequence for each group of participants.

Findings

An analysis of variance confirmed that the ratings of information load varied significantly among the signs. The primary findings of the experiment are descriptive, that is, the group mean information load rating associated with each type of freeway sign. For ease of use, the group mean scores on the 1 to 7 rating scale were linearly transformed to 1 to 100 scale for presentation. The results are summarized in three extensive tables, which are presented in Appendix B. A revised version of the look-up table, keyed to the Millennium Edition of the *MUTCD* (*19*) and including some minor revisions suggested by the next experiment, is presented later in the following section on "Combination Rules for Sign Arrays." The tables in Appendix B are keyed to the 1988 version of the *MUTCD* (*20*), under which the work was conducted.

Table B1 in Appendix B lists the signs in the "bracket set." These are the upper-complexity and lower-complexity examples of each sign type, as permitted by the *MUTCD*. The table indicates the sign type, the appropriate *MUTCD* (*20*) reference, a description of the upper- and lower-complexity content, and the group mean ratings for the upper- and lower-complexity versions. For example, the first entry in the table is for Advanced Major Guide Signs with Separate Exit panels (indicated in the first column of the table). The second column indicates that this corresponds to Signs E1-1 and E1-5 in Figure 2-9 of the 1988 *MUTCD*. The upper-complexity version of this sign used two destinations with long place names and one route marker. The lower-complexity version used one destination with a short place name and one route marker. The upper-complexity version had an information load rating of 26 and the lower-complexity version had a rating of 20. The group mean scores for the various signs in this "bracket set" group ranged from a low of 1 to a high of 37. Of the 89 signs in this set, only 6 had a mean rating of 30 or higher. All six were upper-complexity versions of their category, three of them being diagrammatic guide signs. Two others were the interchange sequence sign and community interchange sign, when these contained three destinations, all with long word length. The final sign rated over 30 was the double gas and lodging sign, when it contained a total of 6 icons. Table B1 is intended to serve as a convenient look-up tool, so that any relevant *MUTCD* sign can be directly looked up, and its relative information load estimated. It should be noted that for many types of signs, there were substantial differences between the upper- and lower-complexity versions, even though both extremes are permitted by the *MUTCD*.

Table B2 presents the effects of certain changes to the upper-complexity version signs of Table B1 for selected sign types. These changes included adding or subtracting an element, or multiple changes (four "short-word" destinations vs. two "long-word" destinations on a guide sign). Not all of these changes were consistent with practice in the *MUTCD*, but they allow an analyst to assess the influence of various changes. A few of these changes resulted in ratings substantially higher than those seen in the bracket set. Three signs had ratings at or above 40. When four long words were used on an advance major guide sign with separate exit and lane drop panels, the rating was 40 (versus a rating of 20 for the upper-bracket condition of two long words). The exit direction sign had a rating of 45 when four long-word destinations were used (versus two in the upper-bracket version). The interchange sequence sign was rated at 41 when four long-word destinations were used (versus two in the upper-bracket version). Thus all three exceptionally high information load ratings were for cases where there were four long words.

Table B3 attempts to summarize the effects of general variables by comparing various versions of a particular sign type that differ with respect to a given variable. The variables considered in the table include word length, number of destinations, number of route markers, number of icons, and sign color. For example, the table begins with word length, and the first entries are for advance major guide signs with integrated exit (Sign E1-1a of Figure 2-9 in the 1988 *MUTCD* and Figure 2E-13 of the 2000 *MUTCD*). The first comparison is for long- and short-word versions of this sign that had one destination; the ratings differed by 2.47 rating scale units. The next comparison is for the same sign type but with two destinations, and here the long- and short-word versions differed by zero units. Over a number of such observations, despite the variation from pair to pair, a general sense of the magnitude of the effect can be drawn. For example, word length

generally had fairly small effects (shifts of from −1.12 to +11.33 units), except for the case where there were four destinations, at which point the extra burden became more pronounced (+25.04 units). Adding additional destinations, beyond a total of two, tended to have large effects on the ratings. The effect of the number of route markers was quite variable. The intent of Table B3 is to provide a general indication of the influence of the selected factors, but no attempt to make a more specific quantification is merited, given the variability among comparison pairs.

COMBINATION RULES FOR SIGN ARRAYS

Overview and Objectives

The second laboratory experiment used a procedure similar to that of the preceding experiment but included arrays of freeway signs rather than just individual sign panels. The procedure was modified in two respects. First, the signs in this experiment were presented in actual roadway contexts. Photographs of actual roadway sites were digitally manipulated to remove, insert, or otherwise modify existing sign arrays in the scene. Second, the viewing time for each scene presented was 3.5 sec. A longer presentation period was required than in the previous experiment because of the greater complexity of the scenes and sign arrays.

The experiment had the following objectives:

- Replicate the findings of the "Individual Freeway Sign Information Load" experiment and determine the reliability of the measures, through the use of a subset of signs common to both experiments;
- Determine the ability to predict the information load ratings of individual signs (in roadway context) through the use of the look-up table developed in the previous experiment;
- Identify any refinements required to the look-up table;
- Determine a rule for predicting the information load of a sign array based on the information load of individual signs comprising the array; and
- Determine if the combination rule requires any adjustments for features, such as sign location within the scene or sign color.

In order to determine how the information load of a sign array relates to the information load of the individual signs comprising the array, the experiment took the approach of manipulating photographic scenes so that identical situations could be evaluated with the only differences being in the signs present. For example, a particular site might be digitally photographed that contained an overhead sign mast with three different sign panels. Through the use of photo-editing software, individual signs could be removed or relocated in the scene, with their original locations realistically replaced with the appropriate background. Thus each sign could be evaluated alone (other two sign panels removed) within the scene; each pairwise combination (two of the three signs) could be evaluated; and the complete set of three signs could be evaluated. Given the large total number of stimuli viewed by participants in the experiment and the brief presentation time for each stimulus, participants generally had little awareness of having viewed a particular scene previously. By systematically manipulating scenes with up to four or more sign panels, an empirical basis was provided for deriving a combination rule for signs within sign arrays.

Method

Sign Stimuli

Of the total of 172 stimuli presented to research participants, 110 were generated from photographed sign arrays that exist in real highway situations, while 62 images consisted of computer-generated signs (primarily from the set of signs used in the previous laboratory study) inserted into photographs of real roadway scenes.

Appendix C provides a description of the 172 stimuli. They are grouped by roadway location. For each scene, the table indicates whether the signs were photographs of those actually present at the site ("photo") or graphically fabricated sign images that were inserted into a scene ("graphic"). For each stimulus, the table indicates the number and type of signs that constitute the array.

Photographed Stimuli. A wide variety of different sign types and arrays were photographed in Northern Virginia; Washington, D.C.; and Maryland. Each scene was photographed at approximately 75 ft from an approaching vehicle, using a Nikon Coolpix 950 digital camera. Minor corrections to the images were made in post-production to standardize the size and quality of the photographic images (discussed below). All photographs were taken on sunny days to reduce variability between photographs and to maximize image quality.

From a large number of initial photographs, a set of 21 roadway scenes was selected for use in the experiment. The sites were selected on the basis of the types and numbers of the signs represented. Some sites were also selected because they were located along the route planned for use in the on-road experiment, which would permit direct comparison of laboratory and on-road ratings. However, the originally planned on-road route could not be used by the time an on-road experiment was conducted, so these comparisons were not possible. From the set of 21 roadway scenes, 110 stimuli were created using a graphics design software package, Adobe PhotoShop, to digitally manipulate the number, color, complexity, location, and spacing of signs in the array. A complete listing of all sign stimuli, including both photographed and fabricated sign stimuli, can be found in Appendix C.

Each stimulus was edited using Adobe PhotoShop to maximize image quality and to standardize the appearance of the highway signs (with regard to sign size, sharpness, location, etc.) within the roadway scenes. In addition, all superfluous background signs and markings or potentially distracting elements were deleted from the stimuli in an effort to focus participants' attention on the sign array. An attempt was also made to standardize the relative size of signs and sign arrays across each stimulus, although it was impossible to keep these factors entirely equal across photographs. In general, an effort was made to keep the sign arrays within the upper third of each stimulus. The widest sign array included in the stimuli set was also used to set the approximate appearance of signs within each stimulus; that is, this particular sign array was used as a benchmark for sign size and location when editing all other stimuli so as to eliminate major differences in sign appearance across the stimuli set. Figure 7 illustrates several versions of a scene with modifications to the sign array. The original scene (upper-left photo) contains three sign panels. Modified versions are shown with only one or two of the signs remaining in the image.

Fabricated/Graphic Stimuli. The remaining 62 stimuli were created by inserting computer-generated signs into actual, photographed roadway scenes. The fabricated sign set consisted of a subset of highway guide signs and recreational guide signs (including some with some modifications) used in the previous laboratory experiment. This allows for benchmarking of findings from the previous study. The fabricated signs were modified using Microsoft PowerPoint. Some of the signs from the previous experiment were altered in terms of complexity by adding or subtracting words to create slightly more or less complex versions of the original signs. In addition, some words were truncated to see if word length played a role in determining information load of signs. The fabricated signs were then digitally inserted into the photographs of actual highway road scenes. The eight roadway scenes used were chosen from the set of photographs taken but not included in the set of 110 photographed stimuli, on the basis of image quality and ease of digital editing. The roadway scenes were edited using the same techniques in Adobe PhotoShop described above for the photographed signs. The actual signs that originally appeared in these photographs

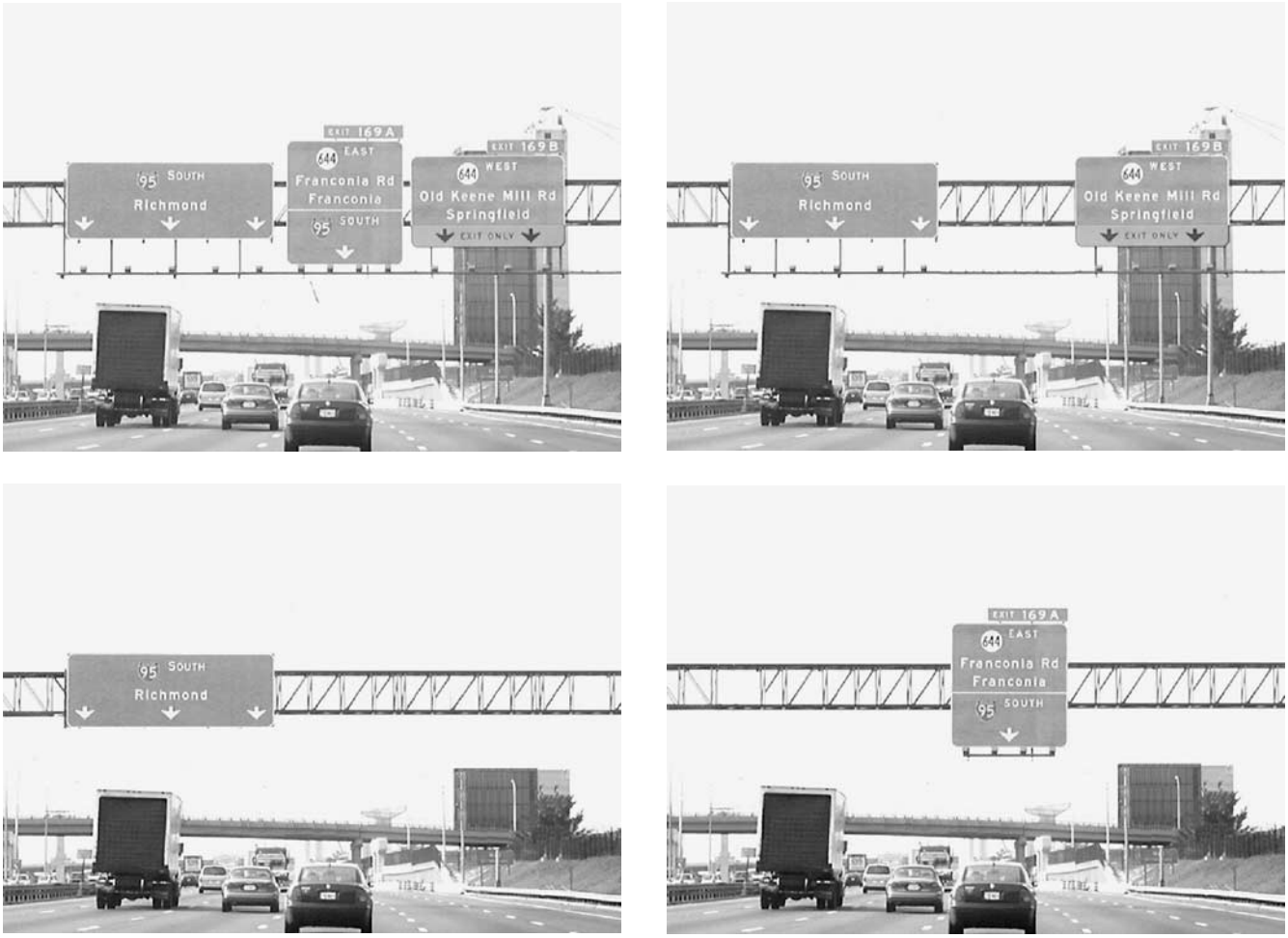


Figure 7. Original (upper-left) and modified versions of a scene.

were removed using Adobe PhotoShop and replaced by the fabricated signs. A total of 62 stimuli were created using Adobe PhotoShop to again digitally manipulate the number, color, complexity, location, and spacing of signs in the array. Details of each stimulus may be found in Appendix C.

Research Participants

Thirty-two participants took part in the study. There were 16 participants in the young group (mean age of 18.3 years, range of 16–20) and 16 participants in the older group (mean age of 75.9 years, range of 69–83), with equal numbers of males and females within each age group. All participants were licensed drivers, English-literate, and drove at least three times a week. The recruitment screening procedure also excluded those who reported frequent use of roads depicted in the stimuli.

Participants were tested in groups of up to five. Typically, a morning and an afternoon session were scheduled each day, recruited so that a given group was homogenous in terms of age group but mixed with regard to gender. Approximately equal numbers of participants were tested in the morning and the afternoon, with similar distributions of age and sex groups.

Procedure

The basic procedure was similar to that of the Individual Freeway Sign Information Load Experiment described previously. Participants viewed brief presentations of each scene and then used a seven-point scale to rate how easy or difficult it was to obtain all the information they needed from the signs. The scene presentation time for this experiment was 3.5 sec. As in the previous experiment, on an unpredictable basis some stimuli were followed by comprehension questions, to ensure that the participants had to actually process sign information. Because of the complexity of the scenes, the procedure included substantial familiarization, training, and practice prior to actual data collection.

The laboratory was configured to allow five participants to view the sign stimuli on a large projection screen (8 ft wide by 6 ft tall). The stimuli were projected onto the screen using an NEC projector. The size of the projected image was 76 in. wide by 56 in. tall. The average width of the advance guide signs, which was also equal to the lane width, was 15 in. Participants sat in chairs aligned in a slight V-shape approximately 11 ft. 7 in. from the projection screen. Thus a sign panel corresponding to the freeway lane in width subtended a visual angle of approximately 6 degrees. Attached to each chair was a hand-held keypad labeled with the keypad (box) number (1, 3, 4, 5, or 6) and the question, "HOW DIFFICULT OR EASY WAS IT TO OBTAIN INFORMATION FROM THE SIGNS?" The keypad contained seven buttons, labeled "1" to "7," on which participants were to enter their ratings. The experimenter sat behind the participants at a computer that controlled presentation of the stimuli onto the screen.

The experimenter first provided participants with an overview of the experimental session and then led the participants through a training session and a practice session before beginning presentation of the actual sign set. Training began by providing participants with an idea as to the types and range of signs they would encounter in the experiment. Five successive example signs were presented on the projection screen. Next, an additional sign, followed by a sample comprehension question, was presented to participants to familiarize them with the types of questions they might encounter as well as the process by which questions would be asked. The training set began with a simple, single sign and progressed incrementally to an example of the most complex scene they might encounter (a 5-sign array). The experimenter stressed that stimuli would vary in terms of the number, types, and complexity of individual signs, and participants should attempt to use the entire range of ratings, from one to seven, when providing difficulty ratings. Following this training, participants were instructed further on using the keypad to enter their ratings and to answer comprehension questions. The experimenter then led the group through a series of nine practice slides that varied in complexity. The experimenter made sure, through a series of questions and discussion, that participants understood that for signs from which it was difficult to obtain all the information, they should provide higher ratings, and for signs from which it was relatively easy to obtain all the information, they should provide lower ratings. The practice set also included two slides followed by comprehension questions to allow participants to become familiar with answering such questions after entering their ratings. After the experimenter completed the instructions and felt that the participants understood the task at hand, the experimental data collection began.

In the data collection portion of the experiment, the participants were presented with the 172 stimuli. Twenty of the stimuli, randomly preselected and the same for all groups, were followed by comprehension questions. The purpose of the comprehension questions was simply to ensure that participants were fully attending to the content of the stimuli and actually attempting to obtain the information from the signs.

Each scene was computer-projected on the screen for 3.5 sec, followed by the message "Please enter your response now." The scenes were presented in a different random order for each group of participants. When all participants had entered their ratings, the experimenter advanced to the next display. The participants could change their answers at any time until the experimenter advanced to the next display; the computer recorded all answers provided (and the order in which they were provided) by participants. If a particular scene was associated with a comprehension question, the question appeared after all participants completed their ratings. The question remained on the screen until all participants had entered an answer using their keypads. All questions

were multiple choice, with four answer options, numbered 1 through 4.

This procedure was followed for all 172 sign stimuli and 20 comprehension questions. A 5-min break occurred approximately halfway through the sign set. The entire session took approximately 1 hour (15 min for training/practice and 45 min for data collection).

Findings

A four-factor analysis of variance was conducted on the ratings. All four main effects—sign stimulus, age group, gender, and time of session—were statistically significant. The two-way interaction of age and gender was significant, as was the two-way interaction of time of session with sign stimulus. Young participants made somewhat higher ratings than older participants (overall mean of 3.0 vs. 2.8 on the seven-point scale) and female participants made higher ratings than male participants (3.1 vs. 2.7). Ratings tended to be higher in the morning sessions than in the afternoon sessions (3.1 vs. 2.7). The interaction of time of day with sign stimulus, although statistically significant, was small and no systematic pattern was evident. Of most importance for the study, information demand ratings were very sensitive to the particular scene and participants tended to use the full range of the rating scale. The mean ratings for individual stimuli ranged from 1.16 to 6.66. Figure 8 illustrates this range of ratings by means of a bar chart. The 172 stimuli are grouped by the number of sign panels in the scene, and ordered by rating within these groupings. As the figure shows, generally scenes with fewer signs got lower ratings, but within any category of number of signs there was still a substantial degree of variation. Although there is the expected relationship with the total number of signs, there also remain substantial differences to be explained by the details of the signs and the scenes.

There are two primary aspects to the analysis and interpretation of the findings of this experiment. One aspect concerns the ratings of individual signs in the stimulus set and the correspondence of these findings with respect to the previous experiment. The second aspect concerns the ability to predict the information demand associated with sign arrays based on knowledge of the information demand associated with the individual signs comprising the array.

Considering first the ratings given to individual signs (i.e., scenes that contained only a single sign panel), it may be seen from Figure 8 that there was a substantial range of ratings even among these single-sign scenes (from just above 1.0 to nearly 3.5). This experiment and the previous experiment shared 15 single signs in common. Figure 9 shows the agree-

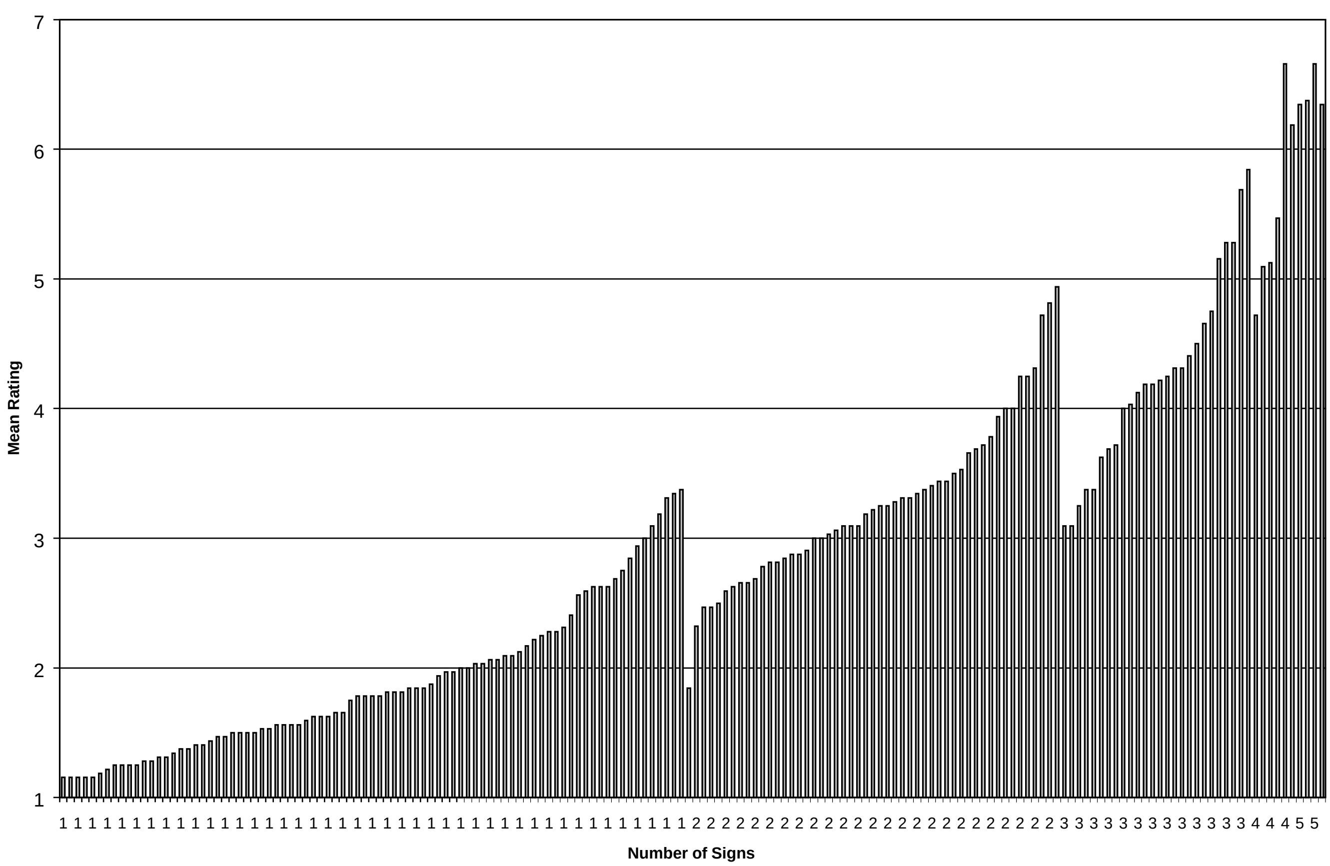


Figure 8. Group mean rating as a function of the number of signs in a scene.

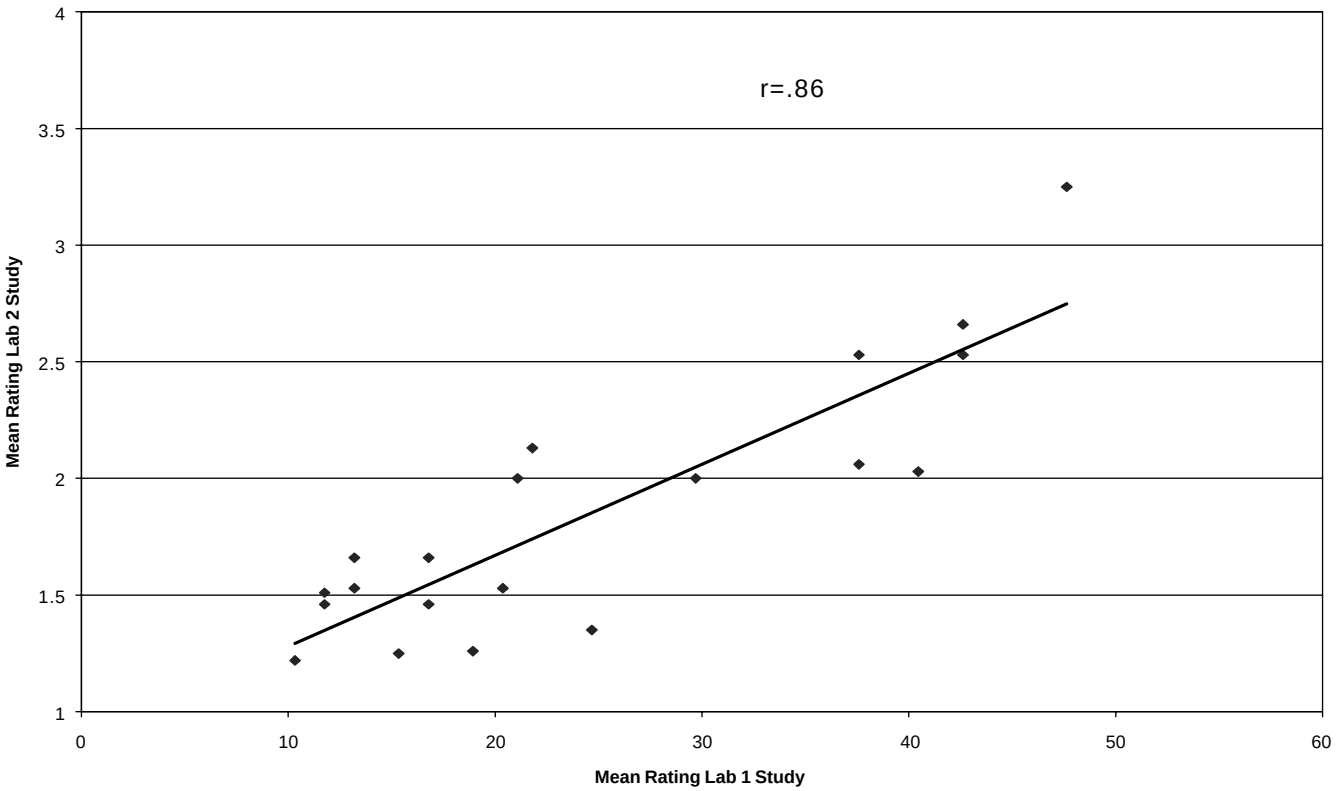


Figure 9. Scatterplot of group mean ratings for signs in common between two experiments.

ment between the two experiments in scatterplot form (the ratings from the previous experiment are transformed to the 1–100 scale, as described earlier). The agreement between the two experiments is quite high, with a correlation of r = 0.86. Thus despite differences in procedure (roadway context, viewing time), the findings of the first experiment are replicated for this subset of signs.

A further replication of the findings is based on use of the look-up table derived in the first experiment (Appendix B). Individual signs not presented in the initial experiment can be assigned predicted values based on the look-up table. The accuracy of these predictions can then be determined by comparing them with the actual ratings made in the present experiment. Figure 10 shows this relationship in scatterplot form. Again, the level of agreement was quite high, with a correlation of r = 0.84. It therefore appears that the look-up tables derived from the initial experiment provide a good basis for predicting the information load ratings of individual signs.

Having confirmed that the look-up table provides a replicable and reasonable basis for predicting the information load rating for an individual sign, the ability to use the table to estimate the information load of multiple sign *arrays* can be explored. Before conducting this part of the analysis, the look-up table was refined slightly from that of Appendix B. Table 2 presents the updated look-up table. In addition, another table (Table 3) was developed to provide standard correction factors that could be used for adding to or subtracting from the bracket values in the look-up table. Table 2 incorporates the following refinements to Table B1 in Appendix B. First, the referencing to appropriate sections and figures within the *Manual on Uniform Traffic Control Devices* was updated to reference the 2000 edition (Millennium Edition) of the *MUTCD* (*19*). Second, the original tabled values for the Exit Direction signs appeared to be aberrantly low, based on values for similar signs and based on deviation in the scatterplot of ratings between the two experiments. Therefore the upper and lower bounds for this sign category were modified from 21/14 to 25/18. Third, because the range between the upper- and lower-complexity values for the Interchange Sequence category was so large (4 to 33), an intermediate value (labeled "Middle") was added to the table. The definition of this middle condition is contained in the table. This should make it easier for a user to select an appropriate value for a given sign and result in better agreement among analysts. Finally, consistent values were defined for use when adding or subtracting a destination or other feature from the upper or lower boundary condition. These are the values shown in Table 3. For example, if an additional destination were added to a sign (relative to the look-up table sign), Table 3 indicates that an additional seven units should be added to the look-up table value. The values in Table 3 were derived from considering the full set of signs and conditions for the tables in Appendix B.

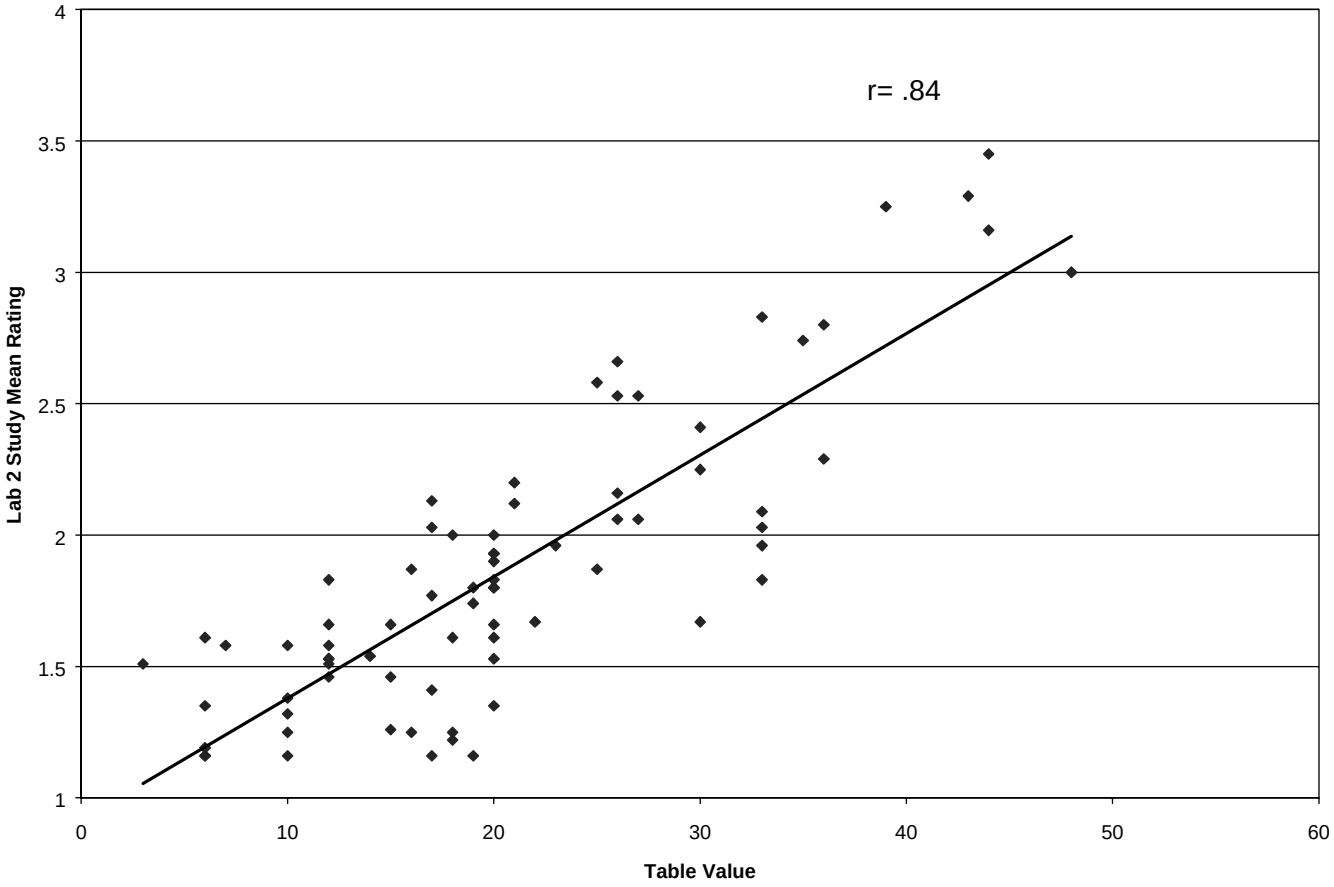


Figure 10. Scatterplot of actual group mean ratings versus values derived from look-up table.

Tables 2 and 3 were then used to examine the ability to predict the information load associated with a sign *array* containing multiple signs. The ability to predict the information load of a sign array depends on finding an appropriate rule for combining the information loads associated with the individual signs that make up the array. There are many potential ways of doing this, beyond simple addition. For example, one might employ transforms of the original ratings (e.g., log transform) of some or all of the signs, or use regression equations. The objective was to find a relatively simple rule that could be applied to look-up table values of individual signs that would accurately predict the sign array demands as reflected in the empirically obtained ratings. A range of possible combination rules were applied to the data, and two emerged as particularly good estimators of sign array information demand. One rule involved adding the information load of the sign with the highest information load to the square root of the information load of the remaining signs. Conceptually, this was a formalization of the idea that the most complex sign has the greatest impact in determining the overall load, with other signs contributing proportionately less, and with very simple signs contributing especially little. Applying this rule to look-up table values for the individual signs, the correlation of actual vs. predicted value for sign arrays was $R = 0.94$, with a standard error of estimate of 0.31 units on the seven-point rating scale. The constants of the linear regression equation were quite small: Array Value = 0.94 (maximum value + square root of others) + 0.08. Therefore the rule could be quite accurately applied even without any linear transform. Figure 11 plots this relationship. The other very successful predictor was based on a linear regression of the simple sum of the individual sign values. In this case R = 0.95, with a standard error of 0.29 units on the seven-point rating scale. The linear regression equation was Array Value = 0.765 (sum of individual sign ratings) + 0.44. Figure 12 plots this relationship. The slope value of considerably less than 1.0 in this equation is, in effect, a means of saying that as one adds more and more to an existing sign array, the influence of each additional unit of information load becomes less and less. Either of these two approaches yields very high predictive value, accounting for about 90 percent of the variance in the ratings. Thus, it is clearly evident that one can predict the information load of a sign array if there is appropriate information on the individual signs comprising the array.

