Laboratory Assessment of Driver Route Diversion in Response to In-Vehicle Navigation and Motorist Information Systems

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A laboratory investigation of driver use of in-vehicle navigation systems is described in this paper. This study is the first phase of a two part project in which the second phase will apply the driver behavior data to a traffic simulation model. The objective of the driver behavior experiment was to compare the effect of four navigation systems on driver diversion decisions when faced with traffic congestion. Three of the systems were developed on the basis of a heading-up map display. These systems varied from a basic map with vehicle position information to a highly complex map with position, congestion, and route guidance information. The fourth system consisted of simplified symbolic directions and distance to change information. The experiment simulated typical freeway trips using sequences of slides of real freeway scenes and auditory feedback controlled by a computer. Drivers were presented information on traffic congestion, vehicle speed and guide signs of off-ramps, and were motivated with monetary rewards and penalties to encourage diversion decisions that would minimize trip travel delays. In addition to several in-vehicle navigation system configurations, experimental variables included driver route familiarity, age group, and either commercial or noncommercial driving experience. The results showed that navigation system characteristics can have a significant effect on driver diversion behavior, with better systems allowing more anticipation of traffic congestion. This result was found over several different levels of congestion. Driver age also was a factor, with old drivers more reluctant to divert from the main freeway route. Route familiarity, commercial driving experience, and gender group variables were not significant factors in driver diversion decision making.

Traffic congestion in the United States causes millions of dollars in lost revenue and millions of hours in lost time every year. In addition, King (*1*) reports that driver navigational waste is equal to 6.4 percent of all distance and 12.0 percent of all time spent in travel by noncommercial motorists. With the increasing number of vehicles on the road, the movement of workers from the city, and the highway network in the United States nearly completed, new solutions to traffic congestion are necessary. The application of available technology, including appropriate human factors design, could potentially provide a large part of the solution to traffic congestion. Driver behavior in response to one potential technical solution, the use of in-vehicle navigation systems, is examined in this paper. A purpose of these systems is to allow drivers to avoid traffic congestion. The main point addressed in this paper is how drivers respond to added navigation information when confronted with traffic congestion.

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Various classes of navigation systems have been defined from Class 0 open-loop systems, which are basically autonomous, to Class 4 dynamic closed-loop systems (*2*). Open-loop systems include simple directional aids, map display systems, and route guidance aids. The Etak Navigator is a currently available autonomous electronic map-based system which includes vehicle and destination position information (*3*). A dynamic closed-loop system contains two-way communication between vehicle and control center (Class 4). Here, centralized vehicle tracking, optimal routing, and information transfer to the vehicle are included such as with the Ali-Scout system (*4*). A system with moderate sophistication (Class 3) might include one-way communication with traffic congestion information being transmitted to the driver.

In developing the technology for navigation systems, several important issues arise associated with system performance and safety of operation. The focus of the human factors study described herein is on driver behavior associated with in-vehicle navigation systems from a system performance point of view. Will in-vehicle navigation systems encourage drivers to take alternate routes and divert early to avoid congestion? The study documented herein approached the testing by simulating trips using slide representations of the freeway environment and prototypes of various navigation system formats. It was hoped that a range of applicable results could be obtained which would otherwise be prohibitive in cost using more expensive simulation techniques or on-the-road evaluations. Human factors principles were used to define the prototype navigation displays, but display design and driver-display interface issues were not explored in detail in this research.

BACKGROUND

Psychological and human factors guidelines for the design of in-vehicle navigation systems have not been established. However, a literature review (*5*) uncovered several issues that should be taken into account. A driver's ability to navigate through a complex environment is largely dependent on the type and extent of cognitive structures representing that environment, the goals of the driver, and the ability of the driver to stay oriented. These three areas, founded in psychology and environmental cognition, are functionally related. First, a destination and travel plan must be formed. Second, knowledge of the local or global network must be known or acquired. Finally, a reference system must exist to relate the driver to the environment.

The cognitive map has been hypothesized as the basis for mentally storing or representing information about the physical world we navigate in (*6*). The internal format for remembering this information could have profound effects on the ease with which one can assimilate information presented by a navigation system. If the information is mentally stored in a prepositional format, then specific verbal directions may be desirable (*7*). However, if the information is in a format analogous to the real world, a different representation, the map for example, may be desired (*8*). In addition, the spatial and verbal skills of drivers may vary significantly among individuals, thereby influencing their ability to use different navigation display formats (e.g., *10*).

Human factors issues of concern include the format and coding of navigation system information (*11*), the attentional demand and safety issues of displays and controls (*12*), and agreement on general guidelines for the development and manufacture of navigation systems. Research into these issues is in its infancy. These issues were considered here in terms of laying out prototype navigation system displays, but were not addressed otherwise in the research. Another important navigation issue is the route choice behavior of drivers. When travel planning before or during a trip, several key variables influence driver decisions. These include cost, total trip time, delay time, distance, trip purpose, and traffic congestion levels (*1*). Many of these variables may be based on secondary environmentally related variables including route complexity, perceived average speeds, number of traffic signals or stop signs, number of lanes, and so on. The weights given to these variables affect a driver's route choice and hence they should be taken into account in designing any navigation system.

The design of the prototype navigation systems and testing procedures reported on herein took these issues and variables into account. Although the prototype display designs are probably not optimal, an attempt was made to follow good human factors interface design practice within the limitations of the PC computer system available for the research. The objective was to achieve prototype systems containing the necessary information to adequately test content and design differences.

APPROACH

Driver use of prototype in-vehicle navigation systems was measured with a part task simulation. The simulation, as described in the following, presented subjects with several traffic congestion scenarios in which they attempted to avoid congestion delays using prototype navigation system information. Four subject groups used different navigation system configurations and a control group was not given any navigation information. The laboratory simulation and experimental procedures were designed to motivate subjects to avoid heavy congestion as they would in the real world.

Navigation System

Four prototype navigation systems were defined for testing that gave varying amounts of information on alternate routing and congestion conditions. Example display conditions are shown in Figure 1 and the basic system capabilities were as follows:

- Static map system—map display with vehicle position indicated (no congestion information was provided by this system);
- Dynamic map system—a static map with traffic congestion level information;
- Advanced experimental system—a dynamic map with highlighted alternate route, additional textual information, and auditory instructions; and
- Route guidance system—a non-map-based system using arrow symbols for direction instructions, a bar graph representing distance to exit, estimated arrival time, and distance to destination.

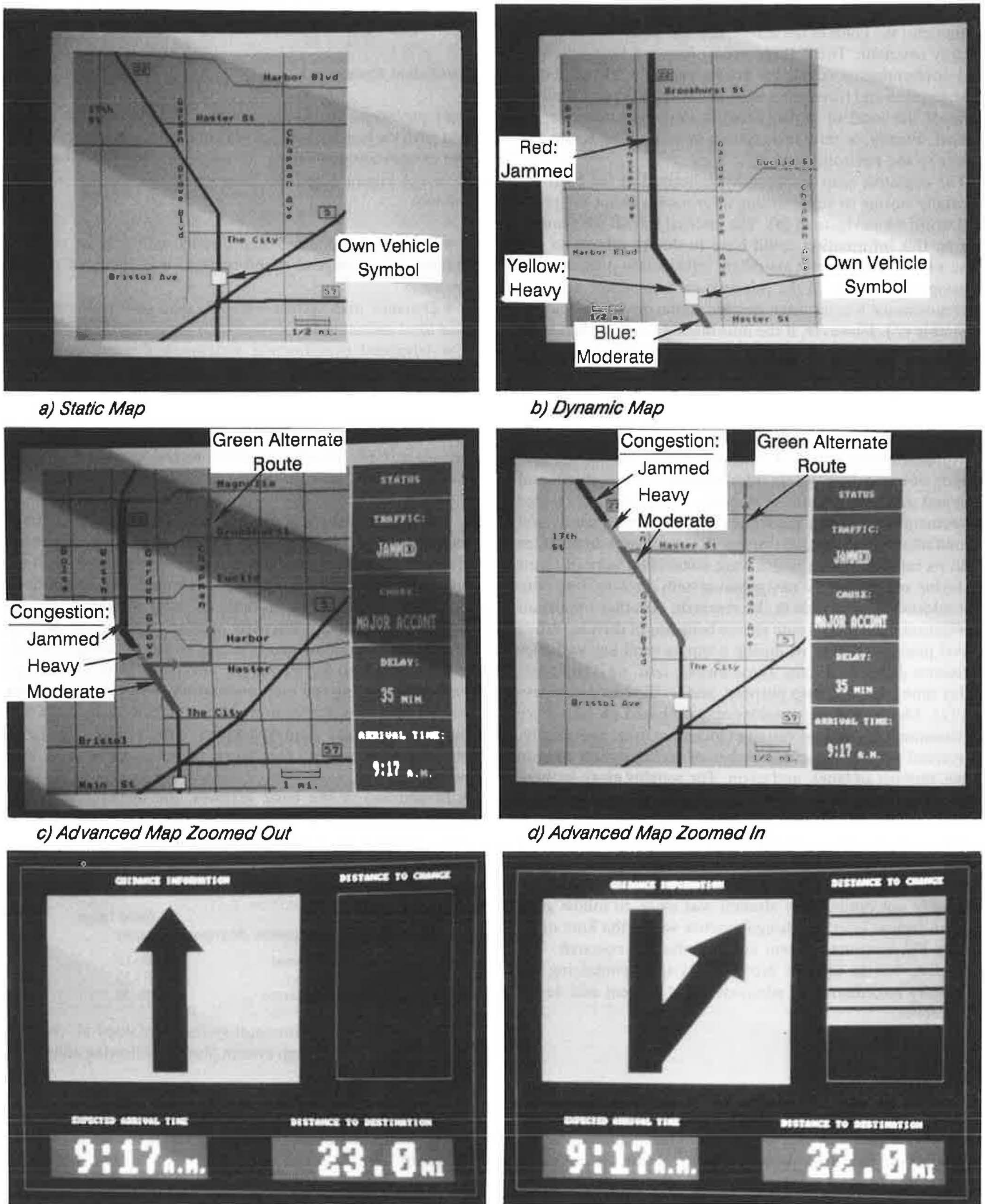
The map systems had several features in common. These included a heading-up display format, the use of two zoom levels, the use of a white square to represent vehicle position, and the use of a black square to represent trip destination. The heading-up format presents all maps relative to the direction of travel. As currently applied, this format did not require constant adjustments in map position. Instead, consistency was strived for with slight deviations from the current path not affecting the map orientation. The vehicle position was placed near the bottom of the screen to increase the portion of the map displayed ahead of the vehicle. The maps were updated every $\frac{1}{4}$ to $\frac{1}{2}$ mi to reflect changes in vehicle position.