Among the modifications to stimuli in the set of slides were a few manipulations of factors such as the location of the sign within the scene, the color of the sign, and the size of the sign. The intent was to see if any such factors need to be taken into

TABLE 2 Look-up table for sign information load

Sign type and category	MUTCD reference (2000 edition)	Sign complexity	Definition	Rating
Advance Major Guide, Separate Exit	Fig. 2E-13, Signs E1-1 and E1-5	Upper	Long Word, 2 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	26
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	20
Advance Major Guide, Integrated Exit	Fig. 2E-13, Sign E1-1a	Upper	Long Word, 2 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	17
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	12
Advance Major Guide, Separate Exit and Lane Drop	Fig. 2E-13, Signs E1-1, E1-5, and Fig. 2E-9, Sign E11-1	Upper	Long Word, 2 Dest., 1 R.M., 0 Icon, Lane, No Dir.	20
		Lower 1	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	20
		Lower 2	Short Word, 1 Dest., 1 R.M., 0 Icon, Lane, No Dir.	14
Advance Major Guide, Integrated Exit and Lane Drop	Fig. 2E-13, Sign E1-1a and Fig. 2E-9, Sign E11-1	Upper	Long Word, 2 Dest., 1 R.M., 0 Icon, Lane, No Dir.	29
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, Lane, No Dir.	25
Advance Minor Guide, without Route	Fig. 2E-13, Sign E1-2	Upper	Long Word, 2 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	17
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	16
Advance Minor Guide	Fig. 2E-13, Sign E1-3	Upper	Long Word, 2 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	20
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	6
Next Exit	Fig. 2E-14	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	5
Multiple-Destination Exit	Fig. 2E-15	Upper	Long Word, 2 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	26
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	3
Multiple-Destination, Next Right		Upper	Long Word, 2 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	19
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	3
Exit Direction	Fig. 2E-18	Upper	Long Word, 2 Dest., 1 R.M., 0 Icon, No Lane, Dir.	25
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	18
Gore, Separate	Fig. 2E-19, Signs E5-1 and E5-2	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	3
Gore, Integrated	Fig. 2E-19, Sign E5-1a	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4

(*continues on next page*)

TABLE 2 ***(Continued)***

Sign type and category	MUTCD reference (2000 edition)	Sign complexity	Definition	Rating
Pull Thru, Small Shield	Fig. 2E-2, Sign E6-2	Upper	Long Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	7
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	7
Pull Thru, Large Shield	Fig. 2E-2, Sign E6-2a	Upper	Long Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	12
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	12
Post-Interchange Distance	Fig. 2E-20, Sign E7	Upper	Long Word, 3 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	21
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	3
Interchange Sequence	Fig. 2E-22, Sign E8-1	Upper	Long Word, 3 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	33
		Middle	Short Word, 2 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	18
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
Community Interchange	Fig. 2E-23, Sign E8-2	Upper	Long Word, 3 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	33
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	13
Next (X) Exits	Fig. 2E-24, Sign E-9	Upper	Long Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	7
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
Park & Ride	Fig. 2E-17	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	18
Milepost	Sign D10-3	Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	9
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
Diagrammatic Guide, Separate Exit	Fig. 2E-3	Upper	Long Word, 2 Dest., 2 R.M., 0 Icon, No Lane, Dir.	34
		Lower	Short Word, 1 Dest., 2 R.M., 0 Icon, No Lane, Dir.	22
Diagrammatic Guide, Integrated Exit	Fig. 2E-3	Upper	Long Word, 2 Dest., 2 R.M., 0 Icon, No Lane, Dir.	28
		Lower	Short Word, 1 Dest., 2 R.M., 0 Icon, No Lane, Dir.	23
Diagrammatic Guide, Integrated Exit and Lane Drop	Fig. 2E-3 and Fig. 2E-9, Sign E11-1	Upper	Long Word, 2 Dest., 2 R.M. 0 Icon, Lane, Dir.	37
		Lower	Short Word, 1 Dest., 2 R.M., 0 Icon, Lane, Dir.	25

Diagrammatic Guide, Separate Exit and Land Drop	Fig. 2E-3 and Fig. 2E-9,Sign E11-1	Upper	Long Word, 2 Dest., 2 R.M., 0 Icon, Lane, Dir.	33
		Lower	Short Word, 1 Dest., 2 R.M., 0 Icon, Lane, Dir.	23
Next Services	Fig. 2E-35	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	5
Services, Integrated	Fig. 2E-34	Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	19
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	3
Services, Separate	Fig. 2E-34	Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	17
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	2
Rest Area, Gore	Fig. 2E-36	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	2
Rest Area, Advance Guide		Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	12
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	2
Rest Area, Exit Direction		Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	7
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	5
Route Marker, U.S. Route	Sec 2E-25 Pg 2E-34	Upper	N/A Word, 0 Dest., 1 R.M., 0 Icon, No Lane, Dir.	1
		Lower	N/A Word, 0 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	1
Route Marker, Interstate	Sec 2E-25 Pg 2E-34	Upper	N/A Word, 0 Dest., 1 R.M., 0 Icon, No Lane, Dir.	2
		Lower	N/A Word, 0 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	1
Gas & Lodging, Double	Fig. 2F-1	Upper 1	N/A Word, 0 Dest., 0 R.M., 4 Icon, No Lane, No Dir.	27
		Upper 2	N/A Word, 0 Dest., 0 R.M., 6 Icon, No Lane, No Dir.	32
		Lower	N/A Word, 0 Dest., 0 R.M., 2 Icon, No Lane, No Dir.	21
Gas & Lodging, Single	Fig. 2F-1	Upper 1	N/A Word, 0 Dest., 0 R.M., 4 Icon, No Lane, No Dir.	29
		Upper 2	N/A Word, 0 Dest., 0 R.M., 6 Icon, No Lane, No Dir.	23
		Lower	N/A Word, 0 Dest., 0 R.M., 1 Icon, No Lane, No Dir.	7

(*continues on next page*)

TABLE 2 ***(Continued)***

Sign type and category	MUTCD reference (2000 edition)	Sign complexity	Definition	Rating
Radio Information, Weather	Sign D12-1	Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	24
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	6
Radio Information, CB Channel 9	Sign D12-3	Upper	Long Word, 0 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	15
		Lower	Short Word, 0 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	5
Radio Information, Traffic		Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	21
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	10
Car Pool Information, Car	Sign D12-2	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	8
Car Pool Information, Van		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	9
Weigh Station, Advance Guide	Fig. 2D-3, Sign D8-1	Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	1
Weigh Station, Exit Direction	FIg. 2D-3, Sign D8-2	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	5
Weigh Station, Gore	Fig. 2D-3, Sign D8-3	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	2
Recreational Guide, Integrated Icons	Fig. 2H-2	Upper	Long Word, 1 Dest., 0 R.M., 3 Icon, No Lane, No Dir.	15
		Lower	Short Word, 1 Dest., 0 R.M., 1 Icon, No Lane, No Dir.	7
Recreational Guide, Separate Icons	Fig. 2H-2	Upper	Long Word, 1 Dest., 0 R.M., , 3 Icon, No Lane, No Dir.	17
		Lower	Short Word, 1 Dest., 0 R.M., , 1 Icon, No Lane, No Dir.	7

Recreational Guide, Distance	Fig. 2H-2	Upper	Long Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	18
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	10
Recreational Guide, Direction	Fig. 2H-2	Upper	Long Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	10
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	6
Boundary, County		Upper	Long Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
		Lower	Short Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
Boundary, State		Upper	Long Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	5
		Lower	Short Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	1

Keys:

Rating = Information load rating (1-100)

Upper = Maximum number of all sign components present as specified in the MUTCD

Lower = Minimum number of all sign components present as specified in the MUTCD

Word = Word length of destinations (Long, Short, N/A)

Dest. = Number of destinations (0-4)

R.M. = Number of route markers (0-3)

Icon = Number of icons (0-6)

Lane = Presence or absence of a lane indicator arrow

Dir. = Presence or absence of a cardinal direction

TABLE 3 Modifications to look-up table ratings

Base value for sign type according to look-up table (upper or lower boundary) plus or minus:

Sign element	Value	Definitions
Exit Panel Number	8, 10	A small panel added to the top of advance guide signs which indicates the exit number (*MUTCD* Fig. E1-5)
Destination	7	A textual destination (road, town, etc.)
Route Marker	6	A state or interstate route marker (a number within a shield)
Direction	4	Text indicating the cardinal direction of a roadís traffic flow
Word Length	2, 4, 6	The overall amount of text on a sign, including destinations. Value varies according to amount of text on sign relative to baseline amount
Icon	3	A meaningful picture, image, or logo, often representing a point of interest
Lane Drop	3	Text, sometimes combined with arrows, indicating that a lane can only be used by exiting traffic (‘Exit Only’ sign)
Lane Arrow (each)	2	Downward-pointing arrows indicating which lane to use for a destination

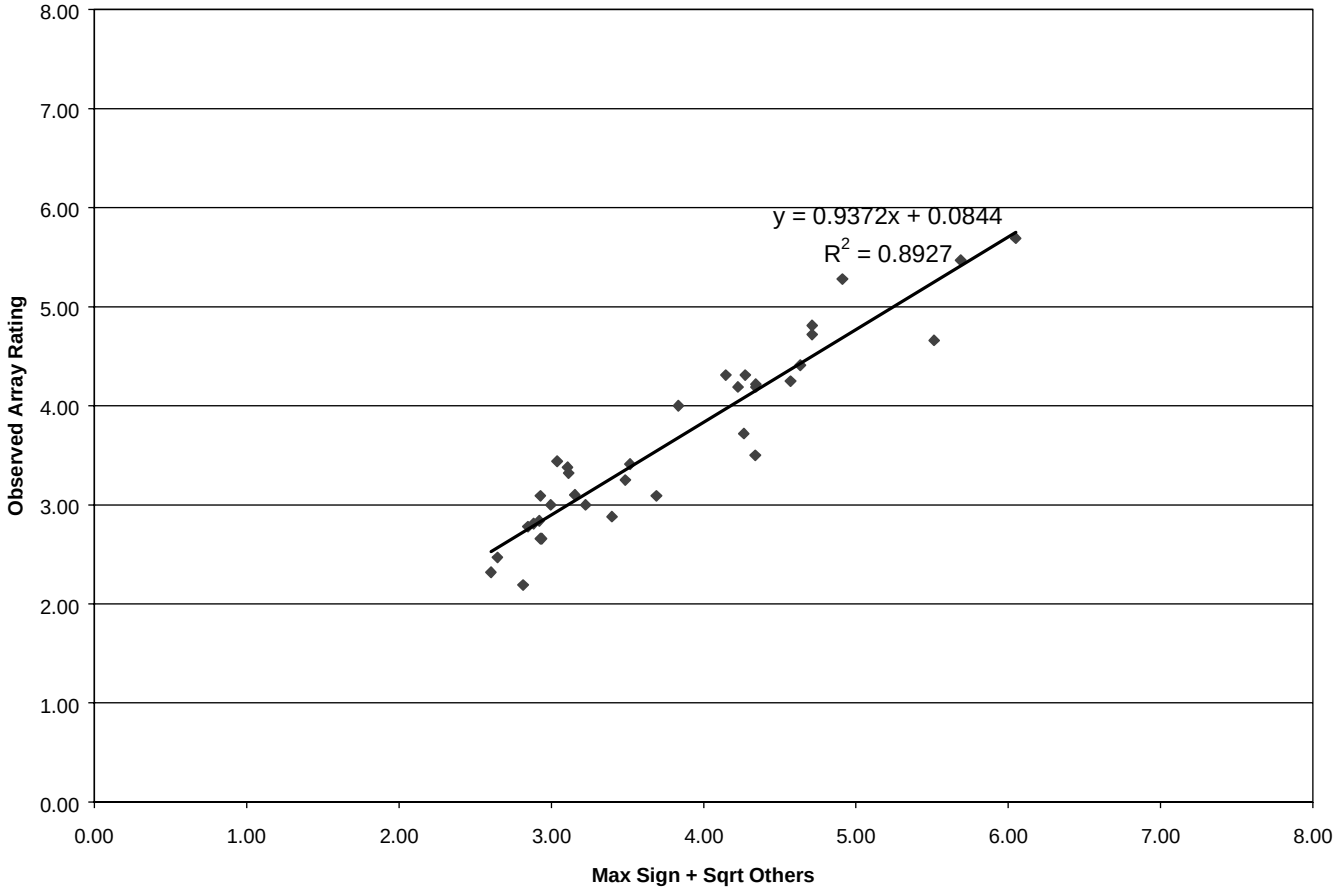


Figure 11. Scatterplot of observed sign array rating versus value predicted by combination rule: Maximum sign plus square root of other signs.

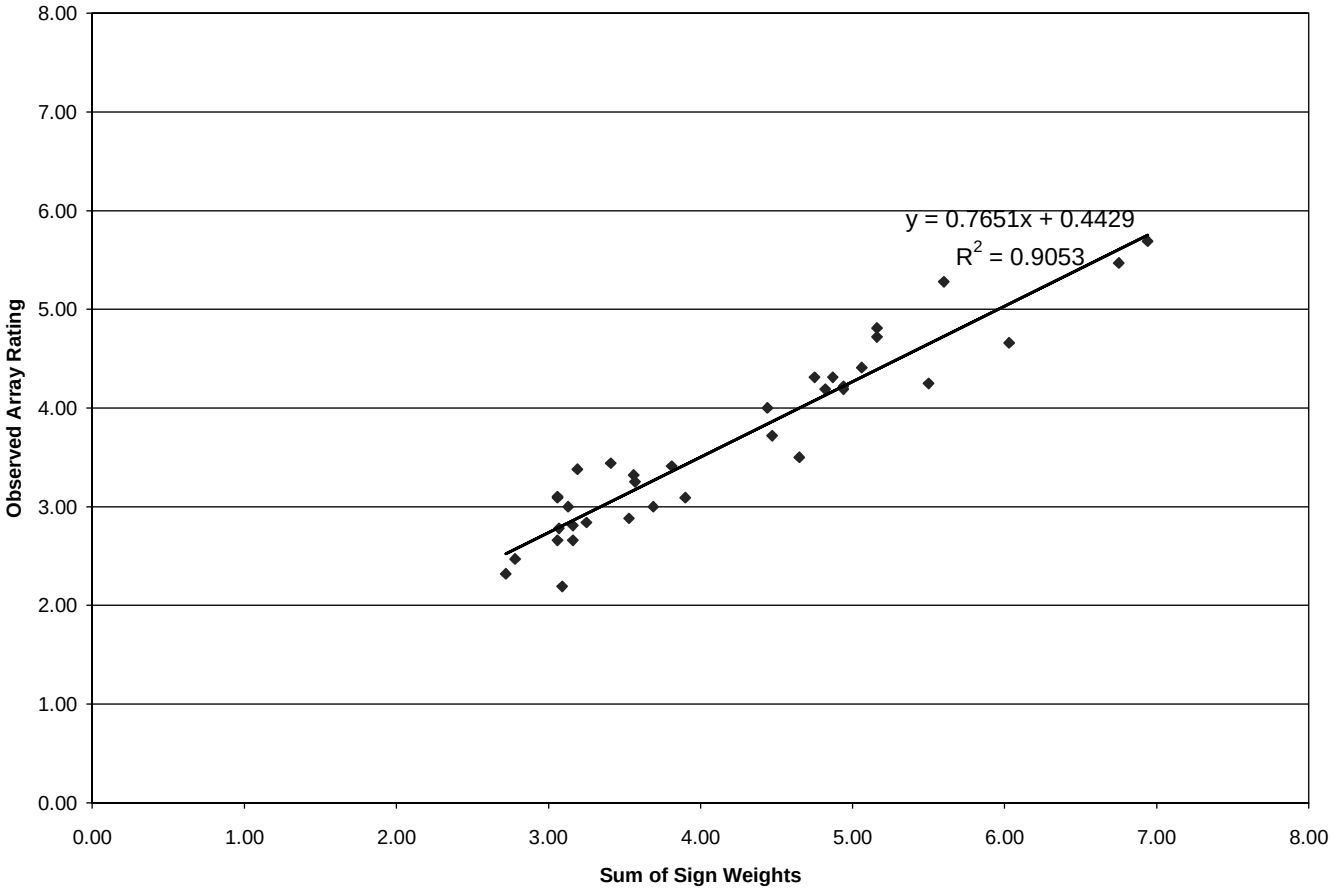


Figure 12. Scatterplot of observed sign array rating versus value predicted by combination rule: Regressed sum of signs.

account when attempting to compute the overall information demand of a sign array. An initial scan of the ratings for signs manipulated in this manner revealed no consistent or substantial effects on the ratings. Given the already very high proportion of variance accounted for by the major variable of individual sign load ratings without including these factors, no formal analysis of these manipulations was warranted, and they do not need to be incorporated into formal modeling.

In summary, the experiment on combination rules for sign arrays replicated the general results of the individual freeway sign experiment and demonstrated that the look-up tables could be used to predict the information load ratings of individual signs. The experiment also determined that the information demand of a sign array could be quite accurately predicted based solely on the information load ratings of the individual signs composing the array.

PRELIMINARY ON-ROAD EXPERIMENT

The purpose of the on-road experiment was to obtain continuous, real-time ratings of information processing demand from drivers as they drove an extended route that incorporated a range of roadway types and signage. This was accomplished by having participants continuously adjust a thumbwheel mounted on their steering wheel in order to continuously reflect how difficult it was to take in all the information they were dealing with. By plotting the thumbwheel setting against the location on the road, an "information load profile" can be generated for each driver, and a group mean profile can be used to characterize typical driver response to a sign array. The objective was to relate the findings to the model of driver information load in terms of the degree of load associated with roadway and sign features and with temporal changes as signs or choice points are approached.

The initial on-road experiment, described in this section, was conducted under NCHRP Project 3-50, and was actually conducted after the Individual Freeway Sign Information Load Experiment but prior to the Combination Rules for Sign Arrays Experiment. Although this initial on-road experiment provided some useful insights, it was superseded by the primary on-road experiment described in the next section. This initial on-road experiment is labeled here as the "preliminary" on-road experiment. It essentially served as a pilot for the later on-road study. Therefore, the methods and findings of the preliminary on-road experiment are treated here in a

summary manner. Greater detail and analysis are provided for the primary on-road experiment described in the next section. The primary on-road experiment improved on the methods and equipment of this initial experiment, which suffered relatively high data loss due to Global Positioning System (GPS) drop-out, equipment reliability, difficulties with precision of location, weather problems, roadway and traffic problems, and experimenter error.

Sixteen participants, eight in the young group (16–20, mean of 18.5 years) and eight in the older group (64–77, mean of 70.0 years) took part. They drove a 60-mi route of primarily freeway and interstate roadways that included sections in Fairfax and Arlington counties in Northern Virginia and Washington, D.C.. Participants drove the route in their own vehicles. The vehicle was outfitted with a temporary PC-controlled data collection system, which included a GPS to document location and a steering-wheel-mounted thumbwheel for use in making ratings. The data collection system sampled vehicle location (latitude/longitude) and thumbwheel rating every second.

The participant was asked to drive his or her car in a normal manner along the route specified by the experimenter, who accompanied them on the trip. While driving, the participant was instructed to continuously adjust the thumbwheel to rate "how easy or hard it is to take in all the information that you need to make your driving decision in a timely manner." The instructions provided detail on what was meant by "information load" and the use of the dial and its 10-point scale. The thumbwheel was mounted on the participant's steering wheel in a location that was selected by the participant as being comfortable and easy to use.

After a practice period to get familiar with the procedure and the use of the thumbwheel, the data collection trip began. Prior to the trip, the participant was shown a map of the route to be taken, and allowed to study it. This provided a general orientation. However, he or she was not expected to memorize the route. On each leg of the trip, the participant was informed of the next destination. The destinations were always in the form of an exit from the current route onto another route. For example, the instruction might be "Take the exit to Route 29 south at Centerville." No indication was given as to the distance or location of the next exit. After each exit maneuver, the participant was informed of the next destination.

Although there was considerable variability among drivers in their ratings, there was general agreement on the approximate locations of major peaks in information load. These peaks were identified based on the location of obvious peaks in individual driver records and also by mapping clusters of the highest ratings over the entire route (e.g., the highest 1%). Two points may be noted regarding these peak areas. First, they tended to correspond to impending maneuvers. Nine of the eleven major information load points identified were approaching areas where an exit maneuver was required. A tenth site was an approach to a very complex set of merging roadways where it was not clear in advance what lane the driver would want to be in. The general observation was that areas of agreement among participants tended to involve regions of approach to an impending maneuver. Another point is that these areas of "approach" can be quite extended, as much as 2 mi from the actual exit point, although this estimate is crude. It may be that signing or geometry becomes more complex in this region, although it appears that drivers may be using the 2-mi interchange advance guide signs as a cue to increase their concentration on the navigational task.

While the analysis of raw individual data was useful for roughly identifying areas of high information load, one would like to be able to combine the data from individual participants to provide a more fine-grained evaluation of group data and its relation to roadway and signing elements. Five sites along the route were subjected to this more detailed evaluation. For each site, the mean information load rating (dial setting) and the mean vehicle speed were computed for the group of 16 participants along the site. Figure 13 presents the group rating and speed profiles for the five sites. The X-axis in each figure shows the distance from the choice point (gore area) in feet. Thus the curves trace the approach of the vehicle from the farthest point analyzed (left side of figure) up to the point where the vehicle reaches the gore (0 point, right side of figure). The left ordinate indicates the scale for the dial ratings and the right ordinate indicates the scale for the vehicle speed. The vertical lines indicate the locations of sign arrays. Each figure is based on data from only those participants who had complete and valid data for that site, which ranged from 9 to 13 participants. Each plot encompasses a distance of 7,000 ft from the exit gore point, although for one site, the actual length of the site was only about 2,500 ft.

There was no obvious, consistent pattern across these various site profiles that related the ratings to sign locations or roadway features, although there was some tendency for the ratings to rise over the approach. Some sites showed pronounced changes in the ratings across the site while others were relatively flat. There was not a clear and consistent peak or hump or shift in the records that corresponded to each major sign array, as conceptualized for the model in Chapter 3 (e.g., Figure 3). It may be noted that for the three sites where there were rather pronounced changes in the dial ratings (Sites 2, 4, 7), vehicle speed roughly mirrored the ratings, with the vehicle slowing as the rating increased. While vehicle speed is subject to a number of influences, these broad changes suggest that where information demand is increasing, the driver slows down somewhat as a behavioral strategy for coping with the information demand. These sites also had slightly lower speeds overall than the two sites where the dial ratings were rather flat, although this could likely be attributed to the roadway category.

As a heuristic device to help suggest possible relationships within the data, the statistical technique of principal component analysis was used to summarize dial setting behavior at the sites. This technique was used to transform the dial settings

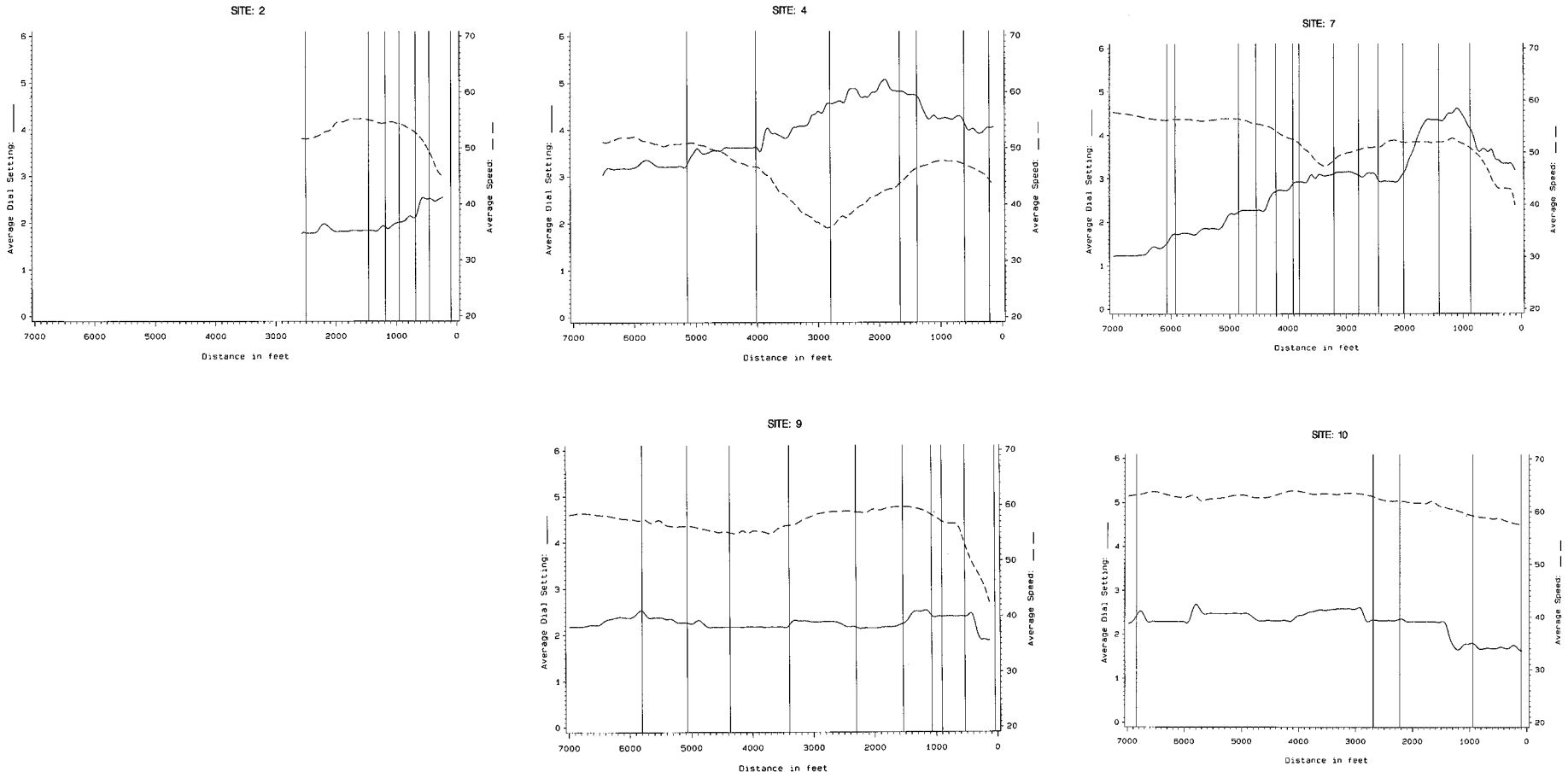


Figure 13. Group mean dial ratings and speed profiles for five sites.

of drivers into their principal component scores. Principal component scores are linear combinations (sort of weighted averages with negative weights permitted) of the original variables, in this instance, the dial settings. The computer program used to implement this analysis selects the transformation from individual dial settings to principal components in a way that would be optimal, assuming certain mathematical conditions. For these data, the approach should be viewed as heuristic because the formal conditions for principal component analysis are not fully met. However, regardless of optimality, the first few principal components can usually provide a very good summary of salient features of the data. In the present case, the first two principal components accounted for most of the explainable variance at all sites, and only these two components were retained for closer consideration.

The first, and dominant, factor (labeled Factor 1) in the rating data explained anywhere from 39% to 56% of the variance at a particular site. At each site, the majority of drivers (50–85%) showed a positive correlation of their dial ratings with Factor 1. Examination of the analysis indicated that Factor 1 is generally related to proximity to the choice point. Figure 14 plots the mean dial ratings, Factor 1 values, and Factor 2 values across each of the five sites. In each case, there is a generally increasing trend in Factor 1, even for those cases where no such trend was obvious in the overall mean dial rating itself. This suggests that the subjective sense of the demand imposed on the driver increases as the exit point is approached, and might be described as an "urgency" factor, although the basis for the feeling is not known. The length of this Factor 1 ramp tends to be large relative to decision sight distances. Figure 15 plots the Factor 1 functions for each of the five sites on a common set of axes. The distance along the X-axis is long (17,000 ft) so as to clearly show the approach and initiation of the upward ramping of the function. Site 2 is clearly different from the others, which is to be expected given that it is much shorter. Site 4 is also somewhat shorter, and begins to ramp up somewhat later than the others. The Factor 1 functions for four remaining sites with longer approaches begin to ramp up at about 6,000 ft from the exit gore. With the exception of Site 2, the Factor 1 function tends to peak somewhere in the 1,100- to 1,800-ft range from the exit point, although for Site 10 (and somewhat for Site 9), there is a second later peak very close to the exit gore itself.

Factor 2 is far more ambiguous. The functions were generally more "jagged" than for Factor 1 and were unsystematic. This factor accounted for relatively little variance in the ratings, and no suitable explanation was found to describe to what it might be related.

In summary, the preliminary on-road experiment found that the continuous on-road ratings of information load varied over sections of the route, despite considerable variance among participants and the substantial data loss occurring in this study. High ratings of information load were associated with locations where a maneuver was required, and evidence was found for the importance of a maneuver proximity factor that gradually increases as the exit point is approached, peaking about 1,500 ft or less from the exit gore. Finer details of the group mean rating functions did not show specific peaks clearly associated with individual roadway signs, although some such association appeared to be present in certain individual participant records.

A number of methodological limitations of this experiment were recognized and the primary on-road experiment attempted to address these.

PRIMARY ON-ROAD EXPERIMENT

Overview and Objectives

The Primary On-Road Experiment made a number of modifications to the methods of the Preliminary On-Road Experiment. These included improvements to the precision and reliability of the data collection system; improvements to the dial-based information load rating task; more extensive and structured training of participants prior to data collection; and more comprehensive collection of information related to the degree of driving performance problems.

The experiment had several objectives. As in the preliminary on-road experiment, the intent was to obtain a continuous measure of the driver's subjective sense of information load over an extended trip, and be able to map these ratings onto specific roadway locations. The analysis could then examine the level of reported information demand as a function of the signs present, roadway features, proximity to maneuvers, or other factors. Both response magnitude and temporal aspects of the ratings could be considered. The study also collected a variety of measures that might reflect driving difficulties associated with coping with high information load. These included both vehicle control measures (based on steering, braking, and speed) and observations recorded by the experimenter (erratic maneuvers, missed exits, verbalizations, etc.). The findings of this experiment, taken together with the findings of the previous experiments, could then be integrated into a quantitative model of driver information load and a procedure for analytically deriving an index of information load.

One of the original objectives of this experiment was not able to be performed. The intent was to have a set of scenes in common between the laboratory experiment on combination rules for sign arrays and the on-road experiment. This would have permitted a direct comparison of static laboratory and dynamic on-road ratings of the same sign arrays in identical contexts. A probable route for the on-road experiment was selected prior to the laboratory experiment. Signs from that route were photographed and included in the laboratory experiment. However, by the time the on-road experiment was implemented, there had been a variety of changes to some sites, traffic patterns had been changed as a result of major roadway work in the vicinity (resulting in frequent unacceptable levels of congestion), and additional road work was planned in parts of the study route during periods that

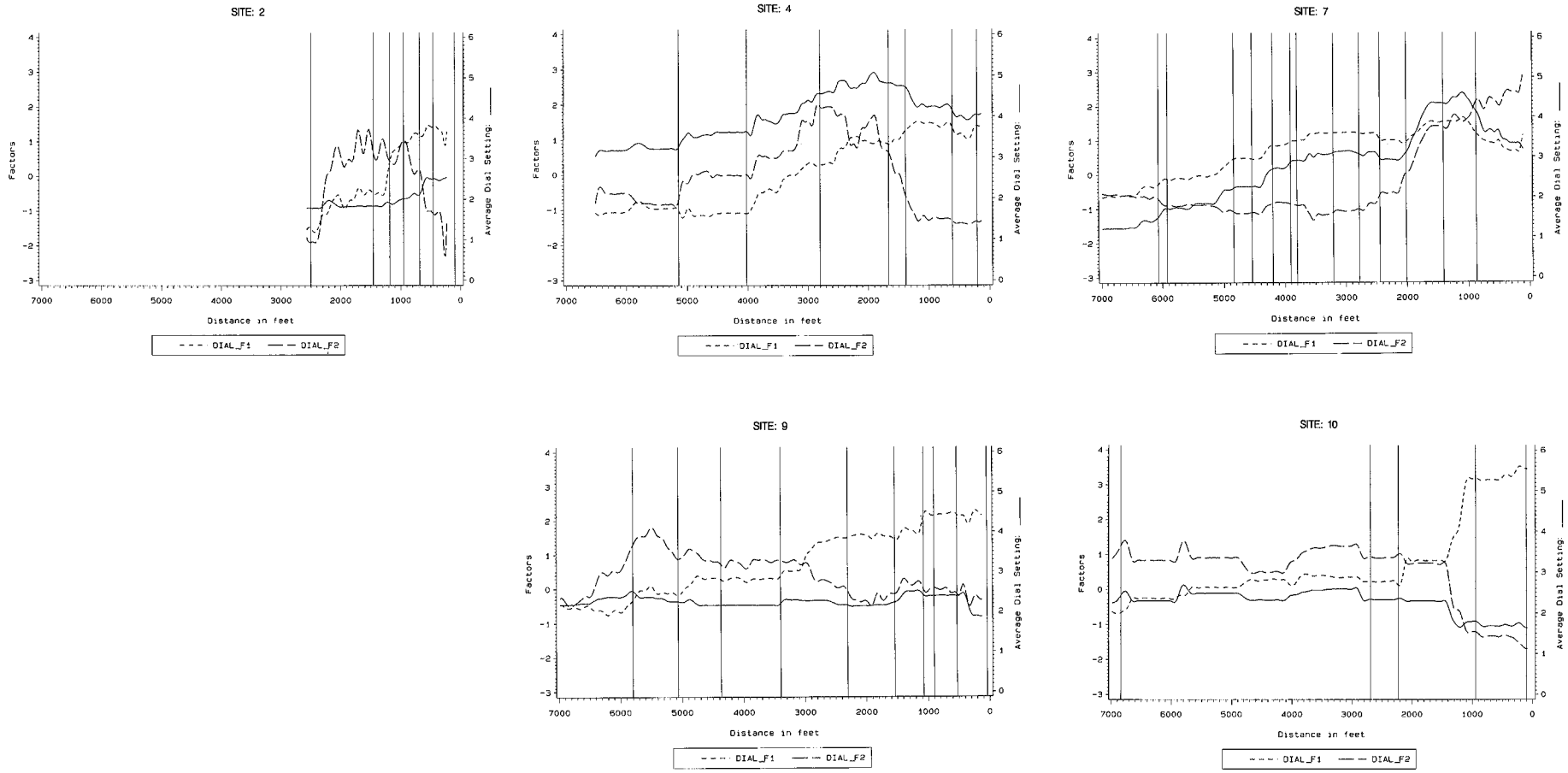


Figure 14. Mean dial rating, Factor 1, and Factor 2 values for five sites.

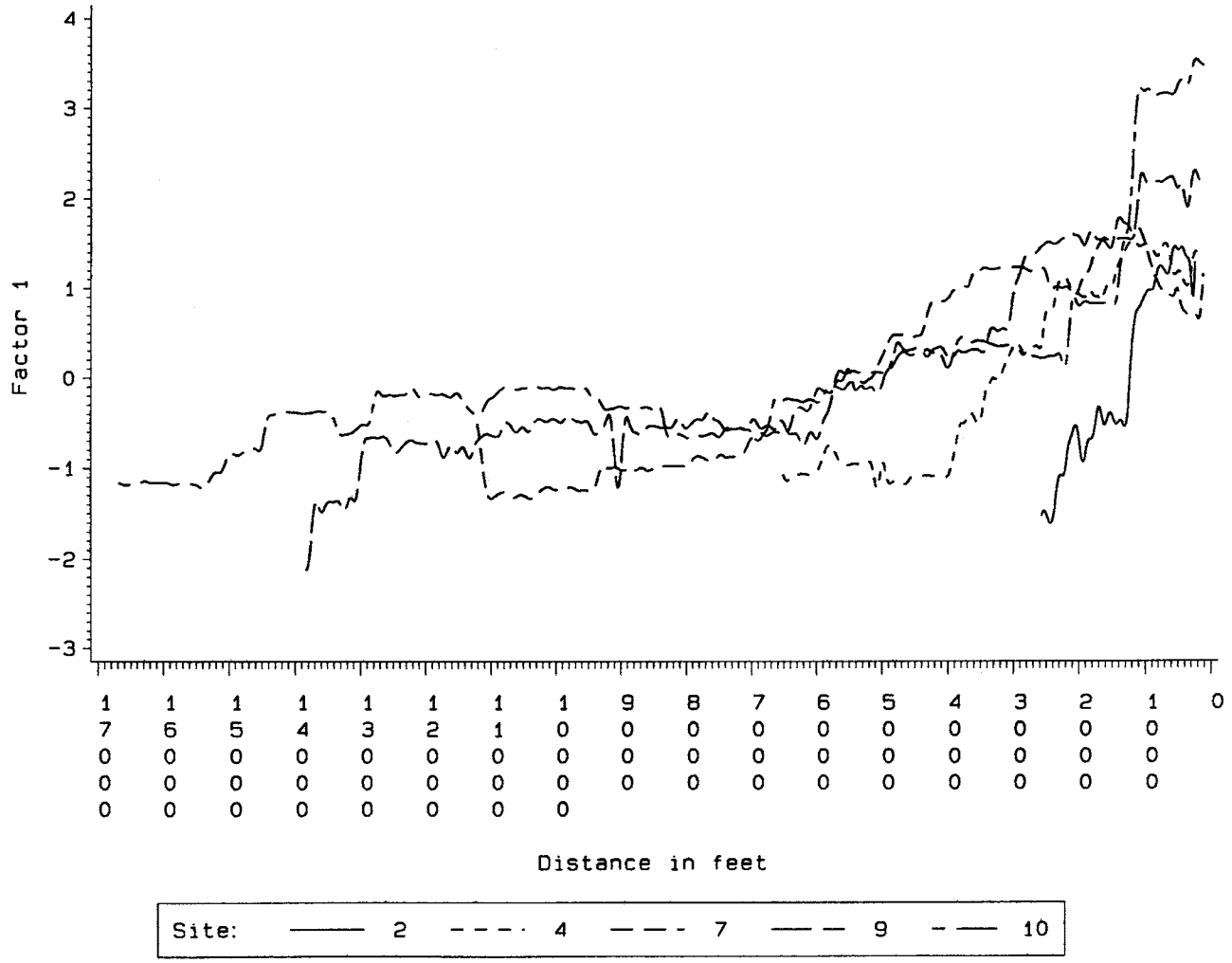


Figure 15. Factor 1 values for five sites on a common axis.

overlapped with data collection. Therefore, an entirely new route had to be planned in a different area. As a result, the laboratory and on-road experiments did not share any common subset of signs, and direct comparisons were not possible.

Method

Route

The route encompassed approximately 60 mi of freeway roads in the greater Baltimore, MD, area, primarily in suburban settings. This included portions of I-95, I-695, I-195, I-395, and MD 295. Exit maneuvers (from freeway to freeway or freeway to surface street) were required at eight locations. These represented the termini of eight "sites" as defined for purposes of data analysis. The route could start at either of two starting points; this permitted counterbalancing among two different sequences of the sites (the starting point for one route sequence was the sixth site for the other sequence). Each route sequence was also associated with a training route, over which the subject received practice in using the steering wheel-mounted dial to make ratings. Appendix D presents the sequence of sites used for training and data collection under each of the two route sequences.

The eight sites involved the following exit maneuvers:

- Site 1: Left exit from I-95 North to I-695 West;
- Site 2: Exit from I-695 West to Security Blvd;
- Site 3: Exit from I-695 South to I-95 North;
- Site 4: Exit from I-95 North to I-395 North;
- Site 5: Left Exit from I-95 South to I-695 East;
- Site 6: Exit from I-695 East to MD 295 South;
- Site 7: Exit from MD 295 South to I-195 West; and
- Site 8: Exit from I-195 West to I-95 North.

Instrumentation

Participants in this experiment drove a 1999 Chevrolet Malibu that was outfitted with a data collection/experimental con-

trol system. Figure 16 shows a simplified schematic of the system and Figure 17 illustrates the physical location of the components in the vehicle.

As the figures illustrate, the system ran off the car battery with a marine battery backup. A laptop computer, at the experimenter station in the back seat, controlled inputs and outputs. The data acquisition system recorded vehicle speed, distance, steering wheel location, brake status, and participant/driver information load rating (from the dial mounted on the steering wheel). The computer also recorded various coded inputs from the experimenter, entered via the keyboard. The computer was time-synched with the video system so that video images and other data could be directly related. Four cameras were located around the vehicle. One recorded the view ahead; another recorded the driver's head and torso. The remaining two looked out directly to the left and right and were used to precisely indicate the point at which the vehicle passed key landmarks along the route (this was a double check on the experimenter's manual entry of these same landmarks and also permitted later definition of any additional landmarks that were desired). The four camera images were integrated into a single recording by means of the quad-splitter. The video titler superimposed various other information directly on the video image. Thus in addition to being stored in the computer file, information such as dial rating, speed, steering wheel position, and other items was also directly visible on the video display. This had several advantages. It provided a redundant data record in the event of any problems. It also permitted later off-line viewing, where it may be enlightening to watch the roadway scene and driver behavior while seeing the changing status of other factors. The audio output (beep rate and pitch changes) related to the dial setting was also recorded acoustically, so it was possible to "listen" to the participant's ratings while watching the scene. Finally, the video image was also displayed on a small monitor at the experimenter station so that the experimenter could monitor and confirm the working status of all inputs (e.g., if there was a problem with the steering-wheel-position recording component, this would be evident from the data on the monitor).

In addition to controlling the experiment and monitoring the status of data collection, the experimenter also entered a variety of information through coded keyboard inputs. Figure 18 shows the experimenter interface screen for the data collection portion of the procedure (other screens were in effect for initial participant coding and for training). The left side of the display allowed the experimenter to monitor time, distance, rating, speed, steering wheel position, and brake status. In the upper center, the "Road Marker" input was used to indicate when the vehicle reached key points along the route. The right side of the display provided additional input keys for the experimenter (entered via the keyboard). The upper-right entry indicated the site number. The "driver problems" section allowed notation of erratic maneuvers, navigation errors, and confusions, with an area for comment entries. The area in the middle of the screen allowed coding of traffic density. The "visual obstructions" field allowed the experimenter to indicate if the driver's view of signs was substantially obstructed by intervening trucks or by severe glare. Finally, any abnormal road conditions or unusual events that

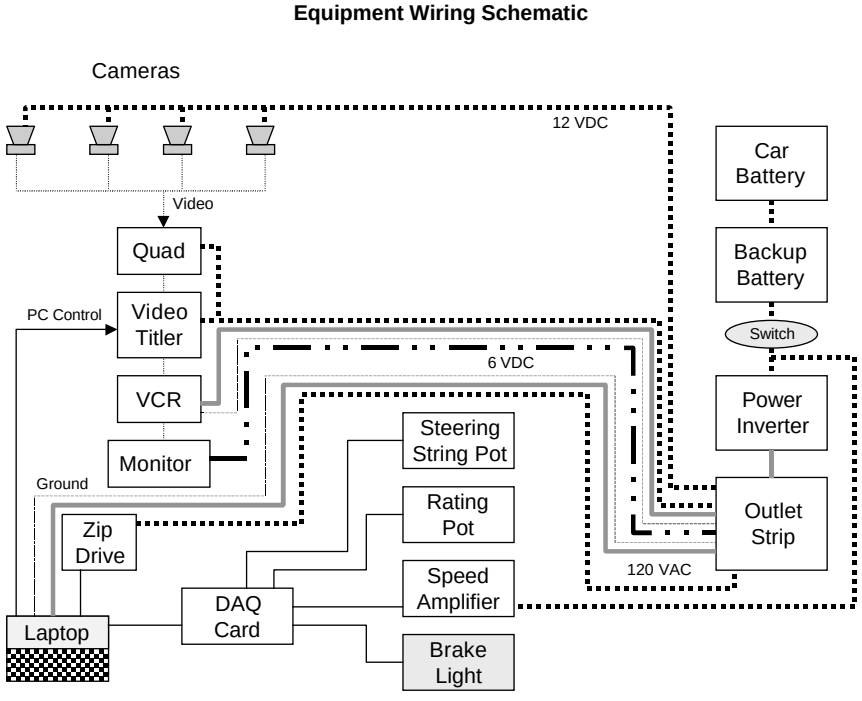


Figure 16. Schematic of data collection/experimental control system.

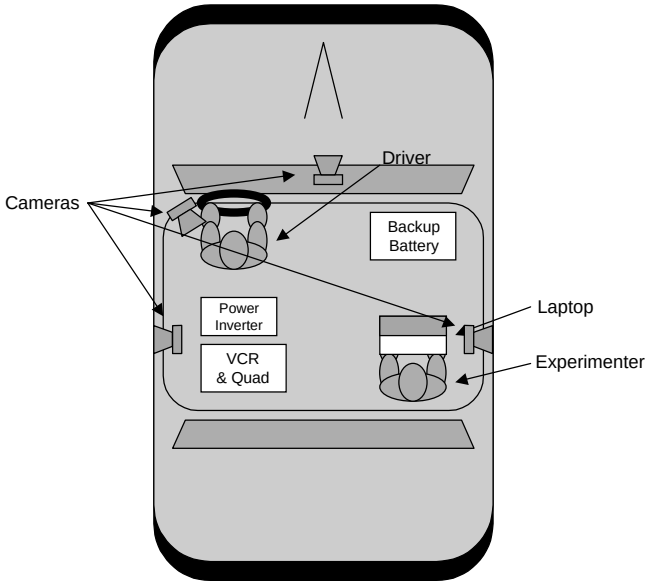


Figure 17. Equipment location schematic.

might influence the data could be noted in the field at the bottom (and expanded on in the comment bar).

A thumbwheel dial was mounted on the steering wheel in a position comfortably reached while driving. This was used by the driver to make continuous ratings of the information demand being confronted while driving. The thumbwheel was labeled with a 0-to-10 scale, and there was also acoustic output associated with the dial position. The 0-to-10 scale took up only a portion of the full range of the dial, with a physical stop at each end of the scale. Figure 19 shows a picture of the thumbwheel, seen mounted inside the steering wheel rim, to the upper left. The small pointer inside the dial rim points to the numeric setting, although the scale numbers were not on the dial shaft at the time of this photograph. The range of throw was set such that the participant could rotate the dial from 0 to 10 with one continuous motion of the thumb or fingers. The acoustic signal was generated using the library functions from a Musical Instrument Digital Interface (MIDI) file (winmm.dll). The selected acoustic signal was the "wood block" sound (voice 115 in the General MIDI standard), which was a brief percussive signal with little reverberation. As the dial was rotated from the 0 position to the 10 position, the rate of the beep increased from a low of once per 1.5 sec to a high of 5 per sec. The pitch of the sound also increased as the dial was turned. This acoustic feedback, together with proprioceptive feedback from the thumb or finger position, provided the participant with a good sense of the approximate dial setting without having to look down at the dial.

Figure 20 shows the vehicle from an exterior view. The four video cameras are visible as white rectangular objects in the picture. The one centered in the windshield is aimed at the forward view, and the one in front of the driver is recording the head and torso. The side-facing "landmark" cameras are more difficult to see, but they are located near the upper edge of the rear windows, and are aimed laterally at the roadside.

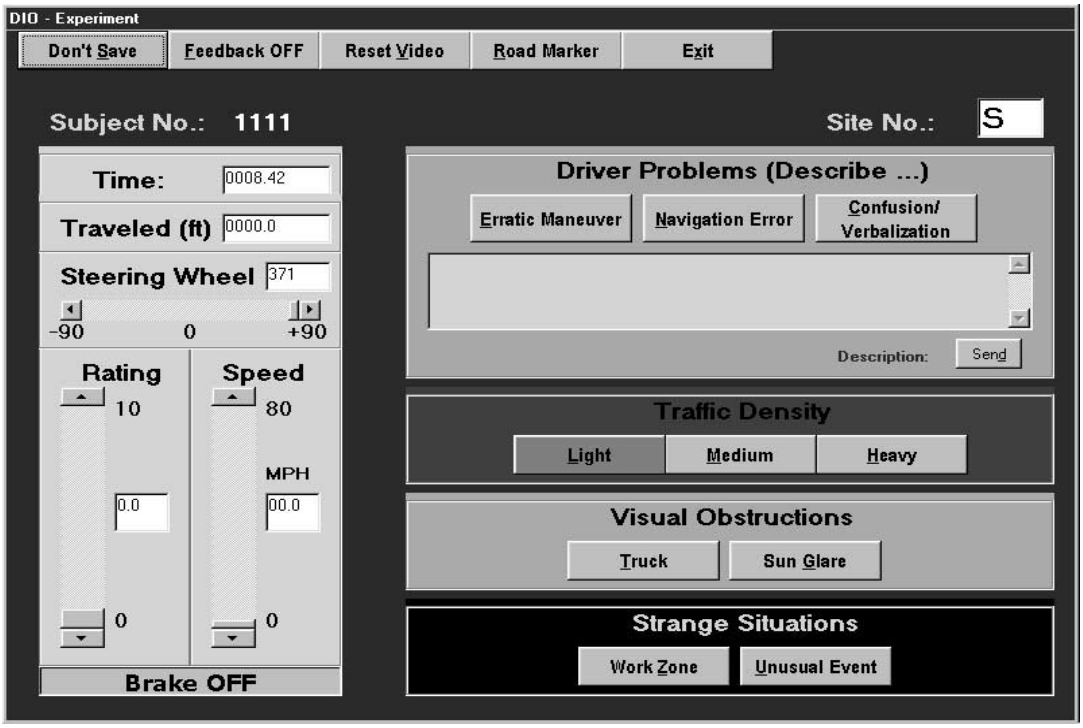


Figure 18. Experimenter interface screen for data collection.



Figure 19. Thumbwheel rating dial mounted on steering column.



Figure 21. Experimenter's position in vehicle.

Figure 21 shows an interior view from the experimenter's position. The laptop computer and small video monitor are being viewed by the experimenter. The VCR and other equipment are to her left (not visible). The participant's steering wheel-mounted dial is visible between the front seats. It is the black circular dial set just inside the steering wheel rim.

Research Participants

Sixteen participants took part in the study. They were recruited from the suburban Washington, D.C., area (Montgomery and Prince George's counties in Maryland), about 25 mi south of the general study site. Participants were screened to exclude those who had local familiarity with sections of the route, although many had occasionally driven sections of the route in the past. Participants were recruited in two age groups, with eight participants in each group (4 male, 4 female). The young driver group was composed of drivers 20 years old or younger (mean of 19.0), with a minimum of 1 year's driving experience. The older group was composed of drivers over the age of 65 (mean of 74.5). All participants were licensed drivers, English-literate, and drove at least three times a week. Age and sex groups were approximately counterbalanced with respect to morning and afternoon test sessions.



Figure 20. Exterior view of instrumented vehicle.

Procedure

The participant's task involved driving an extended route in a normal manner, with the exception of also adjusting the thumbwheel dial as they drove, to reflect the level of information demand confronting the driver. The rating task was made as unobtrusive as possible, through the design and location of the dial, provision for acoustic feedback, and training and practice prior to data collection. During the trip, the participant was navigating from location to location. The experimenter, seated in the back seat of the vehicle, would indicate the next location to which the participant was to drive. The direction was given in the form of a route name, cardinal direction, and destination. For example, the participant might be told to "go to I-695 East to Glen Burnie." No other information (e.g., distance, exit number, preferred lane) was provided. The participant navigated to the exit, made the exit maneuver, and then was directed by the experimenter as to what to do next.

The data collection system continuously recorded distance and dial rating during the trip. Various landmarks were used to calibrate the distance readings. The experimenter hit an indicator key at the moment each landmark was reached, so that the distance reading at that point was known and recorded in the computer file. Later off-line validation of the accuracy of the key timing was achieved through the use of the video

record (side camera views). Thus the information demand rating at any moment could be accurately mapped to the location on the road. Steering wheel position, vehicle speed, and brake status were also automatically recorded. The experimenter was responsible for noting and entering various other factors. One set of observations had to do with driving problems that may reflect information overload or driver confusion. These included late or erratic maneuvers, navigation errors, obvious confusion, and verbalizations. In addition to noting the occurrence of such an event, the experimenter also typed in a descriptive notation in the comment field (see Figure 18). The experimenter also noted traffic density throughout the trip and made a new entry in this field any time the traffic density changed from one level to another. Visual obstructions to sign viewing, such as large trucks or severe sun glare on the sign panel face, were recorded only when such obstructions were clearly beyond normally encountered conditions. Other atypical roadway conditions were also noted, such as work zones or "unusual events" such as police activity or objects in the roadway. Atypical visual obstructions or unusual roadway conditions were rare. This information was used as a means of screening data anomalies from the final database.

The instructions to the participant defined "information demand" and described how to make the dial ratings using the 0 to 10 scale. The definitions and procedures were repeated a number of times through the course of training and practice. The full training protocol, including the precise instructions, is provided in Appendix E. Some example wording taken from a portion of the instructions is:

> We want you to tell us how easy or difficult it is to take in all the information you need as you are driving along. When you drive, information you need to deal with is always coming at you, and so there is always some level of effort involved in dealing with that information. We refer to this as "*information demand*." We'll call it information *demand* because we want to know how much demand this situation is putting on you as you deal with the information coming at you. Some of the information you deal with may come from signs, but it also may come from what you see on the road, or the actions of other traffic around you, or just the work involved in steering and driving properly.

The instructions also indicated that the participant was not to make his or her ratings in a calculated, analytic manner, but rather based on a subjective sense of information demand:

> We want *you* to be the "measuring stick" for deciding, at any given moment, just how hard it is for you to deal with processing the information you are faced with. We don't want you to think hard about it or analyze it; just report your *feelings*. In other words, we are not asking you to think about how much information there is around you or anything else you would not normally do while driving. But we want you to pay attention to your own sense of effort in dealing with information. How easy or hard is it to take in the information you need at this point to make your driving decisions in a timely way?

The participant was given an extensive sequence of training and practice activities prior to data collection. This included the following sequence of events:

- General description of the participant's task;
- Meaning of "information demand," photographic examples of "low-information demand" and "high-information demand" scenes;
- Practice manipulating the thumbwheel dial, experiencing acoustic feedback;
- Detailed explanation of information demand, use of 0 to 10 rating scale;
- Discussion of four photographic examples of scenes of obviously different information demand, sorting in order;
- Use of thumbwheel and 10-point scale to rate information demand for the four pictures;
- Viewing of a video showing a driver making ratings while driving;
- Familiarization with driving the vehicle;
- Practice operating the dial while driving;
- Practice doing the rating procedure, using dial to make information demand ratings while driving and navigating; and
- Feedback from experimenter and continued practice.

After satisfactory completion of this training regimen, the participant entered the experimental route at the appropriate location and data collection was begun. The training portion of the procedure generally took about 30 to 45 min and the data collection portion took about 1 hour. After completion of the data collection portion, the participant was debriefed and paid for participation. Appendix E presents the full instructions and training protocol.

Findings

Data were analyzed for each of the eight sites described in Chapter 4 under "Method." The analyses conducted on the findings of the experiment are treated under several categories below. First is an analysis of the information load ratings associated with individual sign arrays. Next, the distribution of group mean ratings across each site is considered. Following that, the findings of a Principal Components Analysis are reported, which attempts to capture basic underlying patterns in driver information load ratings and identify factors that contribute to observed variance in the rating scores. Next, the relationship of overt indications of driving problems (e.g., erratic maneuvers, verbalizations) to information load ratings is addressed. Finally, findings from this on-road study as well as preceding experiments are used in regression analyses in an effort to derive a quantitative model to predict driver information load.

Information Load Ratings for Sign Arrays

The information load (dial) ratings differed significantly among the eight sites of the experiment. Analyses of variance (ANOVAs) were conducted for both the peak rating (highest rating given by a participant during the course of the site) and mean rating (mean rating for the participant averaged across the entire site). The ANOVAs included site as a within-subjects factor and age, gender, and time of day for the session (morning or afternoon) as between-subject factors. Table 4 summarizes the ANOVAs. As the table shows, both the peak and mean ratings differed significantly ($p < 0.05$) among the sites. For peak rating, the highest and lowest rated sites (Sites 4 and 8) differed by about 2 (1.91) rating scale units on the 10-point rating scale. For mean rating, the difference was about 1 rating scale unit (0.94). Older participants had slightly higher ratings than young participants, although this was statistically significant only for the mean ratings across the site (4.26 for old, 3.86 for young). The difference between male and female participants was significant for both peak and mean ratings, but the direction of the difference was opposite. Males gave somewhat higher mean ratings (4.26 vs. 3.85), but somewhat lower peak ratings (6.18 vs. 6.69). Neither age nor gender interacted with site. Age and gender did interact with one another for the site peak rating measure. As Figure 22 illustrates, older females had higher peak ratings than older males; young females had lower peak ratings than young males. While the time of the session did not affect the mean ratings, peak ratings were higher in the morning (6.88 vs. 5.85). The reason for this difference is not known. It might be related to traffic conditions, environmental conditions (including glare on signs), circadian factors, or imperfect counterbalancing with other factors.

Although the group mean findings appear reasonable and were statistically significant, there was a restriction of range in the rating values. The momentary individual dial setting values could range from 0 to 10, and some individuals used wide portions of this range. But when averaged for the group, the mean dial ratings within a site showed a relatively small range, with the lowest group mean values somewhat above 3,

TABLE 4 Summary of analyses of variance (* indicates a statistically significant effect at the $p < 0.05$ level)

Variable	Peak rating within site	Mean rating across site
Site	*	*
Age		*
Gender	*	*
Time of Day	*	
Site X Age		
Site X Gender		
Age X Gender	*	
Age X Time	*	*
Gender X Time		*

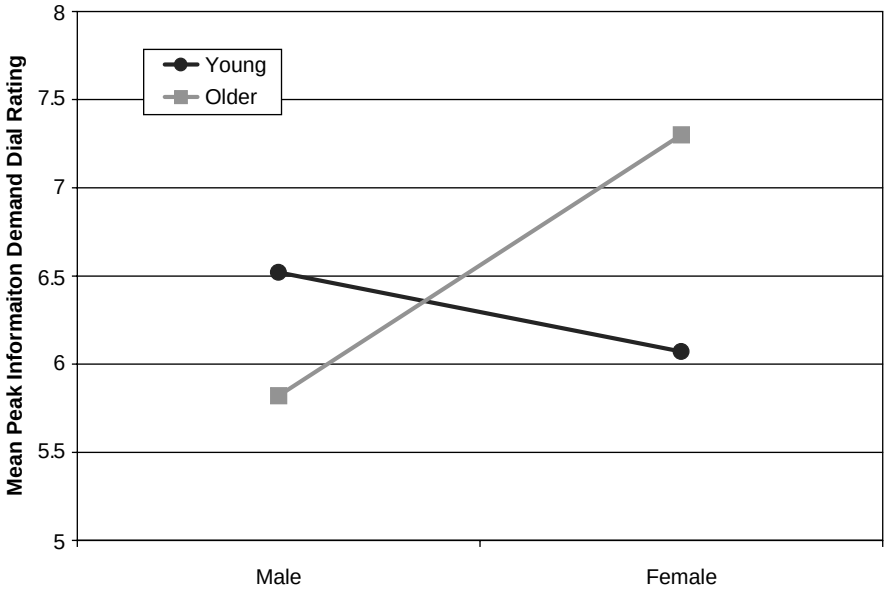


Figure 22. Site peak information load rating as a function of age and gender.

and the highest somewhat over 5 for several sites, and less than 5 for others. There are several reasons for this restriction of range. Various participants used different parts of the scale range, but few used a great deal of that range at any given site. This may be due to effects at both ends of the scale. Even in the absence of signs, the amount of traffic, traffic interactions, and truck traffic tended to move the "floor" up for these sites. The most complex sign arrays on the route were not as extreme as some of those on our originally planned route, which had to be abandoned for logistical considerations. Therefore, we may not be working near either extreme of the scale. Furthermore, participants varied in how they used the dial. Some were relatively unresponsive (little change in dial settings) and others were aberrant in the shape of their distributions. Participants also tended to differ somewhat in where their ratings peaked, even if in response to the same feature. Therefore, when averaged for particular points along the roadway, the group mean dial ratings did not tend to show dramatic differences. Despite the restricted range and the variance in the data as the ANOVAs indicated, individual participants were generally sensitive to differences between sites, both in their average setting and highest setting for the site.

Spatial Distribution of Ratings

Group mean profiles for dial rating and vehicle speed were calculated for each site. This was done by dividing the site into 20-ft segments, or distance "bins," and defining a speed and dial rating value for each participant for each bin (mean of all sampled data points falling within that bin**).** Figures 23a through 23h show the group mean dial rating profiles and vehicle speed profiles for each of the eight sites. The "0" point on the X-axis (extreme left) is the end of the route segment, that is, the gore point where the subject vehicle has just made the exit maneuver. The right-most point on the X-axis is the location designated (for analysis purposes) as the start of the segment, and the furthest point from the exit. Thus, the vehicle may be seen as traveling from right to left through the figure. The vertical lines on the figure show the location of various sign arrays. In general, there appears to be a gradual upward trend in ratings as the exit point is approached, with a drop in the final portion (when uncertainty may be eliminated). Speed also drops at the termination of the segment, reflecting the exit maneuver. There is not a clear and consistent relationship of the shape of the dial rating profile to the location of sign arrays. In a number of cases, there appears to be "peaking" on the approach to a major sign array, rather than at the point of the sign array itself. Site 6 provides a good example. However, this pattern was not consistent and, while somewhat suggestive in the averaged group data, was not obvious in most individual ratings. Formal attempts to describe the location of the peak rating with respect to the location of the sign array did not yield a meaningful result. Various transforms and statistical strategies were used to attempt to improve the direct match of the group mean information rating load functions to roadway features, and to reduce the substantial variability of

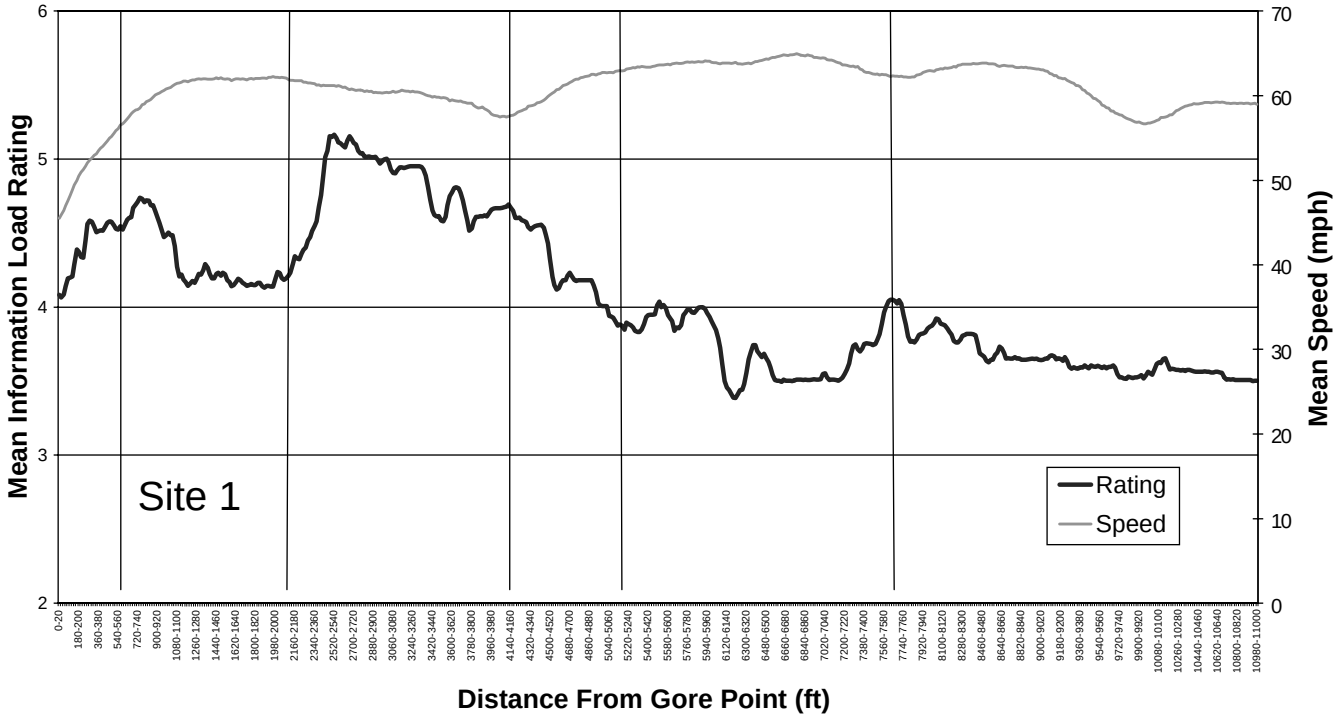


Figure 23a. Mean information load rating and mean speed for Site 1.

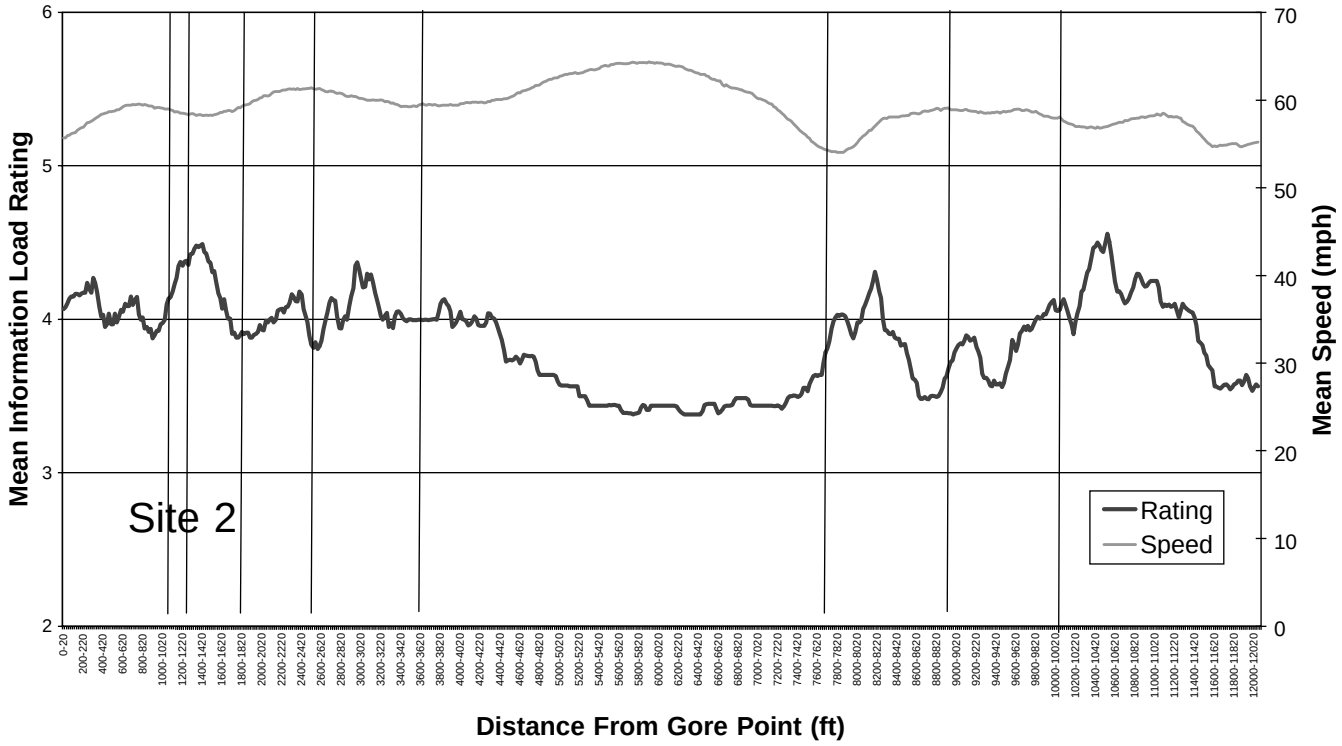


Figure 23b. Mean information load rating and mean speed for Site 2.

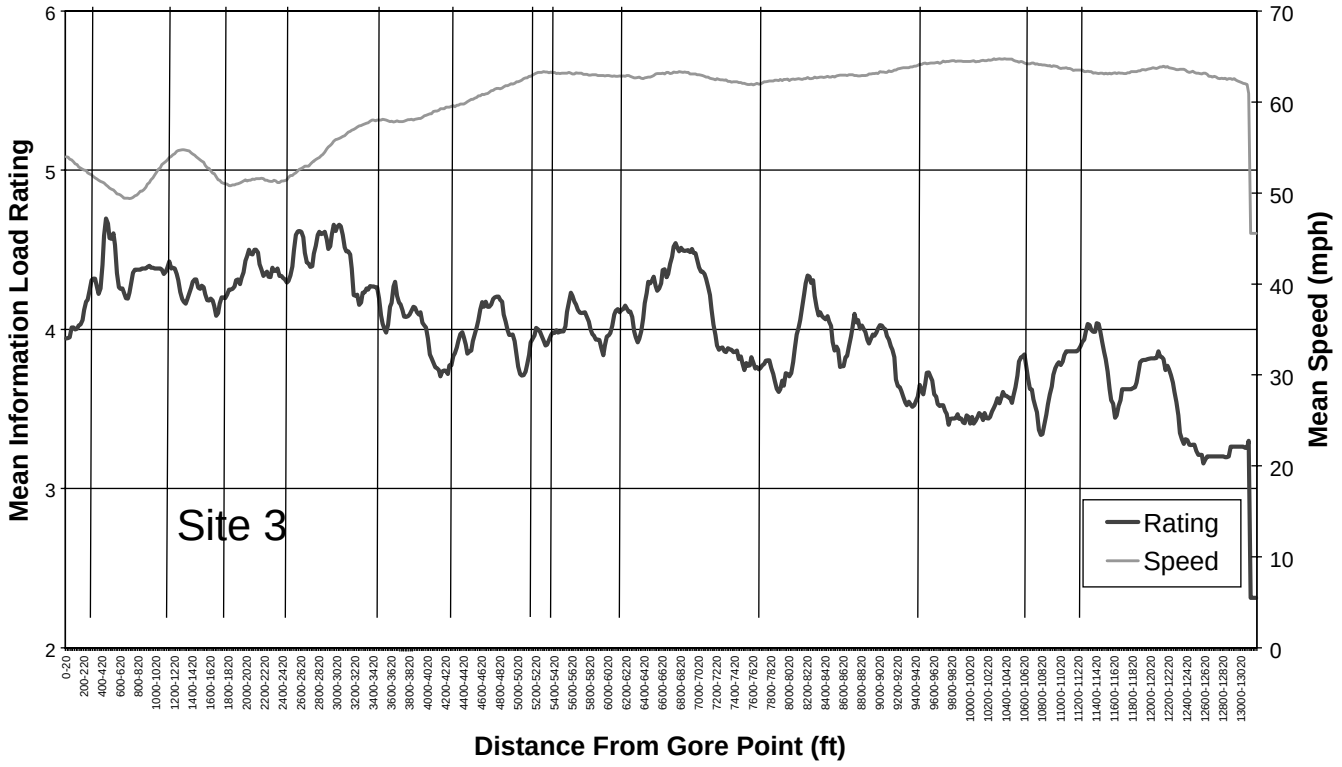


Figure 23c. Mean information load rating and mean speed for Site 3.