In addition to the basic features, the dynamic map and advanced systems included superimposed color codes to represent congestion. Color codes showed congestion levels on freeways, but surface street congestion was not displayed. The three codes and their definitions were as follows:

Color	*Congestion descriptor*	*Speed range (mph)*
Red	Jammed	0–15
Yellow	Heavy	15–35
Blue	Moderate	35–50

The advanced experimental system contained all the features of the dynamic map system plus the following additional features:

- *Highlighted alternate route designation* with the starting or diversion point always ahead of the current vehicle position;
- *Textual display bar* to right of map which defined congestion conditions, amount of delay and alternate route suggestions; and
- *Auditory instructions* that were designed to reinforce the visual display information.



a) Static Map

b) Dynamic Map

c) Advanced Map Zoomed Out

d) Advanced Map Zoomed In

e) Route Guidance, Normal

f) Route Guidance, Recommended Diversion

FIGURE 1 Navigation displays.

The alternate route designation used green color coding superimposed over the suggested route. In addition, green triangles were used to indicate the direction to follow. The display bar to the right of the map had two states. In the nondiversion default state, the system recommended that the driver stay on the current route. The congestion level ahead, the cause of the congestion, the expected delay time, and the destination arrival time were displayed from top to bottom. When the system recommended a route change, an auditory beep was first displayed. Then, the cause of the congestion changed to display a diversion message and the expected delay time changed to display the distance to the recommended exit. Advanced system auditory messages were used to provide redundant information. At the start of the trip, the system presented the distance to the congestion, for example, "Jammed Congestion—3 Miles Ahead." Then, as the driver approached a recommended exit, the system gave a diversion message, for example, "Alternate Route—¾ Mile Ahead."

The route guidance system was designed as a simple non-map-based system with features similar to Ali-Scout (*5*) and AUTOGUIDE (*12*). The guidance information included an arrow, expected delay time, and a display of distance to diversion. This system also had two states. In the default non-diversion state, the arrow pointed straight ahead. When the system recommended a change, an auditory beep was first displayed. Then, the arrow changed to point diagonally and the distance to diversion was presented. The route guidance system does not give any advanced notice of congestion as the dynamic map and advanced systems do, and basically provides only diversion recommendations.

Driver Decision Making Simulation

The simulation approach taken here has previously been used to measure both driver and pilot decision making (*13–15*). As indicated in the Figure 2 block diagram, this approach uses a PC computer to control slide projectors, an auditory display, and a computer monitor to provide desired stimuli to experimental subjects. In the current application, slides were presented in sequence once every 5 sec showing an out-the-window scene including freeway traffic and guide signs, and a partial instrument panel showing a speedometer, odometer, and digital clock. The slide sequences represented a 10-mi drive west on a southern California freeway (i.e., the Garden Grove Freeway, or Route 22, in Orange County) and represented varying amounts of traffic congestion. Auditory feedback of engine sounds was given that was consistent with the displayed speed. At the same time, a computer monitor presented prototype invehicle navigation displays that were consistent with the congestion scenario.

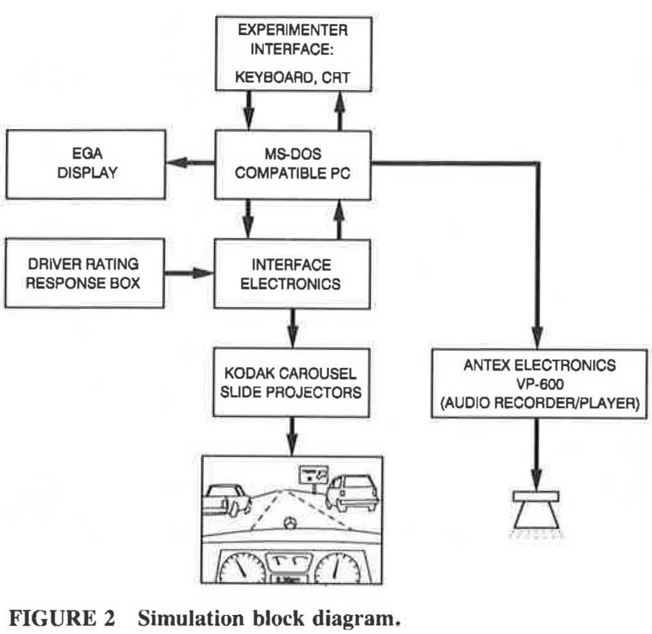


FIGURE 2 Simulation block diagram.

On the basis of the preceding visual and auditory stimuli, the driver-subject's task was to decide when to divert from the freeway to an alternate route in order to minimize trip delay. To motivate these decisions, driver-subjects were given rewards and penalties according to their performance in minimizing trip delays and in estimating traffic congestion levels in the process of driving to a destination. The reward-penalty structure was designed to simulate real-world motivations, such as saving time, avoiding being late for work, and so on, (e.g., *16*). A summary of the reward-penalty structure as related to trip delay was as follows:

Time Increment (min)	*Reward (saved) ($)*	*Penalty (lost) ($)*
Less than 5	0.00	−0.00
5 to 10	1.00	−1.00
10 to 15	2.00	−2.00
15 to 20	3.00	−3.00
20 to 25	4.00	−4.00
More than 25	5.00	−5.00

The simulation computer kept track of where subjects decided to divert from the freeway route and also queried them about their strategy for returning to the freeway. On the basis of the subject's decision making performance during the driving scenario, the computer then calculated the subject's reward-penalty payoff according to the preceding components. The simulation computer monitor and auditory display were also used for instructions and to present questionnaires to the driver-subjects. The four navigation system visual displays were presented on an EGA color graphics monitor. This provided adequate resolution for displaying street names, street layouts, route guidance symbols, and other textual information. The traffic environment slides were displayed using a Kodak Ektagraphic slide projector. An add-on Tecmar baseboard controlled sequencing and duration of the presented slides. A second slide projector presented slides used for designation of alternate routes.

Auditory stimuli were produced and presented using two add-on boards including an Antex VP-600 which reproduced digitize verbal instructions, and an Adlib sound card which simulated engine sounds representing various vehicle speeds. Specialized keypads were used for answering questions, indicating diversion decisions and designating alternate routes. One keypad included numerical keys, an enter key, and four arrow keys representing up, down, left, and right cursor movements. This keypad was used in lieu of the computer keyboard for answering questions and designating alternate routes. A second keypad with five buttons was used to indicate perceived congestion severity and designate diversion decisions. The physical layout of the simulation is shown in Figure 3.

Driving Scenarios

Several plausible driving scenarios including traffic congestion were needed to provide realistic motivation for use of the prototype navigation systems. Experimental driving scenarios included aspects of traffic incident severity, time constraint, and trip destination. Traffic incident severity involves two factors: (*a*) number of lanes blocked and (*b*) arrival time of the driver relative to the start of the incident. From a traffic engineering point of view, arrival time affects the maximum and minimum average speeds over the travel route in question. It will also affect the distance, or back-up of congestion, from the point of the incident (*17*). To set up realistic congestion scenarios, computer simulation runs were made on the FHWA CORFLO traffic simulation model (*18*) in a scenario that covered the Orange County network, which includes the Garden Grove Freeway. The resulting runs showed that a closure of two-thirds of the available freeway lanes with arrival times of 6:40, 13:20, and 20:00 min after incident occurrence produced the desired delay times.

On the basis of the above traffic flow simulation runs, three incident conditions were defined for the driver behavior simulation consisting of approximately 11-min, 18-min, and 30-min delays based on the freeway speed profiles shown in Figure 4. Road environment slides were prepared that showed traffic congestion consistent with the displayed scenario speeds. Examples are shown in Figure 5. Time constraint or time pressure felt by the driver-subject is affected by trip purpose, amount of time allocated for a specific trip, and time of day. With increasing time constraints imposed on the subject, the level of subject motivation to save time is assumed to increase. The current experiment used commuting to work as the trip purpose. In addition, minimal time was allocated to make the trip. Thus, a relatively high time constraint was achieved. This time constraint level was applied to all of the scenarios tested.

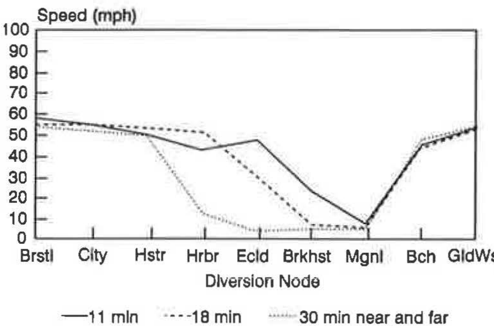
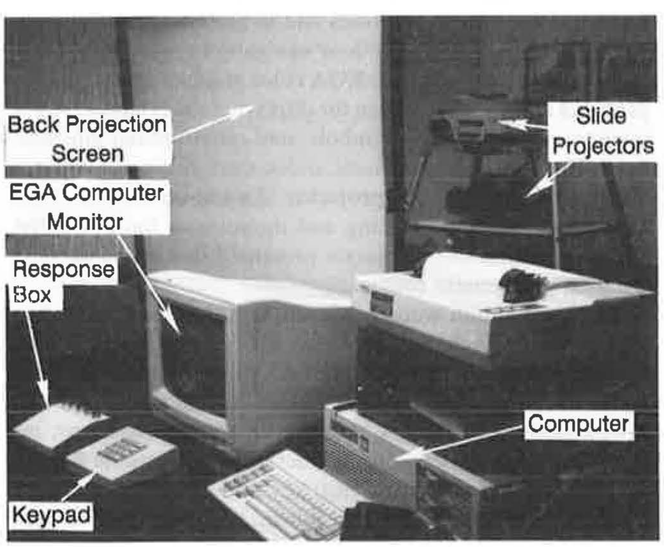


FIGURE 4 Traffic congestion speed profiles.

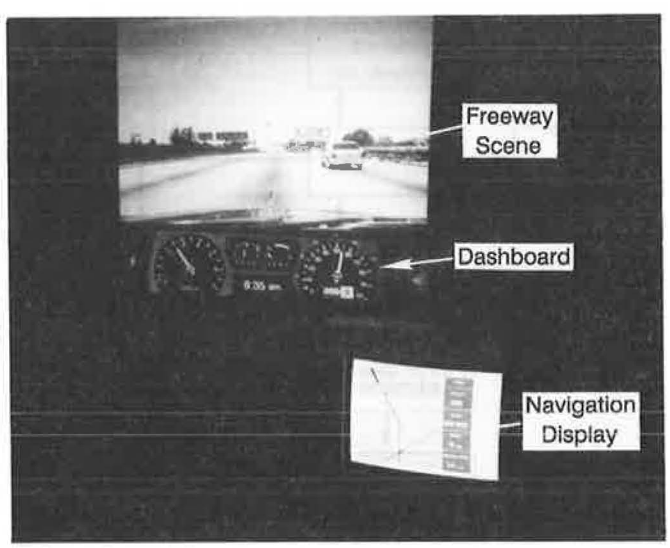
Trip destination may also have some effect on the percentage of drivers diverting and the selection of alternate routes. For far trips, drivers may see little benefit to leaving the freeway unless encountering severe congestion. For near trips, however, drivers may be more willing to divert from the freeway and go directly to their nearby destination. Most of the drivers in the Orange County network leave the area via one of the freeways. Simulation trips beginning at the Garden Grove Freeway (22 mi) and heading west towards a destination 23 mi away were defined as far trips, while a short trip of 9-mi was defined as a near destination as illustrated in Figure 6. Out of four available scenarios encountered by simulation subjects, three trips involving the 11- , 18-, and 30-min delays were associated with far destinations (23 mi), while a fourth 30-min delay was assigned a near destination (9 mi).