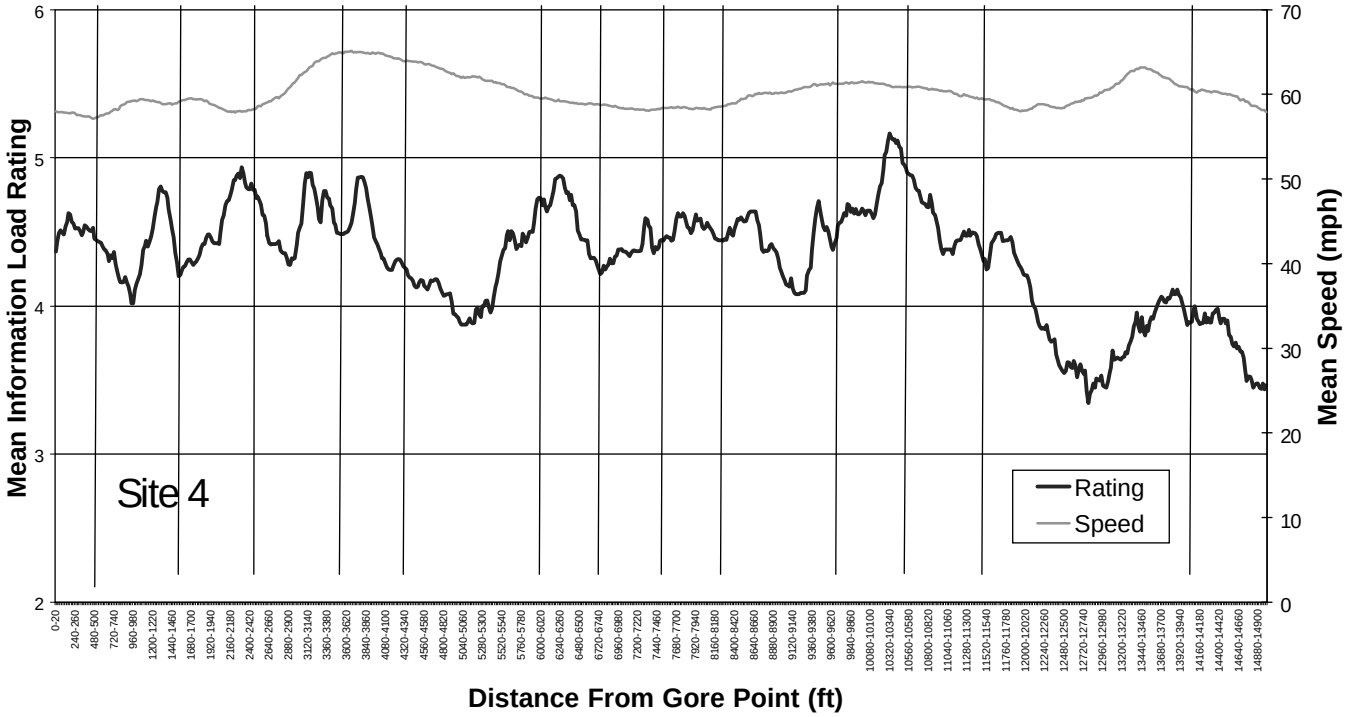


Figure 23d. Mean information load rating and mean speed for Site 4.

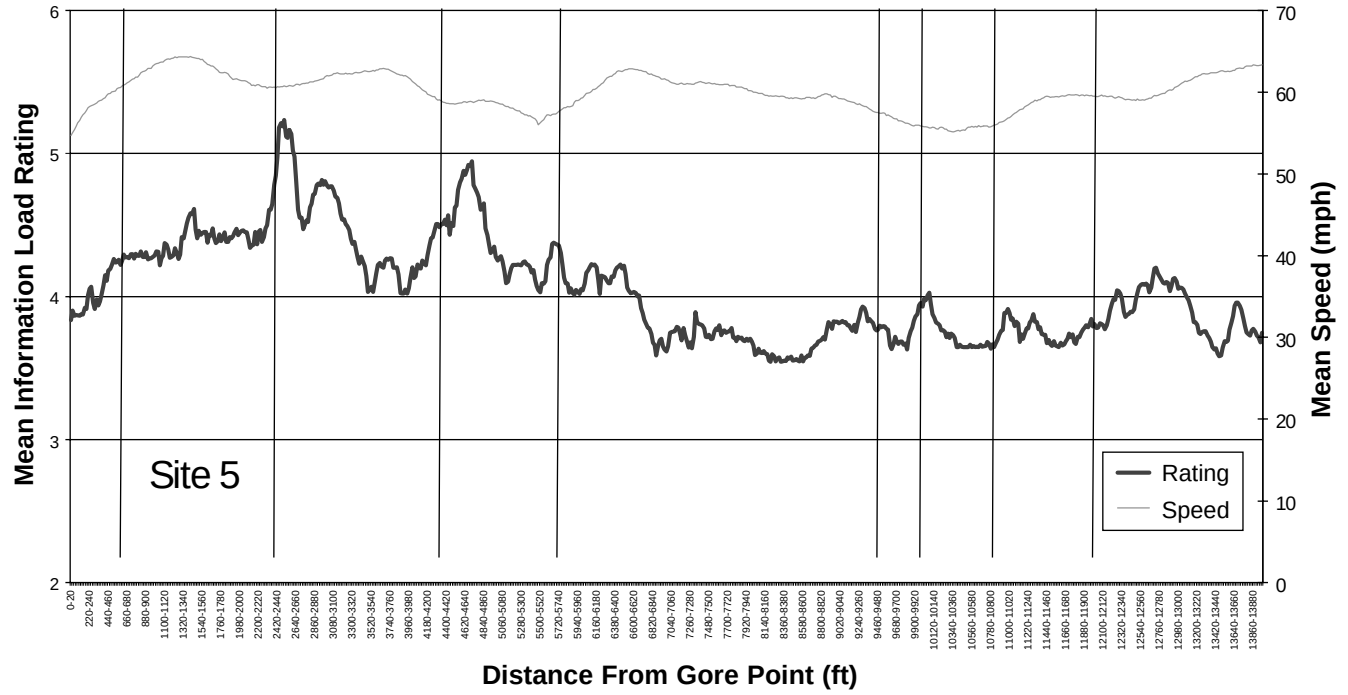


Figure 23e. Mean information load rating and mean speed for Site 5.

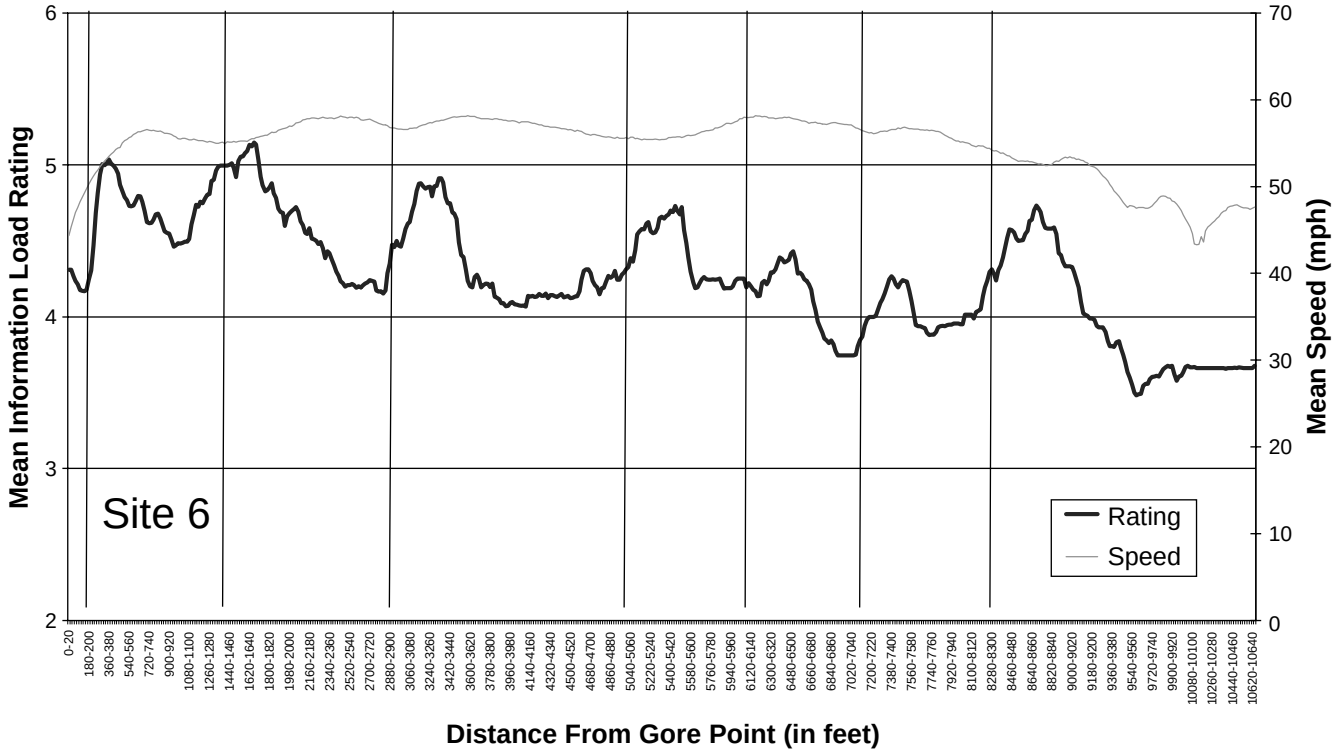


Figure 23f. Mean information load rating and mean speed for Site 6.

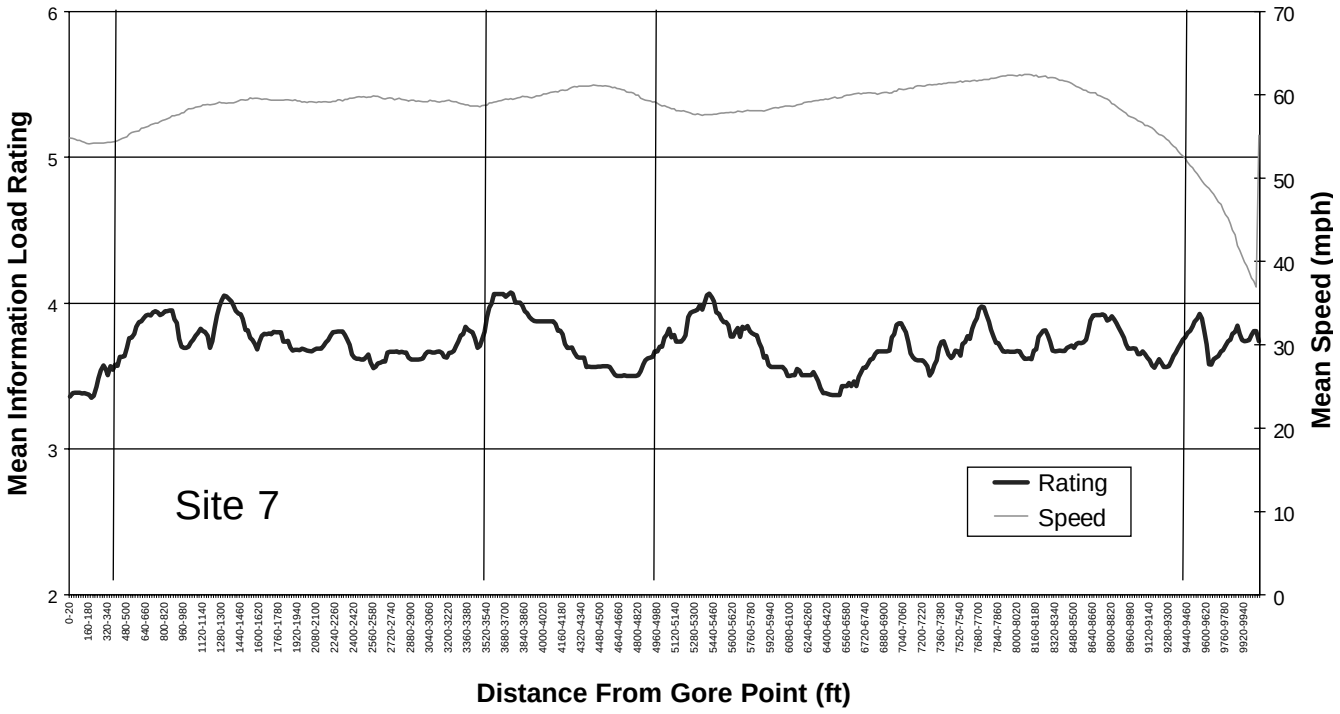


Figure 23g. Mean information load rating and mean speed for Site 7.

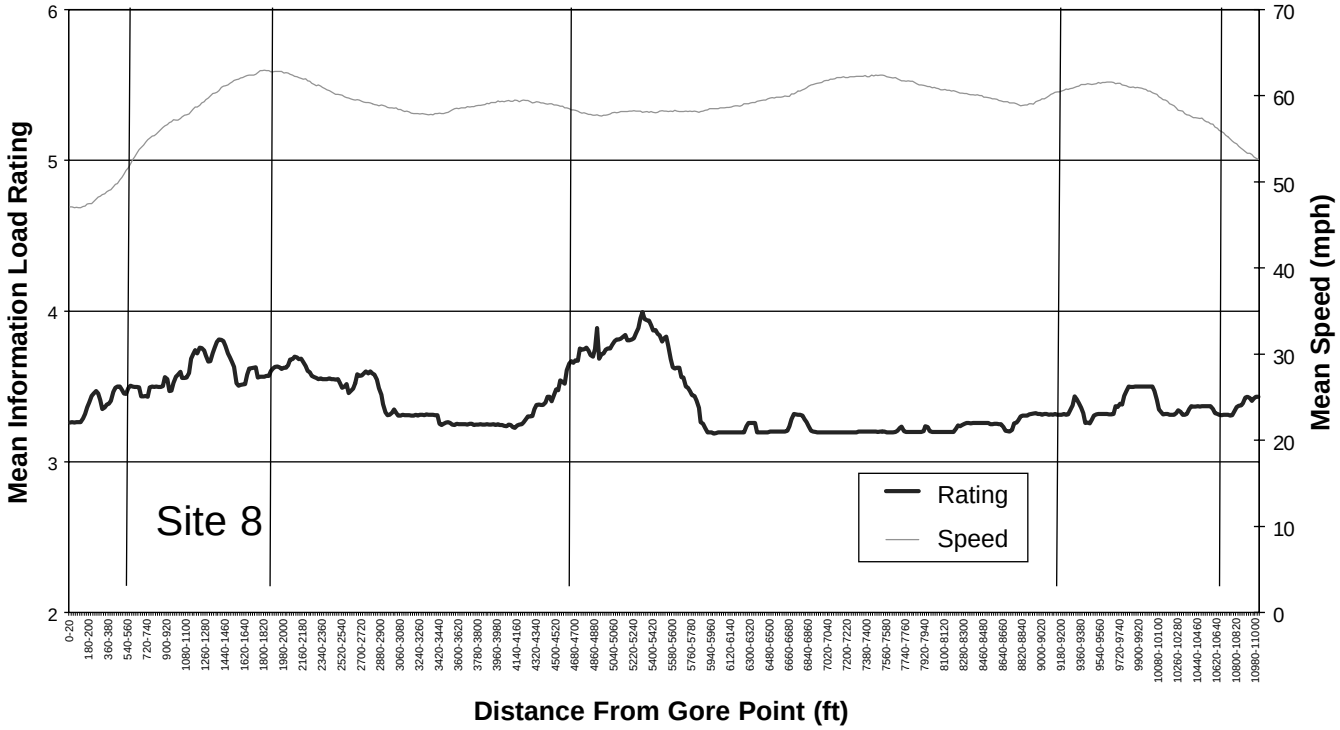


Figure 23h. Mean information load rating and mean speed for Site 8.

the individual subject ratings. Although the Z-transform was used to normalize individual data and provide a more uniform basis for combining and comparing subject data (combining individual data into group curves), the inter-subject variability and "noisy" group functions remained. Based on these data, it did not appear warranted to try to describe a typical "envelope" shape of information demand around each sign array.

Principal Components Analysis

In an attempt to better understand the nature of the data and provide deeper insights into how drivers experience "information demand," the data were subjected to factor analytic techniques (specifically, principal components analysis). This resulted in the definition of two, and perhaps three, factors underlying the data structure (Factor 1, Factor 2, and Factor 3). These factors were extracted and plotted for each site, to help us try to understand their meaning. Figure 24 plots these data for Site 6. The X-axis plots the distance from the exit gore of the site. The "0" point on the left side is the point of the exit gore at which the subject vehicle is making a maneuver. The numbers along the axis show the distance in feet from this gore, or "end point" of the road segment. The vertical lines show the locations of individual signs or sign arrays. The Y-axis shows the relative value of the strength of a particular factor. The four tracings on the graph show the group mean functions for Factor 1, Factor 2, Factor 3, and standardized dial rating. Factors 1 and 2 turn out to be quite interpretable. For the various sites, Factor 1 accounts for from 17 to 33 percent of the variance in the analyses, averaging 24 percent. Factor 2 accounts for from 13 to 18 percent of the variance, averaging 15 percent. Factor 3 is more ambiguous in interpretation and accounts for less of the variance (8 to 13 percent, averaging 10 percent).

Factor 1 generally increases in value as a geometric feature (interchange) is approached and then drops somewhat prior to the point of the gore. This replicates the similar observation from the preliminary on-road experiment. Figure 25 averages the F1 functions for all eight sites of the experiment. This is the factor that accounts for the largest portion of variance in the principal components analyses. Some sites show a Factor 1 increase, then dip, then increase again in a few places, as in Figure 24. Comparison with roadway features found that this is generally related to the presence of exit lanes or ramps on the road section, prior to the one that the subject driver is navigating to. *Factor 2* was initially more difficult for us to interpret, since it was not directly linked to an obvious geometric feature. The sites were examined in detail to attempt to determine what might relate to the Factor 2 profiles. Factor 2 appears to reflect lane or path uncertainty. It rises as questions about lane/path arise, and drops at the point where it becomes clear where the lane or path goes or what lies ahead. This resolution of uncertainty can come from direct view, initiation of a dedicated lane, division of lanes, or signage. *Factor* 3 was not clearly interpretable and was relatively weak statistically (accounting on average for about

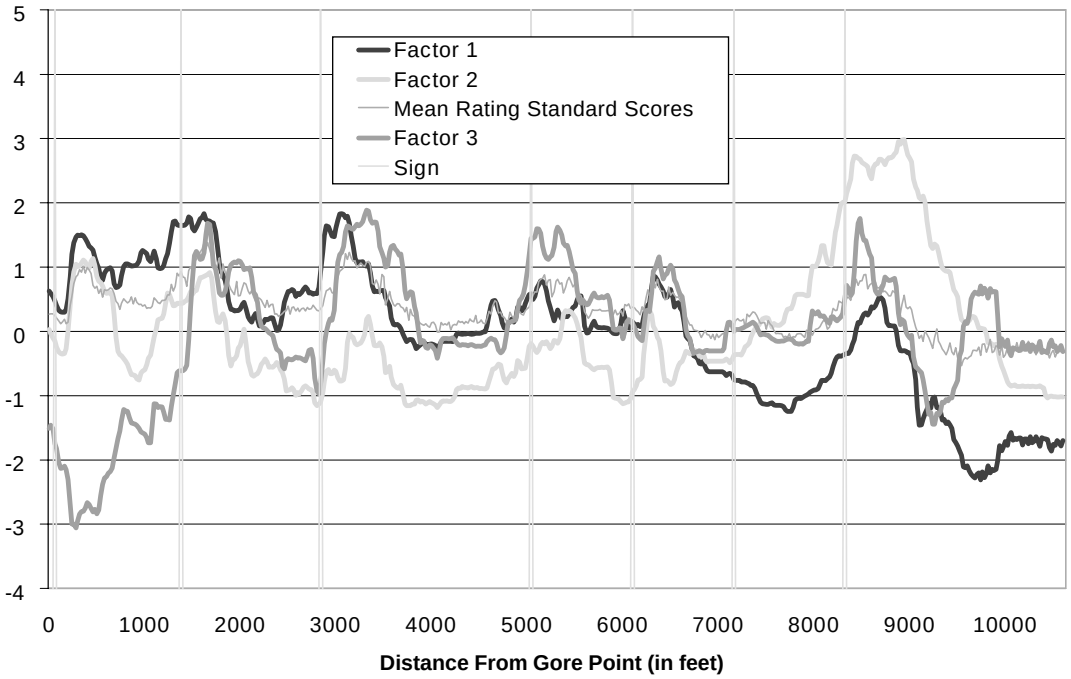


Figure 24. Factor and standardized scores for Segment 6 across all subjects.

10% of the variance). It may relate indirectly to "information load," although the relationship is not clear or consistent.

As the researchers conceptualize it, Factors 1 and 2 are related to driver planning and execution of navigational maneuvers:

Factor 1: Execution

- Being where you want to be;
- Confirmation of your proper location;
- Dealing with interacting traffic; and
- Dealing with complex geometry.

Factor 2: Planning (Resolution of Uncertainty)

- Where must I be?
- When must I be there?
- What is coming up? Are there more choices to make?

Factors 1 and 2 are the largest factors, in terms of accounting for variance (on average, 24% and 15%, respectively). While this helps us understand the data, it does not directly address driver information load, related to *sign content*. What seems to be emerging is a picture that the information demand experienced by the driver is a function of various factors, with the amount of sign information being only one of those factors. "Demand" is driven by the *need* for information as well as the *presence* of information, as well as by the additional demands of the *driving* task

More generally, it appears that information processing driven by the need to try to acquire information to resolve ambiguity is an important factor that must be considered along with information processing driven by the need to extract the information in signs. Factor 2 is not restricted to signs, and perhaps more critically for modeling, it deals with the *qualitative* information in the sign. While Factor 1 may be readily incorporated into the general scheme of the information load model developed here, the qualitative nature of Factor 2 makes it more difficult to incorporate. Factor 2 appears to reflect good sign practice, in the sense of providing clear direction, reducing ambiguity, delivering guidance in a timely way, relating destinations to proper lane choice, and so forth.

Overt Indices of Driving Problems

One aspect of the on-road study was to attempt to determine if there was some level of information load that corresponded to the point at which drivers began to evidence overt indications of confusion and driving difficulty. This would correspond to a "red zone" for applying the model and recognizing where the absolute value of the information demand is unacceptably high. It was recognized from the outset that the small scale of the study, in terms of number of participants and the range of sites, would not permit any very refined analysis and quantification of this criterion point. However, it was hoped that the data might allow at least a crude estimate of a region in which overt driving problems began to occur.

A variety of events indicated driving problems. These included navigation errors, erratic maneuvers, verbal indications of confusion, and obvious confusion. For purposes of analysis, a drive through a site was considered to exemplify a problem if any one of these events occurred anywhere in

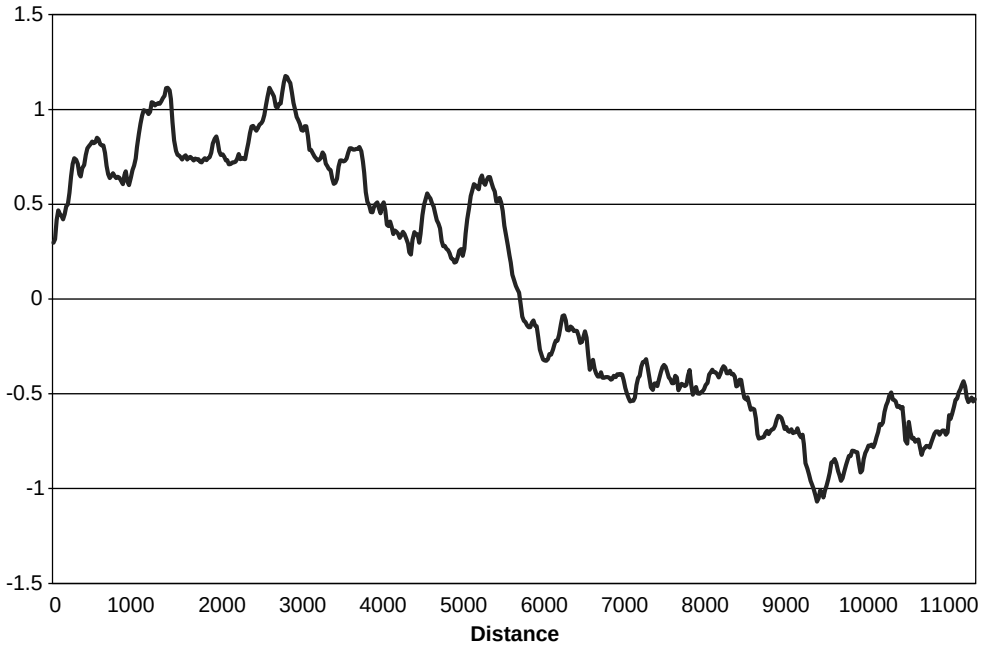


Figure 25. Mean F1 ("Proximity to Maneuver") Function (average of eight sites).

the site. Even using this liberal criterion, overt indications of driving problems were rare. Of the 128 cases (16 participants times 8 sites), a driving problem was recorded for only 15 of them (excluding a few erratic maneuvers that were clearly related to crash avoidance due to the aggressive actions of other vehicles). These were distributed across sites, with one to three incidents per site. Even of these 15 events, the cause of many were not clear. Across all 128 cases, there were only two instances of missed exits and three near misses of exits.

Because overt indices of problems were infrequent, often ambiguous, and distributed across the eight sites, the experiment therefore was not able to objectively define a "red zone" for driver information load. Ratings must be treated as relative. A larger driver sample, and sites with more extreme information demands, will be required to empirically establish a criterion level for "overload."

Regression Models

The information demand of a given sign array is only one of various elements that contribute to the overall driver information load. The conceptual model developed earlier in the project and described in Section 3 indicated factors related to "Information Search Demand" (ISD) and factors related to "Driving Task Demand" (DTD). ISD factors included the sign arrays, their relative locations, and the information density of the site. The DTD factors included the roadway type, features, and proximity to the exit choice point. The on-road experiment confirmed the reasonableness of the basic structure of this model. The "proximity to the exit choice point" again emerged as a major consideration. During this portion of the analysis, research findings from all experiments and their interrelationship were expressed in terms of a multiple regression model. The model assessed the ability of various factors, individually and in combination, to predict the peak rating for a given sign array on the road.

The experiment on combination rules for sign arrays established that the information demand of a particular sign array (as measured in the laboratory) could be well predicted from table-based estimates of the demand of each sign that was part of the sign array. However, the actual demand associated with a sign array in a real roadway context will be influenced by various additional factors. The issue then becomes whether there are reasonably simple rules that can be used to predict the information demand of a sign array in its roadway context for an unfamiliar, navigating driver.

A variety of different predictors were explored. Table 5 lists the simple correlation coefficients for a number of individual variables as they correlate with the on-road peak ratings for each sign array (a number of variants of many of these concepts were also explored, although no important improvements occurred). Many of these simple correlations were statistically significant. The highest correlation ($r = 0.57$) was with the sign array information load value (derived from the look-up tables); by itself this accounted for about one-third of the variance in the on-road peak ratings ($r^2 = 0.32$). Correlations were also substantial for the value of Factor 1 at the location of the sign array and with the two closely related measures of the complexity of the roadway (number of elements, and number of elements divided by segment length). There was also substantial correlation with a measure that summed all of the sign array information loads for the site.

TABLE 5 Simple correlations of variables with peak on-road rating of individual sign arrays

Variable	Correlation (r)	Statistical significance
Sign Array Information Load (from lookup table)	0.57	P<0.0001
Factor 1 (proximity to maneuver factor)	0.44	P<0.0002
Factor 2 (path uncertainty?)	0.10	NS
Total number of signs in site	0.23	NS (p<0.06)
Sum of information loads of all arrays in site	0.42	P<0.0004
Local information density (sum of information loads for preceding and following arrays, over distance)	0.25	P<0.05
Average distance to nearest array (mean of distance to preceding and following signs)	-0.21	P<0.05
Number of roadway elements in site (curves, exits, etc.)	0.47	P<0.0002
Roadway baseline (number of elements divided by length of roadway segment)	0.48	P<0.0002

Various measures of the information surrounding the target sign array were also correlated, although to a lesser degree.

Applying multiple regression fits to the data accounted for substantially more of the variance. Combinations of four factors (sign array information load, Factor 1, plus others) yielded R^2 values ranging from 0.65 to 0.70, and using five or six factors yielded R^2 values in the area of 0.71. While this indicates that the on-road rating of information demand can be well-predicted by these factors, there is the practical concern that one of the key variables (Factor 1) is empirically derived from the experiment. It is not an observable characteristic measured from the physical features of the site. Since the ultimate objective is to develop simple rules for the analyst to use, the variables that constitute the regression model should not require such empirical data. The model should be based on factors that can be derived entirely from physical characteristics of the site and the signs. Therefore, a simple ramping function was substituted for the empirical Factor 1 variable and some other measures were also simplified. The "maneuver proximity" ramping function rose beginning 6,000 ft from the exit gore, peaked 1,500 ft from the exit gore, and then dropped again to the point of the exit (formal definitions of all the terms used in the model can be found in the subsection "Driver Information Load Model Status and Limitations"). The resulting multiple regression, using five factors, resulted in an R^2 of 0.66. Essentially the same R^2 was obtained after dropping one of these factors (information density across the site), so a four-factor model appears appropriate. The four factors that predicted the peak on-road rating for a sign array were as follows:

1. Sign *array* value, based on the look-up table;
2. Proximity to the exit choice point, using a ramping function;
3. Local information density measure, based upon the sign array values of the preceding and successive arrays, divided by the distance spanned; and
4. Roadway demand baseline value, based on the density of geometric features such as merges, curves, etc.

The key finding is that this simple four-factor linear regression is quite successful in predicting what the peak rating will be (based on group mean data) for a given sign array at a given site. The resulting four-factor multiple regression equation predicted the peak rating for on-road information load for a given sign array with a multiple correlation coefficient of $R = 0.81$. This means that the four factors of the model were able to account for about two-thirds in the variance of the peak ratings ($R^2 = 0.66$) for sign array. The high level of correlation is especially noteworthy, given that there are additional, presumably important, variables that were uncontrolled in the experiment (e.g., traffic), individual differences among drivers, and qualitative aspects of the sign message that are not included within the information load concept (e.g., ambiguity, expectancy). Thus, the model is quite successful in predicting driver information load, as measured by the driver's on-road dial ratings.

SUMMARY OF KEY FINDINGS AND INTEGRATION INTO MODEL

Relation of Findings to Key Research Questions

The purpose of the research experiments was to contribute to the development of a model of driver information load related to freeway guide signage. The structure of the model involved the following components:

- Determination of information loads associated with individual signs (based on look-up tables);
- A rule for combining the information load associated with individual sign panels into a single figure to represent the information load associated with a particular array of co-located signs; and
- A means of combining the information load associated with a sign array with the information load generated by the roadway and other nearby signage, in order to derive

an overall information load associated with the sign array at its roadway location.

Several key research questions relate to the accomplishment of these goals. The questions and the primary findings that bear on them are summarized here.

Are the information load ratings for individual signs reliable and replicable?

Systematic and strongly significant variation in ratings of individual sign information load were observed in both laboratory experiments. The two experiments shared a common subset of 15 signs. The ratings for these signs between the two experiments correlated at $r = 0.86$, despite a number of methodological differences between the experiments (e.g., viewing time, sign context). Thus the answer to this question is "Yes:" the sign ratings appear meaningful and replicable."

Do the look-up tables accurately predict the information load ratings of individual signs?

The look-up table for sign information load developed in the initial laboratory experiment was used to predict the actual rated information load of a new set of individual signs presented in the subsequent laboratory experiment. The correlation of predicted and observed ratings was $r = 0.84$. This is nearly the same as the correlation with which ratings of the *same* sign could be replicated across the two experiments. Therefore, the answer to this question is "Yes: the look-up tables provide a good basis for predicting the information load of individual signs."

Is the information load of a sign array predictable from knowing the information load of the individual signs making up the sign array?

The greatest sign complexity encountered on the road is assumed to be where there are multiple signs located in an array. Since the look-up tables only dealt with individual signs, there remained the question of whether the table information could be used to estimate the information load ratings given to sign arrays. Various rules for combining the individual sign ratings into a single sign array weighting were explored. Using the best of these rules (linear function of arithmetic summation), the correlation between observed and predicted sign array weightings was $R = 0.95$, with a standard error of estimate of about 0.29 units on the seven-point rating scale. This strong correlation accounts for about 90% of the variance among the ratings. Therefore, the answer to this question is "Yes." A very simple equation, based solely on the information load values of individual signs, accurately predicts the directly rated information load of a sign array. Therefore, the assumption of the modeling approach—to use categorized sign look-up tables as a basis for determining complex sign array information demand—is supported.

Can the on-the-road peak information load associated with a sign array be predicted based on sign and roadway variables?

The ultimate question addressed by the experiments was whether it was possible to predict on-the-road findings regarding information load, based on knowing the characteristics of the signs and the roadway. The answer to this question for predicting the peak information load associated with a sign array was "Yes." A simple multiple regression equation based on four factors predicted the peak rating, with a correlation coefficient of $R = 0.81$. This means that the four factors of the model were able to account for about two-thirds of the variance in ratings for the sign array. The four factors were (1) sign array information demand (derived from the look-up tables); (2) maneuver proximity; (3) roadway demand (based on a count of roadway features); and (4) local information density (based on the information demand of surrounding signs). The high level of correlation is especially noteworthy, given that there are additional, presumably important, variables that were uncontrolled in the experiment (e.g., traffic actions), individual differences among drivers, and qualitative aspects of the sign message that are not included within the information load concept (e.g., ambiguity, expectancy).

Can the spatial aspects of on-road information demand be predicted?