Experimental Design

The experimental design was subdivided into between group and within group factors as follows:



a) Physical Layout



b) In Operation

FIGURE 3 Simulation physical layout and in operation.

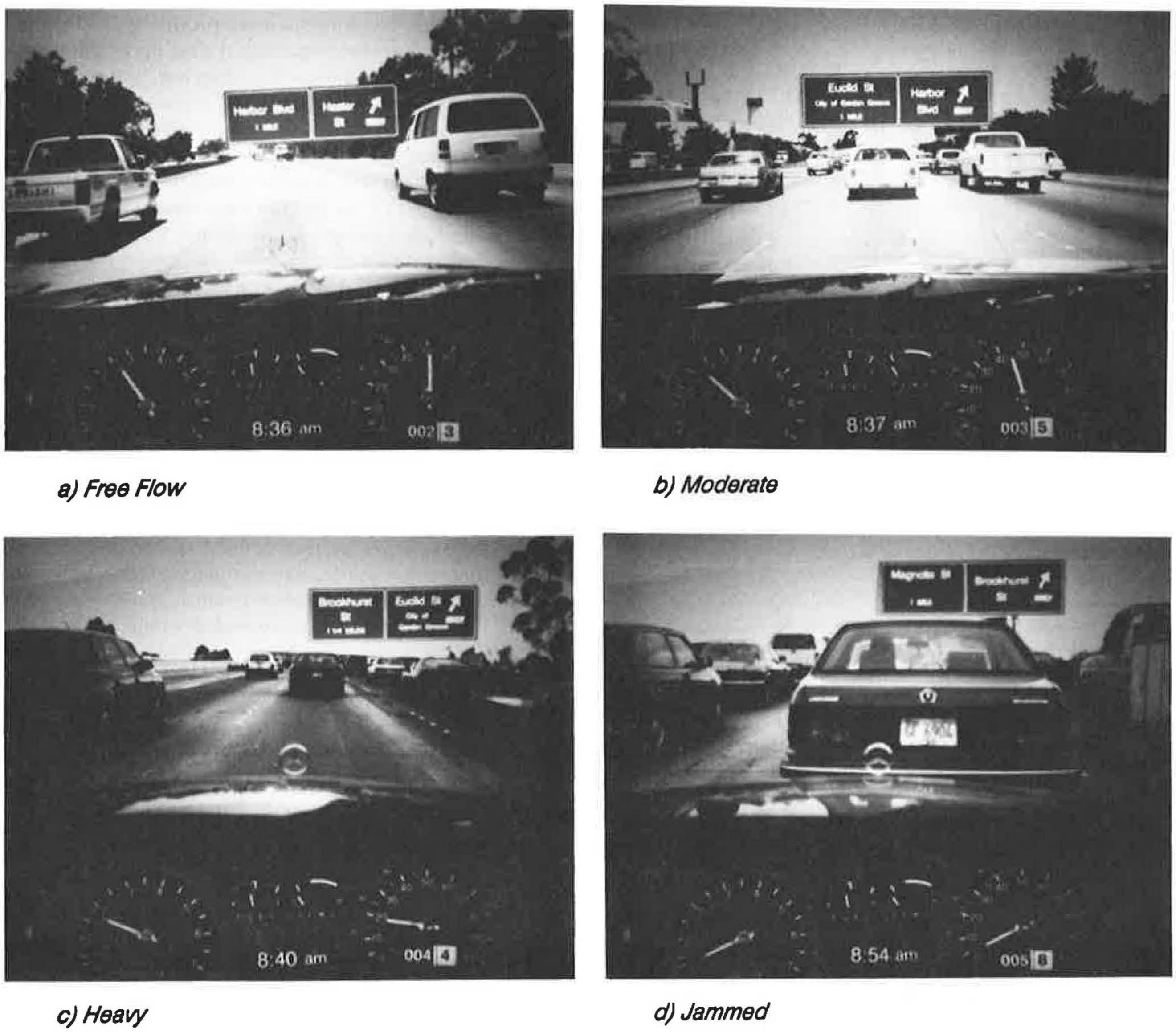


FIGURE 5 Road environment slide examples (moderate, heavy, and jammed traffic conditions).

Navigation System (between group)	*Driving Scenario-Congestion Condition (within group)*
None (control)	11-min delay, far
Static Map	18-min delay, far
Dynamic Map	30-min delay, far
Advanced Map	30-min delay, near
Route Guidance	

Each subject-navigation system group was further subdivided as follows:

Age-Background	*Route-Familiarity*	*Gender*
Young (18–29 years)	Familiar	Female
Middle (30–54 years)	Unfamiliar	Male
Old (>55 years)		
Commercial (all ages)		

The basic variable of interest was navigation system configuration. It was felt that a given subject could only be expected to master one system configuration in the limited training time available, so different groups of subjects were assigned to each navigation system condition. Each subject was given all four of the driving scenarios, however. Each of the five subject groups (for each of the navigation system conditions) was broken down into three age groups for noncommercial drivers plus a commercial driving group that included all ages. Driver-subjects were then further categorized according to familiarity with the freeway route and gender.

The sample size of the design totaled 277 drivers taken from various populations. Of the total, 215 were noncommercial drivers and 62 were commercial drivers. Of the 215, approximately 101 were familiar and 114 unfamiliar with the route tested. Finally, an attempt was made to test equal numbers of males and females. Within each gender group, three age brackets were categorized as young (18–29), middle (30–55), and old (> 55). Of the commercial drivers, approximately half were familiar and half unfamiliar. This group was not controlled for gender or age differences.

The majority of subjects were Southern California Automobile Association employees, with unfamiliar subjects recruited at the downtown Los Angeles headquarters and fa-

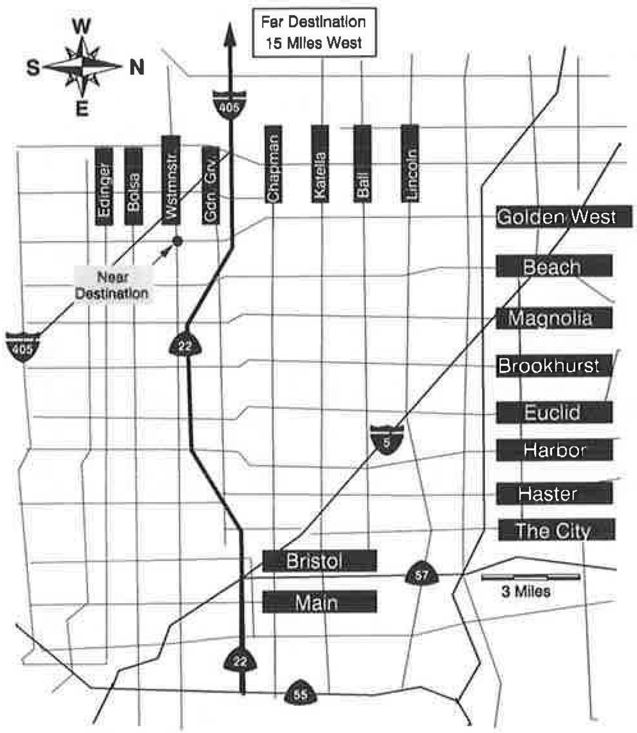


FIGURE 6 Freeway network showing near and far destinations.

miliar subjects recruited from the Costa Mesa processing center near the Garden Grove Freeway route. Additional subjects were recruited from local advertisements and retirement centers to fill out the young and old age categories. Commercial drivers were solicited from airport shuttle services at two locations, one in Santa Ana near the Garden Grove Freeway route and another 30 mi away near the Los Angeles International Airport. The latter location was intended to produce unfamiliar commercial drivers. As a practical matter, it was difficult to obtain commercial drivers unfamiliar with the freeway route and it was also difficult to get familiar drivers in the old-age group. Regardless of the location where subjects were recruited, they were categorized on the basis of answers to a set of pre-experimental questions given verbally by the experimenter.

Experimental Procedures

The experiment was conducted at offices of the Southern California Automobile Club and senior citizens centers where noncommercial driver subjects were obtained and at offices of an airport shuttle service which provided access to commercial drivers. Familiar drivers were obtained at experimental locations near the Orange County freeway network while unfamiliar drivers were obtained at locations 30 mi northwest in the Los Angeles area. Subjects were solicited randomly to the extent possible at each of the locations to fill out the driver demographics required for the experimental design. Upon selection, subjects were randomly assigned to one of the navigation system conditions.

Procedures included orientation, a pre-experiment questionnaire on subject demographics, training, administration of the four driving scenarios discussed previously, and a post-experiment questionnaire regarding typical diversion behavior and attitudes and opinions regarding navigation systems. The orientation, questionnaires, and training for the experimental tasks were automatically administered by the simulation computer to ensure uniformity of presentation. A voice reproduction system was used to administer verbal instructions regarding use of the keypad entry device and interpretation of the visual scenes. Experimental training included familiarization with the visual scenes, navigation system conditions, and the reward-penalty structure. Two practice trials were given, the first without a navigation system for all groups. For the noncontrol groups, orientation was given to the appropriate navigation system. A second practice trial then involved use of the navigation system. The training trials involved exposure to a nonsense scenario involving letter designated offramps (e.g., A St., B St., etc.) to avoid giving any knowledge of the Orange County network to the unfamiliar group.

Formal experimental trials on the Orange County network were preceded by a slide that defined the driving scenario (time of day, trip purpose, and destination). Subjects were then started on the actual scenario which commenced with slides of on-ramp entry, then proceeded with actual Orange County network scenes including appropriate off-ramp signing. Appropriate traffic congestion was portrayed for each of the congestion conditions. Order of presentation of the four congestion conditions was varied across subjects to avoid biasing any condition because of experimental experience. Data collection was automatically performed by the computer in all phases including questionnaire responses and test results. Questionnaire responses, traffic level estimations, diversion decisions, and subject feedback data were all stored in separate data files. Separate files were also used for each subject. At the conclusion of the testing the data files were combined in a spreadsheet for overall analysis. Borland's Quattro Pro (*19*) and Harvard Graphics (*20*) were used for summary analysis and plotting. Stats+ (*21*), which can read data directly from a spreadsheet format, was used for statistical analysis.

RESULTS

The main experimental effects are summarized in Figure 7. The effect of congestion condition on subject diversion patterns summed across navigation systems is illustrated in Figure 7a. Chi-squared analysis shows congestion condition × diversion node to have reliable differences ($p < .001$). The cumulative percentage distributions for diversion show the 30-min delay conditions to be much different than the 11- and 18-min delay conditions. Drivers diverted much earlier for the 30-min delay conditions. The 11-min delay condition also shows a lower overall total diversion percentage (about 84 percent) compared with the other three delay conditions (95 to 97 percent).