Although the peak information demand associated with a sign array can be well predicted, it would also be desirable to quantitatively describe the region over which a sign array exerts its influence and the shape of any function describing the magnitude of these effects. The initial model conception described in Chapter 3 visualized an "envelope" of demand around each sign array. The on-road experiments did not establish any such functions. There was no clear evidence of any typical function shape for information load surrounding sign arrays. This could be due to limitations of the data (which were limited as well as "noisy" and quite different from person to person). It may also be because the concept that information demand changes in a highly systematic manner on the approach to and pass by a sign array is not realistic. In any case, the findings of the experiments did not permit prediction of the location of a peak for each sign array in the group mean information load function. Thus while the model predicts the magnitude of the peak rating for each sign array, it does not describe spatial aspects.

Is there an empirically determined information demand level that defines a "red zone" for information overload?

Although the primary on-road experiment attempted to address this question, the data were simply too limited to provide an answer. Various indices of driver problems, such as unusual steering or braking events, navigation errors, erratic maneuvers, and verbalizations were recorded. The intent was

to relate the frequency of these problem indices to the model output of information load, in hopes of observing some range of information load in which these problems were seen to emerge more frequently. However, there were relatively few occurrences of these events. With only eight sites, 16 participants, and few extreme examples of sign complexity within the set, there were not enough problems observed. This was the case even though the study employed relatively old or relatively inexperienced drivers who did not have good familiarity with the area. Therefore the experiment did not provide an empirical estimate of the model output level that corresponds to a "red zone" for information overload.

Driver Information Load Model Status and Limitations

The laboratory and on-road experiments have led to the development of a relatively simple model of driver information load that predicts the peak information load associated with a given sign array in its actual on-road setting. The model not only includes information about the target sign array but also incorporates features of the roadway and surrounding sign arrays. The model begins with the following assumptions:

- The driver is assumed to be navigating to an unfamiliar destination (since familiar drivers may not need to process the information in the signs);
- A navigational maneuver (e.g., exiting) is required at an approaching interchange or decision point (since this appears to be the worst-case condition for a given sign array);
- There is available information (content and location) regarding all relevant navigation-related signs for the roadway segment (11,000 ft prior to the exit gore); and
- There is available information regarding road geometry for the site.

Given these assumptions, the information load associated with a particular sign array is estimated by the multiple regression formula:

$$IL = 0.012SA + 0.062MP + 5.649RD + 0.082LD + 3.17$$

IL = Driver information load
SA = Sign array information demand
MP = Maneuver proximity
RD = Roadway demand
LD = Local information density

Operationally, these factors are defined as follows:

1. Sign Array Information Demand (*SA*)
   a. Value for each individual sign is estimated using look-up table.
   b. Sum values for individual signs, where array information demand = 0.765 (Sum) + 0.44.
2. Maneuver Proximity (*MP*)
   a. Determine the point of the exit gore for the navigational maneuver.
   b. The value of the Maneuver Proximity factor is described by a ramp function:
      1. From 0 ft (maneuver point) to 1,500 ft prior to the maneuver point, the function ramps up from 1.0 to 3.5.
      2. From 1,500 ft to 6,000 ft, the function ramps down from 3.5 to 0.
      3. Beyond 6,000 ft, the value is 0.
3. Local Information Density (*LD*)
   a. Determine the sign array information demand for the array preceding and the array following the target sign array.
   b. Sum the before array and after array values and divide by the distance between them to derive local information density; multiply by 100.
4. Roadway Demand (*RD*)
   a. The roadway segment is defined as the 11,000 ft preceding the navigation point. If the roadway segment is shorter than this, use only the appropriate length, not preceding entry ramps or other roadways.
   b. Over the roadway segment, sum the number of relevant features. Features include the following items:
      1. Maximum number of lanes (not counting weaving sections),
      2. Number of merges,
      3. Number of exits,
      4. Number of weaving sections (merges and exits counted separately),
      5. Number of lane drops, and
      6. Number of horizontal curves.
   c. Divide the sum of the number of features by the roadway segment length, and multiply by 100.

The implementation of this model into a usable tool for traffic engineering applications is the subject of subsequent sections of this report.

Although this model worked well in predicting observed on-road subjective judgments of information load for the sites employed in the on-road experiment ($R = 0.81$), there are still a number of significant limitations to the data and to the model as it now stands. These should be explicitly recognized and may require additional research in order to refine the model. One limitation is simply the size and variability of the experimental database itself. Ideally, a substantially larger sample would have been used to enhance the precision of the findings, but sample sizes were dictated by available project resources. Beyond this, there were some more specific limitations to the data collected, including the following:

- The sites studied were fairly homogeneous, all being in suburban Baltimore. In particular, there were no complex urban areas. Some complex urban sites were included in the originally planned route that had to be abandoned,

and no suitable urban sites were found in the new area. Ideally, data from a broader range of geographic regions and a broader range of roadway environments would be included.
- The research did not address off-road signing, such as billboards and commercial signs. It is not known to what extent the model needs to include these displays and how to best incorporate them.
- The model assumes that there is a finite "universe" of navigation-related signs that can be assigned information load values and used in look-up table form. There are two significant exclusions from the set included in this research. The first of these is logo signs (motorist services). The other is the broad category of variable message signs and their related display technologies. Ultimately one would want these TCDs incorporated into the look-up tables.
- One problem related to sign visibility is that signs can be obscured by large trucks in the surrounding traffic stream. Truck traffic was well represented in the route used for the on-road experiment, but it was not systematically measured or incorporated as a variable. It may or may not be useful to include some index of truck traffic in the information load model.
- The model does not include an explicit treatment of sign legibility. This may not be necessary, in part because of the general similarity of signs within any category of the look-up table. In model development at this point, it was felt to be an unnecessary complication to the model and the associated engineering tool. However, it is possible that incorporating some legibility factor might enhance the model, particularly for extreme cases.
- One goal of the research was to provide objective data for the definition of a problem zone ("red line") for information load that defines "overload." Overt indications of driver problems were too infrequent in this small data set to permit any estimates of this zone.
- The model does not attempt to incorporate various qualitative aspects of the specific message of a sign. The driver will presumably have to devote more effort if the message is unclear, if expectancies about the display or maneuver are violated (e.g., expect to see an interstate logo, expect a right hand exit), or if there are other unusual or confusing aspects.
- The implementation of the model requires operational definitions of various factors (e.g., maneuver proximity, roadway demand). The choices reflected in the definitions described above were based on simplicity, general logic, and comparisons between various alternatives. The choices may not be optimal and in some cases might be overly simplified. On the other hand, given the general success of the model in predicting the on-road data, there may not be great return in efforts to further refine these factors. The need for improved definitions of the model factors remains an open question.
- The model is based on the relationship of sign and roadway factors to a driver's subjective sense of the difficulty of coping with information. Some measures of overt driving problems were taken, but there were few instances of these occurrences. Ultimately, the predictions of the model should be validated against objective indices of driving problems, such as erratic maneuver rates or crash occurrences. Such studies present some difficulties, since site factors other than information overload may contribute to the problems and it is difficult to know whether a given motorist is unfamiliar with the site and is actually navigating and using sign information. Despite such issues, it will be important to provide some external means of model validation.

Although this discussion of limitations points out the incompleteness of the modeling effort, one should not lose sight of the fact that this initial model appears to have been reasonably successful despite its limitations. The approach appears both workable and promising and also practical as the basis for an engineering tool or procedure. There may be substantial benefit in addressing some of the limitations discussed above, but there also might be little practical change to the current version of the model. The issues are empirical and the significance may not be known without additional research.

Suggestions for Additional Research

Given the limitations cited above, the following topics are recommended for subsequent research:

- **Validation of the model.** Because the model was developed, in part, from on-road data from a small set of drivers and roadway sites, there is a general need to replicate and extend the findings. The model based on the findings is intended to help identify and mitigate conditions where driver information overload (DIO) causes safety or operational problems. Research is required to validate the model by demonstrating a substantial relationship between the model output and the ultimate safety or operational consequences. It would also be desirable to do before-after studies to determine the effectiveness of countermeasure improvements suggested by the model. The research method would require a means of determining to what extent observed safety and operational events are related to high information load demands. To the extent other factors contribute to problems at a site, indices of information load would not be expected to be very predictive.
- **Defining the relationship of model output to overt driving consequences.** The research to this point has defined a relationship among sign and roadway factors and the subjective sense of "information demand" faced by the driver trying to cope with these factors. However,

the on-road experiment was too limited to determine the levels at which the index of driver information load begins to have negative effects on overt driver actions. Research is needed to effectively map model outputs to behavioral effects so that thresholds for problem regions (e.g., red lines) could be objectively defined.

- **Expanding the research base to a broader range of site types.** Because the model was developed using a small set of suburban interchanges, the possibility of generalizing the findings to a broader set of sites is not demonstrated. Research should determine whether any refinements are needed to encompass a broader range of conditions. Research should investigate urban settings, a broader range of geometries and operational conditions, the effects of the vehicle mix (large trucks), and more complex sign arrays.
- **Expanding the types of information sources included.** The present research focused on static highway signs related to navigation. Other information sources that may affect the information load of the driver may also need to be included in a more comprehensive model. Subsequent research should include sign categories not included in the present research: logo signs, TODS, and variable message signs. The influence of off-road commercial signing should also be considered. Also, as in-vehicle technologies such as route guidance systems become more commonplace, the interaction of in-vehicle displays with external signage may need to be investigated.
- **Refining the component elements of the model.** The model bases driver information load on four component computations: sign array information demand, local information density, maneuver proximity, and roadway demand. While the predictive success of the regression model suggests that these general concepts are addressing important factors, they still might not be ideally conceptualized. Additional research may suggest better ways of defining these attributes. Each component is based on a simple computation; there may be more precise ways of quantifying these attributes. Also, there may be additional components of importance not addressed by the current model. Among these may be legibility factors or qualitative aspects of the quality and clarity of sign information content. Subsequent research should investigate the completeness and precision of the model components and whether there would be practical benefits to including additional factors.

CHAPTER 5

DRIVER INFORMATION LOAD MODEL COMPUTATIONAL TOOL

INTRODUCTION

A computational tool was developed using software and analytical capabilities of readily available off-the-shelf computer programs. This software tool allows the user to readily compute the driver information load (DIL) based on the model developed under this project and described in detail in the earlier chapters. As discussed earlier, the model of DIL uses information about the roadway and signage as input and provides a quantitative index of the information load associated with each set of signs present on a section of roadway as output. DIL is a quantitative index of the information load for each set of signs on a section of roadway associated with a particular destination (e.g., an exit off the freeway). It refers to the level of demand placed on the driver in order to process and respond to the information presented about the subject exit within the section of highway preceding that exit.

The tool was developed to make the DIL model easy to use for evaluating and analyzing information loads associated with an array of guide signs on freeways. The tool can be used to identify potential information overload problems and to compare alternatives for the design and placement of signs. However, it must be recognized that the model and the associated software tool deal specifically with the problem of DIL, that is, the ability of the driver to safely process the amount of information in the time available. The model does not address the full process of designing an informational sign system, including consideration of motorist information needs, the accuracy or clarity of the message, the choice of wording or destinations, and other features. Managing the information load is only one part of the process, and it is the part dealt with in a quantitative fashion by this tool.

A detailed description on how to use this tool and some underlying theory of the model are presented in the User's Manual, which is attached as Appendix F. Appendix F includes illustrations of the input screens and output formats and a glossary that defines the terms and concepts used in the program.

DIL COMPUTATIONAL TOOL DEVELOPMENT

The DIL software tool was first developed in a spreadsheet format for analytical purposes, that is, generating the DIL values and its various components. It was realized that the data entry, including scrolling through the look-up tables could be very tedious and time consuming. Hence, an input module with forms, drop-down list, and check boxes was developed using the database program. This was done to make the model more user-friendly and simple to use. An interface between the input module and the analysis (output) module was created so that once the data are entered in the input module, they could be sent to the output module by a click of the mouse button. All the analysis is automatically performed and the user can open the output module to see the results.

The output is provided in both tabular and graphic format, and shows the overall DIL rating at each sign location as well as contributions of various component elements of the model to the overall information load. The graphical output is easier to understand by most people. It shows the distance of each sign array from the subject exit gore and the DIL rating and its components, thereby creating a "profile" for DIL distribution. This allows the user to assess the demand on the freeway driver imposed by a sign array in relation to other factors. The term "sign array" refers to a set of individual sign panels that are installed together at a given point on the roadway, typically on the same sign mounting structure or assembly. For example, three individual sign panels mounted on an overhead mast would constitute a single sign array.

The model is based on the use of roadway sections, where a section ends at the point where a driver makes a navigational maneuver, such as an exit or a change into the appropriate lanes at a diversion point. The road section is defined as the section from the exit gore point at one end to an upstream point normally 11,000 ft from the gore. This distance is slightly more than 2 mi, thus encompassing where the initial advance signing for an exit typically occurs. A particular sign array might be included in multiple segments defined by different exit points. Even though the sign array itself would be constant, the information load associated with dealing with the sign may vary because of the changing road segment and proximity to the choice point. Therefore, the DIL computed for a sign array is specific to the assumption made about where the navigation maneuver takes place.

As such, the DIL software tool's input module requests data from the user regarding the section first, then the sign arrays, and then the individual signs on each array. Details on the use of this tool and data that should be assembled prior

to using it are presented in the User's Manual section in Appendix F.

USING THE DIL PROFILE TO IDENTIFY DIO

While the DIL model does not provide any thresholds for driver information overload (DIO), it can be used to compare relative complexities of alternative information systems. At the heart of the model is the DIL "Profile," as described in Chapter 3. An example of using the DIL for an actual situation, where several interchanges exist in close proximity and is believed to exhibit DIO, is presented here.

Application of the Model

A comparison of the DIL Profile for an alternate signing scheme is also provided. This example is for a section of NB I-395 toward the District of Columbia from Virginia ending at the interchange for the George Washington Memorial Parkway. An inventory of the then-existing signs was conducted by BMI on the subject highway for a project in 1997 and recommendations were made to modify several guide signs to improve navigation. The current DIL model was not available then, and recommendations were based on standard engineering practices, *MUTCD* guidelines, and knowledge of local conditions. This example illustrates the application of the DIL model to compare the relative complexity of signs for alternative information highway sign information systems.

Existing Signing Conditions

Figure 26 shows the array of signs leading up to the subject interchange. To develop the DIL Profile, the following steps were taken based on the guidelines presented earlier:

1. A computerized program was used to develop the DIL Profile.
2. The total number of sign arrays (multiple signs on a single structure constitute an array) related to the subject interchange was identified and distances of these sign arrays from the exit gore were obtained.
3. Data on geometric features within 11,000 ft of the exit gore, e.g., number of curves, merges, weaves, exits, lane drops, and maximum number of lanes, were obtained and entered into the computer model, which computes the Roadway Density component of the DIL.
4. Each sign within every sign array was related to one of the sign categories listed in the look-up table and a base sign load rating was selected based on the upper and lower bound guidance provided in the look-up table.
5. Elements of a selected sign that were different than the base sign in the selected category were identified. Appropriate modification to the base rating was applied to obtain the adjusted sign rating.
6. Based on all these inputs, the model computes the other components of the DIL, namely, Maneuver Proximity (MP), Local Information Density, and Sign Array Information Demand for each sign array.
7. Finally, the total DIL Profile is shown in Figure 27, which is a numerical value corresponding to each sign array location. This value is shown by the star symbol, with the numeric value immediately above it. It includes the four components of DIL.

The DIL Profile indicates that there is a definitive peaking of information load around Sign Array 105 along with high rating at Sign Array 104 location. At each of these locations, the Sign Array Information Demand component of the DIL is significantly higher than for other signs. This is indicative of high complexity of these two sign arrays. Total DIL for Sign Array 106 is also high. But it should be noted that the Local Information Density Component is largely responsible for this high rating, which is due to its proximity to Sign Array 105. As shown in Figure 27, Sign Arrays 104 and 105 each have multiple signs on a single structure and are complicated, whereas Sign Array 106 is simply an exit gore sign. Hence, the results of the model appear to be reasonable.

Proposed Signing Scheme

As mentioned earlier, a set of modified signs for this section was developed and recommended. Figure 28 shows the array of signs proposed for this section. The DIL Profile was developed for the proposed signing scheme following similar steps as for the existing signs and is shown in Figure 29. It can be seen from this chart that the peak DIL rating (star symbol) at the Sign Array 105 location would be reduced significantly with the proposed signing scheme. Moreover, the model estimates elimination of a sharp "spike" in the DIL Profile and the profile of total information load rating follows more closely to the MP component of the DIL. Comparing the DIL profiles for the two scenarios, there is a marginal increase in the total information load rating estimated to result from the proposed signing scheme at Sign Array 101 location. However, the reductions in the information load at other locations are more significant and important because of their proximity to the exit gore.

Hence, this model provides a tool to evaluate the effectiveness of guide signs in terms of not overburdening the drivers with too much information. This model can be used to identify the critical locations with peak DIL ratings in a busy highway corridor. It also points to factors that highway engineers should investigate further to ascertain the causes of a high DIL rating.

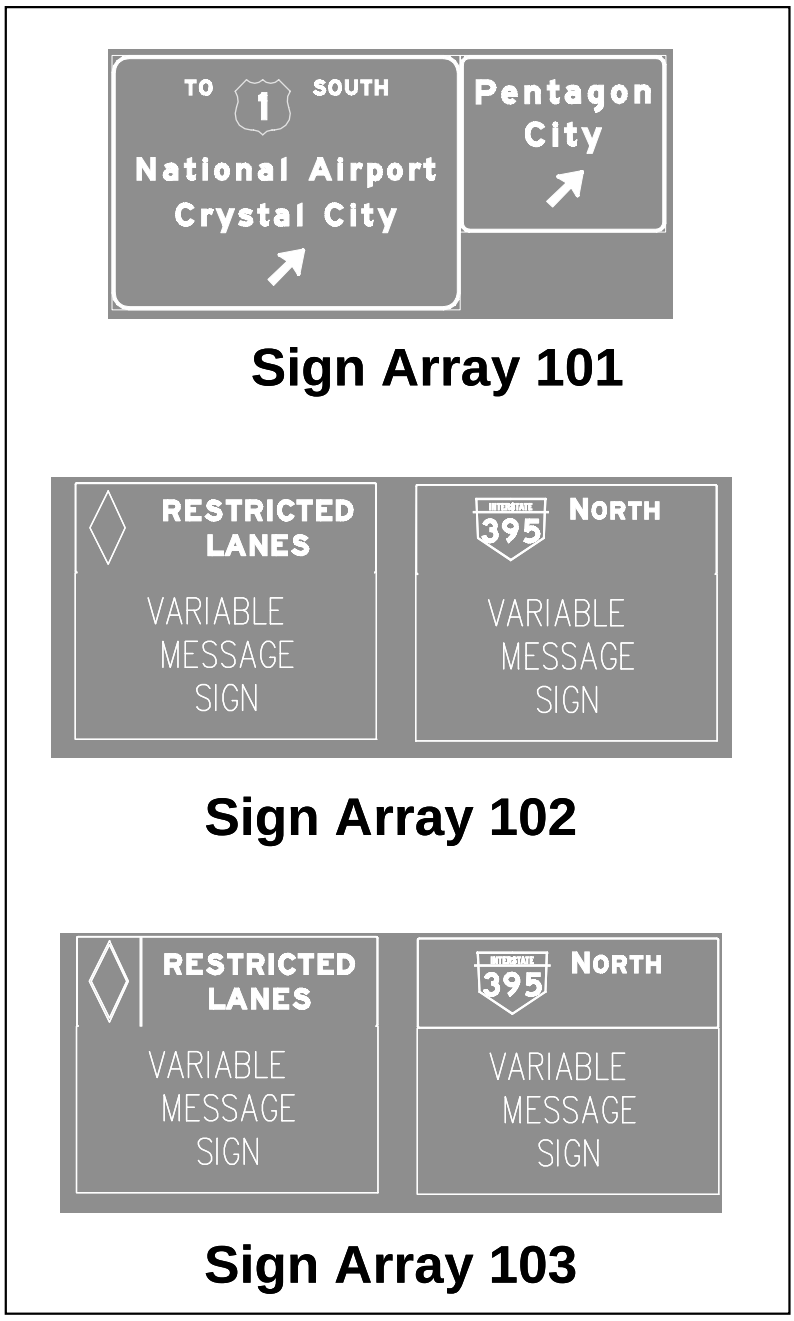


Figure 26. Sign arrays for example—Existing signs.

Evaluation of the Model

The model and the software were presented to the Guide and Motorist Information (GMI) Technical Committee of the National Committee of Uniform Traffic Control Devices (NCUTCD) at their annual meeting in January 2002. Several participants indicated interest in using the DIL tool, and the tool was sent to four interested professionals for their review and comments. All members of the NCHRP Panel for this project were also sent a copy of the DIL program for their review and comments. All recipients of the program were asked to respond to address the following questions:

1. Do you feel this analytical tool is useful for practical application or is it too academic?
2. Are there any improvements you can suggest that would improve its usefulness?
3. Was the program easy to use, understand, and follow?



Sign Array 104



Sign Array 105



Sign Array 106



Sign Array 107

Figure 26. (Continued)

The researchers received four responses from practitioners, one of which was from an NCHRP Panel member. While some respondents indicated that they used the program, none of them actually applied it to any real world situation. Some indicated that they will be using this tool later in the year for evaluating some actual signs.

The responses generally pointed out that for the program to become more practical, there was a need to establish some thresholds for DIL to estimate when an information overload situation will occur. This seemed to be their biggest concern. Also, the respondents felt that this program will not be able to help solve the "urban clutter" caused by closely spaced interchanges and associated signs. Others wanted more "utility" features added to the software.

The program was then presented to the NCHRP Project Panel at a meeting in June 2002. The panel members made some specific comments and suggestions related to the software, including specific situations when the program "crashed," need for additional fields, or the capability to parse unwanted records. The tool was then modified to incorporate those comments.

In terms of responses to the comments, the project team has the following to offer:

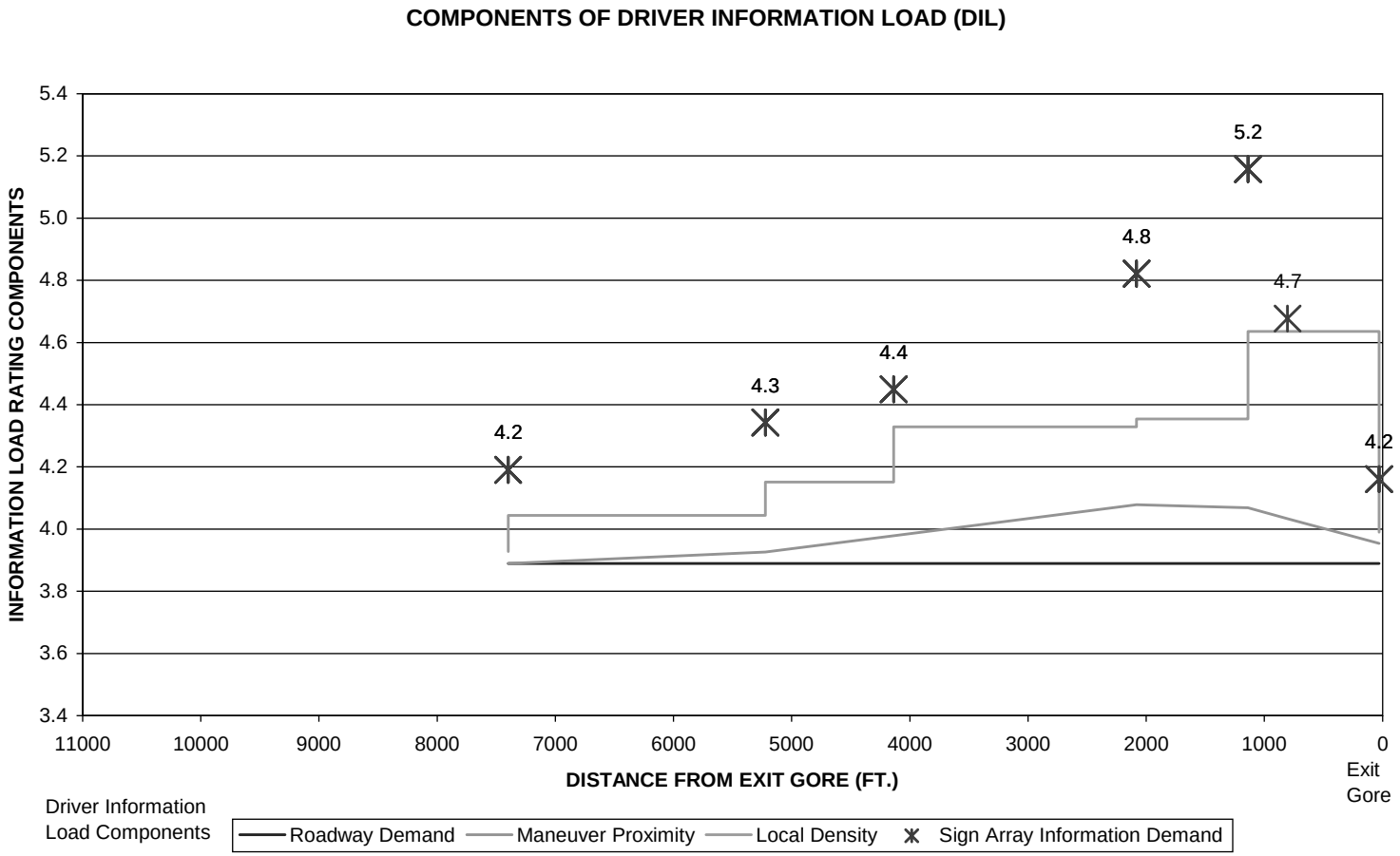
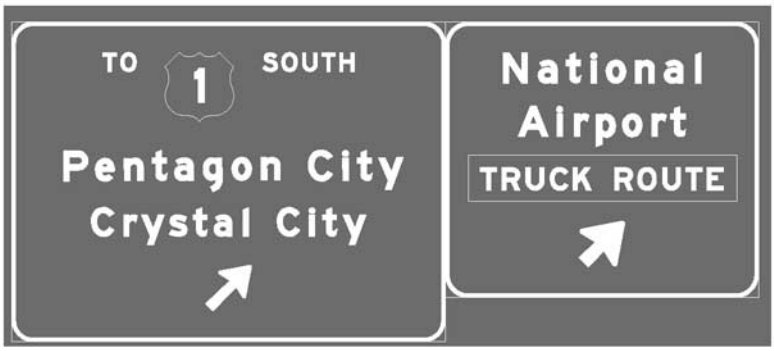


Figure 27. DIL profile for example section—Existing conditions.



Sign Array 101



Sign Array 102



Sign Array 103

Figure 28. Sign arrays for example section—Proposed signs.

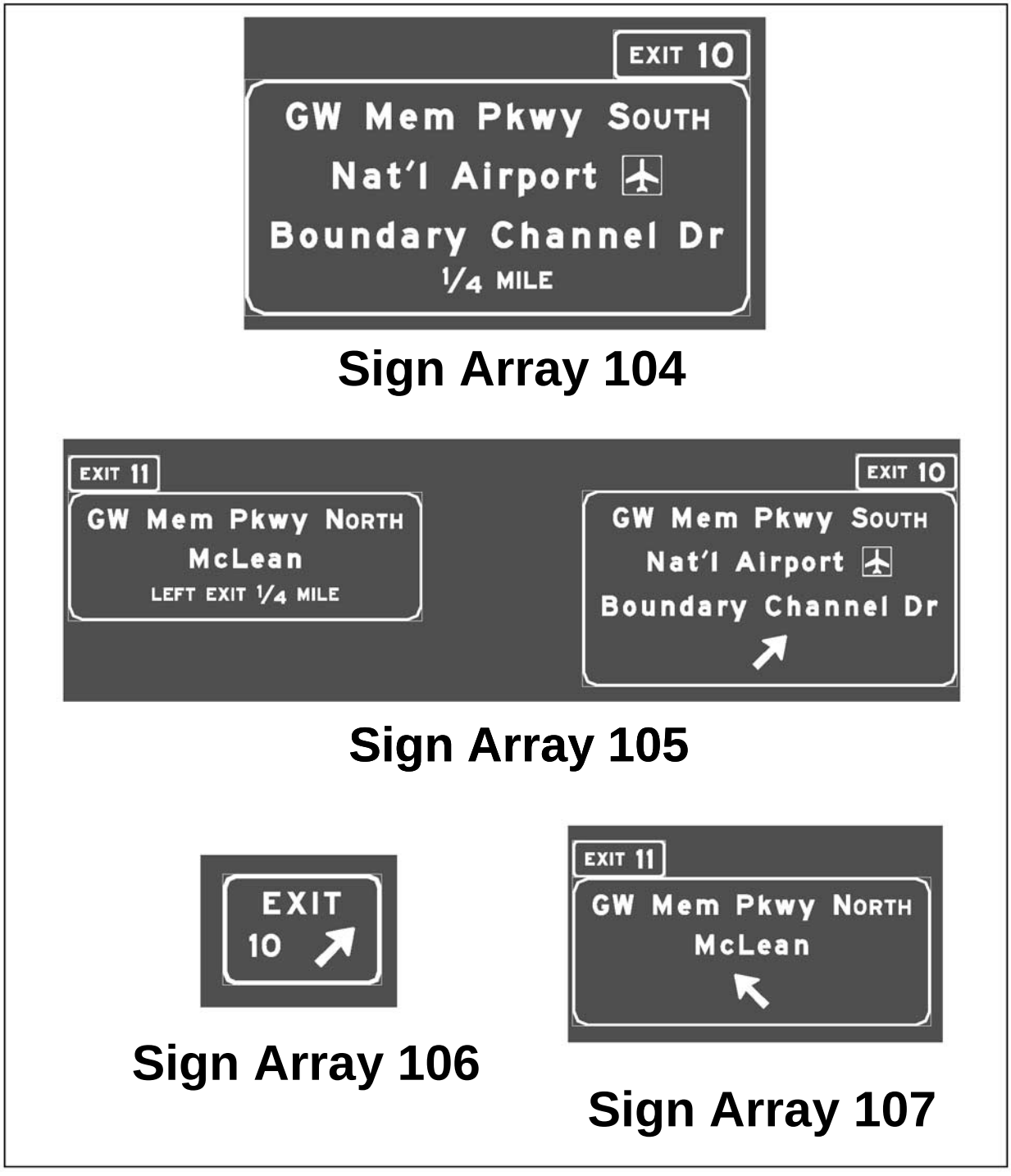


Figure 28. (Continued)

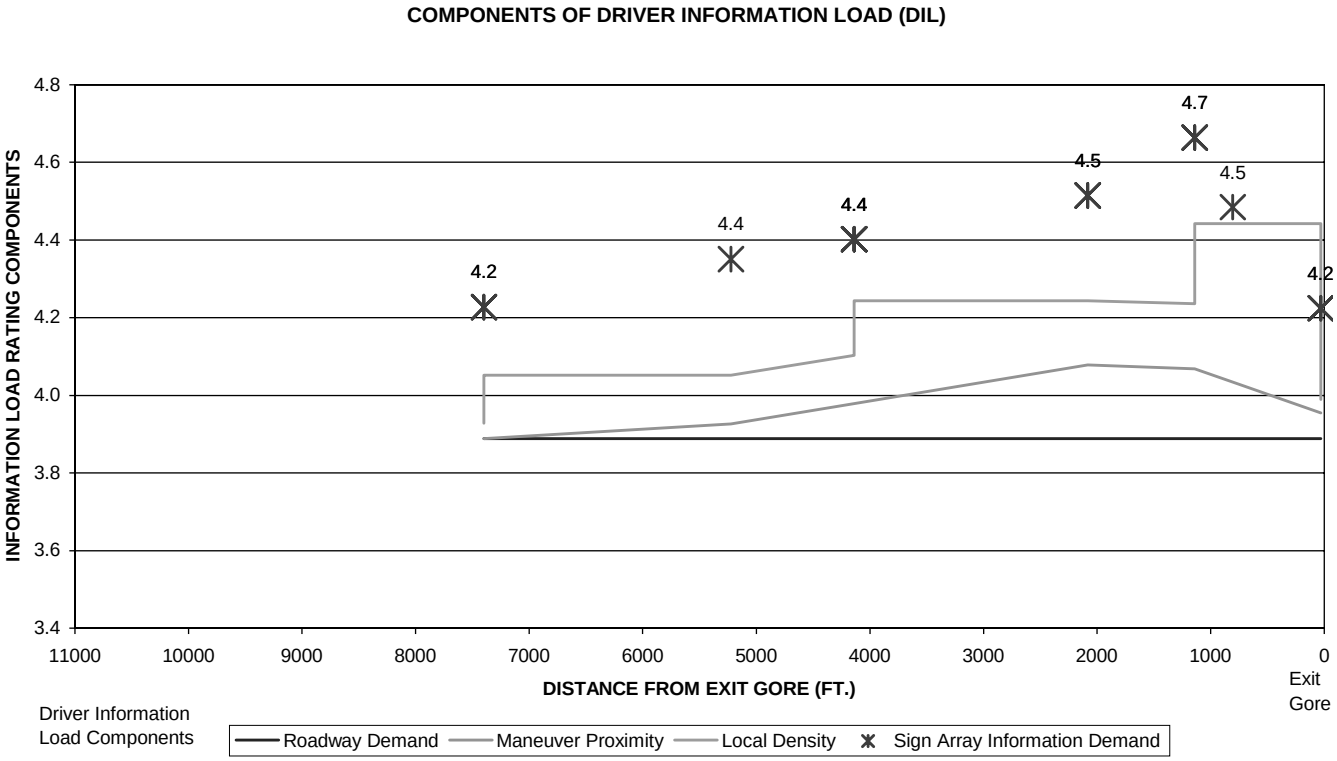


Figure 29. DIL profile for example section—Proposed signs.

- The DIL program is intended to be used by experienced traffic engineers who would assemble all the required information before using the tool.
- Once the data are properly assembled, the actual data entry into the input module takes a very short time to complete.
- Urban freeway segments with closely spaced interchanges can be analyzed and evaluated using this tool. In fact, this tool provides an excellent opportunity to identify the problem locations and contributing factors within the scope of the model. This has been illustrated in the "Application of the Model" section of this chapter.

CHAPTER **6**

GUIDELINES FOR IDENTIFYING AND PREVENTING DRIVER INFORMATION OVERLOAD RELATED TO GUIDE SIGNS ON FREEWAYS

INTRODUCTION

Normally driving is a relatively simple task and does not overly tax the ability of the driver to process information and respond in a correct, efficient, and safe manner. However, there are situations when a significant percentage of the drivers, especially the elderly drivers or inexperienced younger drivers, find that there simply is so much information, or possibly confusing information, that they either have to compensate by reducing speed, or knowingly or unknowingly miss information that is critical to their driving task. Also, drivers of all ages and experience unfamiliar with the highway, especially in the vicinity of urban areas, may have similar experiences. Driver information overload (DIO) is commonly used as a rubric for this condition.

DIO can occur, for certain drivers, when there is more information presented than can be processed in sufficient time. The information can come from all types of traffic control devices identified in the *MUTCD*, but most notably from traffic signs. It can also stem from the roadway geometrics, e.g., complicated interchanges with left- and right-side ramps, and can be compounded under heavy-volume, high-speed traffic and in work zone areas. Non-highway features, such as billboards or signs on buildings can also add to the information load. While there are numerous contributors to DIO and it can occur on all types of roads, this study has focused on what is believed to be the more frequent condition, guide and related signs on freeways.

Highway guide signs are critical devices that provide guidance and navigation information to the driver. For the driver unfamiliar with the route, they are crucial for finding one's way. Even with adequate trip preparation and use of a map (now with the possibility of in-vehicle navigation systems), motorists would not be able to find their destination without adequate guide signs. Motorists have many destinations and are hopeful that highway guide signs will provide those destinations in their sign messages. However, this is not practical with fixed highway signs. Providing too many destinations and other guidance and way-finding information on a specific sign or group of signs would certainly cause DIO.

The guidelines that are provided here are meant to assist the engineer responsible for designing and/or maintaining roadway information systems to avoid DIO, at least for the vast majority of the driving public. The guidelines are structured as follows:

- A working definition of DIO, at least with respect, to highway guide and related signing, is provided.
- Guidance is provided on how to identify DIO with current or proposed signing.
- Guidance is provided on what measures can be taken to minimize the driver information loading through the application of already established principles of information, i.e., sign design.

The guidance is drawn from the research conducted for this study, already existing state-of-the-art knowledge, and the combined judgments of the research staff.

DEFINITION OF DIO

Most people feel that there are locations or situations (combination of location, traffic, etc.) where, as motorists, they have felt "information overload." They know it when they experience it, but they have difficulty defining or describing it. They likely felt uncomfortable and/or confused, may have had to reduce their speed, were possibly not sure of their direction, and possibly even took the wrong turn (perhaps even making an erratic maneuver in doing so). Even traffic engineers are not unanimous as to what constitutes DIO.

In the early stages of this project, a questionnaire was sent to 20 state and 20 local traffic engineers selected to represent all areas of the country. Responses were received from 27 persons. For one of the questions, those surveyed were asked to define DIO. While most stated that, in essence, it was too much information for the motorist to process in sufficient time, there were a few who believed that other signing deficiencies could contribute to information overload, such as small letter size, missing or misleading information, etc. Therefore, a definition of DIO is needed, at least with regard to this study, and the following is offered:

> *DIO occurs when the driver cannot process the roadway information in sufficient time to respond properly and safely at the design speed or the 85th percentile operating speed, whichever is higher.*

This definition is explained as follows:

Roadway information—While the roadway features, design elements, and the various traffic control devices (signs, markings, signals, etc.) collectively provide the roadway information upon which decisions about a driver's desired guidance and control are made, this project focused on roadway signing, and in particular, guide and guide-related signing (signs found in Section 2E of the *MUTCD*, Millennium Edition). Hence, ***guide sign information*** could replace ***roadway information*** for the purposes of this study.

Driver—Guide signing is designed primarily to meet the needs of the unfamiliar driver who must rely on the message for way-finding. It must accommodate those segments of the driving population who are likely to require longer than average processing and response times, such as the elderly and novice drivers.

Process—This term is meant to include all elements of information processing from initial detection of the device, to reading and comprehension of the message, to making an appropriate decision on whatever maneuver may be required, and ending with initiation of the required response based on the decision made.

Sufficient time to respond properly and safely at the design speed—This term means that the driver has been able to process the information (signing) at a distance upstream sufficient to accommodate the desired maneuver (e.g. lane change for exiting) at the design speed or the 85th percentile operating speed, whichever is higher.

WHY IS DIO A PROBLEM?

DIO is problematic to the driver for a number of reasons. If the driver is confronted with information overload, then he/she may reduce his/her speed in order to have more time to process the information; this action could result in traffic slow downs, conflicts, and possibly collisions. At a freeway exit, where this overload is likely to occur, the driver may make a late exit resulting in an erratic maneuver, such as crossing the gore area or even backing up on the shoulder or the ramp to correct the wrong turn. That erratic maneuvers are more frequent at locations with high-information load has been shown in an earlier research by Taylor and McGee (*21*). In an NCHRP study entitled, "Improving Traffic Operations and Safety at Exit Gore Areas," they evaluated what factors caused drivers to make erratic maneuvers when exiting the freeway. Their findings were that there are numerous reasons, which relate to the deficiencies of the driver (distracted, not sure of direction, etc.), the information (confusing sign legend, insufficient advance warning, etc.), and the geometrics of the interchange (e.g., sight distance to the ramp). While the study did not attempt to relate erratic maneuver occurrence to the amount of sign information, it is noted from their study that of the nine sites that were studied, the two sites that experienced the highest erratic maneuver rate (erratic maneuvers per volume) were those that had the highest sign density and highest information loading on the guide signs.

HOW TO DETERMINE IF DIO EXISTS

Specifying when DIO exists is not easy. There are no precise rules or values that resulted from this research, nor has there been any offered from previous research. What this project did develop is an evaluation tool—the DIL Profile—that can be used for evaluating alternative sign systems based on the relative DIL produced. That tool was discussed in Chapter 5.

The DIL Profile is partially based on the results of the experiment discussed in Section 4.2. The results of that experiment are found in Table 2, which provides a load rating value for numerous sign types. Although these values cannot be used directly to determine if any given sign or array of signs has too much information, they provide a simple means of estimating a rough relative demand.

Aside from using the DIO model, some general guidance, drawn from the results of this project and from previous research, about when an individual guide sign will likely cause DIO is as follows:

- The number of destinations exceeds two, especially if the word length is long (eight letters or more); and
- The number of route markers exceeds two; a sign with more than two destinations and/or more than two route symbols is likely to cause an information processing problem for some drivers.

For situations where there are multiple signs on a sign structure, DIO can result from the following:

- Two sign panels with more than two destination names and two route symbols on any one sign;
- Three guide sign panels with any one sign having more than two destination names; or
- More than three sign panels, regardless of message content.

DIO is likely to occur at those locations that have heavy density of information in terms of proximity of signs and sign message content. More specifically, DIO is likely under the following condition:

- Spacing between two guide signs, including supplemental signs, is less than 800 ft, where there is one destination on the second sign, and 1,200 ft where there are two or three destinations on the second sign.

Figure 30 shows a simple advance guide sign for a freeway exit. This certainly would not be considered information overload for any reasonable driver. Figure 31 shows an array of signing for a freeway location that has interchanges in close proximity. Some drivers experiencing this situation for the first time are likely to consider this as DIO. From these examples it is easy to say what may or may not be DIO. However, it is not so easy to provide guidelines on when DIO begins for drivers of varying information processing capabilities. Nonetheless, it can be stated that, in general, DIO can occur with:

- An individual sign with too much message content;
- Multiple sign panels at the same location with or without an individual sign having too much information;
- Signs in close proximity (i.e., short spacing between signs), with or without an individual sign having too much information; or
- Other situations when other distracting factors may cause DIO.

These situations are elaborated upon with examples below.



Figure 30. Example of sign with low-information load.



Figure 31. Example of a sign array with high-information load.

Too Much Information on One Sign

There is no doubt that a single guide sign panel or other navigation-related sign can have too much information in the form of destinations (i.e., place name, street name, and route symbol), cardinal directions, exit numbers, arrows, and other exit directions. Figure 32 shows a sign that is not a typical highway guide sign, but it has so much information content that most would agree it could cause DIO. What determines "too much" is based on many interrelated factors including the size of the sign legend, the complexity of the message (word length), the driver's visual and information processing capabilities, and the vehicle speed.

Examples of signs with multiple destinations can be often found on our highways, as shown in Figure 33. But the question related to these signs is, "Is it too much information?"

There is no standard in the *MUTCD* as to the maximum amount of legend allowed on one guide sign. However, the *MUTCD* does provide guidance (i.e., should statements) on this item where it states in Section 2D-07 regarding guide signs on conventional roads:

> *. . . the legend on a guide sign must be kept to a minimum to be legible at a glance during the few moments that a driver can turn his eyes from the road. Guide signs should be limited to three lines of principal legend . . . Principal legend includes only place name, route numbers, and street names. Symbols, action information, cardinal directions, and exit numbers may make up other lines of legend, within reasonable limits.*

For guide signs on expressways, the *MUTCD* provides the following guidance in Section 2E-09:

> *No more than two destination names or street names should be shown on any Advance Guide Sign or Exit Direction sign. A city name and street name on the same sign should be avoided. Where two or three signs are placed on the same supports, destinations or names should be limited to one per line, or to a total of three in the display. Sign legends should not exceed three lines of copy.*



Figure 32. Example of a sign with too much message content.





Figure 33. Examples of signs with a lot of information—Is it too much information?

Providing message content that exceeds these guidelines, does not necessarily mean that the sign(s) will cause DIO, but they are reasonable thresholds beyond which the possibility increases significantly.

Multiple Sign Panels at the Same Location

While an individual sign's message content may not be considered information overload, DIO can occur where there is more than one sign on a sign structure. Figure 34 shows four sign panels on a single overhead structure; this is likely to be considered information overload for some drivers.

Section 2E-10 of current version of the *MUTCD*, which deals with the number of signs at an overhead installation, states that

> *. . . the number of signs at these locations [i.e. where overhead signs are warranted] should be limited to only those essential in communicating pertinent destination information to the road user. Exit Direction signs for a single exit and the Advance Guide signs should have only one panel with one or two destinations. Regulatory signs, such as speed limits, should not be used in conjunction with overhead guide sign installations. Because road users have limited time to read and comprehend sign messages, there should be no more than three guide signs displayed at any one location either on the overhead structure or its support.*

Signs in Close Proximity

Motorists need time to detect, read, process the information, and make a decision and respond, if appropriate, to each and every sign. This time equates to a distance that varies by the highway speed. In urban areas, interchanges are frequently close to one another or there are several destinations for which directional guidance is deemed necessary. In these situations, spacing between signs can be so short that the motorist may have difficulty processing the needed information, which constitutes a DIO situation.

As part of an improvement feasibility study for a section of I-395 in Northern Virginia, the guide signs were evaluated to determine if they could be simplified or otherwise improved. Along a 3.33-mi section from Glebe Road to the Potomac River bridges, there are three interchanges that have a combined count of 20 sign structures with 40 individual sign panels. Many of the sign panels have three lines of copy. In some areas, the spacing between signs is less than the minimum 800 ft specified in the *MUTCD*. This area is well known for



Figure 34. Example of potential DIO situation due to multiple sign panels at one location.

causing navigational problems for drivers unfamiliar with the area and can be considered as an area of DIO.

As noted above, the current Millennium Edition of the *MUTCD* offers the following guidance regarding spacing between signs:

> *. . . Guide signs placed in advance of an interchange deceleration lane should be spaced at least 240 m (800 ft) apart. (Section 2E.7)*

Other than this spacing guidance, the following statements are provided in the *MUTCD*:

- Where there is less than 800 ft between interchanges, Interchange Sequence Series signs should be used instead of the Advance Guide sign for the affected interchanges. [Section 2E-37]
- If only one advance guide sign is used, the supplemental sign should follow by at least 800 ft. [Section 2E-32]
- With regard to Specific Service Signing [Section 2F.06]: ". . . There should be at least 800 feet spacing between Specific Service signs, except for Specific Service ramp signs." [As depicted by Figure 2F-2 in the *MUTCD*, this spacing applies to distances between two logo signs and between a logo sign and a guide sign.]

Other Situations Causing DIO

It was observed from both the early field reconnaissance drive by the research team and during the on-road experiments that drivers felt uncomfortable (overloaded) at complex interchanges, especially under high volume conditions. This was observed even where the signs themselves may not suggest excessive information load. At these locations, the driver must pay attention to driving control tasks.

At least two other situations, occurring on freeways, can result in or influence DIO:

- One geometric situation that occurs frequently in urban areas is where an interchange is in close proximity of the merge of two major Interstate roadways. In this situation, motorists who wish to exit at the interchange have to weave across a heavy volume of merging traffic from the other Interstate. These maneuvers take up much of the attention of the driver making it more difficult for the driver to process the guide sign information. The example shown in Figure 2 earlier represents such situations. As the signs indicate, there are interchanges in close proximity, one with a left-hand exit, another with a right-hand exit, and the third one has a lane drop. Besides, this sign is located where there are other interchanges in close proximity upstream of the sign location.
- Any time there is construction on a freeway, especially near an interchange, it is more difficult for the motorists to give full attention to the signing. Quite often in construction zone areas, there is a lane reduction, lane width reduction, or a lane shift. Attending to these situations detracts from the motorist's ability to process the information from the signing.

HOW TO AVOID OR MINIMIZE DIO

Since DIO is partly a function of the information processing capability of the driver, and since there is a wide range of information processing capabilities among the driving population, it is unlikely that DIO could be eliminated. Some drivers will experience DIO at certain situations no matter how well the information is presented. Nonetheless, a variety of principles can be followed that will at least minimize the occurrence of DIO for the vast majority of drivers. These principles are enumerated below.

Avoid Complex Highway Design Configurations

It has been often stated within the highway engineering community that "if you can't sign it, don't design it." Sometimes, especially in urban areas, highway designers will prepare designs of interchanges that are fairly complex with left and right exits, exit ramps that split, lane drops, exit ramps in close proximity, etc. These designs often are dictated by the need to design within a given right-of-way. The designs result in multiple decision points in close proximity making it difficult to adhere to principles of good sign design. Recognizing that there are budget and right-of-way limitations, the designer should seek a plan that avoids these multiple decision points and will result in a less dense signing plan.

Consider Signing Needs Early and Throughout the Road Design Process

During the preliminary engineering phase of a new or reconstructed facility, the traffic engineering department or those responsible for sign design should be consulted about the ability to adequately sign for the design options. This is especially true for complex designs as discussed above, but should hold for even relatively simple designs.

Throughout the design process, the sign designer should think beyond what specific sign would be needed at a certain location. The designer should consider the demands placed upon the driver from the road design as well as from the expected traffic levels. Well ahead of peak demand points, which are in an area of about 1,500 ft from the gore, the designer should clearly provide the information the driver needs to resolve any uncertainty. The signs, markings, and geometry should work together to clarify answers to: where must I be, when must I be there, and what is coming up?

Follow Standards and Guidelines of the MUTCD

While the *MUTCD* is not a "how to" manual, it provides several guideline-type statements that, if followed, will minimize the occurrence of signing systems causing DIO. Several excerpts from the current edition of the *MUTCD* that directly or indirectly provide sign guidance for expressway/freeway signs to avoid DIO have been presented earlier. Adherence to these guidelines should minimize the possibility of a sign information system that would cause DIO.

Spreading of Information Load

As has been discussed, DIO occurs when there is too much information presented at any one location for the motorist to process in sufficient time. The information load profile conceptually demonstrates how the information loading significantly increases with sign message density, as determined by number of destinations, length of words, number of symbols, exiting information, spacing of signs, etc. There may be opportunities where this sign message density can be reduced by spreading some of the information along the route, i.e., moving less critical information to other locations away from the high density area.

Another example of sign spreading would be the use of supplemental signs. At some locations, it may be necessary to provide directional information for several destinations. The *MUTCD* recommends that no more than three destinations be on any one guide sign. However, even a single sign with three destinations along with route symbols and exiting information can be a problem for some motorists on a high-volume, urban freeway. Consideration should be given to using a supplemental sign where the third, or even a fourth, destination could be placed. In this way the information load is spread out along the route. However, based on the results of the studies conducted for this project, it appears that the advantages of spreading sign density are not seen until about 800 ft of separation, which is consistent with the guidance provided in the *MUTCD*. Because of the interaction and competition for the driver's information processing time, signs too close can be more demanding as one sign with the same information.

Sign Repetition

Sign repetition is defined as repeating the same sign message on another sign downstream. In general it is not a good sign practice to repeat a sign as this leads to excessive signing and would unnecessarily add to the information overload. However, in the case of a complex interchange, where there must be multiple signs on a sign structure, DIO could occur. If this cannot be avoided, then it may be advisable to provide another sign support further downstream with all or a portion of the sign information repeated. This, in essence provides another opportunity for the motorist to "take in" the entire message, and respond accordingly. Obviously, to accomplish this there needs to be sufficient distance upstream of the interchange to provide the additional sign(s) and still maintain at least the 800-ft spacing recommended in the *MUTCD*.

Increase the Size of the Legend

The time and distance it takes to read a sign are partly due to the size of the legend, and more specifically, the size of the letters and symbols. The former rule of thumb for the provision of letter size of "1 in. of letter height for every 50 ft of legibility distance" has been updated in the current *MUTCD* to be "1 in. of letter height for every 40 ft of legibility distance" based on research on letter size as required by the elderly driver, which increases the legend sizes by as much as 20%. Specific sizes of letters and numerals are specified in the *MUTCD* and range from 8 to 30 in. depending upon the type of interchange and sign placement (i.e., overhead or ground-mounted). The FHWA *Highway Design Handbook for Older Drivers and Pedestrians* recommends "not more than 33 ft of legibility distance for each 1 in. of letter height." If followed, this would increase the letter sizes by up to 18% more than the current *MUTCD* guidelines.

For situations where there has to be high information load to meet the guidance information requirements, it may be advisable to increase the size of the sign legend. By doing so, it will afford the motorist longer distance to read the sign, thereby compensating, to some degree, for the possible information overload. Figure 35 shows an example of signs with larger than standard route markers. As it can be seen, this sign array has too much information, including four destinations and seven route designations combined. The middle sign has four route marker symbols along with their cardinal directions. Hence, larger route designation symbols have been used for the U.S. routes to compensate for too many routes on one sign.



Figure 35. Example of signs with larger symbols to offset information overload.

Maintain High Level of Sign Legibility at Night

It is important that all signs are legible at night. This is accomplished by using retro-reflective materials, of varying quality, for all guide signs and for some overhead signs and by also using external illumination. Retro-reflective materials have improved over the years and materials are now available that will provide a high level of brightness, thereby, allowing the driver to read the sign well within the required legibility distance. Adding sign lighting enhances the legibility of the sign even more.

It is advisable, therefore, that signs within a section of high information load be made of the brightest practical retro-reflective material and, if overhead, be illuminated by sign lighting.

POTENTIAL ADVANCES AND APPLICATIONS OF THE INFORMATION LOAD PROGRAM

In Chapter 5, the concept of the DIL Profile diagram was presented and examples of its application were shown. While the DIL in its current state should be a good tool for analyzing highway information systems to determine if they may cause DIO, further research is needed to validate the model with more data and potentially develop thresholds for quantifying information overload situations. That is, a measure of information load needs to be developed so that the vertical scale on the diagram has an absolute meaning. Researchers need to better understand and quantify how individual signs and signs as a system affect this measure of information load. They also need to understand how different road types affect the various components of DIL. Then a threshold level of DIO is needed. As this is likely to vary by one or more driver characteristics, it is likely that this threshold will need to be presented as a percentile of the driving public.

Once these issues are resolved, the engineers developing and evaluating sign systems can use the DIL model more effectively during the sign design stage. With existing computer hardware and software advances, it should be relatively simple to automatically create the DIL in a computer-aided design (CAD) environment. Information load ratings could be assigned to each sign using the values generated by the software tool already developed. Also with the horizontal and vertical plans available in the CAD file, the load ratings for the Driving Task Demand (DTD) component would come from values based on various geometric and traffic elements. A review of the DIL would then identify whether or not a potential DIO situation exists with the proposed sign design.

CHAPTER **7**

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APPENDIXES A, C, D, AND E
UNPUBLISHED MATERIAL

Appendixes A, C, D, and E as submitted by the research agency are not published herein. For a limited time, they are available from the NCHRP. Their titles are as follows:

- Appendix A: Review of Selected Literature
- Appendix C: Description of Stimuli Presented in the Experiment on Combination Rules for Sign Arrays
- Appendix D: On-road Sequence of Sites for Primary On-road Experiment
- Appendix E: Primary On-road Experiment Instructions and Protocol

APPENDIX B

SUMMARY TABLES FOR SIGN CATEGORIES FROM "INDIVIDUAL FREEWAY SIGN INFORMATION LOAD EXPERIMENT"

TABLE B-1 Information load ratings for signs in bracket set

Sign Type and Category	*MUTCD Reference (1988 Edition)*	Sign Complexity	Definition	Rating
Advance Major Guide, Separate Exit	Fig. 2-9, Signs E1-1 and E1-5	Upper	Long Word, 2 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	26
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	20
Advance Major Guide, Integrated Exit	Fig. 2-9, Sign E1-1a	Upper	Long Word, 2 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	17
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	12
Advance Major Guide, Separate Exit and Lane Drop	Fig. 2-9, Signs E1-1, E1-5, and Fig. 2-33, Sign E11-1	Upper	Long Word, 2 Dest., 1 R.M., 0 Icon, Lane, No Dir.	20
		Lower 1	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	20
		Lower 2	Short Word, 1 Dest., 1 R.M., 0 Icon, Lane, No Dir.	14
Advance Major Guide, Integrated Exit and Lane Drop	Fig. 2-9, Sign E1-1a and Fig. 2-33, Sign E11-1	Upper	Long Word, 2 Dest., 1 R.M., 0 Icon, Lane, No Dir.	29
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, Lane, No Dir.	25
Advance Minor Guide, without Route	Fig. 2-9, Sign E1-2	Upper	Long Word, 2 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	17
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	16
Advance Minor Guide	Fig. 2-9, Sign E1-3	Upper	Long Word, 2 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	20
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	6
Next Exit	Fig. 2-10	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	5
Multiple Destination Exit	Fig. 2-11	Upper	Long Word, 2 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	26
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	3
Multiple Destination, Next Right		Upper	Long Word, 2 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	19
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	3
Exit Direction	Fig. 2-13	Upper	Long Word, 2 Dest., 1 R.M., 0 Icon, No Lane, Dir.	21
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	14
Gore, Separate	Fig. 2-14, Signs E5-1 and E5-2	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	3
Gore, Integrated	Fig. 2-14, Sign E5-1a	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4

Pull Thru, Small Shield	Fig. 2-15, Sign E6-2	Upper	Long Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	7
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	7
Pull Thru, Large Shield	Fig. 2-15, Sign E6-2a	Upper	Long Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	12
		Lower	Short Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	12
Post-Interchange Distance	Fig. 2-17, Sign E7	Upper	Long Word, 3 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	21
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	3
Interchange Sequence	Fig. 2-18, Sign E8-1	Upper	Long Word, 3 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	33
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
Community Interchange	Fig. 2-19, Sign E8-2	Upper	Long Word, 3 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	33
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	13
Next (X) Exits	Fig. 2-20, Sign E-9	Upper	Long Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	7
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
Park & Ride	Fig. 2-26	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	18
Milepost	Sign D10-3	Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	9
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
Diagrammatic Guide, Separate Exit	Fig. 2-32	Upper	Long Word, 2 Dest., 2 R.M., 0 Icon, No Lane, Dir.	34
		Lower	Short Word, 1 Dest., 2 R.M., 0 Icon, No Lane, Dir.	22
Diagrammatic Guide, Integrated Exit	Fig. 2-32	Upper	Long Word, 2 Dest., 2 R.M., 0 Icon, No Lane, Dir.	28
		Lower	Short Word, 1 Dest., 2 R.M., 0 Icon, No Lane, Dir.	23
Diagrammatic Guide, Integrated Exit and Lane Drop	Fig. 2-32 and Fig. 2-33, Sign E11-1	Upper	Long Word, 2 Dest., 2 R.M. 0 Icon, Lane, Dir.	37
		Lower	Short Word, 1 Dest., 2 R.M., 0 Icon, Lane, Dir.	25

(continued on next page)

TABLE B-1 ***(Continued)***

Sign Type and Category	*MUTCD Reference (1988 Edition)*	Sign Complexity	Definition	Rating
Diagrammatic Guide, Separate Exit and Land Drop	Fig. 2-32 and Fig. 2-33, Sign E11-1	Upper	Long Word, 2 Dest., 2 R.M., 0 Icon, Lane, Dir.	33
		Lower	Short Word, 1 Dest., 2 R.M., 0 Icon, Lane, Dir.	23
Next Services	Fig. 2-43	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	5
Services, Integrated	Fig. 2-43	Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	19
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	3
Services, Separate	Fig. 2-43	Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	17
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	2
Rest Area, Gore	Fig. 2-44	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	2
Rest Area, Advance Guide		Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	12
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	2
Rest Area, Exit Direction		Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	7
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	5
Route Marker, U.S. Route	Fig. 2-45	Upper	N/A Word, 0 Dest., 1 R.M., 0 Icon, No Lane, Dir.	1
		Lower	N/A Word, 0 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	1
Route Marker, Interstate	Fig. 2-46	Upper	N/A Word, 0 Dest., 1 R.M., 0 Icon, No Lane, Dir.	2
		Lower	N/A Word, 0 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	1
Gas & Lodging, Double	Fig. 2-47	Upper 1	N/A Word, 0 Dest., 0 R.M., 4 Icon, No Lane, No Dir.	27
		Upper 2	N/A Word, 0 Dest., 0 R.M., 6 Icon, No Lane, No Dir.	32
		Lower	N/A Word, 0 Dest., 0 R.M., 2 Icon, No Lane, No Dir.	21
Gas & Lodging, Single	Fig. 2-47	Upper 1	N/A Word, 0 Dest., 0 R.M., 4 Icon, No Lane, No Dir.	29
		Upper 2	N/A Word, 0 Dest., 0 R.M., 6 Icon, No Lane, No Dir.	23
		Lower	N/A Word, 0 Dest., 0 R.M., 1 Icon, No Lane, No Dir.	7

Radio Information, Weather	Sign D12-1	Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	24
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	6
Radio Information, CB Channel 9	Sign D12-3	Upper	Long Word, 0 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	15
		Lower	Short Word, 0 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	5
Radio Information, Traffic		Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	21
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	10
Car Pool Information, Car	Sign D12-2	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	8
Car Pool Information, Van		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	9
Weigh Station, Advance Guide	Fig. 2-8, Sign D8-1	Upper	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
		Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	1
Weigh Station, Exit Direction	FIg. 2-8, Sign D8-2	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	5
Weigh Station, Gore	Fig. 2-8., Sign D8-3	Lower	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	2
Recreational Guide, Integrated Icons	Fig. 2-52	Upper	Long Word, 1 Dest., 0 R.M., 3 Icon, No Lane, No Dir.	15
		Lower	Short Word, 1 Dest., 0 R.M., 1 Icon, No Lane, No Dir.	7
Recreational Guide, Separate Icons	Fig. 2-52	Upper	Long Word, 1 Dest., 0 R.M., , 3 Icon, No Lane, No Dir.	17
		Lower	Short Word, 1 Dest., 0 R.M., , 1 Icon, No Lane, No Dir.	7
Recreational Guide, Distance	Fig. 2-52	Upper	Long Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	18
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	10
Recreational Guide, Direction	Fig. 2-52	Upper	Long Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	10
		Lower	Short Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	6

(continued on next page)

TABLE B-1 ***(Continued)***

Sign Type and Category	*MUTCD Reference (1988 Edition)*	Sign Complexity	Definition	Rating
Boundary, County		Upper	Long Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
		Lower	Short Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	4
Boundary, State		Upper	Long Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	5
		Lower	Short Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	1

Key:

Rating = Information load rating (1-100)
Upper = Maximum number of all sign components present as specified in the MUTCD
Lower = Minimum number of all sign components present as specified in the MUTCD
Word = Word length of destinations (Long, Short, N/A)
Dest. = Number of destinations (0-4)
R.M. = Number of route markers (0-3)
Icon = Number of icons (0-6)
Lane = Presence or absence of a lane indicator arrow
Dir. = Presence or absence of a cardinal direction

TABLE B-2 Information load ratings for added sign components

Sign Type and Category	"Upper" Complexity Definition	"Upper" Complexity Rating	Added Component	Definition	Rating
Advance Major Guide, Separate Exit	Long Word, 2 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	26	2 Destinations	Short Word, 3 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	18
			3 Destinations	Short Word, 4 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	27
Advance Major Guide, Integrated Exit	Long Word, 2 Dest., 1 R.M., 0 Icon, No Lane, No Dir.	17	1 Destination	Short Word, 2 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	17
			1 Route Marker	Short Word, 1 Dest., 2 R.M. 0 Icon, No Lane, No Dir.	19
			Long Word	Long Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	15
Advance Major Guide, Separate Exit and Lane Drop	Long Word, 2 Dest., 1 R.M., 0 Icon, Lane, No Dir.	20	2 Destinations	Long Word, 4 Dest., 1 R.M. 0 Icon, Lane, No Dir.	40
Multiple Destination Exit	Long Word, 2 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	26	2 Destinations	Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	27
Exit Direction	Long Word, 2 Dest., 1 R.M., 0 Icon, No Lane, Dir.	21	1 Destination	Short Word, 2 Dest., 1 R.M. 0 Icon, No Lane, Dir.	16
			Long Word	Long Word, 1 Dest., 1 R.M. 0 Icon, No Lane, Dir.	24
			2 Destinations	Long Word, 4 Dest., 1 R.M. 0 Icon, No Lane, Dir.	45
			1 Destination	Long Word, 3 Dest., 1 R.M. 0 Icon, No Lane, Dir.	23
			1 Route Marker	Short Word, 1 Dest., 2 R.M. 0 Icon, No Lane, Dir.	23
			3 Destinations	Short Word, 4 Dest., 1 R.M. 0 Icon, No Lane, Dir.	20
Pull Thru, Small Shield	Long Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	7	Lane Indicator	Long Word, 1 Dest., 1 R.M. 0 Icon, Lane, Dir.	12
Pull Thru, Large Shield	Long Word, 1 Dest., 1 R.M., 0 Icon, No Lane, Dir.	12	1 Route Marker	Short Word, 1 Dest., 2 R.M. 0 Icon, No Lane, Dir.	25
Post-Interchange Distance	Long Word, 3 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	21	1 Destination	Long Word, 4 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	27
			Long Word	Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	6
			2 Destinations	Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	20
			3 Destinations	Short Word, 4 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	28
Interchange Sequence	Long Word, 3 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	33	1 Route Marker	Short Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	11

(continued on next page)

TABLE B-2 ***(Continued)***

Sign Type and Category	"Upper" Complexity Definition	"Upper" Complexity Rating	Added Component	Definition	Rating
Interchange Sequence (Ct'd.)			3 Route Markers	N/A Word, 3 Dest., 3 R.M. 0 Icon, No Lane, No Dir.	30
			Long Word	Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	10
			2 Destinations 2 Route Markers	Short Word, 3 Dest., 2 R.M. 0 Icon, No Lane, No Dir.	30
			2 Destinations	Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	26
			1 Destination	Long Word, 4 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	41
			1 Route Marker	N/A Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	9
			1 Destination 1 Route Marker	N/A Word, 2 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	21
Community Interchange	Long Word, 3 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	33	2 Destinations 2 Route Markers	Short Word, 3 Dest., 2 R.M. 0 Icon, No Lane, No Dir.	29
			1 Route Marker	Short Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	23
			2 Destinations	Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	33
			1 Route Marker	N/A Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	17
			Long Word	Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	24
			3 Route Markers	N/A Word, 3 Dest., 3 R.M. 0 Icon, No Lane, No Dir.	30
			1 Destination 1 Route Marker	N/A Word, 2 Dest., 2 R.M. 0 Icon, No Lane, No Dir.	25
			3 Destinations	Short Word, 4 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	33
Diagrammatic Guide, Separate Exit	Long Word, 2 Dest., 2 R.M., 0 Icon, No Lane, Dir.	34	1 Direction	Short Word, 1 Dest., 2 R.M. 0 Icon, No Lane, Dir.	29
			1 Route Marker	Short Word, 1 Dest., 3 R.M. 0 Icon, No Lane, Dir.	30
Services, Integrated	N/A Word, 0 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	19	3 Icons	N/A Word, 0 Dest., 0 R.M. 3 Icon, No Lane, No Dir.	13
			6 Icons	N/A Word, 0 Dest., 0 R.M. 6 Icon, No Lane, No Dir.	20
			1 Icon	N/A Word, 0 Dest., 0 R.M. 1 Icon, No Lane, No Dir.	1
Route Marker, Interstate and U.S. Route	N/A Word, 0 Dest., 1 R.M., 0 Icon, No Lane, Dir.	Interstate = 2 U.S. Route = 1	1 Route Marker	N/A Word, 0 Dest., 2 R.M. 0 Icon, No Lane, Dir.	15
			1 Route Marker	N/A Word, 0 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	4

Recreational Guide, Integrated Icons	Long Word, 1 Dest., 0 R.M., 3 Icon, No Lane, No Dir.	15	3 Icons	Short Word, 1 Dest., 0 R.M. 4 Icon, No Lane, No Dir.	17
Recreational Guide, Separate Icons	Long Word, 1 Dest., 0 R.M., , 3 Icon, No Lane, No Dir.	17	5 Icons	Short Word, 1 Dest., 0 R.M. 6 Icon, No Lane, No Dir.	25
Recreational Guide, Distance	Long Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	18	Green Color	Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	10
			1 Destination	Long Word, 2 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	19
			2 Destinations	Long Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	29
Recreational Guide, Direction	Long Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	10	1 Destination	Long Word, 2 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	14

Key:

"Upper" Complexity = Maximum number of all sign components present as specified in the MUTCD

"Upper" Complexity Rating = Mean information load rating for the defined "upper" complexity sign (1-100)

Rating = Mean information load rating for the defined sign with added components (1-100)

Word = Word length of destinations (Long, Short, N/A)

Dest. = Number of destinations (0-4)

R.M. = Number of route markers (0-3)

Icon = Number of icons (0-6)

Lane = Presence or absence of a lane indicator arrow

Dir. = Presence or absence of a cardinal direction

TABLE B-3 General effects of sign components on information load

Sign Component	Type and Category	Definition	Rating	Difference
Word Length	Advance Major Guide, Integrated Exit	Short Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	12.48	
		Long Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	14.95	+2.47
		Short Word, 2 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	17.46	
		Long Word, 2 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	17.46	0
	Advance Major Guide, Integrated and Lane Drop	Short Word, 1 Dest., 1 R.M. 0 Icon, Lane, No Dir.	24.99	
		Long Word, 1 Dest., 1 R.M. 0 Icon, Lane, No Dir.	29.14	+4.15
	Exit Direction	Short Word, 1 Dest., 1 R.M. 0 Icon, No Lane, Dir.	14.06	
		Long Word, 1 Dest., 1 R.M. 0 Icon, No Lane, Dir.	23.58	+9.52
		Short Word, 2 Dest., 1 R.M. 0 Icon, No Lane, Dir.	16.07	
		Long Word, 2 Dest., 1 R.M. 0 Icon, No Lane, Dir.	21.21	+5.14
		Short Word, 4 Dest., 1 R.M. 0 Icon, No Lane, Dir.	20.33	
		Long Word, 4 Dest., 1 R.M. 0 Icon, No Lane, Dir.	45.37	+25.04
	Post-Interchange Distance	Short Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	3.15	
		Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	6.02	+2.87
		Short Word, 4 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	27.75	
		Long Word, 4 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	26.63	-1.12
	Interchange Sequence	Short Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	4.21	
		Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	10.3	+6.09