The overall effect of age and commercial group subject categorization on diversion patterns is summarized in Figure 7b. Chi-squared analysis indicates the differences to be reliable ($p < .001$). The cumulative diversion distribution shows that the young and middle-aged noncommercial drivers are about the same as commercial drivers in their diversion pat-

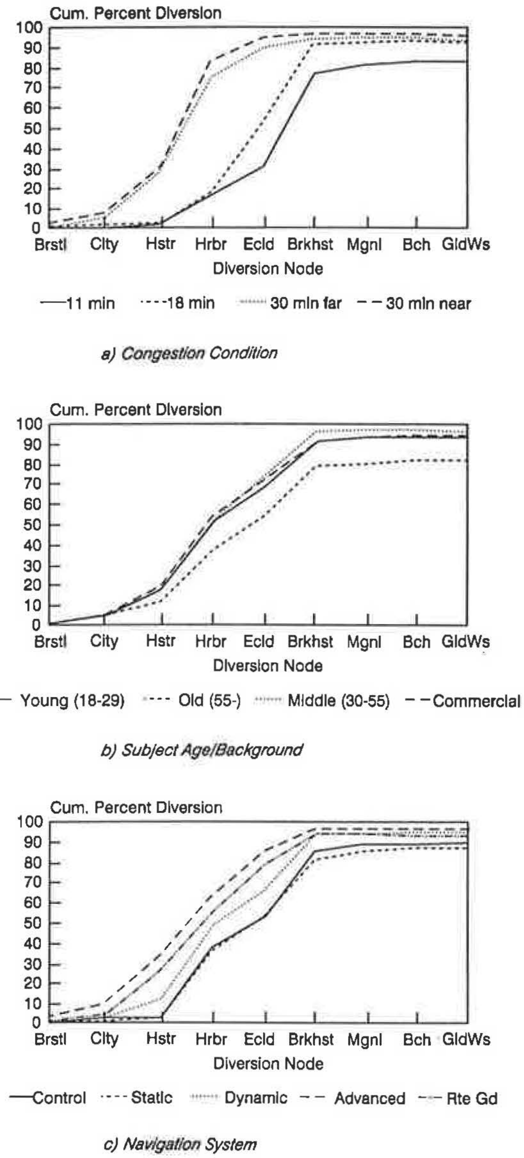


FIGURE 7 Effect of main experimental variables on diversion.

tern, and that the old noncommercial drivers provide the basic difference. The old drivers are more reluctant to divert, with more than three times as many drivers refusing ultimately to divert. Neither route familiarity nor gender had a statistically reliable influence on the diversion results.

The general effect of navigation system on driver diversion was statistically reliable ($p < .001$) and significant as illustrated in Figure 7c. The cumulative distribution shows that the more sophisticated navigation systems allow more anticipation of the congestion condition and ultimately give higher diversion percentages. The advanced system is clearly the best, allowing for the greatest anticipation of the congestion condition and the highest overall diversion rate. The static map condition is basically no different from the control (no navigation system) condition, which is not surprising since it gives no congestion of routing information. The route guidance system gives results similar to the advanced system, the static map is comparable to the control condition, and the dynamic map condition falls somewhere in between.

The advanced and route guidance systems can be compared for compliance with the presented freeway diversion recommendations as summarized in Figure 8. These navigation systems recommended diverting at Euclid for the 11- and 18-min delay conditions and Haster for both 30-min delay conditions. If the subject did not divert at the first recommendation the system recommended diverting at the next exit. To interpret the results, the prevailing speed of the vehicle, the actual level of traffic, the type of navigation system information presented, and subject expectations must be taken into account. For the 11-min delay condition (Figure 8a) the advanced system showed 33 percent diversion at the first recommended exit while the route guidance showed 23 percent diversion. The apparent difference can be explained by noting that the prevailing speeds (Figure 4) were 40 to 50 mph up the point of recommended diversion and only the advanced system subjects received explicit warning of upcoming heavy congestion. The result is a larger number of advanced system subjects diverting before and at the first recommended exit. Generally, the more sophisticated systems produce a greater degree of compliance.

The 18-min delay condition showed about the same 10 percent difference between the advanced and route guidance systems for diversion at the first recommended street (Figure 8b). However, because the prevailing speeds were lower (15 mph), the overall compliance at the recommended node is higher (about 50 percent). The difference between systems may be explained by noting that the advanced system resulted in about 10 percent of subjects diverting at Haster, long before they actually encountered congestion. The cumulative distribution shows equal percentages of subjects diverting by the time they pass Euclid, the recommended exit.

The 30-min delay condition with near destination (Figure 8c) shows 50 percent and 38 percent diversion ratios at Haster, for the advanced and route guidance systems, respectively. Here, the prevailing speeds are relatively high (50 mph in Figure 4), the delay is relatively high and the destination is relatively close. Therefore, the expectation is that drivers will be compliant and divert. The results indicate that the advanced system, which displays the congestion levels and possible alternate routes, may be encouraging more drivers to divert at the first recommended exit than the route guidance system. The redundant verbal messages, the visual coding of traffic, and the textual information of the advanced system give the subject many more cues to upcoming traffic conditions than the simple delay time shown on the route guidance system.

The 30-min delay condition with far destination (Figure 8d) shows only a 5 percent difference between the route guidance and advanced systems at the first recommended exit. The cumulative distributions for these two systems are virtually identical, indicating that the far destination may give the advanced system subjects no greater motivation to divert earlier than the route guidance system subjects. The differences between the advanced and route guidance systems with regard to strict compliance at the first recommended exit may be modified by considering more liberal definitions of compliance. For example, subjects could be considered compliant

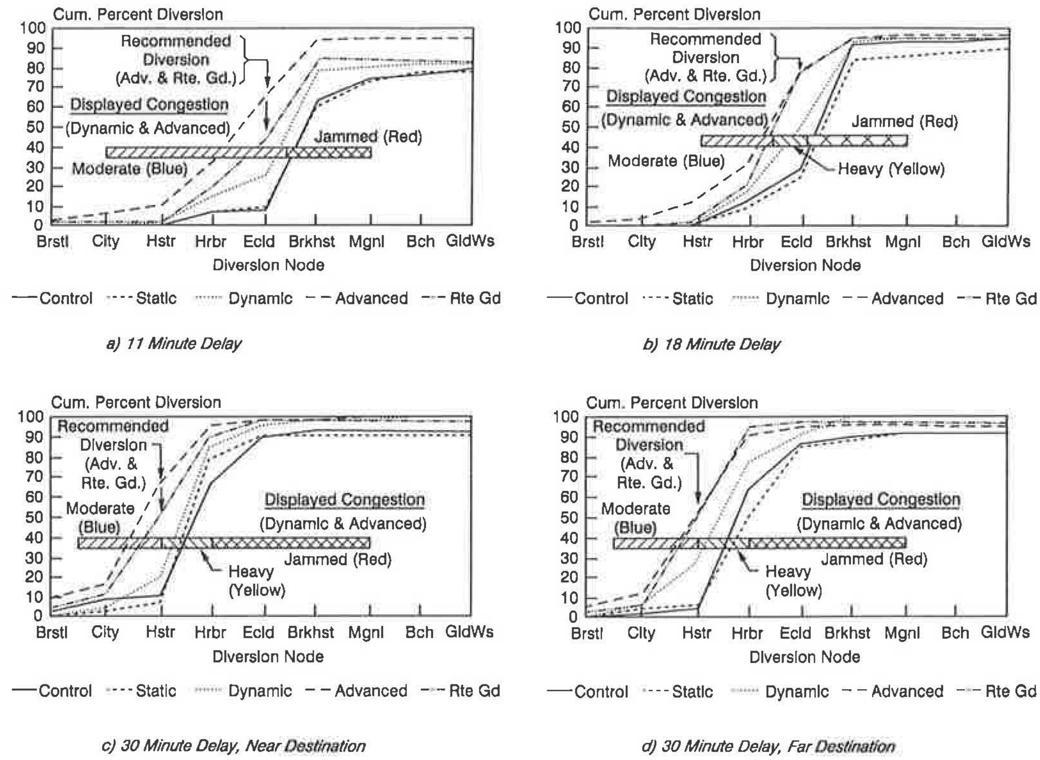


FIGURE 8 Effect of navigation system on diversion distributions.

if they diverted at either the first or second recommended exit.

DISCUSSION

The subject population for this experiment was relatively diverse and probably reasonably representative of typical commuters. Subjects related reasonably well to the simulation and experimental procedures. Diversion response to the congestion conditions as compared to the speed profiles seems quite rational. Of all the subject grouping variables, only age seemed to have any consistent effect on diversion behavior, with the old age group (>55) being more hesitant to divert than younger subjects. Interestingly enough, route familiarity did not seem to have a bearing on route diversion behavior. In this experiment unfamiliar drivers were not any more reluctant to divert than familiar drivers. This could suggest that drivers are comfortable in general with southern California driving conditions so that knowledge of a specific area is not critical. It is also possible that many familiar drivers, although familiar with the Garden Grove Freeway, were not familiar with its environs so that the familiar and unfamiliar populations may not have been significantly different.

Navigation system configuration influenced diversion decisions for all congestion conditions. The static map proved to be no better than the control condition (no navigation system), which is not surprising because the static map gave no feedback on traffic congestion. The advanced and route guidance conditions gave the best results, which is consistent with their navigational capability. The dynamic map system does give feedback on congestion conditions, but offers no route guidance assistance, and so gave performance that was worse than the advanced and route guidance systems but better than the static map and control configurations. This result suggests that a static map system is of marginal help in deciding when to divert from the freeway, although once diverted it would assist in route finding. The route guidance system proved to be nearly as good as the advanced system. For people that have some facility for using maps, a map-based system might be better, again because subsequent to diversion, the map-based system could provide further help in route finding. Computer and display technology is developing at such a rapid rate that a map-based system may not be any more expensive than a route guidance system, and both display formats could be easily provided using the same basic set of information.

The diversion rates for all of the navigation system conditions (including the control or no system condition) were quite high indicating significant aversion to congestion, high compliance with navigation system recommendations, or both. Since the emphasis in this experiment was on diverting to avoid congestion, it is possible that subjects were overly motivated in their diversion response. However, if navigation systems become popular and traffic control management systems are considered to be reliable, it is probable that commuters will have a similarly high motivation for route diversion. For the purposes of subsequent traffic flow analysis of the consequences of driver route diversion, it is possible to scale the cumulative diversion distribution plots to account for lower or higher diversion motivation (e.g., to account for trip purpose, confidence in traffic management system, and so on). Subjects did respond that other conditions, such as trip purpose and certain environmental conditions, would cause lower diversion tendency (or tolerance for longer delays) so a basis does exist for scaling diversion rates. Scaling the cumulative distribution functions by multiplicative factors to vary the effect of subject diversion motivation is suggested. The old-age group effect on the diversion distributions can be considered approximately as a multiplicative effect, and this subject group result should be maintained in further analysis.

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Publication of this paper sponsored by Task Force on Advanced Vehicle and Highway Technologies.