Sign Component	Type and Category	Definition	Rating	Difference
Word Length (Ct'd.)	Interchange Sequence (Ct'd.)	Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	26.36	
		Long Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	32.77	+6.41
	Community Interchange	Short Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	12.82	
		Long Word, 1 Dest., 0 R.M., 0 Icon, No Lane, No Dir.	24.15	+11.33
		Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	33.48	
		Long Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	33.36	-0.12
	Recreational Guide, Distance	Short Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	10.33	+7.8
		Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	18.13	
Number of Destinations	Advance Major Guide, Separate Exit	Short Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	20.01	
		Short Word, 3 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	18.42	-1.59
		Short Word, 4 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	27.37	+7.36
	Advance Major Guide, Separate Exit and Lane Drop	Long Word, 2 Dest., 1 R.M. 0 Icon, Lane, No Dir.	19.9	
		Long Word, 4 Dest., 1 R.M. 0 Icon, Lane, No Dir.	39.73	+19.74
	Multiple Destination Exit	Short Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	3.15	
		Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	27.03	+23.88
	Exit Direction	Short Word, 1 Dest., 1 R.M. 0 Icon, No Lane, Dir.	14.06	
		Short Word, 2 Dest., 1 R.M. 0 Icon, No Lane, Dir.	16.07	+2.01
		Short Word, 4 Dest., 1 R.M. 0 Icon, No Lane, Dir.	20.33	+6.27
		Long Word, 1 Dest., 1 R.M. 0 Icon, No Lane, Dir.	23.58	
		Long Word, 3 Dest., 1 R.M. 0 Icon, No Lane, Dir.	23.45	-0.13
		Long Word, 4 Dest., 1 R.M. 0 Icon, No Lane, Dir.	45.37	+21.79

(continued on next page)

TABLE B-3 ***(Continued)***

Sign Component	Type and Category	Definition	Rating	Difference
Number of Destinations (Ct'd.)	Post-Interchange Distance	Short Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	3.15	
		Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	19.63	+16.48
		Short Word, 4 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	27.75	+24.6
		Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	6.02	
		Long Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	21.27	+15.25
		Long Word, 4 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	26.63	+20.61
	Interchange Sequence	Short Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	4.21	
		Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	26.36	+22.15
		Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	10.3	
		Long Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	32.77	+22.47
		Long Word, 4 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	40.62	+30.32
	Community Interchange	Short Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	12.82	
		Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	33.48	+20.66
		Short Word, 4 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	33.02	+20.2
	Recreational Guide, Direction	Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	9.59	
		Long Word, 2 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	14.27	+4.68
Number of Route Markers	Advance Major Guide, Integrated Exit	Short Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	12.48	
		Short Word, 1 Dest., 2 R.M. 0 Icon, No Lane, No Dir.	18.89	+6.41
	Exit Direction	Short Word, 1 Dest., 1 R.M. 0 Icon, No Lane, Dir.	14.06	
		Short Word, 1 Dest., 2 R.M. 0 Icon, No Lane, Dir.	22.82	+8.76
	Interchange Sequence	Short Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	4.21	
		Short Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	10.66	+6.45

Sign Component	Type and Category	Definition	Rating	Difference
Number of Route Markers (Ct'd.)	Interchange Sequence (Ct'd.)	Short Word, 3 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	26.36	
		Short Word, 3 Dest., 2 R.M. 0 Icon, No Lane, No Dir.	29.84	+3.48
		N/A Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	8.53	
		N/A Word, 2 Dest., 2 R.M. 0 Icon, No Lane, No Dir.	21.4	+12.87
		N/ A Word, 3 Dest., 3 R.M. 0 Icon, No Lane, No Dir.	29.84	+21.31
	Community Interchange	Short Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	12.82	
		Short Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	22.52	+9.7
		Short Word, 3 Dest,. 0 R.M. 0 Icon, No Lane, No Dir.	33.48	
		Short Word, 3 Dest., 2 R.M. 0 Icon, No Lane, No Dir.	29.03	-4.45
		N/A Word, 1 Dest., 1 R.M. 0 Icon, No Lane, No Dir.	17.14	
		N/A Word, 2 Dest., 2 R.M. 0 Icon, No Lane, No Dir.	24.61	+6.96
		N/A Word, 3 Dest., 3 R.M. 0 Icon, No Lane, No Dir.	30.17	+13.03
	Diagrammatic Guide, Separate Exit	Short Word, 1 Dest., 2 R.M. 0 Icon, No Lane, No Dir.	21.97	
		Short Word, 1 Dest., 3 R.M. 0 Icon, No Lane, No Dir.	29.88	+7.91

(continued on next page)

TABLE B-3 ***(Continued)***

Sign Component	Type and Category	Definition	Rating	Difference
Number of Icons	Recreational Guide, Integrated	Short Word, 1 Dest., 0 R.M. 1 Icon, No Lane, No Dir.	6.74	
		Short Word, 1 Dest., 0 R.M. 4 Icon, No Lane, No Dir.	17.1	+10.36
	Recreational Guide, Separate	Short Word, 1 Dest., 0 R.M. 1 Icon, No Lane, No Dir.	7.46	
		Short Word, 1 Dest., 0 R.M. 6 Icon, No Lane, No Dir.	24.59	+17.13
Sign Color	Recreational Guide, Distance	Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	18.13	
		Long Word, 1 Dest., 0 R.M. 0 Icon, No Lane, No Dir.	9.59	-8.54

Key:

Rating = Mean information load rating for the defined sign (1-100)

Difference = The difference in the ratings for the two signs under comparison. The rating of the first sign is subtracted from the rating for the second sign. In the case of a three-sign comparison, differences are calculated for the first and second signs and the first and third signs. The difference appears next to the row containing the second sign in the comparison.

Dest. = Number of destinations (0-4)

R.M. = Number of route markers (0-3)

Icon = Number of icons (0-6)

Lane = Presence or absence of a lane indicator arrow

Dir. = Presence or absence of a cardinal direction

APPENDIX F
MANUAL FOR DIL SOFTWARE

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SECTION 1—INTRODUCTION

Application

The purpose of this software tool is to allow the user to derive a quantitative index of the *information load* imposed upon a motorist who is encountering an array of navigation-related signs. Drivers are frequently confronted with a multitude of information displays, which they must perceive, comprehend, and evaluate while they are simultaneously controlling their vehicles, monitoring other traffic, dealing with distractions, and navigating to a destination. Where drivers are confronted with more information than they can process, in consequence they may decelerate severely or drive unduly slowly, make late or erratic maneuvers, take an improper route alternative, ignore critical information, fail to monitor other traffic, or take their eyes off the road for extended periods. These effects of high information load may have safety and operational consequences.

Under NCHRP Project 3-50(2), a model of driver information load was developed that uses as input information about the roadway and signage and provides as output a quantitative index of the information load associated with each set of signs present on a section of roadway. "Driver information load" (DIL) refers to the level of demand placed on the driver in order to process and respond to the information presented in the time available. The information load imposed by a set of signs is determined not only by the characteristics of the signs themselves, but also the driver's task and the roadway context in which the signs are located. The model incorporates all of these factors in computing the index of driver information load. The current version of the model is specific to navigation-related signs (guide signs, service signs, recreational signs, etc.) on freeways and expressways.

The DIL software tool allows the user to assess the demand on the freeway driver imposed by an array of signs. The model output is provided in both tabular and graphic format, and shows the contributions of various component elements to the overall information load. The tool can be used to identify potential information overload problems and to compare alternatives for the design and placement of signs. However, it must be recognized that the model and the associated software tool deal specifically with the problem of driver information load, that is, the ability of the driver to safely process the amount of information in the time available. The model does not address the full process of designing an informational sign system, including consideration of motorist information needs, the accuracy or clarity of the message, the choice of wording or destinations, and so forth. Managing the information load is only one part of the process, and it is the part dealt with in a quantitative fashion by this tool.

Overview of the Driver Information Load Computational Model

The model is based on determining the driver information load associated with a particular sign array. The term "sign array" refers to a set of individual sign panels that are co-located with one another at a given point on the roadway, typically on the same sign mounting structure or assembly. For example, three individual sign panels mounted on an overhead mast would constitute a single sign array.

The general structure of the DIL model is shown in Figure 1. The model recognizes that a driver's ability to deal with the information in a sign array is a function of two broad sets of demands. One is termed the Information Search Demand (ISD); this is the demand imposed upon the driver by the effort of searching and processing the formal information sources (primarily signs) provided on the roadway. The other category is termed the Driving Task Demand (DTD); this is the attentional demand placed on the driver controlling and guiding the vehicle, monitoring the situation, making decisions and executing

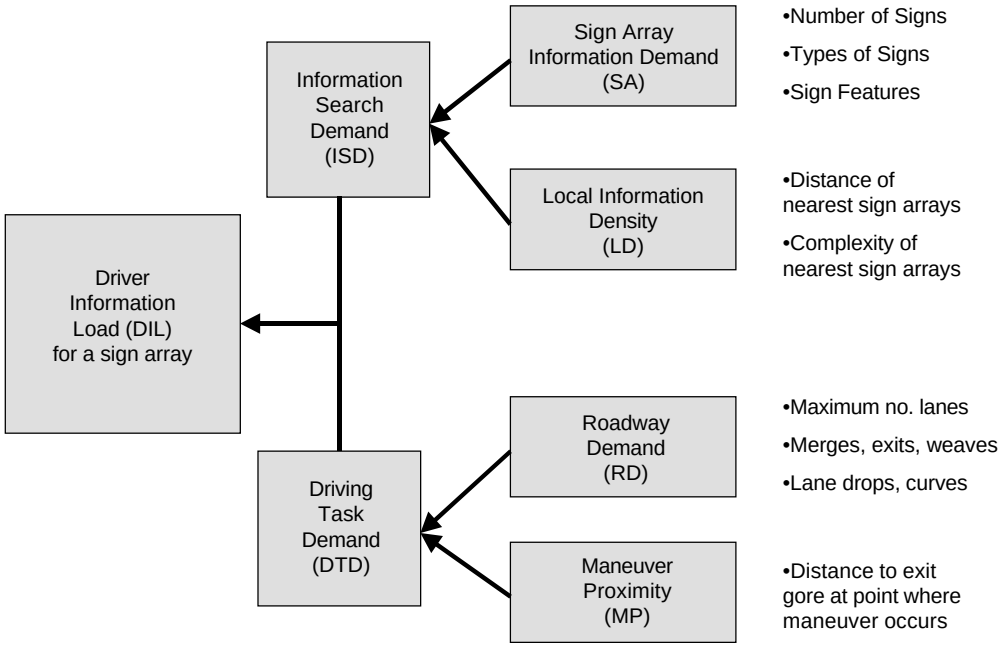


Figure 1. Conceptual Model of Driver Information Load

maneuvers. DTD and ISD operate together to determine the overall driver information load (DIL) placed on the motorist who is confronting a particular sign array.

As Figure 1 illustrates, both ISD and DTD are in turn conceptualized as having two component factors. For ISD, one component is the demand imposed by the information within the particular sign array itself. The other component is the density of other sign information in the general area (how close and how complex are neighboring sign arrays). For DTD, one component is the geometric and operational complexity of the section of roadway leading up to a navigation maneuver point (exit or diversion point). The other component is the proximity to that choice point. Research supporting the development of the model found that drivers devoted more attention to DTD as they got progressively nearer to the point where they must make a navigation-related maneuver.

Figure 1 also shows the factors that go into the determination of each component of DIL. These are the inputs to the model that the user provides, and they are defined further below. Based on the user's input for these factors, the software tool provides estimates of each component of informational load (ISD and DTD and their subcomponents), and then computes the total information load confronting the motorist when dealing with the sign array (DIL).

The model is based on the use of roadway segments, where a segment ends at the point where a driver makes a navigational maneuver, such as an exit or a change into the appropriate lanes at a diversion point. This approach is necessary because the information load associated with a sign array is not the same for every driver. The worst case (therefore the one of interest) is where an unfamiliar driver must make a maneuver at an approaching choice point. Therefore the model assumes that the driver is making a maneuver at the choice point that defines the end of the road section. The road segment is defined as the section from the exit gore point at one end to an upstream point normally 11,000 feet from the gore. This distance is slightly over two miles, thus encompassing where the initial advance signing for an exit typically occurs. A particular sign array might be included in multiple segments defined by different exit points. Even though the sign array itself would be constant, the information load associated with dealing with the

sign may vary because of the changing road segment and proximity to the choice point. Therefore, the DIL computed for a sign array is specific to the assumption made about where the navigation maneuver takes place.

SECTION 2—SYSTEM REQUIREMENTS

The program files for this model were designed for IBM-compatible PCs. Hence, the computer must have Windows Operating System (Windows 95 or later). The computer also must have Microsoft Excel (Excel97 or later) installed on it.

The computer must have adequate hardware (e.g., memory, disk space, etc.) to be able to load and run Access Runtime and Excel application programs simultaneously. In general, 32 MB of memory and at least 4 MB of free hard disk space should be enough to run the program.

SECTION 3—INSTALLATION

The package can be installed on a PC by running the setup program from the DIL Installation CD. Insert the DIL Installation CD into your CD-ROM drive. Open the DIL Installation CD directory and run the "setup.exe" file.

Note: If you are prompted to install Microsoft Access 2000 Runtime files, follow the onscreen directions. You may be prompted to restart your computer several times during this process. After restarting, run the "setup.exe" file on the installation CD again to continue the installation process.

The installation wizard window will appear to guide you through the rest of the installation. By default, setup will assume the following path for installation:

C:\Program Files\DIL New\

You may choose to install the program files in a folder other than the default folder. After choosing the install folder, click the large computer icon in the dialog box to continue installation.

The program will set up a shortcut on your "Programs" list. By default, it will be named "Driver Information Load Program." You may elect to change this name.

When installation is complete, the following two files should be present in the folder where the program was installed:

- DIL New.mdb
- DIL New.xls

It is essential that these two files reside in the same folder, otherwise the program will not be able to complete the Driver Information Load analysis.

SECTION 4—DRIVER INFORMATION LOAD PROGRAM OVERVIEW

Driver Information Load (DIL) is computed and output in three steps using this software package:

1. **Enter roadway segment information.** This includes segment length, roadway geometric information, number of sign arrays, and the site ID/name.

2. **Enter sign array data.** This includes entering information about each navigation-related sign array and individual signs within the arrays.

3. **Transfer data to spreadsheet.** Once all array and sign data have been entered, the data can be transferred from the Microsoft Access file to a Microsoft Excel spreadsheet that presents the DIL output. The output includes a graphic depiction of DIL at each array location. The output shows the level of contribution of each component element to the total DIL.

SECTION 5—GETTING STARTED

Open the DIL program by selecting it from the "Programs" menu (from the "Start" button). The first screen that appears is the **Main Menu**, as shown in Figure 2. You may choose to perform one of the following operations:

- **Enter New Data:** Enter roadway and sign component data into the database.
- **Manage Data:** Transfer existing data to a spreadsheet for analysis.
- **View Report:** View and print reports for specific segments.
- **Exit Database:** Exit the database.

Select the appropriate menu option. When beginning data entry for a new roadway segment, select **Enter New Data**.

SECTION 6—ENTERING NEW DATA

Overview

It is recommended that all the required data be collected and organized before attempting to enter it into the database. Roadway and sign data may be obtained from a variety of sources such as field observations or measurements, computer inventories of signs and roadway designs, sign design plans, etc. The model only deals with freeway sign arrays that are relevant to navigation, such as guide signs and motorist information signs. Stand-alone regulatory and warning signs (e.g., speed limit, added lane) are not relevant and should not be entered in the data.

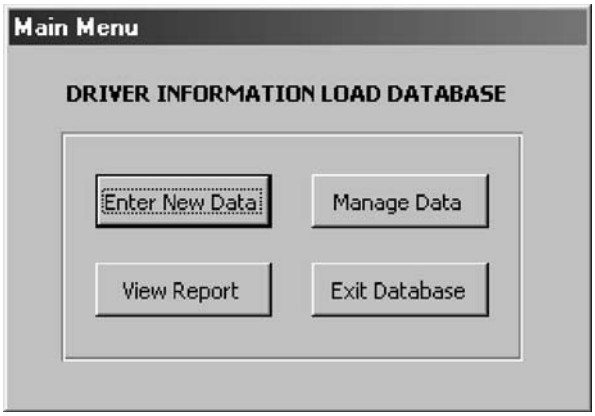


Figure 2. Main Menu

Data entry involves two major steps:

1. Enter information related to the roadway segment, which extends from the exit gore point to a point 11,000 feet upstream of the gore

2. Enter information related to the sign arrays and individual signs located within the roadway segment

After entering the roadway segment data, you will be prompted to enter data for the first sign array of the segment. After entering the data for the first sign array, you will be prompted to enter information about each sign panel within the array. When all sign panels are completed for the first array, you will be prompted to enter data for the second sign array. This procedure continues until all arrays and signs are entered. This data entry process is outlined in Figure 3. The data is then transferred to a Microsoft Excel spreadsheet where the output can be analyzed. The steps of data entry and analysis are described in detail in the following sections.

Note: See Appendix A for a glossary of terms used in this manual and in the DIL program.

Step 1: Enter Segment Info Data

A. To enter new data, click the "Enter New Data" from the Main Menu. The **Segment Info** form for entering roadway segment data, as shown in Figure 4, will appear.

B. In the **Segment Info** form, enter the following data in the appropriate input box:

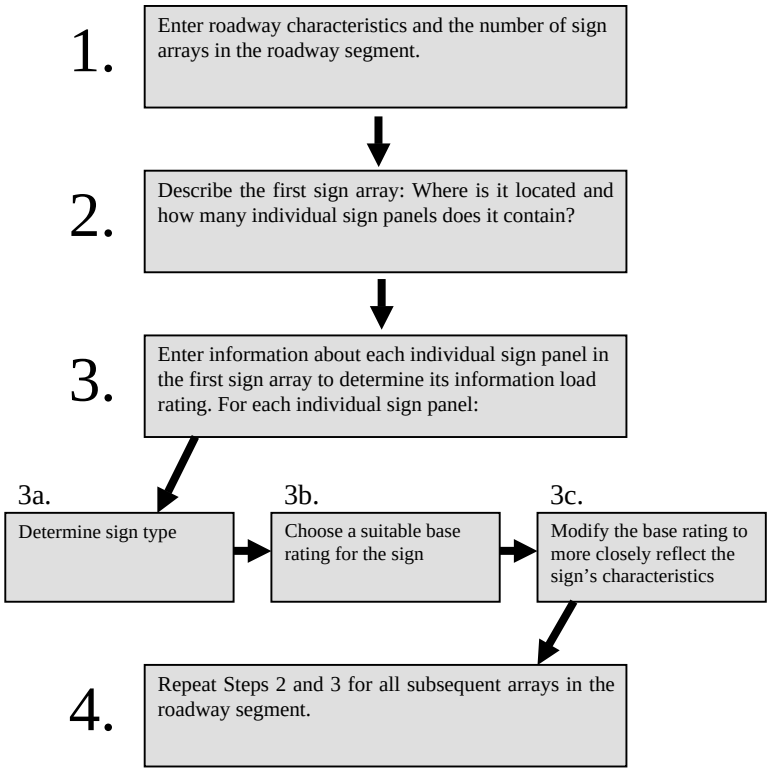


Figure 3. Flow Chart of Data Entry Procedures

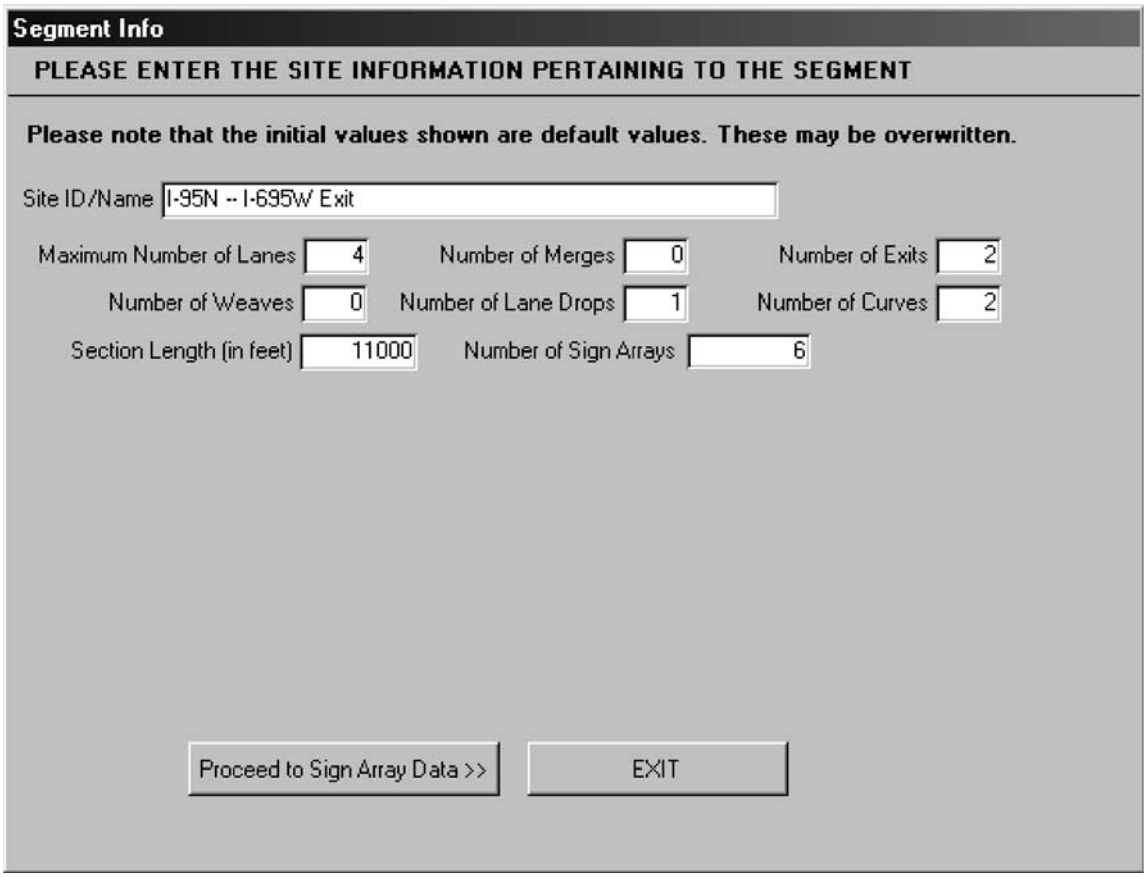


Figure 4. Road Segment Data Input Form

- A suitable name or identification number (ID) for the segment. This can be an alphanumeric entry.
- Length of roadway segment in feet, if less than 11,000 feet. A section extending 11,000 feet upstream of the gore point is the normal default, capturing normal advance signing for the exit and the area over which an approaching driver is most engaged in search and decision making. In some cases, a segment length less than 11,000 feet must be used if the roadway itself is not this long.
- Maximum number of through lanes in the roadway segment, excluding merges, exits, and weaving sections.
- Total number of merges, exits, and weaving areas in the segment.
- Number of lane-drops in the segment.
- Number of curves in the segment.
- Total number of sign arrays in the segment. Note that there may be multiple signs in a single sign array. Enter only the number of sign arrays here.

C. After entering all the relevant data on the **Segment Info** form, click the "Proceed to Sign Array Data button." Follow the steps to enter the sign array and individual sign rating data. A sequence of two forms will be used for this purpose.

Step 2: Enter Sign Array Data

Note: Be sure to enter all data accurately. Once data for a sign array have been entered, it cannot be deleted or edited. However, segment information (the data in) can be edited and additional sign arrays may be added after initial data entry is complete.

A. On the **Sign Array Subform**, which is shown in Figure 5, enter the following data in the appropriate input box:

- A suitable name or identification number (ID) for the sign array for which data is being entered.
- Distance (in feet) of the current sign array from the downstream end point of the segment.
- Number of individual signs in the sign array. It is important to enter this number correctly so that you will be presented with the correct number of entry forms.

The **Sign Array Subform** will display blank spaces under several DIL components at this time. These components will be computed and displayed once the individual sign information has been entered in the form that will follow.

B. After completing the **Sign Array Subform**, click the "Enter Individual Signs" button. A **Sign Lookup Table** form similar to the one displayed in Figure 6 will appear. Information related to individual signs is entered on this form. It should be noted that familiarity with the guide sign designations in the *Manual on Uniform Traffic Control Devices (MUTCD)* will be helpful in expediting data entry on this form. Specifically, the following information should be entered in the order shown below (Note that pressing the <Tab> key on the keyboard move to the next field in the form):

B-1) A suitable name or identification number (ID) for the sign. This entry can be alphanumeric. For reference, the form displays the name/ID of the sign array on which this sign is located and it cannot be overwritten on this form.

B-2) Next, assign the sign a type and category from the drop down list. This list is primarily based on the standard guide signs defined in the *MUTCD*. The sign type and category should be determined before beginning data entry. Based on the sign type and category selected, additional information appears on the form:

- The sign's corresponding *MUTCD* reference is cited in the box below it.
- Below the *MUTCD* reference is a table with the characteristics of the selected sign. The top row represents a typical complex sign of the selected sign type and the bottom row represents a typical uncomplicated sign of the selected sign type. The two rows have different sets of characteristics representing their varying levels of complexity. The complex ("upper") and simpler ("lower") versions of a sign type differ in terms of characteristics such as word length, number of destinations, and the presence of various features such as route markers or icons.

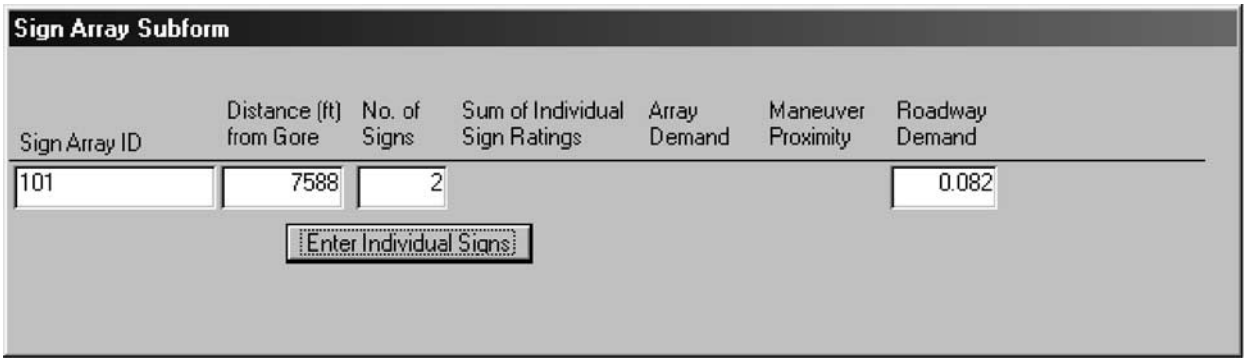


Figure 5. Sign Array Information Form

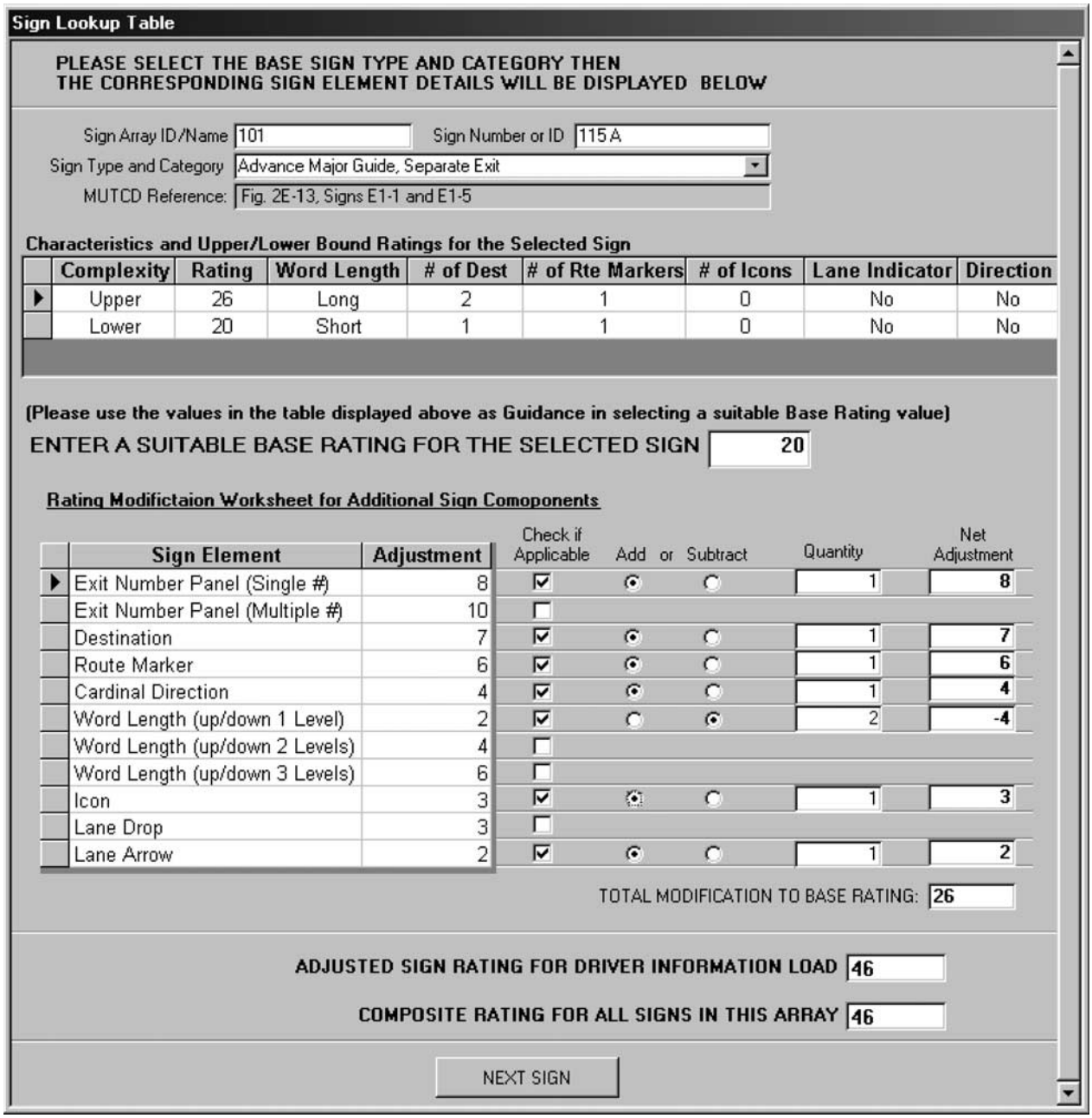


Figure 6. Individual Sign Data Input Form with Base Rating and Modifications

B-3) The next step is to assign a base load rating for the sign. The upper and lower complexity rating values shown in the table should be used for reference. The characteristics of the sign should be compared to those displayed in the table. Engineering judgment should be used in deciding whether to use the higher complexity value, the lower complexity value, or a value in between these two values. A value outside the range of higher and lower values may also be selected if it is determined that the sign warrants it when compared to the selected sign category.

To simplify Step B-4, selecting one of the predetermined complexity ratings is recommended. If you decide that neither the upper nor lower sign complexity

characteristics reflect the subject sign, however, you may choose an intermediate value that reflects your personal judgment of the sign's complexity. Because the intermediate value deviates from the predetermined complexity levels, the Rating Modification Worksheet for Additional Sign Components in Step B-4 should not be completed. Upon deciding on an appropriate base rating, enter it in the input box provided. Scroll the form down to view the lower section of the form.

B-4) The final section of the **Sign Lookup Table** is the **Rating Modification Worksheet for Additional Sign Components**. This section allows you to enter information to modify the rating of the sign based on components that vary from the predefined components for the selected sign category. For example, there may be additional route markers or less text on the sign than is specified in the table of characteristics. To account for these variations, you may adjust the base rating that you selected for the sign. This is done using the worksheet below the base rating input box in the current form.

Note: If you do not want to use the rating adjustment worksheet, but rather just select an intermediate value between the upper and lower values based on analyst judgment, a sign rating value may be entered directly in the base rating box.

You may add/subtract points to/from the specified base rating for the following sign components:

- Exit number panels for single or multiple exit numbers
- Number of destinations listed on the sign
- Number of route markers on the sign
- Cardinal direction (e.g., East, West, etc.) associated with routes
- Word length, i.e., length of text message on the sign
- Icons
- Lane drop
- Lane arrows depicted on sign

These items are listed in tabular format in the worksheet along with associated points that will be added or subtracted for each item selected. There is a selection box next to each item which can be checked or unchecked. Upon checking a box for a selected item, more input options will become available to the right of the checked box. This will allow you to choose whether you want to add or subtract a sign component as well as the quantity of that component that will be adjusted. For example, if the base rating for a sign type specifies 1 route marker but the actual sign has 3 route markers, you should select "Add" and fill in a quantity of 2. Quantity must be entered using the keyboard. After each modification, press <Enter> or <Tab> to calculate the modification. The total points to be added to or subtracted from the base rating will be displayed in the far right column, labeled "Net Adjustment." The total modification to the base rating is presented directly below the "Net Adjustment" column.

B-5) Two display boxes are present at the bottom of the **Sign Lookup Table** form. The top box displays the total adjusted rating for the current sign (the user-defined base rating plus or minus the total modification to the base rating). The other box displays the sum of sign ratings for all signs in the current sign array. Upon completing the entry for a given sign, click the "Next Sign" button at the

bottom of the form. The program will automatically determine if this is the last sign in the current array based on the number of signs entered in the **Sign Array Subform**. If this is not the last sign, then a blank **Sign Lookup Table** form will appear for entering data for the next sign. Otherwise, this form will close and the **Sign Array Subform** will reappear and will display the various computed components of Driver Information Load for the sign array, as shown in Figure 7 for the sample data.

Note that the **Sign Array Subform** now (as shown in) has a "Next Array" action button instead of the "Enter Individual Signs" button. Click the "Next Array" button to proceed. If this is not the last sign array in this segment, a blank **Sign Array Subform** will appear to enter data for the next array. Otherwise, this form will close and the **Segment Info** form will be displayed with a summary of all the sign arrays in the segment along with the roadway data. Figure 8 shows the **Segment Info** form with sample data.

Step 3: Transfer Data to the Spreadsheet

If all information has been entered correctly and you are prepared to view the DIL analysis output, you may transfer the data now (for instructions, skip to the second subheading: "If Data Entry is Complete and You are Ready to Transfer the Data and Begin Analysis"). If additional data is required, you may enter it now or exit the program and come back to it later. Remember that additional sign arrays may be added to a roadway segment, but existing sign arrays may not be deleted or edited. Whether you are ready to transfer data or not, the following paragraphs will give further instructions.

Note: If you have transferred roadway segment data previously, but have not renamed the "DIL New.xls" spreadsheet, please do so now. If you do not, the new output will overwrite this earlier spreadsheet.

If You Would Like to Add Additional Data Before Beginning DIL Analysis

The data you have entered have been automatically saved to disk, so you can click the "Exit" button to close this form and return to the Main Menu. From the Main Menu, you may exit the program, manage data, or view summary reports. If you are not ready to finish data entry at this time, click "Exit Database" to close the DIL program.

When you are ready to complete data entry for the roadway segment, open the DIL program again and click "Enter New Data" from the Main Menu. This will bring up the same form that you used to enter the roadway data in Step 1. Enter the name of the seg-

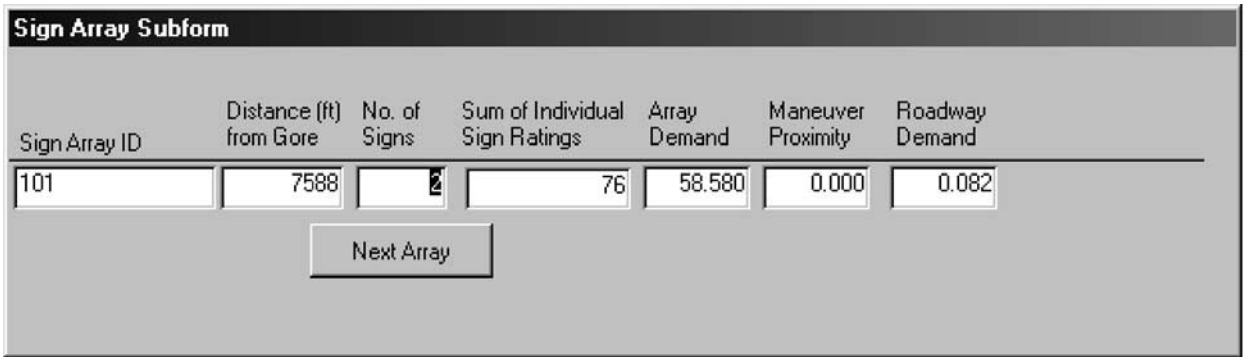


Figure 7. Sign Array Form After Entering Individual Sign Data

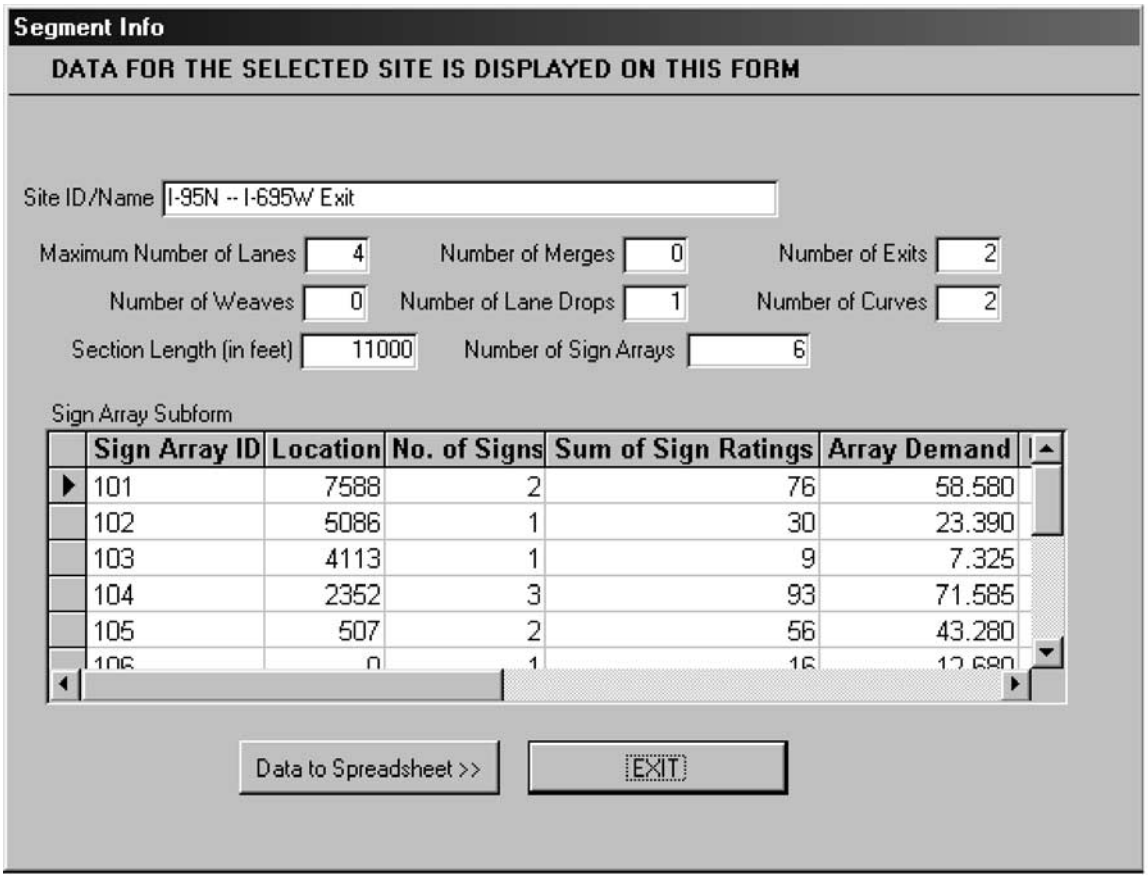


Figure 8. Segment Summary After Entering Sign Array Data

ment exactly as you did during initial data entry. Re-enter the segment information. The information that you enter will overwrite the previous segment information. For number of sign arrays, however, enter the number of sign arrays that you would like to *add* to the segment, rather than the total number of sign arrays. Continue to enter all necessary information for the additional sign arrays as you did in Step 2. When the information for the additional sign arrays has been entered, you may exit to the Main Menu (your data will be automatically saved) or transfer the data to the spreadsheet. If you are not ready to transfer the data, click "Exit" and continue to the next paragraph for instructions on transferring data from the Main Menu. If you are ready to transfer data to the spreadsheet immediately, skip ahead to the next subheading.

To transfer data from the Main Menu, click "Manage Data." This will bring up the **Selection Form** seen in Figure 9. Select the name of the segment that you would like to transfer from the "Section ID/Name" drop down menu and click the "View/Transfer Data" button to bring up a **Segment Info** form similar to the one in which displays the information entered for the site. You are now ready to transfer the data. Continue to the next subheading for further instructions. If you wish to transfer the data to an Excel spreadsheet at this time, click the "Data to Spreadsheet>>" button. The data will be transferred to an Excel spreadsheet named "DIL New.xls" in the folder that you designated during installation.

<u>If Data Entry is Complete and You are Ready to Transfer the Data and Begin Analysis</u>

If you are ready to transfer the data to an Excel Spreadsheet, click the "Data to Spreadsheet>>" button on the **Segment Info** form to transfer all relevant data for the current



Figure 9. Segment Selection Form

segment/site to a Microsoft Excel spreadsheet file named "**DIL New.xls**" in the folder that you designated during installation (the default folder is "DIL New"). The Excel file must not be open at the time of data transfer because data will not be transferred and an error message will be displayed. Section 8 describes the Excel spreadsheet in detail.

SECTION 7—VIEW AND PRINT SIGN SUMMARY REPORTS

The program can generate two reports for each roadway segment. You can preview them on the computer screen and print hard copies as well. One of the reports is a detailed report of all the individual signs under all sign arrays associated with the segment. The other report is a summary of all the sign arrays for the segment. Sample reports are presented in Figure 10 and Figure 11, respectively. Note that these sign summary reports are not the final output of the DIL model. The full model output comes from the spreadsheet analysis described in Section 8.

To view a report, click the "View Report" button on the DIL program's Main Menu. The **Report Selection Form**, as shown in Figure 12, will appear. From the drop down menu, select the segment for which the report is desired and then press the appropriate button for the type of report desired. Select "Preview Sign Report" for a summary of sign rating data for each array in the segment (see). Select "Preview Array Report" for a broader overview of each array in the segment, along with its associated "Array Demand" and "Maneuver Proximity" scores (see). The selected report will be displayed on the computer screen. The program's Print menu can be used to print the report.

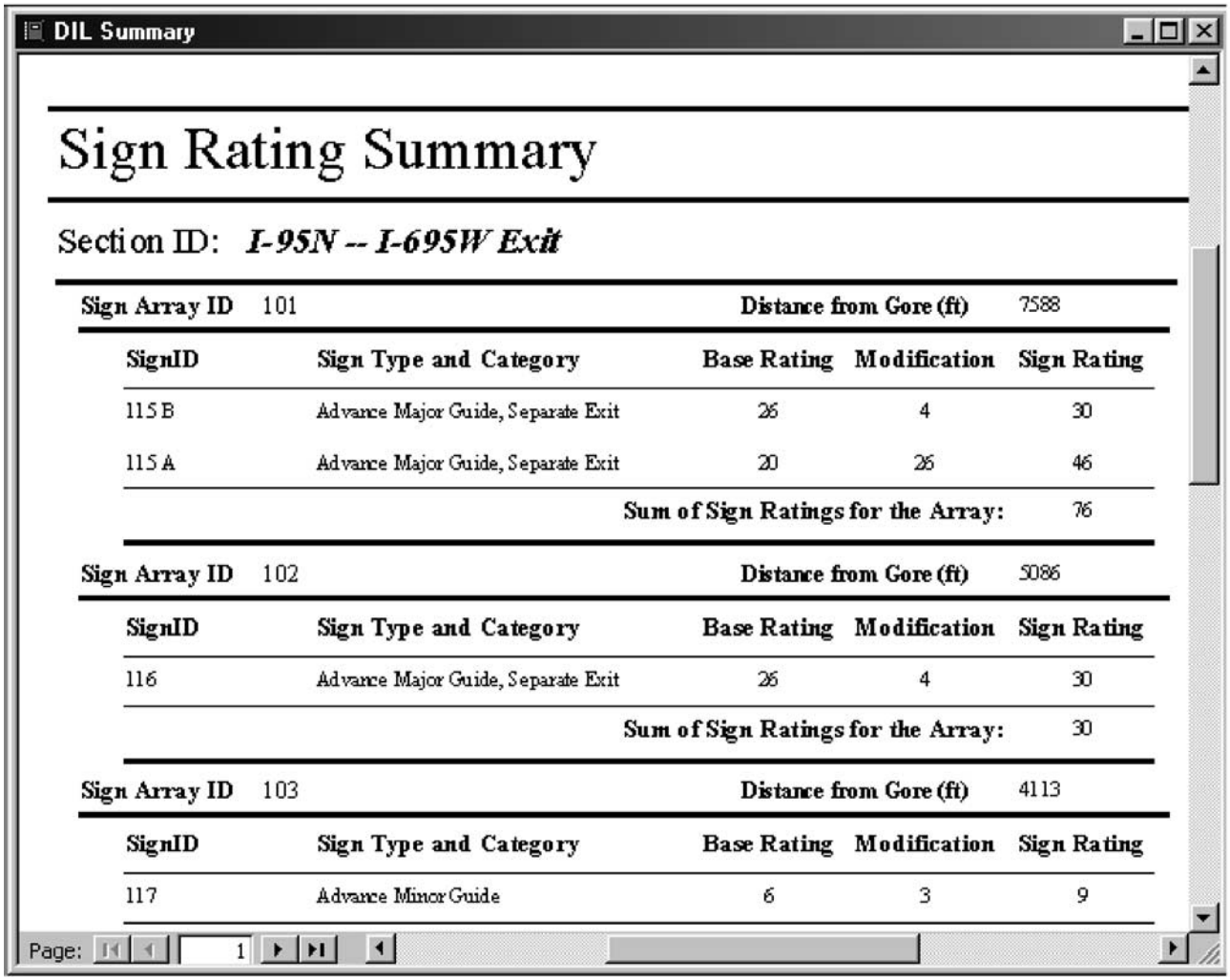
SECTION 8—DRIVER INFORMATION LOAD SPREADSHEET ANALYSIS

Spreadsheet Overview

This step provides the primary output of the DIL model. It provides, in both tabular and graphic formats, the DIL associated with each sign array, and the contributions of the various components of DIL. This output can be manipulated in order to explore the effects of making various changes to the sign system (e.g., alter a sign's content or relocate an array).

After a set of data for a roadway segment has been transferred to the spreadsheet (as explained in Section 6, Step 3), you may open the spreadsheet to begin analysis.

First, open the file named "DIL New.xls". This file is in the directory or folder specified at the time of program installation. If the default path was selected, then this file will be in the "C:\Program Files\DIL New\" directory.



DIL Summary

Sign Rating Summary

Section ID: ***I-95N -- I-695W Exit***

Sign Array ID	101		Distance from Gore (ft)	7588
SignID	**Sign Type and Category**	**Base Rating**	**Modification**	**Sign Rating**
115B	Advance Major Guide, Separate Exit	26	4	30
115A	Advance Major Guide, Separate Exit	20	26	46
			Sum of Sign Ratings for the Array:	76

Sign Array ID	102		Distance from Gore (ft)	5086
SignID	**Sign Type and Category**	**Base Rating**	**Modification**	**Sign Rating**
116	Advance Major Guide, Separate Exit	26	4	30
			Sum of Sign Ratings for the Array:	30

Sign Array ID	103		Distance from Gore (ft)	4113
SignID	**Sign Type and Category**	**Base Rating**	**Modification**	**Sign Rating**
117	Advance Minor Guide	6	3	9

Page: 1

Figure 10. Sample Sign Rating Report

> ***Warning! You must save the "DIL New.xls" file with a new, unique name.*** *Every time new data is transferred to the spreadsheet, the "DIL New.xls" file is updated with the new data, overwriting any previously existing data in the file. A name that includes the segment ID is recommended.*

You do not need to perform any computations in the spreadsheet; the program has already computed the total Driver Information Load and its components for each sign array and created a chart plotting these values versus the distance of the sign array from the exit gore.

The Excel spreadsheet contains a number of worksheets listed as tabs along the bottom of the screen. Each worksheet is described in detail in the next section.

Worksheet Descriptions

The primary output of the Driver Information Load model is presented in tabular form in the "DIL" worksheet and in graphic form in the "DIL Components Chart" worksheet.

DIL Summary

Array Summary

Section ID: *I-95N -- I-695W Exit* Roadway Demand 0.082

Sign Array Name or ID	Distance (ft) from Gore	Sum of Sign Ratings for Array	Array Demand	Maneuver Proximity
101	7588	76	58.580	0.000
102	5086	30	23.390	0.711
103	4113	9	7.325	1.468
104	2352	93	71.585	2.837
105	507	56	43.280	1.845
106	0	16	12.680	1.000

Page: 1

Figure 11. Sample Array Summary Report

DIL

The worksheet titled "DIL" presents the DIL for each sign array in the roadway segment, as well as the contributions of the four factors in the model (e.g., sign array information demand, maneuver proximity, roadway demand, and local density). A sample worksheet is shown in Figure 13. The four rightmost columns are the components that contribute to the final DIL (second column). This worksheet may be formatted to your preference, but care must be taken not to unintentionally alter data or formulas. Data in the highlighted sections of the worksheet may be altered, but all other sections are protected and cannot

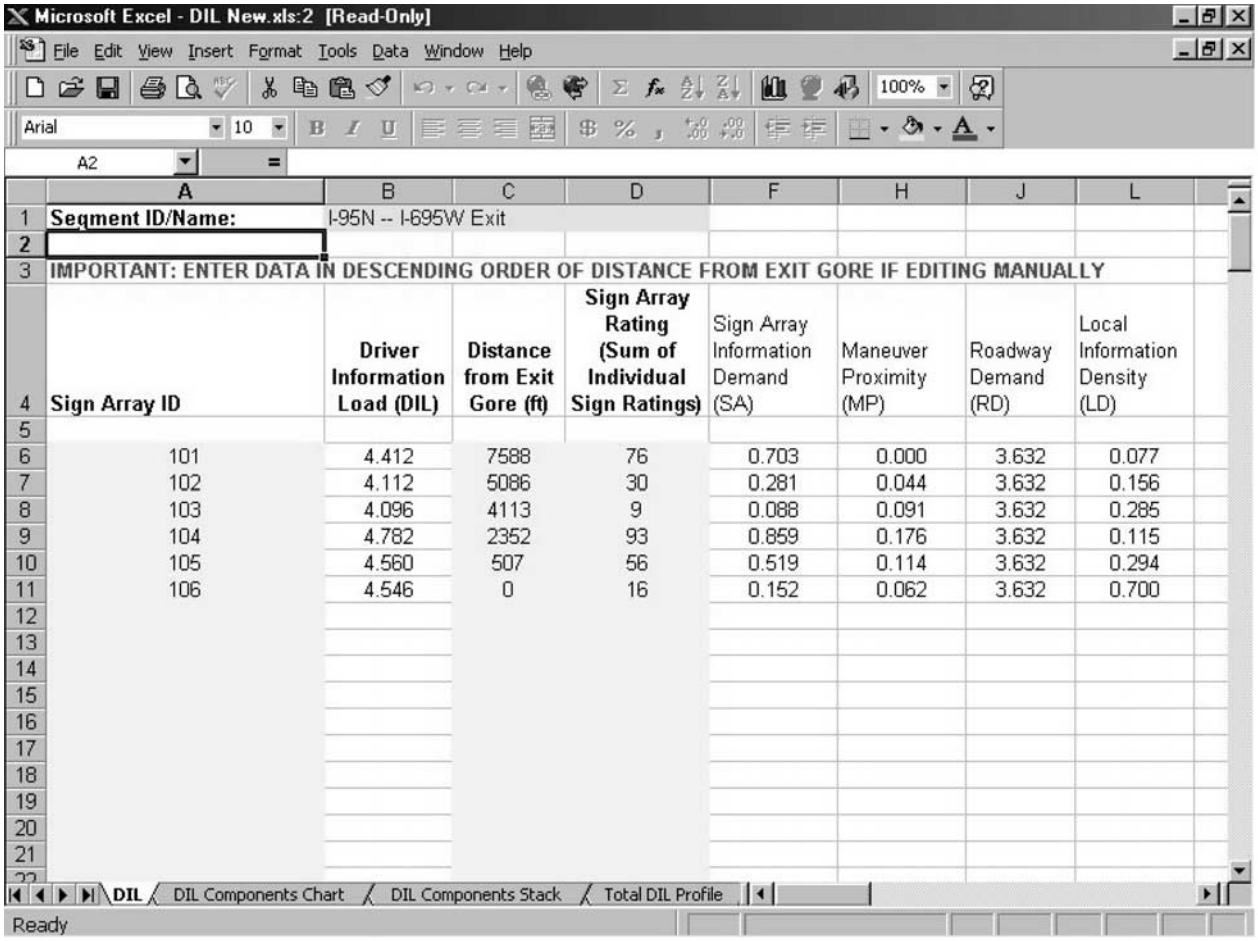
Report Selection Form

PLEASE SELECT THE SECTION FOR WHICH REPORT IS DESIRED

Section ID/Name: I-95N -- I-695W Exit

Preview Sign Report Preview Array Report

Figure 12. Section and Report Selection Form



Microsoft Excel - DIL New.xls:2 [Read-Only]

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A2 =

	A	B	C	D	F	H	J	L
1	**Segment ID/Name:**	I-95N -- I-695W Exit						
2								
3	IMPORTANT: ENTER DATA IN DESCENDING ORDER OF DISTANCE FROM EXIT GORE IF EDITING MANUALLY							
4	**Sign Array ID**	**Driver Information Load (DIL)**	**Distance from Exit Gore (ft)**	**Sign Array Rating (Sum of Individual Sign Ratings)**	Sign Array Information Demand (SA)	Maneuver Proximity (MP)	Roadway Demand (RD)	Local Information Density (LD)
5								
6	101	4.412	7588	76	0.703	0.000	3.632	0.077
7	102	4.112	5086	30	0.281	0.044	3.632	0.156
8	103	4.096	4113	9	0.088	0.091	3.632	0.285
9	104	4.782	2352	93	0.859	0.176	3.632	0.115
10	105	4.560	507	56	0.519	0.114	3.632	0.294
11	106	4.546	0	16	0.152	0.062	3.632	0.700
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								

DIL | DIL Components Chart | DIL Components Stack | Total DIL Profile

Ready

Figure 13. DIL Worksheet—Driver Information Load Computations

be changed. You may experiment with the effects of adding, removing, or altering arrays and view the resulting effect on DIL.

DIL Components Chart

This tab contains a graph of Driver Information Load (here referred to as Sign Array Information Demand) and its components plotted by distance (in feet) from the exit gore. A value is calculated at each point where an array is located. Roadway demand remains constant for each segment. This graph is linked to the "DIL" worksheet, so changes in the "DIL" worksheet will be reflected in the graph. The graph may be formatted for individual preferences, but care must be taken not to alter the source data. A sample chart is shown in Figure 14. Since Local Density (LD) shifts value at the point of each sign array, the chart shows the highest LD value at any point and the diamond symbol indicates the LD value for the sign array at that point. This chart provides a visualization tool that may be useful for considering alternate sign treatments.

DIL Components Stack

This tab contains a stacked bar chart that represents the individual contributions of each DIL component toward the total DIL for each sign array in the roadway segment. A sample chart is shown in Figure 15. The total height of each stack is the DIL of that array. Unlike the DIL Components Chart, the DIL Components Stack chart does not display rel-

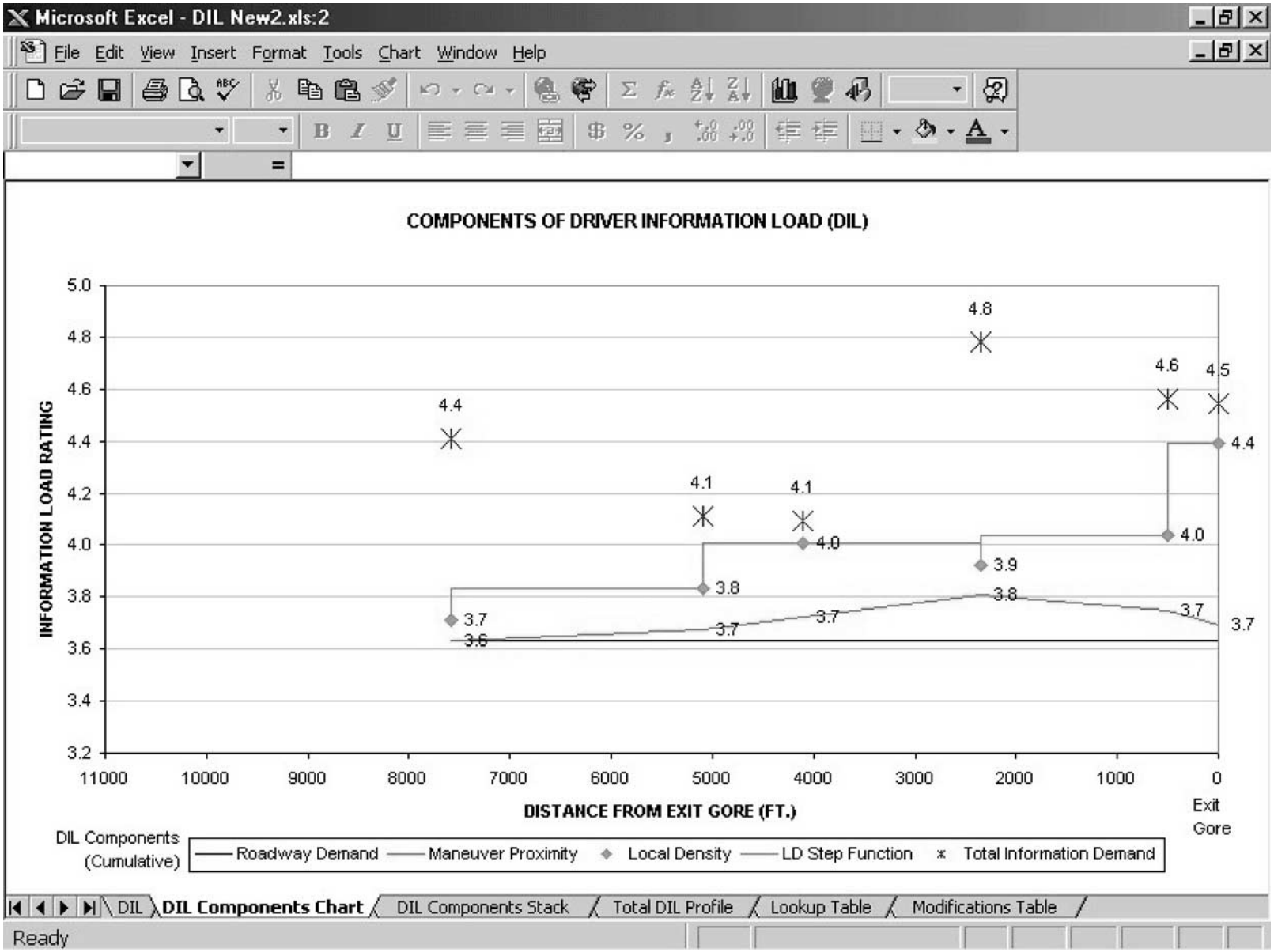


Figure 14. DIL Components Chart

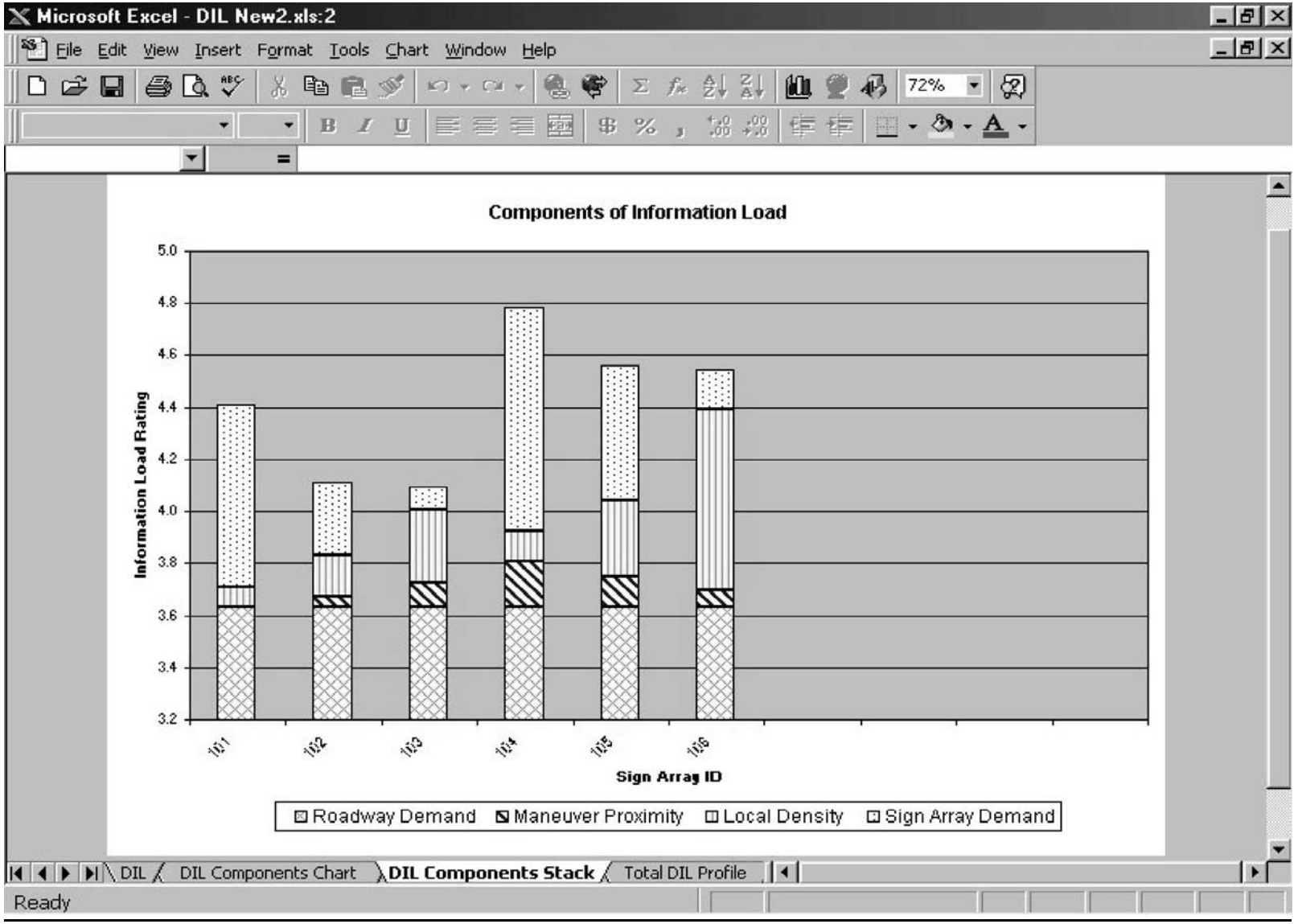


Figure 15. DIL Components Stack

ative or actual distance from the exit gore. The chart area is formatted to display a maximum of ten sign arrays. If there are more than ten arrays in the roadway segment, you may format the Excel chart to fit the additional sign arrays.

Total DIL Profile

This tab is a simplified version of the “DIL Components Chart” described above. This graph displays the Driver Information Load value for each array, but not the individual components. In this graph, a straight line connects each array’s DIL value.

Lookup Signs

This worksheet contains sign characteristics used in the **Sign Lookup Table** form during data entry. This worksheet may be used as a reference guide for information on the characteristics of various sign types.

Lookup Signs—Diff Format

The same information as in the “Lookup Signs” worksheet; formatted differently.

Lookup—Added Comps

This worksheet gives a number of sample sign types and the effects of hypothetical additions and subtractions from the standard sign components. This worksheet is particularly useful for reference when selecting a baseline sign rating between the two standard definitions.

GLOSSARY OF TERMS

Ordered According to the Form in Which Each Term Appears

Term	Definition
SEGMENT INFO	
Site	A roadway segment less than or equal to 11,000 feet from the exit gore point to the upstream end of the segment.
Site ID/Name	User-defined name/number used to identify the site
Maximum Number of Lanes	The maximum number of through lanes in a site, excluding exit, entrance, and weave lanes.
Number of Merges	The total number of locations where vehicles may enter the highway from another road, excluding weaving sections.
Number of Exits	The total number of locations where vehicles may exit the highway, excluding weaving sections.
Number of Weaves	The total number of weaving sections where the pattern of traffic entering and leaving at contiguous points of access results in vehicle paths crossing each other. Where a weaving section is present, DO NOT count the merge and exit individually.
Number of Lane Drops	The total number of through lanes which end (traffic must merge into other highway lanes) or become “exit only” lanes.
Number of Curves	The total number of discrete horizontal curves in the roadway segment.
Section Length (in feet)	The total length of a site measured from the exit gore point at one end to an upstream point normally 11,000 feet from the gore (the point where a driver makes a navigational maneuver, such as an exit or a change into the appropriate lanes at a diversion point).
Sign Array	A set of individual sign panels that are co-located with one another at a given point on the roadway, typically on the same sign mounting structure or assembly.
Number of Sign Arrays	The total number of sign arrays in a site.
SIGN ARRAY SUBFORM	
Sign Array ID	User-defined name/number used to identify the array.
Distance (ft) from Gore	Distance (in feet) of the current sign array from the downstream exit gore point where a driver will make a navigational maneuver such as an exit or a change into the appropriate lanes at a diversion point.
No. of signs	The total number of signs in an array.
Sum of Individual Sign Ratings	The additive sum of the ratings of each sign in an array.

Term	Definition
Array Demand	A value derived from the Sum of Individual Sign Ratings for each array. This value is a component of the Multiple Regression Formula for Driver Information Load.
Maneuver Proximity	A value determined by the array's proximity to the downstream end point of the roadway segment (the point where a driver must make a navigational maneuver). This value is a component of Driver Information Load.
Local Density (*not shown on Sign Array Subform*)	A value derived at each sign array by taking the mean of the array demand values for the array immediately preceding it and the array immediately after it. The mean value of the two signs is then divided by the distance between them. This value is a component of Driver Information Load.
Roadway Demand	A value derived from the complexity of the site's roadway geometry (e.g., merges, exits, curves, etc.) as entered in the "Segment Info" form. This value is a component of Driver Information Load.
SIGN LOOKUP TABLE	
Sign	An individual panel in an array
Sign Array ID/Name	User-defined name/number used to identify the array. This ID was created on the previous form.
Sign Number of ID	User-defined name/number used to identify the individual sign
Sign Type and Category	Sign types according to the 2000 edition of the Manual on Uniform Traffic Control Devices (MUTCD). Refer to the MUTCD for detailed descriptions. Select the most appropriate sign type from the drop down menu.
MUTCD Reference	The location and/or figure reference for a particular sign in the MUTCD.
Complexity	Notes whether the specifications for a sign's components relate to the upper or lower boundary of complexity.
Rating	The base value associated with a sign's upper or lower bound.
Word Length	The average amount of text for all destinations on a sign. The 4 lengths to choose from are 'no word,' 'short word,' 'long word,' and 'very long word.' Value varies by increments of 2 according to amount of text on sign relative to the baseline amount. For example, if the baseline sign word length is 'short word' and the actual sign's word length is 'very long word,' the baseline word length must be increased by 2 increments. $2 \times 2 =$ total adjustment of +4. If the baseline word length is the same as the actual sign's word length, no adjustment is necessary.

Term	Definition
# of Dest	The total number of text destinations (e.g., road, town, etc.) on a sign.
# of Rte Markers	The total number of state or interstate route markers (a number within a shield).
# of Icons	The total number of meaningful pictures, images, or logos, often representing a point of interest.
Lane Indicator	The total number of downward-pointing arrows and/or text indicating which lane to use for a particular destination/exit.
Direction	The total number of direction indicators (text indicating the cardinal direction of a road's traffic flow).
Suitable Base Rating for the Selected Sign	A user-defined sign complexity rating based on the sign's characteristics and the upper/lower bounds established in the table above this item.
Exit Number Panel (Single #)	A small panel attached to a larger sign indicating an exit number or letter.
Exit Number Panel (Multiple #)	A small panel attached to a larger sign indicating multiple exits (often at the same interchange).
Destination	A text destination (e.g., road, town, etc.) on a sign.
Route Marker	A state or interstate route marker (a number within a shield).
Cardinal Direction	Text indicating the cardinal direction of a road's traffic flow.
Word Length (up/down 1 Level)	Increase or decrease length of baseline word by 1 increment. See "Word Length" above for more detail.
Word Length (up/down 2 Levels)	Increase or decrease length of baseline word by 2 increments. See "Word Length" above for more detail.
Word Length (up/down 3 Levels)	Increase or decrease length of baseline word by 3 increments. See "Word Length" above for more detail.
Icon	A meaningful picture, image, or logo, often representing a point of interest.
Lane Drop	A through lane which ends (traffic must merge into other highway lanes) or becomes an "exit only" lane.
Lane Arrow	A downward-pointing arrow and/or text indicating which lane to use for a particular destination/exit.
Total Modification to Base Rating	The net sum of all added and subtracted sign elements. This value will be applied to the user-defined base rating to generate the sign's Adjusted Rating for Driver Information Load.
Adjusted Sign Rating for Driver Information Load	See "Total Modification to Base Rating" above.
Composite Rating for All Signs in this Array	The sum of the "Adjusted Sign Rating for Driver Information Load" for all signs in the present array.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation