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Human Factors Evaluation of the Volvo Dynaguide and Indikta RBDS-TMC Receivers

This report was distributed to the following:

1. Report No. MN/RC - 96/03U	2.	3. Recipient's Accession No.

4. Title and Subtitle HUMAN FACTORS EVALUATION OF THE VOLVO DYNAGUIDE AND FORD INDIKTA RBDS-TMC RECEIVERS	5. Report Date March 1995
	6.

7. Author(s) Max Burrus, Sara Johnson and Stirling Stackhouse	8. Performing Organization Report No.

9. Performing Organization Name and Address Human Factors Research Laboratory Room 141 Mariucci Arena 1901 4th Street S.E. University of Minnesota Minneapolis MN 55455	10. Project/Task/Work Unit No.
	11. Contract (C) or Grant (G) No. (C) 71274 TOC #123

12. Sponsoring Organization Name and Address Minnesota Department of Transportation 395 John Ireland Boulevard Mail Stop 330 St.Paul Minnesota, 55155	13. Type of Report and Period Covered Final Report 1994-1995
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This report presents the results of a one year comprehensive human factors analysis on the Volvo Dynaguide Mapping system and the Indikta Voice messaging devices supplied by the Minnesota Department of Transportation. RBDS-TMC devices provide a means of transmitting traffic information to motorist using the existing Traffic Management Center's (TMC) resources. This study examined the devices and the means of transmitting information using ergonomic and human factors principles. This study expanded upon the functions of these devices and their ability to transmit information, as well as their integration within the automobile. Further we examined the message assembly software and the resultant messages delivered to the end users. To complete this study we completed a feasibility of on-road study methods, and surveyed the TMC control room staff as to their desires and needs in workplace design and management.

Six tasks were completed with the following findings: Ergonomically, both devices require further refinement to provide a user friendly interface. Linkage analysis and flow charting extracted areas where operation of the device was impeded by design as well as highlighting the many positive features of each device. Simulation study elicited the need for further examination of user preferences and the need to use a wide age-based study group. This was evident in the differing opinions of younger versus older drivers. Assessment of the message assembly program and delivered message content revealed several areas of needed refinement, including beta testing of the outputs of the devices with the message assembly software. Finally, an on-road protocol feasibility study was completed and a workplace assessment was completed at the TMC control room.

17. Document Analysis/Descriptors		18. Availability Statement
Human Factors Evaluation RBDS-TMC (Radio Broadcast Data Systems-Traffic Message Channel)	ITS Ergonomics In-Vehicle Devices	

19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 138	22. Price

Human Factors Evaluation of the Volvo Dynaguide and Ford Indikta RBDS-TMC Receivers

Final Report

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March 1995

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TABLE OF ABBREVIATIONS

C.O. or C.O.s   Crusader Operator (Crusader software data entry person(s))

HFRL   Human Factors Research Laboratory (University of Minnesota)

I.O. or I.O.s   Information Officer(s)

RBDS   Radio Broadcast Data System

RBDS-TMC   Radio Broadcast Data System-Traffic Message Channel

TMC   Traffic Management Center

TP   Traffic Program Annunciator (The letters "TP" appear on receiver screen when radio station regularly broadcast traffic reports)

EXECUTIVE SUMMARY

Introduction

This report is part of the Minnesota Department of Transportation (Mn/DOT) Trilogy project for evaluation of radio based traveler information systems for the Twin Cities (Minneapolis-St. Paul) Metropolitan area. The present study's focus was on two RBDS -TMC (Radio Broadcast Data System - Traffic Message Channel) receivers which could deliver traffic information for personal route planning. Current traffic information was sent to the two RBDS-TMC radio receivers which incorporated unique means of relaying the information to the drivers. The Dynaguide system used an attached LCD screen which displayed a map of the Twin Cities. The incoming traffic information is represented by iconic symbols which appeared over the highway or route effected by the traffic incident. Further, the driver was able to display the text version of the message on the screen if the icon or symbols did not give them sufficient information or if the driver preferred more specific information. The Indikta system used a voice synthesis chip to "speak" the message received from the Traffic Management Center (TMC).

The RBDS-TMC is a technology that allows the transfer of digital information along with a normal F.M. transmission. A data stream was added to the regular F.M. signal as a digital sideband which carried the current traffic information. To provide a useful human factors and ergonomic evaluation of the receivers required an evaluation of performance, public perception of the device, and the components used to assemble and send messages.

Testing and Results

The Human Factors Research Laboratory at the University of Minnesota conducted an evaluation of the Dynaguide and Indikta receivers and all components for message delivery and reception. This evaluation consisted of the following four tasks; (1). A static ergonomic and human factors analysis of all features of the device. (2). An evaluation of device performance in a dynamic driving simulation. This was a direct comparison of the two devices and their abilities to deliver traffic information (3). A subjective evaluation of the receivers by the participants in the studies. (4). An evaluation of the Crusader message assembly software and the message and location databases. This required the assembly and transmission of all possible messages to each device and recording the subsequent displayed or spoken messages. Finally, two additional tasks were undertaken with the first examining the current literature and state of the art in on-road testing with in vehicle devices, and the second a workplace analysis survey at the TMC control room.

Task One was a static evaluation of the devices including task analysis, task design, luminance considerations, and static testing of the two modalities to deliver information to the drivers. We found that the devices were fundamentally well designed with both having well conceived user centered devices. We did find several areas on each device for modification where the goal was to reduce and simplify the steps required of the operator or to improve device performance. Static testing revealed areas for further modification and study.

We recommend that the Dynaguide system needs the following adjustments:

- Elimination of the "TP" function's two step initiation and completion search as well as returning to the previously tuned station when the search was completed and disengaged.
- Reduction of the preset volume level that the radio achieves when a TP search has found a station broadcasting traffic information.
- Improvement of the Dynaguide display screen's selection buttons to increase ease of operation as well as movement of the on/off and luminance buttons from the rear to the front of the screen.
- Guidelines for mounting the Gooseneck system used in this evaluation to reduce the chance of movement of the screen during an accident.

We recommend the following for the Indikta system:

- Redesign of the encoder, where the buttons on the decoder are arranged in a user centered approach.
- Elimination of several menu choices or redundant programming steps in the use of the Indikta's menus for route selection and function operation.
- Use of digitally sampled voice or other higher response voice synthesis to eliminate the drawn out, indistinct vocal tone to the voice chip.

Static testing revealed:

- Icons used by the Dynaguide system need revision to incorporate current, common traffic symbols (using American street signs for example). Subjects tested preferred common symbols as a means of getting quick information on the traffic conditions.
- The Dynaguide display screen suffered little wash-out from luminance considerations.
- The voice synthesis of the Indikta suffered from low inflection deviation and reduced diction and clarity compared to a digital voice sample. The voice technology should be explored and a higher quality voice synthesis method employed to increase the ability of the Indikta to relate clear and understandable messages.

Task Two was a simulation study of both device in the dynamic driving simulator at the Human Factors Research Laboratory (HFRL) at the University of Minnesota. The purpose of this study was to assess how helpful the two RBDS-TMC devices were to users driving on a simulated roadway. We assessed both the ability to receive complex information from the systems (user interaction) and the driver's decision-making based upon the information given (user reaction). The objective was to find out how the public would rate the usefulness and the extent to which they would trust in these radio devices.

A balanced study was run where forty subjects (twenty younger <40 and twenty older >50) drove on a freeway approaching a well know intersection. Drivers were told that they had to reach downtown Minneapolis as quickly as possible. At the intersection they were given the choice of turning onto a major freeway that allow them to reach downtown quickly, or the proceed straight ahead which would increase their travel time significantly. The major freeway that they would turn onto had two states of traffic conditions, free flowing traffic moving at 55 mph or congested with stop and go traffic evident. The drivers used this visual information (free flowing or congested traffic) and compared it to the messages received by the Dynaguide and Indikta devices. The messages could either confirm or contradict their visual observations. To further compare the devices the drivers also received information on a text screen of four lines of twenty-four characters, and from a radio announcer reading the current traffic conditions. Each driver had random presentations of traffic on the highway, used each device independently, and was able to decide based on either their visual or message information. If a driver turned into heavily congested traffic, because the message received by a device stated that traffic was moving well, it was considered a strong indication that the driver trusted the device messages over the visual information presented. Results showed that age of the subject was very important in their trust of the devices. Young subjects most readily believed the Dynaguide and Indikta system while older subjects (over 50) preferred the radio announcer strongly. This showed the expected distrust of gadgets by the older subjects and their reluctance to use technology. Younger subjects preferred the Dynaguide because it was highly visual. Older subjects also preferred the Indikta over the Dynaguide due to its similarity to a radio announcer.

Task Three was a survey of the participants in Task Two. This survey confirmed that the older drivers preferred the radio 3:1 over all other modalities, while the younger subjects preferred the Dynaguide 2:1 over the others. All subjects preferred the text screen the least. Most subjects cited the Dynaguide's map feature as their favorite due to the ability to see the Twin Cities and decide quickly where an incident was occuring. Interestingly, older subjects stated that they trusted the radio announcers the most while younger subjects distrusted them due to personal experiences. Several younger subjects noted an annoyance with the voice quality of the Indikta and the lack of alternative route information from both devices.

Task Four was a complete cataloging of the entire message and location database responses on the Dynaguide and Indikta devices. All possible message were assembled and sent with the message assembly software package and all responses on the two systems were recorded. A copy of the database can be attained from the HFRL.

Task Five was a feasibility study of on-road evaluations. This task required a search of the current literature to determine the state of the art in on-road evaluation of in-vehicle devices. The conclusion from this task was a cost analysis and practicality study of outfitting an on-road vehicle for future in-vehicle device study.

Task Six was a report on a limited workplace analysis study performed at the TMC control room. The study asked for responses on issues in the control room, including noise, workplace, work conditions, operation of the various components used in traffic control, likes and dislikes.

Responses included:

- Reduction of noise through limiting access to the control room by unauthorized persons.
- Establishing guidelines for ramp meter operation to improve consistency.
- Workspace redesign to increase space, ease of operation, sharing resources, and increasing the ability to the view monitors.

HUMAN FACTORS EVALUATION OF THE
VOLVO DYNAGUIDE AND INDIKTA RBDS-TMC RECEIVERS

CHAPTER 1

TASK ONE
EVALUATION OF STATIC MEASURES

INTRODUCTION

Task One was a static evaluation of the Dynaguide and Indikta receivers. First, we conducted a study of the functions that could be performed by the devices. This included descriptions of the ways in which users could avail themselves of these functions. We have analyzed these functions using human factors methods such as link analysis, flow charting, and redesign. This allowed us to apply ergonomic principles to highlight possible revisions that could be useful as either a guideline for design or as a foundation for evaluation of subsequent devices. Further we evaluated the receiver's controls and how they function. For this subtask, we installed the receivers in the lab's simulation vehicle and conducted static evaluations without using simulated driving. These static tests consisted of; (i). Positioning measurements to assess the effects of varying environmental conditions, and (ii). Functional tests using current traffic messages broadcast by the Traffic Management Center (TMC).

The purpose of Task 1 has been divided into two subtasks. In the first subtask (1.1) we use task analysis to assess the functions of the receivers. In the second subtask (1.2) we examine the layout of the device and ways in which users can avail themselves of these functions.

In Task 2, we will conduct dynamic tests of the current systems using the full capability of the driving simulator at the Human Factors Research Laboratory (HFRL) at the University of Minnesota. However, for Task 1 we installed the system in a vehicle and conducted static evaluations without using simulated driving. We needed to see in detail how well users can perform the various functions, and we needed to know how environmental variables, such as luminance and positioning, affected the users and their use of the message delivery systems.

The data we have collected and analyzed in Task 1 will enable the design of efficient simulated driving experiments in Task 2. This data and its analysis have also allowed us to suggest certain design changes that might well add to the functionality of operating the RBDS-TMC devices while driving.

For the sake of consistency we will examine the Task analysis for the Dynaguide system first and then for the entire Indikta system. This will be followed by the static evaluations performed on each device with the Dynaguide being listed first, followed by the Indikta tests.

SUBTASK 1.1 TASK ANALYSIS

INTRODUCTION

The main goal was to use ergonomic and human factors principles to evaluate the functions, the steps required to illicit these functions, and the physical layout of the two receivers. With this type of study ways of improving the user's performance when interacting with the devices were formulated. Applications of these principles are used in formulating instructional procedures, potential problem areas, and action points.

METHODS OF EVALUATION

The first step was for us to practice with and become experienced users of both systems until we felt we thoroughly understood the receivers' operations and capabilities. We then assessed the design of the receivers to evaluate their usefulness. The method we used to accomplish this was task analysis. Through task analysis we established the actions or behaviors individuals must perform to fulfill the requirements of device operation. To study these actions we selected three methods of task analysis based upon Wilson and Corlett's ergonomic methodology. We used linkage analysis, flow charting, and design ergonomics (Wilson & Corlett, 1991).

Linkage analysis is a process of discovering the steps or sequences of movement involved in a single operative procedure. Lines or links were drawn between each step in a sequence. A starting point was established and then all buttons pressed and their related response actions were connected by links. This allowed us to visualize if functionally related controls and displays were physically close to each other, if they required redundant operational steps, or if the progression of steps was in an awkward order. We use linkage analysis to define the complexity of each task and to design simulation studies to bring out the difficulties in operating a device that required this many steps. Finally, it allowed us to develop an overall relationship between the physical elements of the receiver and the tasks to be performed. (See Appendix A).

Flow charting allowed us to analyze the decision making process necessary in operating the device. If a user was given several choices or sequential choices to reach a single goal, it might be diverting the driver's attention away from the primary task of driving (Hancock, et al, 1990). In flow charting we selected the starting point of one of the functions to be performed on the receiver. The chart was then formed by using a method designed by logistic and computer programming specialists, where decisions were answered "Yes or No" with the resultant actions connected by arrows to other decisions until a solution or completion of the task was reached. This allowed the development of a scheme of decision making which was used in simulation study design to determine the levels of complexity of the tasks. (See Appendix B).

SUBTASK 1.2 CONTROL AND FUNCTIONAL ANALYSIS

INTRODUCTION

A summary of the controls and functional requirements for the two receivers are presented here. We will form a critique of all three parts of the Dynaguide system: The receiver, the LCD screen, and the goose neck mounting system. Likewise we will analyze the three components of the Indikta system: the receiver, the decoder, and the display pod. We will use these findings as the basis for:

- Evaluating the static measurements we will make as part of Task 1;
- Recommending those functions which we believe should be implemented and suggesting the means by which existing implementations could be improved;
- Designing the tasks for the driving simulation experiments.

METHODS OF EVALUATION

We used design ergonomics to determine whether the buttons were conveniently spaced, the steps followed a logical order, and the most frequently used buttons were in the easiest places to see and reach. These principles have been well established through military research (U.S. Dept. of Defense, 1981 & 1989). We also used the guidelines collected by Woodson, Tillman, and Tillman in the <u>Human Factors Design Handbook</u> (Woodson et al, 1992) and those used in design of the Automated Highway System by the Honeywell Technology Center. (Burrus, Dewing, & Levitan, 1994). We discussed the design changes necessary for ease of operation and where appropriate provided redesign or functional adaptations.

In order to ease the readability of this report each device will be evaluated completely by task. The Dynaguide receiver and all of its components will be analyzed first using Task 1.1 and Task 1.2, followed by the same evaluation on all components of the Indikta system. In this way we will be able to keep continuity between the components of each system. The static evaluation will follow with the same order of the complete Dynaguide evaluation then the entire Indikta evaluation listed second. In future tasks, we will directly compare the two systems.

DYNAGUIDE RECEIVER

The Volvo Dynaguide receiver resembles an average car radio system with an attached Liquid Crystal Display (LCD) flat screen. By using the extra broadcast capability of the RBDS-TMC and the current information of the Traffic Management Center, this LCD screen can show multiple maps of the Twin Cities with representations of areas of traffic advisories and messages. The screen can show iconic and text representation of the advisories and the accompanying route information. It employs a search function that will interrupt a tape for a traffic announcement or switch radio stations to the one broadcasting advisories. There are three types of symbols or text that can be displayed with each level relaying more and more information to the driver. These three levels of information are; 1) small directional icons (these are further grouped as "arrows" pointing in the traffic incident's direction, "stars" representing stopped traffic, or circles and squares), 2) symbolic icons (construction symbols, stopped traffic, or slippery when wet symbols) and 3) the final level is text consisting of six lines of eighteen character each. These three levels are chosen by control button presses by the driver.

FINDINGS
Subtask 1.1

Linkage diagrams and flow charting revealed a well-conceived design that minimized control presses and located the most common functions closest to the operator. The linkage diagrams pointed out that the "TP" function did not return to a default setting but continued an uninterrupted search until canceled by the user. This search was done in complete silence by the receiver, (it also shut off the tape player during TP search), which was frustrating to users who wanted to hear something during this potentially long search.

- The "TP" search function required an initiation and cancellation step. It should be one button press. The default should be that if a station was not found during one complete search through the entire radio frequency bandwidth the search should end.
- Return users to the station previously heard or to the playback device when a search does not locate a station with traffic messages. Currently a canceled TP search stops at whatever radio frequency the search has reached during the progression of the search. This means an empty band frequency can be found.
- The search function did not allow a search to be completed in the background. In other words, the search was not done by the radio while the operator continued to listen to their choice of music.
- Several steps were required to operate the device. It was critical to safe operation that users did all tasks on the receiver or their screens before beginning to drive.

Subtask 1.2

I. Dynaguide RBDS Receiver
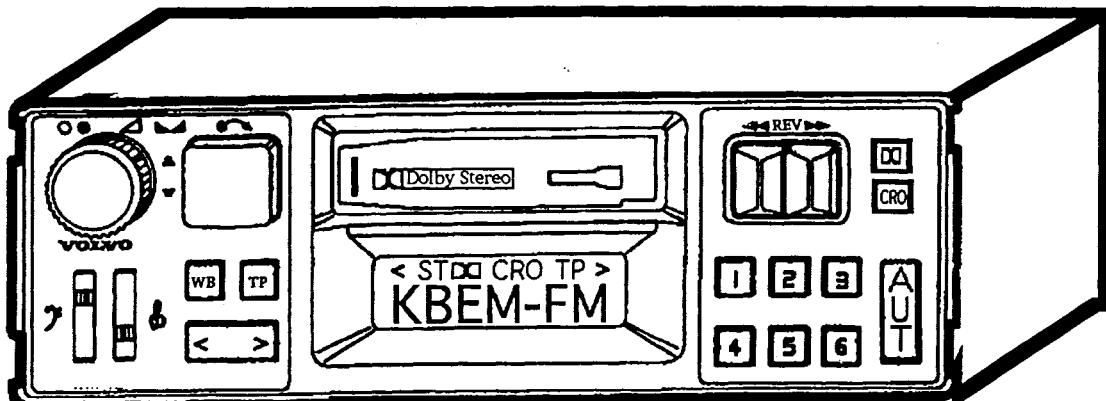
Figure 1. *Dynaguide receiver.*

FUNCTION OF CONTROLS

1) Volume Knob: Controls the Power On/Off and Volume, Left/Right and Front/Back speaker operation. This is well designed, incorporating the power On/Off with the volume, and normal conventions of a radio for adjusting stereo sound.

2) A small equalizer is provided underneath the volume knob that contains two draw bars, one for "Treble" and one for "Bass" control. Unfortunately, the label uses musical notation (Treble clef and Bass clef), instead of more standardized Bass and Treble labels. This will lead to slight confusion but the user will quickly learn the icons' meaning.

3) The Dynaguide has normal tape function buttons in proximity to the tape player including; Eject, Forward and Reverse Tape, Dolby N.R., and Chrome Oxide tape equalization. Tape direction is indicated on text screen by < > symbols. These are well labeled and appear on the text screen when active.

4) A "WB" button switches between FM labeled "U" and AM labeled "M" and an Unknown band labeled "L" that displays a frequency range of 153-279MHz. This will be very confusing, at first, to novice users. Conventional labeling of FM and AM will eliminate this problem.

5) A "TP" button is next to the WB button that sets the radio to search for RBDS-TMC-stations currently broadcasting the TP program code. This means they are currently broadcasting traffic information. The radio will stop its search when it reaches the first RBDS-TMC radio station currently broadcasting traffic information or a "TP" station code. If the tape player is engaged it will stop the tape when a station has been reached. If the radio is playing, it will switch to the radio frequency of the station broadcasting traffic information.

6) A tuning/station search button is provided next to the text screen. This is an excellent design; placing the control button next to the function provided.

7) Six programmable channel selector buttons are provided and follow normal radio conventions.

8) An "AUT" button is next to the channel selectors that allow scanning to the next station of higher frequency. Pressing AUT several times switches among the last four stations found. This appears to be a redundant and unnecessary control button. The normal operation of the station tuner that allows station scanning performs this function.

9) An eight character text screen is located under the tape player which displays the frequency of the radio and frequency band. With RBDS-TMC broadcasts the station call letters can be displayed. This text screen does not display any message information. Unlike the Indikta text screen, this display is reserved for station information. Although, displaying the station's call letters is a desired function for the station broadcasting the signal.

Above the letters are icons for tape direction, the letters "ST" for Stereo broadcast, The Dolby symbol when activated, The letters "CHO" for Chrome tape when activated and "TP" for traffic program search when activated, or when the current station broadcasts traffic information on RBDS-TMC.

OPERATIONAL FUNCTIONS

There are several concurrent functions of the radio, its text screen, and tape playing that provide unique radio operations. One feature of both receivers is the ability to search for RBDS stations or signals. The receivers can scan the frequency band and tune into only those stations broadcasting RBDS. This operates in much the same way as the seek or scan function on a normal radio. This will allow drivers to scan the stations to search for traffic information.

It is important to examine this function of the receivers as this will be operated by the user while driving. In the Dynaguide receiver this function is handled by the "TP" button, which searches through all FM frequencies attempting to locate RBDS-TMC signals.

This function provides two areas of interest to users: the TP button and it's function, and the ability to display "TP" when a station tuned into is broadcasting RBDS-TMC. The function allows searching by RBDS-TMC, while the indication of a station's ability to broadcast RBDS-TMC allows users to glance down and know that a station will provide messages.

1) The TP button: When the TP button is pressed the following text appear on the eight character display of the receiver:

<div style="text-align: center;">

```
┌─────────────┐
│ <        TP │
│   SEARCH    │
└─────────────┘
```

The tape will continue to play or the radio will stop while the test screen displays "search"

```
┌─────────────┐
│ <        TP │
│  TRAF INF   │
└─────────────┘
```

When the radio finds an RDS station broadcasting traffic information it switches to that station and the text appears on the screen.

```
┌─────────────┐
│ <        TP │
│  KBEM -FM   │
└─────────────┘
```

If the TP button is pressed again, the radio will remain on the RDS station found or the tape player will resume operation.

</div>

Figure 2. *TP control presses and associated screens of text.*

Once the TP button is engaged the search can not be stopped unless TP is pressed again. If the radio is on and TP is selected, it will search until it finds an RBDS-TMC station. If a radio channel select button is pressed during a TP search, the radio will tune to that station for one second and then return to the search mode. The search can only be disengaged by pressing the TP button again. Once a search is initiated it will not stop, even if there are no stations broadcasting TP. It continues to look for TP stations. If an RBDS-TMC traffic station is found the radio's volume is adjusted to a preset (loud) level. When TP is pressed again the volume is returned to the previous level. When returning to normal radio play if the TP button was used and it found a station, when disengaging the TP button it does not return to the previously tuned station. It will remain on the RBDS station that was found during the search. It does not return (or remember) what station you had previously tuned in.

2) Likewise, when a tape is playing the radio text screen continues to display the radio station previously tuned. This is an excellent feature that allows the user to scan down at the radio when a tape is playing and observe whether or not they are tuned into a station where the TP indicator light is lit (indicating it is broadcasting traffic messages to the Dynaguide).

RECOMMENDATIONS

A possible redesign is included in Appendix C. that follows these recommendations.

- The Equalizer is used solely to control treble and bass, a simple two adjustment function. Change the Equalizer control to the volume button control or provide a two position switch. The volume knob could be pushed in and turned for treble and pulled out and turned for bass.

- Eliminate the slide bar controls that dominate the side of the radio closest to the driver. It is imperative to place the most frequently used or most important radio controls near the driver. (Department of the Defense, 1989).

- The controls for the tape player are properly placed next to it and are relatively easy to read and use. The eject button is enormous compared to the other buttons, and that is a good feature because a driver does not need to look down at the radio to eject the tape. To balance the radio make the TP button larger or the band selection button larger. We would prefer a large TP button.

- The bandwidth button "WB" should be re-labeled AM/FM to increase ease of use. The text screen should display AM or FM for quick sight confirmation. Further the "L" band should be eliminated as it is unnecessary for current U.S.A. broadcast frequencies.

- The channel select and scan buttons are very small and should be replaced with a larger, easier to operate buttons. The position of this button is excellent and could even be moved closer to the driver enhancing its proximity as one of the most frequently used controls.

- The AUT button should be eliminated as it serves no purpose that can not be matched by pressing the channel select button.

- The TP button should be enlarged and placed underneath the volume knob. It is the most important button for RBDS-TMC operation.

- The TP function should establish a default that if no stations are found broadcasting traffic information in one complete pass of all frequencies then it should revert to normal mode. Currently it requires two button presses to initiate and stop the TP function when no stations are broadcasting RBDS-TMC. Users will be annoyed by having to start and stop this search when it continuously cycles through all stations.

- Reduce the preset volume level for the TP located stations. To do this either allow the current radio volume to be the same as the TP function or find a quieter value. This loud volume has a startle effect at its present setting.

II. Volvo Dynaguide Screen
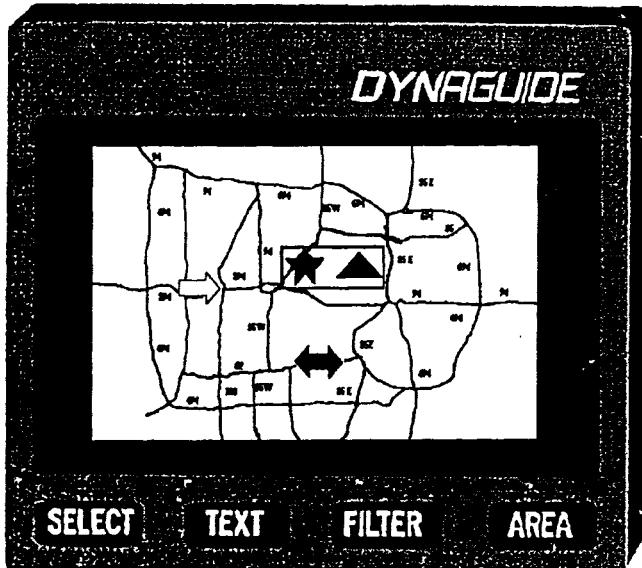
Figure 3. *Dynaguide screen with maps and icons.*

The screen is well designed to ensure easy operation. It will be examined in two parts: its controls, and its map and text screen.

SELECTOR BUTTONS

There are four selector buttons on the screen:

Select Button: This allows the user to switch between the various icons displayed on the current map (stars, arrows, circles or boxes). When an icon is selected the icon is highlighted, boxed and an accompanying icon symbol appears (a triangle sign with a graphic icon). Similar to Figure 4.

Figure 4. *Selected icon.*

Once this icon is selected, pushing the Text Button will display the accompanying explanatory text. The Dynaguide screen can display six lines of text of 18 characters each.

Text Button: This toggles between the selected icon and the white letters on black text screen.

Filter Button: This allows the user to switch between a map that shows all currently displayed icons, and a screen that only shows the RED colored icons (which presumably pose the greatest hazards and delays for the driver). The map screen displays a RED border above and below the map when the Filter button is activated. When deactivated there is no red highlighting border on the maps.

Area Button: The area button currently allows scanning among three successive screens, which are displayed as:

1. Full Twin Cities Map
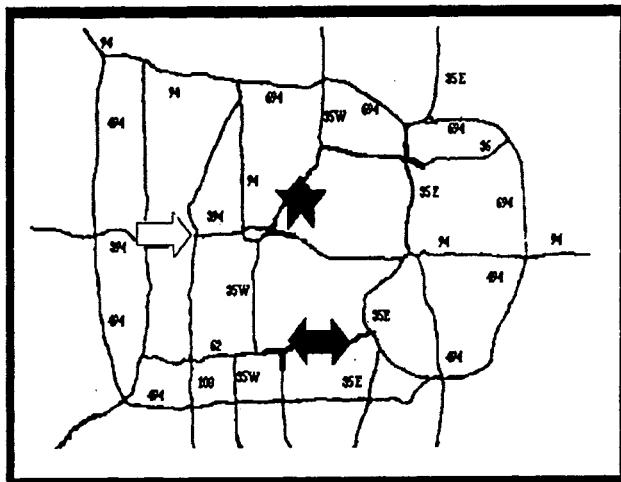
Figure 5. *Full twin cities map from Dynaguide screen.*

2. Upper North-West Quadrant of Minneapolis.
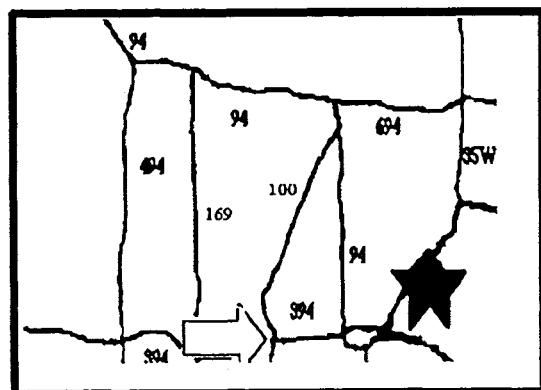
Figure 6. *Upper quadrant map from Dynaguide screen.*

3. Lower South-West Quadrant of Minneapolis.
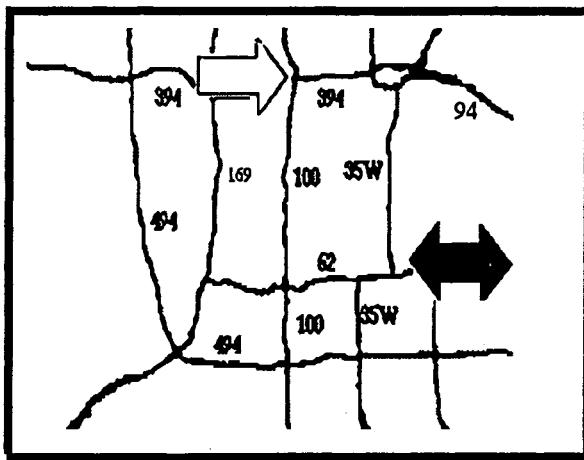
Figure 7. *Lower quadrant map from Dynaguide screen.*

This allows the user to select only the area traveled in the Twin Cities. A user can select the lower quadrant if that is the only area to be traveled. The #2 and #3 screens provide more detailed maps of the roads than the general large area map. It takes a few seconds between each screen to update the arrows and icons.

SCREEN

The Map and Text screens have an on/off switch and a luminance adjustment (brightness control) on the back of the display pod. These are located on the right hand side when looking straight at the display screen. The operator must reach around the back of the Dynaguide screen to turn the screen on and off and to adjust the contrast in the cases where glare or bright light interferes with reading text screens or the map.

The Maps are full color with Green representing land, Blue bodies of water, Black all highways and roads, Red hazard, accident, or major problems, and Yellow cautions and general traffic information and problems. The maps are back lit and can be adjusted if glare is a problem. The Text screen is a black background with white text letters. This screen can handle six lines of eighteen characters.

If the selected icon is a Red icon, it is boxed and highlighted in Red, if it is a Yellow icon it is boxed and highlighted in Yellow. These colors are determined by the message encoder software that assigns priority to messages based on their severity. This assignment function will be examined in Chapter Four.

RECOMMENDATIONS

Selector Buttons -

The controls are well positioned and labeled, with the most frequently used buttons next to the driver. The user will most likely press the select button first, then the text button, and then perhaps filter or area. We assume that drivers will have used the filter and area buttons before starting their journey and will not need to use them (or infrequently use them) while traveling.

- Move the on/off switch and luminance controls to the front or at least to the driver's side of the Dynaguide screen. This will eliminate reaching around the device.
- The buttons take an excessive amount of force to operate (operators may need to hold on to the back the LCD screen while they push the buttons to have enough force to activate the controls). Reduce the force necessary to activate the buttons to a level that allows industrial usage and maintenance while permitting easy operation.
- Selection of the icons is time consuming when there are several icons present. Encourage users to first select the area of the Twin Cities that they are traveling, and then select between the icons present.
- The default setting for filtering is all icons (not red only). This is the best default as users will be forced to see all icons first and can make the choice if they want to filter. If this system used defaults where red filtering is the main setting, the user might forget that the filter is on, there might be several yellow icons present, and the driver might believe that there are no icons at all.
- Increase the detail of the quadrant maps to include more trunk roads and labeling of roads. Currently the maps are hard to distinguish without a common frame of reference. If a driver switches the area button it often takes a few moments to become oriented as to which quadrant and what highways are present.

Screen -

The use of a full color GUI display is a strong point. Color contrast is at least as important as luminance contrast for recognition tasks. However, there is a large number of Red/Green and Blue/Green color-blind people (7.9 percent of all persons in the United States) who will not be able to use this system with this configuration. (Braunwald, 1987).

- Increase the luminance contrast of the display to compensate for bright lighting conditions and night time driving.
- Develop a white/black/gray contrast system that could be toggled or installed for color vision impaired persons.

III. "Gooseneck" mounting system
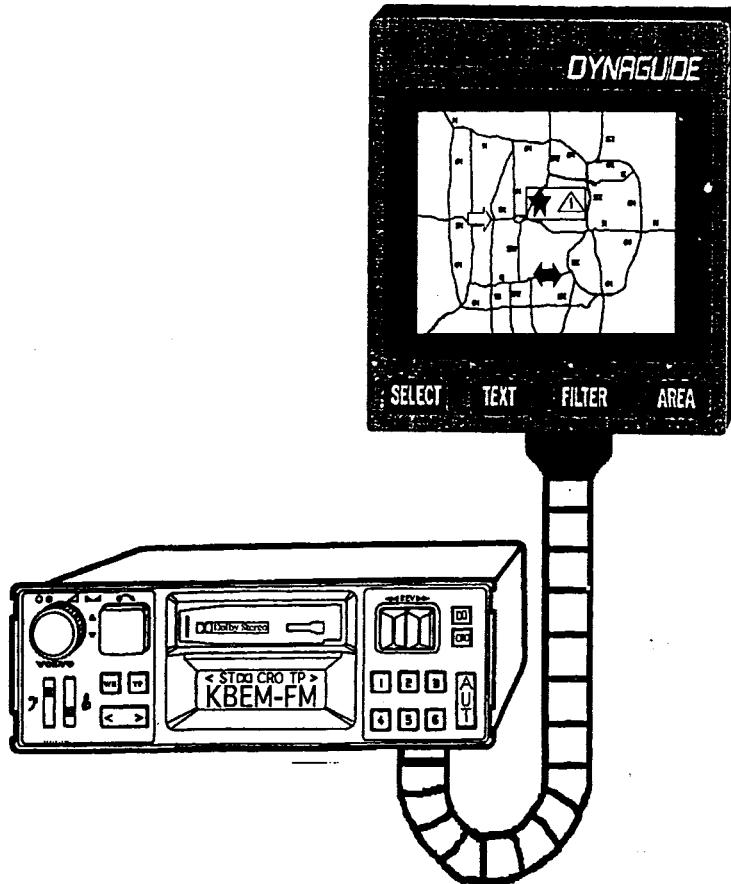
Figure 8. *The Dynaguide system with the screen attached by a gooseneck mounting.*

The gooseneck mounting of the Dynaguide screen provides the user with the ability to adjust the screen to the height and distance that provides the easiest access and readability. However, even at a level for normal viewing, the gooseneck can not be adjusted enough to eliminate all of the washout caused by ambient light during day driving. The screen can also get in the way of other dashboard controls. The screen is easily moved out of the way, but this diverts the driver's attention from the road for a longer time, especially if they must search for the dashboard controls they want.

Two problems arise because of the gooseneck design. The first problem is that during a trip that is bumpy or during extended driving, the gooseneck can drift downward and the driver must reposition it while driving.

The second problem relates to safety during an accident. The entire heavy screen would recoil onto the passenger who is driven towards the screen during a head on collision, or it would be driven back onto a passenger's leg or body if the car was rear ended.

RECOMMENDATIONS

- Mount the gooseneck at a higher position on the dash so that the screen can not move from the dash. This would limit the ability to adjust the screen for each driver, but would allow limited positioning (swiveling) while at the same time enhancing safety.
- Use a second bracket system that holds the Gooseneck in relative position but allows for full movement to either side or back and forth. This would serve as a restraint in case of accident. (See Figure 9.)
- Mount the LCD screen directly to the dash board.

DYNAGUIDE

DASH BOARD

MOUNTING
BRACKET

SELECT   TEXT   FILTER   AREA
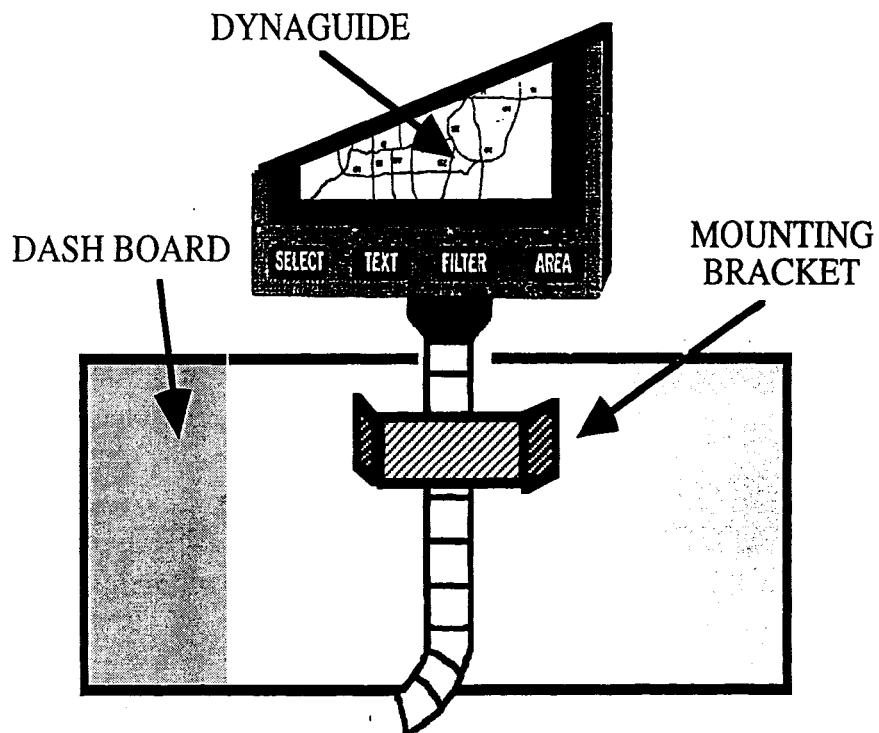
Figure 9. *Gooseneck mounting system with extra bracket attached high on the dash board.*

- A major disadvantage to this extra bracket mounting is that the view through the windshield becomes obscured as the screen is held higher and cannot be adjusted downward.

INDIKTA DECODER

The Indikta receiver is a Kenwood™ RDS radio system with an attached display pod for text messages and a programmable decoder with a programmed voice card. The traffic messages are decoded and relayed to the driver using synthesized voice messages. These voice messages will interrupt the radio broadcast or playback device being used by the driver. The display pod can be used to read the message if the voice message was either shut off or not comprehended entirely, or if the driver wants verification of the message received. The decoder allows the driver to pre-program their route or trip to be undertaken and it will then filter out all messages except those that are pertinent to the driver's programmed trip.

FINDINGS
Subtask 1.1

The Indikta decoder was the only portion of the device that required task analysis. The display pod was restricted to showing the messages being broadcast, and operated whenever a message was sent. The user only looked at the pod when messages were received to clarify or verify message content. As such, the pod was always on and constantly displayed whatever the decoder sent; messages, programming information (it showed what the small screen on the decoder showed), or No Message To Display. The radio portion was a European Kenwood™ RDS Receiver/CD player. This receiver included an RDS scan button that searched the entire FM bandwidth looking for stations broadcasting RBDS-TMC signals. In this way it operated exactly like a normal radio scan button, with the exception of searching for RBDS-TMC signals. The radio portion did not require further task analysis except for indication of the single step of pressing the RDS button to scan for RBDS-TMC stations.

The area of greatest importance was, therefore, the Indikta decoder and its programming functions, known as the "Set-up Mode."
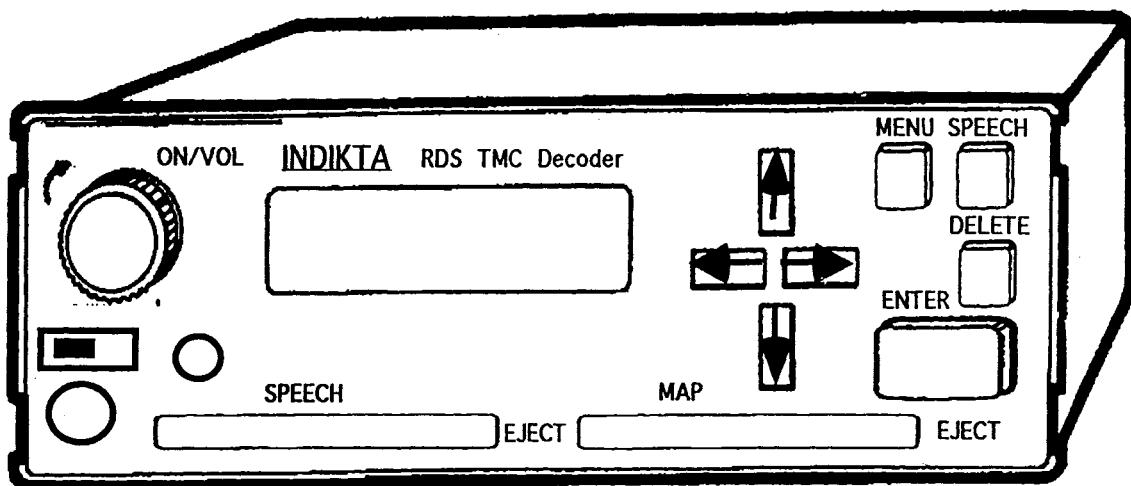
Figure 10. *Indikta Decoder*

Linkage diagrams and flow charts of the setup mode functions revealed that sequenced control presses were within close proximity to each other. It was important that controls that operate in sequence with each other, should be close to one another. (Woodson, Tillman, & Tillman, 1992). The most commonly used buttons were located farthest from the driver. Normally, this would be considered a violation of ergonomic principles which specify that controls that were used most frequently should be the closest and most accessible to the driver. (Department of the Defense, 1989).

However, the Indikta manual specified that programming of the decoder was to be done only when the car was parked, and never during driving. Therefore, these buttons were only used in the "setup mode" that was done with the car out of gear. Linkage diagrams and flow charts revealed that set-up mode functions were extremely complex. Some of the setup mode functions could require many control presses. For example, selecting a route and then naming the route, required a minimum of ten control presses and a maximum of four hundred and ninety-five control presses. The arrow buttons and the enter button were used most frequently for selecting a route function and they were correctly placed together at the far side of the decoder.

There was also repetition in button presses in the submenus for configuration. Many trials were required to become proficient in these programming steps. The manual was required for drivers to learn most programming steps, with several attempts needed until proficiency was learned. (See Appendix A & B, for diagrams and flow charts).

Subtask 1.2

A brief description follows of how to access and use the Indikta decoder's functions. We point out problems or ergonomic principle violations in this operation. We will examine the set-up mode and three of the submenus; Configure, Select Route, Current Messages. See Appendix D for menu choices.

SET-UP MODE

Turning on the Indikta decoder causes the decoder to display: "NO MESSAGE TO DISPLAY". Pressing the MENU button switches between the "normal mode" and the "setup mode". When the MENU button is pressed a configuration screen appears with four submenu selections:

Table 1. *Menu choices displayed after first menu button press.*

> 1) **CONFIGURE**
> 2) **SELECT ROUTE**
> 3) **SELECT EVENTS**
> 4) **CURRENT MESSAGES**

Pressing the down arrow moves the cursor to each submenu. Pressing ENTER selects the submenu that has the arrow next to it. Within each submenu mode there are other options to choose. Pressing the ENTER button switches between each option on that line and using the up and down arrow buttons moves the cursor to each option. The MENU button is pressed to exit the current submenu mode and will return to "normal mode". In order to get back to the four submenu selections in "setup mode", the MENU button must be pressed again. Since, all four submenu selections should be programmed before returning to "normal mode", an "EXIT" button could be used to exit the submenus, instead of the MENU button. "EXIT" could be employed in a way consistent with this usage throughout the control procedures.

CONFIGURE SUBMENU

In the configure submenu mode there are six options:

Table 2. *Menu choices displayed after selecting Configure.*

>   1) SOUND
>   2) PRIORITY
>   3) BRIGHTNESS
>   4) SCROLL
>   5) UNDELETE
>   6) RESET

Using the up and down arrow buttons moves the cursor to each option and pressing the ENTER button toggles between each option on the line. Of the six options in the Configure submenu mode Sound and Reset will be discussed, as the other four are toggle on/off functions and operate efficiently.

Sound Option

Sound can be toggled between ON and OFF, by pressing the ENTER button. This is a poor choice of legends since ENTER means neither ON nor OFF. However, this function is redundant and does not need to be included in the "setup mode" because sound can also be turned ON and OFF by pressing the SPEECH button while in "normal mode". If sound is not chosen the default is ON, therefore if sound is not wanted the SPEECH button can be pressed while in "normal mode". Having a choice in the Menus to turn sound off, encourages turning the sound off, which defeats the purpose of the receiver. The Sound selection option is the Indikta receiver's main benefit. It can voice traffic messages. If speech is turned off the receiver is of little value to the traveler. Eliminating this step will also speed the "setup mode" operations.

Reset Option

The Reset option provides the following options:

Table 3. *Menu choices during the reset option.*

SET SOUND TO ON
SET SCROLL TO OFF
DELETES ALL ROUTE FILTERS AND THEIR NAMES
DELETES THE REGION FILTER
DESELECTS ROUTE AND REGION FILTERING
ENABLES ALL EVENT TYPES
DELETES ALL RECEIVED MESSAGES

These options are unnecessary because of the following:

- SOUND ON, SCROLL OFF and EVENT TYPES ALL are the default setups. These defaults can be changed in other areas of the configuration menus discussed earlier.
- DELETES and DEFAULTS can be done using other buttons that are already provided. Having the Reset option is redundant and could, therefore, be eliminated from the list of options.

SELECT ROUTE SUBMENU

The Select Route submenu allows the user to select a Route or Region, so that only messages affecting these routes or regions are displayed and spoken. The Route choice allows the user to choose a new route or an already pre-programmed route.

Route

When "new" route is chosen a list of roads appears. These roads are selected by pressing up and down with the arrow buttons until the desired road appears. On this screen the cursor arrows are reversed from the usual conventions. Moving the cursor down should be represented by an arrow that is pointed down, while upward movement should be represented by arrows or indicators that point upward. (See Table 4).

Table 4. *Cursor arrows when choosing roads.*

Task	Conventional	Indikta
Move Cursor Up	↑	< > ∨
Move Cursor Down	↓	∧ < >

To select an already existing route, the down arrow is used to move the cursor through the list and then ENTER or MENU is pressed.

After a route is chosen (new or pre-programmed) a star (*) will appear next to the chosen route. To get rid of the chosen route while in "setup mode", the DELETE button can be pressed. The user's manual for the Indikta states that if you wish to enable the filters at a later time, enter the menu again and press delete so that the stars reappear. There are two problems with this;

1.) The DELETE button should be used for deleting not re-selecting. These are contradictory functions and

2.) We tried this function and it does not work. Pressing the DELETE button does not re-enable the route filter. The driver must go through the route choosing steps again.

- To enable a route the ENTER button should be pressed, to be consistent with the other submenu options. The DELETE button should only be used to delete a selected route.

Route Data

The Route data consists of roads within the Twin Cities Metro area. Some of the roads have the name of a city after them (See Table 5). The context of the city name with respect to routes, is not explained, which could cause confusion for the user when choosing routes.

Table 5. *A part of the road list, used to select routes.*

I35	
I35E,	**ST. PAUL**
I35W,	**MINNEAPOLIS**
I394	
I494,	**MINNEAPOLIS**
I694,	**ST. PAUL**
I90	
I94	
I94,	**MINNEAPOLIS**

It is correct to list I-35E with Saint Paul, and likewise I-35W with Minneapolis. It is incorrect, however, to list I-694 as Saint Paul and I-494 as Minneapolis, when these roads cross the boundaries of both cities. I-694 at the Junction to I-94 and East River Road, is no where near St. Paul. Likewise the junction of I-694 and I-494 at I-94 on the east side of the city is far removed from Minneapolis.

Region

As discussed previously in Table 4, the confusing cursor arrows are also used when choosing the regions.
- These cursor arrows should be changed to a single cursor arrow. This will allow for consistency throughout all of the submenus and the selection process when programming the decoder.

CURRENT MESSAGES SUBMENU

The Current Messages submenu allows the user to: 1) automatically hear all messages in sequence that have been broadcast to the receiver when scrolling is turned on (SCROLL=ON) or 2) when scroll is turned to the off position (SCROLL=OFF) the up and down arrow buttons can be used to travel through the list of received messages and the receiver will speak each message.

In SCROLL=ON, if a new or updated message is sent, the receiver will jump to that message, speak it and then continue on to the next message. It will not return to the previous message being spoken before the new message appeared.

In SCROLL=OFF, the most recent message is placed at the end of the list. This is a waste of time for the user, since the most current message is usually the most pertinent to the driver. The most current message should go to the top of the list. Also, the down arrow will take the user to the end of the message list and will not go any further. This should be changed to allow the cursor to wrap around to the top of the list.

RECOMMENDATIONS

- A single cursor arrow (➢), like those used in the rest of the program should be used with all choices displayed.
- Limit the control presses in the Select Route Submenu to using ENTER since the MENU button does not apply in this context. The ENTER button should select the pre-programmed route, in order to keep consistency with the rest of the submenu options. MENU is used to toggle between "setup mode" and "normal mode" and does not need another function.
- Only one button should select the pre-programmed route, so that simplicity is maintained.
- Have the legends on the buttons be consistent with the action they perform throughout the entire system.
- The legends on the buttons should perform the actions related to their meaning.
- Add an "EXIT" button to be used at least in the "setup mode" to exit submenus.
- The sound option in the Configure submenu does not need to be included.
- Eliminate the reset option in the Configure submenu. This option is redundant.
- Change the arrow configuration in the Route submenu to be a one arrow cursor.
- The ENTER button should be the only button to be pressed to select the routes. The MENU button should not be used for this function.
- The DELETE button should only be used to delete messages when in "normal mode". DELETE does not need to be used in "setup mode".

- In the Route submenu use the ENTER button to select the route and the DELETE button to delete the chosen message.
- In the Route submenu either explain what the city name next to the road name represents or get rid of the city name reference.
- In the Current message submenu when SCROLL=ON, the scrolling should return to the message it was on before the new message interrupted the scroll.
- In the Current message submenu, when SCROLL=OFF, the most current message should go to the top of the list and the cursor arrow should wrap to the top or bottom of list.

FUNCTIONS OF CONTROLS
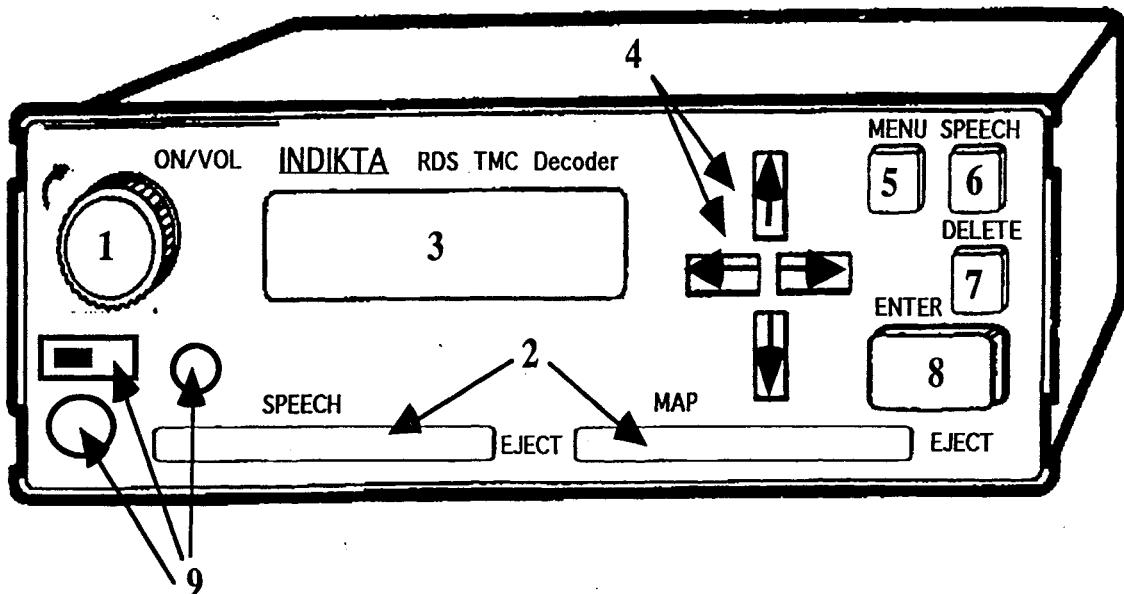
Figure 11. *Labeled controls to identify functions.*

1) The "ON/VOL" knob, is located in the upper left corner of the encoder and controls the power ON/OFF and volume. Turning the knob clockwise turns the encoder on and the volume is increased by continuing to turn the knob clockwise.

2) Two memory card slots, along the bottom of the encoder box, labeled SPEECH and MAP, are for speech and map memory cards. These memory cards enable the encoder to have the speech option and to know the roads that are in the area. Both the speech and map cards have been consolidated onto one memory card. This card is currently placed in the "map card" slot.

3) A display screen is located to the right of the ON/VOL knob. This displays text messages.

4) Four buttons with arrow legends are located to the right of the display screen. These buttons are used for configuring the system.

5) A MENU button is next to the arrow buttons. ˉ This button switches between "setup mode" and "normal mode". It also is used as a NO response in the Route option mode.

6) A SPEECH button is next to the MENU button, in the upper right corner. This button switches the spoken messages on and off. This is done in the "normal mode" setting.

7) A DELETE button is below the SPEECH button. Delete operates in two ways:

1) In "normal mode", it removes messages shown on the display from the current message list, and

2) In "setup mode", DELETE turns on or off a selected route or region filter that is designated by a star appearing next to the item selected.

8) The ENTER button is below the "delete" button, in the lower right corner of the encoder. This button has four functions: 1) It can select a submenu, 2) it will select/de-select an option in a sub menu, designated by a star next to the item selected, 3) it can act as a "YES" response in some menus, and 4) when in "normal mode", it repeats the spoken message on the display.

9) There are two icons below the ON/VOL knob that do not have any functions.

RECOMMENDATIONS

- All buttons should have the same consistent functions throughout all menus and submenus. This will eliminate the "modes" confusion and the button legend confusion.
- The MENU and ENTER buttons are used most frequently when using "setup mode". Thus, these buttons should be larger and the same size. The enter button is already big enough and the menu button should equal this.
- The arrow buttons should be separated, so the up and down functions are next to each other and the left and right arrow buttons are below them. This will keep the two functions separate and minimize accidental activation. Also, the up and down buttons are used more frequently than the left and right buttons.
- The ENTER, up and down arrows, left and right arrows, and the new button "EXIT", should be placed in the right corner of the encoder. These buttons are used in "setup mode", which is done before driving, and thus do not need to be close to the driver.
- The display screen on the receiver should be moved slightly to the right and enlarged so that it can be easily seen when sitting in the driver seat. The top row of words on the screen is obscured, when sitting in the driver's seat.
- The SPEECH and DELETE buttons may be used while driving and should be moved to the left side of the encoder next to the ON/VOL knob. Also, these buttons should be larger. They should be the same size as the MENU and ENTER buttons. The DELETE button should be distanced from the other buttons so that accidental activation does not happen. The MENU button can be placed on the left side, it is only pushed to toggle between "normal mode" and "setup mode", which is to be done before the car is moving.
- The DELETE button should be used for deleting messages only.

- Since the speech and map cards have been consolidated, only one slot is needed. This slot can be moved to the middle of the bottom of the encoder. The slot could be renamed "memory".

- The eject button next to this slot is currently at the same level as the card when the card is in place making operation difficult. Increase the height of the eject button to extend just past the height of the inserted card. When a card is inserted the eject button should pop out to a length just beyond the inserted card to make for easy removal.

- The names above the buttons and the arrows should light when the encoder is activated. This will allow better visibility of the controls and thus less accidental activation.

- A white line should be added to the ON/VOL knob, so the operator can see the volume level on the encoder.

- When in "setup mode", speech is called sound. The selection in the "setup mode" should be called speech so there is consistency between the button and the selection.

- The ENTER button should be renamed the "RETURN" button, because this is what it is called in the "setup mode" or ENTER should be used in the instructions not RETURN.

- The icons below the "ON/VOL" button should be taken off the encoder. Headsets should never be used while driving, and there is no other reason to need headsets to use this receiver. The box icon has no logical meaning and is not needed.

- Add another button called "REPEAT", that when pressed in "normal mode" will repeat the spoken message on the display. The ENTER button performs this function now.

- The buttons are hard to push and should be made easier to press. The following dimensions for controls are suggested: (Department of the Defense, 1982 & 1989).

1) Knobs:

   optimum height >= 0.75 inches and the optimum diameter 1.0 to 2.0 inches.

2) Push buttons:

   a) Without gloves; Diameter minimum 0.4 inches, maximum 0.75 inches; Resistance minimum 0.06 LB/f, maximum 2.5 LB/f; and Displacement minimum 0.1 inch, maximum 0.25 inches.

   b) With gloves; Diameter minimum 0.5 inch, no maximum given; Resistance not given; Displacement minimum 0.6 inches, maximum 0.77 inches.

DISPLAY POD
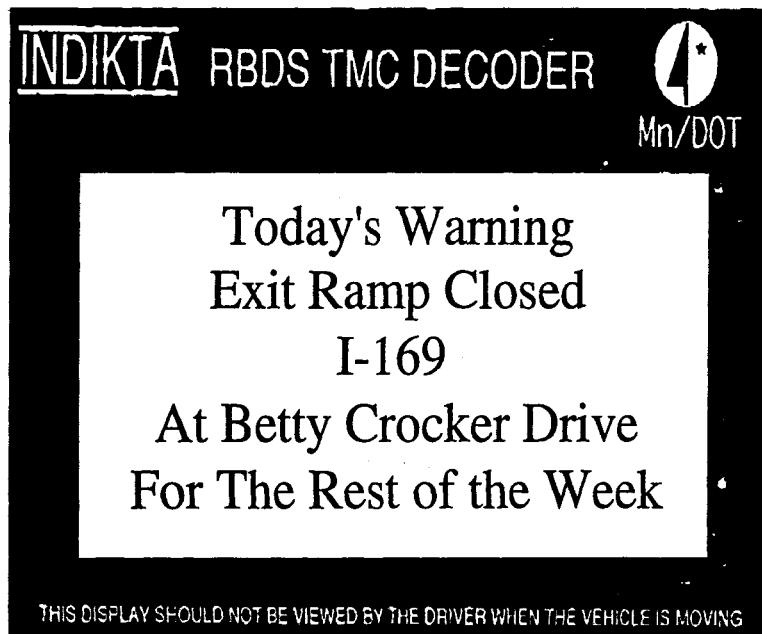
Figure 12. *Indikta display pod.*

The display pod is to be used in "setup mode" only. On the display it says, "This Display should not be viewed by the driver when the vehicle is moving." However, the display pod is not next to the controls, thus users must move their gazes up and down from the encoder and the controls to the display pod. The display pod may not be needed if the screen on the decoder were bigger, allowing more characters to be displayed at once and seen during "setup mode".

Another suggestion to reduce the chance of drivers looking at the display pod and using "setup mode" while driving, is to have the display pod automatically turn off when the car is moving or when the car leaves "park" or neutral. The "setup mode" should only be available when the car is in park, as was done in the PATHFINDER and other IVHS projects.

RECOMMENDATIONS
- Make the screen on the Indikta decoder bigger, so the display pod is not needed.
- If the display pod is needed, then have the display pod turn off when the car is moving or make the "setup mode" only available when the car is in park.

SPEECH

The speech mechanism is an unique device for relating traffic incidents but the clarity of the speech synthesis chip in this prototype is of poor quality. A clearer speech mechanism should be examined. The speech has a deep drawn out timbre which causes drop out of resonant consonants such as; L's, N's, R's and W's, while reducing clarity of vowel sounds such as; A Ã Æ, AU, O, Õ, and U. To increase user satisfaction, it becomes highly important for the voice to be as clear and non-irritating as possible. Further, in order to accommodate the large range of users, including the elderly, diction and clarity must take high priority.

RECOMMENDATIONS

- Employ digital sound sampling at a rate of 11 Hz or higher sampling rate. Music synthesis has had great success with vocal music styling sampled at 22 Hz, to the extent that during tape mastering and when using laser disc or CD quality sound, there is no perceivable difference between actual human voice characteristics and sampled human voice. Digital sound spectral analysis has presented no significant differences between a human voice through an amplification system and a digital sampled voice at the same volume level. (Keyboard Magazine, 1993).

- Increase the memory of the speech card or use separate speech and roadway cards. The speech card needs to have the memory space available to contain more individual data sound bits, less compressed data, or higher sampling rate digital voice data. Unfortunately, the higher the sampling rate the more memory space that is needed for each individual word or phrase. The long list of Crusader software assembly messages requires an enormous amount of speech data. By using a high sampling rate the individual memory card would be filled completely by the speech data leaving no space for map data. This might be preferable as there is another memory card slot that could be used for the map information. The voice quality would more than double with this higher quality samples. There would be a tradeoff between high quality sound and the available memory, but as a prototype system, it should be easy to add memory with a larger capacity RAM card or internal SIMM or PROM chips.

- Increase the quality of the sound to near CD or laser disc specifications handling 96 dB or higher. This will ensure proper volume, and compatibility with the receiver and playback devices as the speech will use the same audio standard as the receiver.

STATIC EVALUATION

DYNAGUIDE ICONS
Task 1. Evaluation of current symbols and icons.

INTRODUCTION

The icons used by the Crusader software serve the most important feature of the Dynaguide interface; the level of information transferred. A user of this system may look at the map and see if any icons appear on their route. Depending on whether the icon is on their route, they can decide between taking the route or an alternate. The Dynaguide screen, therefore, allows selectivity of messages based on the icons present. These messages are presented in three levels. The first are simple colored stars and arrows which represent direction of and/or stopped traffic (See Figure 13). The user can assess at a glance whether or not any icons are on their planned route, on their direction of travel, and then have an approximate estimation as to the severity of traffic. This requires careful use of the colors of the icons where red would indicate severe or urgent problems while yellow would indicate incidents but of a lesser nature. Trust in the system will be based upon whether the icons give accurate information and the first step is that the red icons must indicate a greater threat than yellow to the user's driving plans.

SYMBOL	COLOR	MEANING *
★	Red	Stopped Traffic
☆	Yellow	Incident
⬌	Red	Stop & Go Traffic Two Ways
➡	Red	Stop & Go Traffic One Way
⬅⮕	Yellow	Slowed Traffic Two Ways
⮕	Yellow	Slowed Traffic One Way
◯	Yellow	Information Available
▬	Red Yellow	Regional Message Available

* Examples of Possible Meanings

Figure 13. *First level of symbols (icons) and their meanings.*

The next level is when an icon on your route is selected using the selection button. The arrow or star is highlighted and a second icon appears that resembles a street sign with an associated picture. This picture might be a road worker to represent construction, or the symbol for slippery pavement (Figure 14).
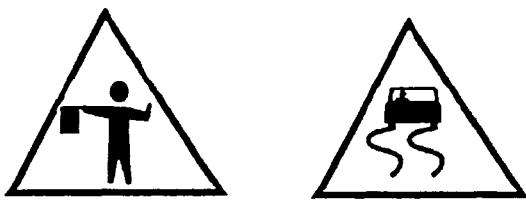
Figure 14. *An example of icons.*

Using this second level the driver can quickly assess the type of incident or traffic situation. They have looked at their route, observed an arrow on one of the roads, selected the arrow, and they receive a second icon which tells them the type of incident or traffic message. This is an excellent method because the driver can quickly receive the main information they need to know;

(i) What problems exist on my route?

(ii) What is the severity of the problem?

(iii) What direction is the problem? Will I be effected?

(iv) What type of problem is it?

This may be enough information for a driver to change their planned trip.

Finally, the text button can be pressed and a text message will be displayed giving all relevant information on the icons selected. This is limited only by the maximum number of characters that can be displayed on one screen (64). The Dynaguide screen will display the entire text message on one screen eliminating the need to scroll through any successive screens. This allows quicker reading than a scrolled system. The font used by the text messages is large and easily read when the screen is mounted in its normal position. The driver does not need to readjust the screen to read the text screens.

We assessed the effectiveness of the icons presented. Currently there are only eight second level icons which need to convey "universal meaning" to users in the United States. (Figure 15). This implies that anyone driving a car must be able to glance at an icon and understand it's implicit meaning. Although people will learn whatever symbol is presented it is necessary to provide them with an easy to comprehend icon to allow them to quickly understand the implied meaning. (Woodson, Tillman, & Tillman, 1992).

An assessment was carried out on novice users who have never seen the Dynaguide symbols which we compare to street signs and other made-up icons.
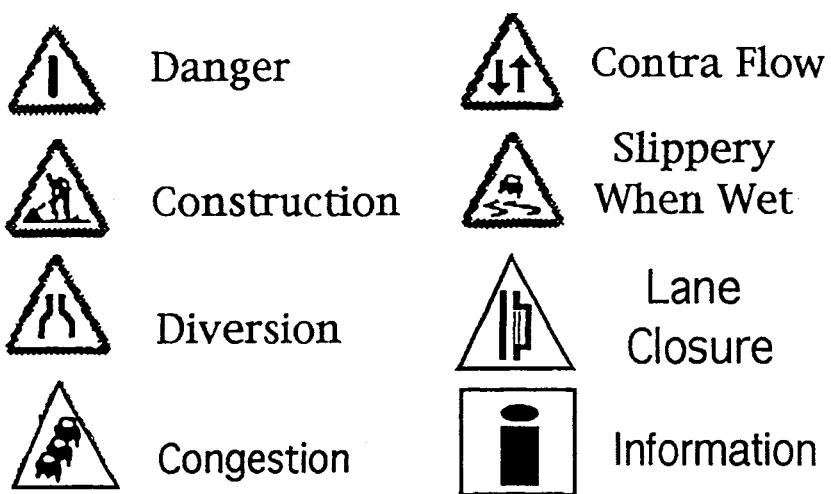
Figure 15. *Dynaguide second stage icons and their implied meanings.*

METHODS OF EVALUATION

We designed a questionnaire using six of the above secondary icons intermixed with common U.S. street signs/symbols and several control (made-up) icons. The purpose of this study was to survey which icons were the easiest to understand and comprehend. For example, we used the international symbol for construction which resembles a flag person as well as showing the icon from the Dynaguide which shows a man digging. We assessed what meaning people gave to the various samples which were presented to them in random order. A copy of the questionnaire is included as Appendix E.

We surveyed forty-nine participants ranging in age from 19 - 63, where 20 were female and 29 were male. The participants were given the instructions and quizzes and were allowed to ask questions of the experimenter. There was no time limit. Participants were instructed to answer all questions even if it meant attempting to describe the icon rather than giving a one word answer.

FINDINGS

The U.S. street sign icons were favored at least by a 2:1 margin over the Dynaguide symbols. Several Dynaguide icons were labeled with incorrect meanings which matched more common U.S. interpretations. The following icons were intended for direct comparison with each other and are listed by their intended meaning and percentages of correct responses found.

Construction

 96%
U.S.

 68%
Dynaguide

Comments: U.S. - Flagman (1) / Dynaguide - Digging man (6), Shoveling person, (1).

Danger or warning

 21%
Made-up

 0%
Dynaguide

 12.5%
Made-up
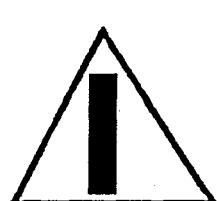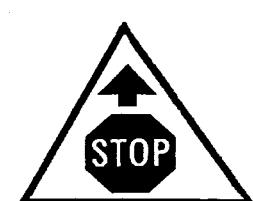
Comments: Made-up - Exclamation (23), Stop ahead (40), Hey (1) / Dynaguide - Black line (20), Don't know (21), Road ahead (1), Drive straight (2).

Diversion Dynaguide

 0%

Comments: Divided highway ends (43), Divide traffic ends (4), Merge (2).

Contra flow Dynaguide
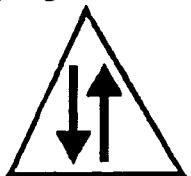
 0%

Comments: Two way traffic (45), No divider (1).

Slippery Pavement   Dynaguide
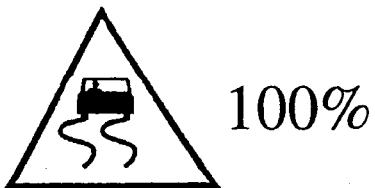
100%

Accident Dynaguide symbol not used due to Swedish words on icon.

77.5%
Made-up

42.5%
Made-up

Comments: Two cars - Don't know (3), Car/truck - Tow away zone or Towing (24).

Merge U.S. Merging Arrows and Lane Merge - 100%
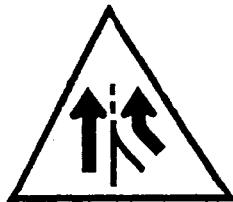
100%

Lane Narrows U.S. Lanes narrowing - 87.5%
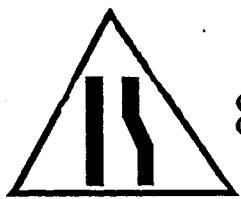
87.5%

Comments: Lane ends.

All Others (Made up icons) Less than 10% correct identification with intended meaning.

RECOMMENDATIONS

- The Dynaguide system needs to be revised to use American street signs and common symbols to be most effective. (Flagman versus digging man)

- The use of the following Dynaguide symbols; Danger, Accident, Contra Flow, need to be reexamined and possibly replaced by an exclamation or stop sign, a picture representing an accident, and two-way traffic or other symbols.

- Further study of icons should be completed and the Dynaguide system modified to support more than the current eight icons before the large operational test. Several studies have been completed on the relevance of iconic characters, Woodson, Tillman, and Tillman in their book *Human Factors Design Handbook*, devote a chapter on street signs, icons, and text representations reviewing all current literature. (See also; Woodson, et al, 1992; Potter, Kroll, & Harris, 1979; Clark & Clark, 1968; Oldfield & Wingfield, 1965; Dewar, 1993; Konz, 1990; Woodson & Conover, 1964; and McCormick, & Sanders, 1982).

LUMINANCE
Task 2. Luminance considerations of the Dynaguide screen display.

INTRODUCTION

The back lighted LCD display and its brightness/contrast controls allow for usage of the Dynaguide screen within the parameters set up by the Illuminating Engineering Society for bright light and dim light situations. (See IES, 1994). The device is very effective at low or night time illumination. The buttons and labels on the receiver are also well lit and easy to read. The system was tested to determine washout caused by moving the device on its gooseneck mounting system. The gooseneck permits optimal viewing angles and adjustability but may need to be constrained due to accident concerns raised earlier. It was decided to determine the maximum "X", "Y", and "Z" coordinate movements that cause washout of the Dynaguide screen. (See Figure 16). Drivers will experience an effect termed parallax when the viewing angle of an LCD screen is at an angle greater than the effective focal length of the screen. In other words, if a screen is angled away from a viewer the screen develops it own natural glare or washout due to the nature of back lighted displays. When the Dynaguide device is turned in a coordinate plane its green screen will turn white rendering the map on the screen un-readable. Participants in this study adjusted the Dynaguide screen to where they believed their maximum viewing position was attained. The experimenter then turned the Screen along its coordinates and asked the driver to state when wash-out started and when the display become entirely un-readable.
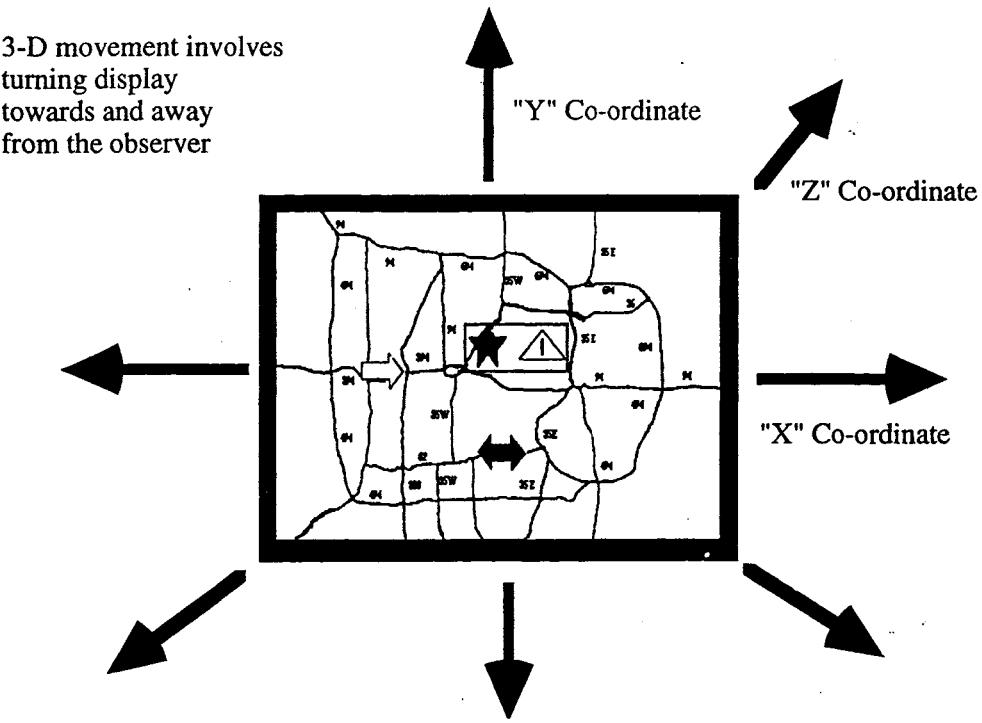
Figure 16. *Screen movement in all planes to determine parallax limits.*
This involves adjusting the device forward and back, up and down,
and side to side to determine three dimensional limits.

FINDINGS

In testing ten subjects, five male and five female with an experimenter moving the device and another using a protractor to measure angular displacement, the following results were obtained. In movements of the screen in the X-axis (side to side) it required a 40° rotation away and a 32.7° towards the driver to start wash-out, and 39° for complete washout towards the driver. All participants reported that the physical edge of the screen began blocking out the screen before wash-out was complete for the away measurements. This means that when turning away from the driver the screen is never completely washed-out. The actual sides of the Dynaguide casing box begin blocking the screen before it became un-readable.

With movements in the Y-axis (up and down) the limits of the possible movement because of the gooseneck were never exceeded by the parallax present. You may only move the Dynaguide screen a small amount up and down when held in place by braces on the dash board. A driver would never experience parallax except in the rare case of when the entire gooseneck and screen were pulled down. This would not be done when a driver is trying to read the

Finally, movements in the "Z" coordinate are also limited by the gooseneck and no data was significant for wash-out due to movement in this plane.

RESULTS

These results indicated that the Dynaguide screen does not suffer from parallax viewing problems when mounted correctly. It was important to have the device securely mounted on the gooseneck and the gooseneck securely mounted to the dash board to eliminate any shifting during driving. The results suggested that only the X-axis movement, which would be the most common form of adjustment, suffered from wash-out when moving towards the driver, with an area of un-readability at its extremes. From this data we could be assured of efficient operation of the device and a confidence in the mounting system's ability to keep the device in optimum viewing angle. The user in all cases was able to adjust the Dynaguide screen for best viewing with the current mounting system. Individual preference was not compromised by wash-out or glare caused by the mounting of the system.

SPEECH SYNTHESIS QUALITY
Task 1. Quantification of the speech synthesis quality of the Indikta device.

INTRODUCTION

Due to the speech synthesis card's lack of clarity we decided to quantify the voice synthesis by comparing an Indikta phrase to the same phrase spoken by five participants. To accomplish this we used a digital sound sampler to record the Indikta device and the five participants stating the phrase: "Warning; Off Ramp Closed; I-169; At Betty Crocker Drive; Situation Is Expected To Continue Through The Rest Of The Week." This was accomplished by attaching a microphone to a Ensoniq™ Digital Sampling Keyboard SQ-1, and sampling the Indikta radio and participants at a 44Hz sampling rate (The highest fidelity sampling rate available which compares to a CD quality with a 98 dB clarity). Sampling involves recording the voices and the Indikta with an analog microphone and converting the recorded sound into digital data. These digital samples represent a better standard of measure than conventional analog sound and can be manipulated through the use of computer enhancement or analyzed using any of the commercially available wave form analysis software packages. The five participants that we sampled were instructed to use as clear of pronunciation and diction as possible when repeating the phrase.

These digital samples were entered into a Macintosh computer with an Audio Board attachment and analyzed by a program called SoundEdit™. This program produced a schematic representation of the spoken sentence along a continuos time graph (See Figure 17).

Warning   Off   Ramp   Closed   At   Betty Crocker Drive   Sit.,

Intensity   Sampling Level   "X" Axis Value   Inflection Deviation
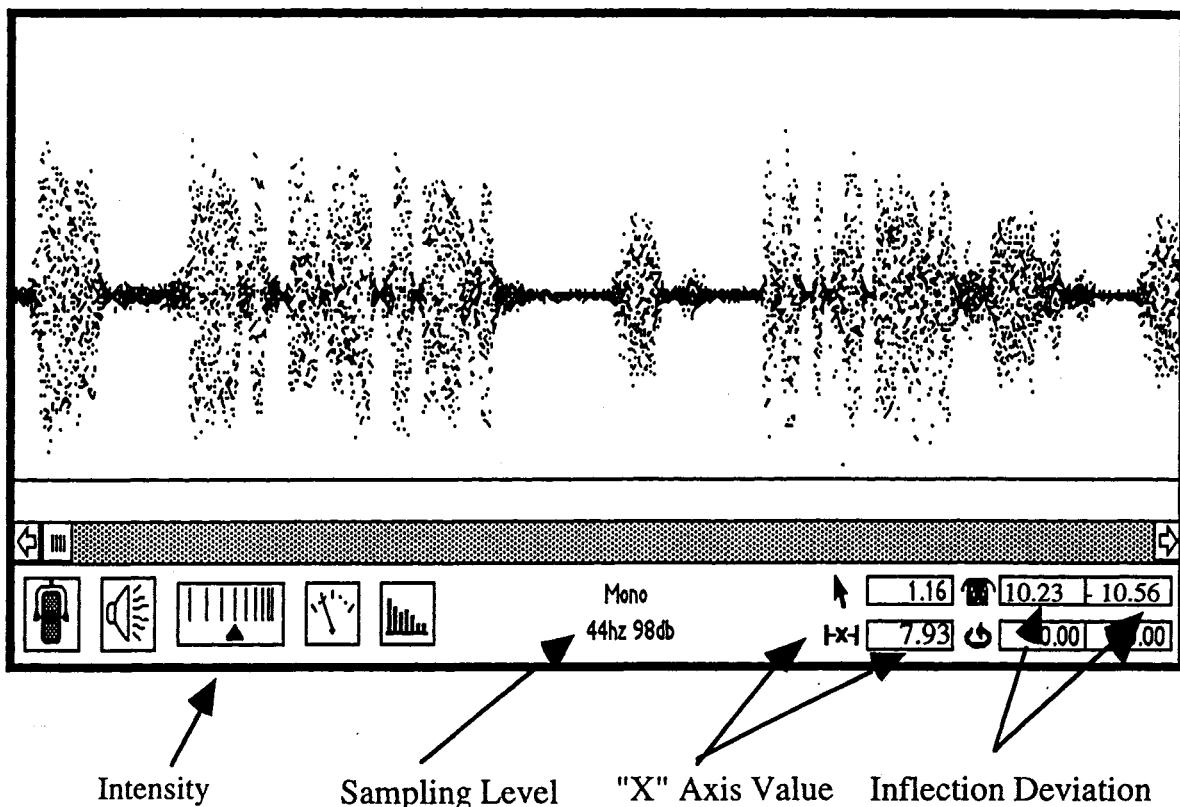
Figure 17. *SoundEdit™ schematic representation of speech pattern.*

This schematic can be visually analyzed to note difference in the voice print, as well as quantifying the inflection deviation on a scale of 20.00 to (-)20.00. μHz. The closer the positive and negative values are to zero the worse the inflection and diction between syllables. This software estimates an "X" axis range value, which indicates the average length of start and stoppage of distinct diction. The larger the X value the more drawn out the speech and diction.

RESULTS

All voice patterns have different inflections and therefore, different schematic patterns. The five participants have non-recognizable differences with visual inspection and their inflection values ranged from a high of 10.23 to (-)10.56 to a low of 7.66 to (-) 5.11. The Indikta ranged from 0.58 to (-)0.58. The participants have a low "X" range from 12.21 to 4.62 while the Indikta is 28.18. This shows how drawn out the vowels and consonants are from the voice chip in the Indikta. The Indikta pattern is highly varied compared to the five participants. (See Figure 18). This figure clearly shows the clear diction of the participants, compared to the fuzzy, muddled tone of the Indikta voice. Both graphs depict the two syllables of the word, Warning.

- 40 -
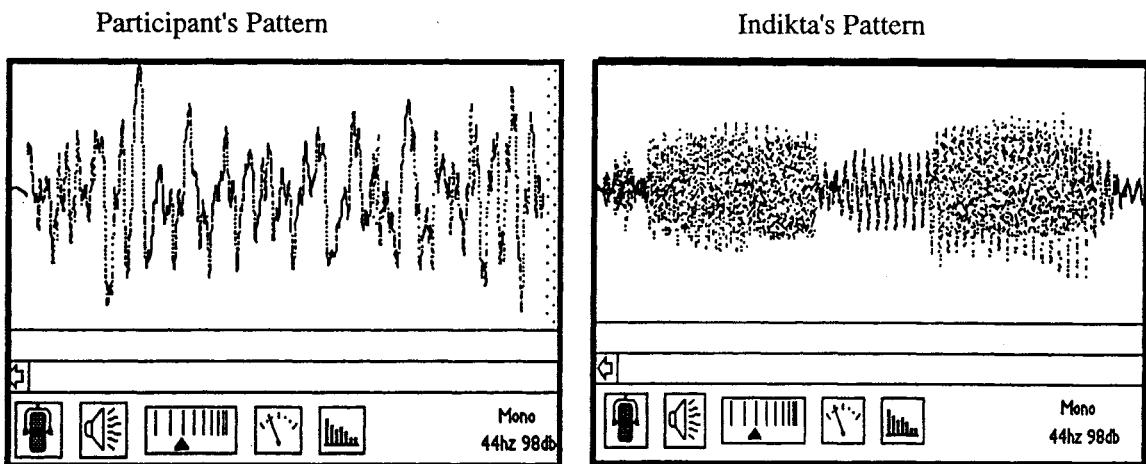
Figure 18. *Schematic representations of the word "Warning" spoken by participant #3 and the Indikta receiver. Participant #3 was representative of all five participants.*
Note: This is a microanalysis of a simple two syllable word.
The inflections present are greatly magnified by this process and are presented as visual confirmation of two different inflection and diction types.

A complete example is shown in Figure 19 where the sentences spoken by participant #1 were compared directly to the Indikta's pattern. All five participants had no recognizable differences between their speech pattern when analyzed as an entire phrase. Micro analysis provides minute differences in inflection and diction but they were unnoticeable unless examined syllable by syllable. We were only interested in the gross changes noticeable when comparing the Indikta to all five participants.

Note that what was spoken was at a different spot in each graph, we wished only to show the difference in inflection and pattern over the same range and intensity settings for both graphs.

The reader should also note that the inflection difference range was much higher for the participants than the Indikta. Quantitatively, the participants are over 10 times higher in inflection difference levels. This could be compared to the difference of a whisper to normal voice, or in this case, normal inflection with careful diction; to slightly muddled and indistinct speech.

It was interesting that creating these high fidelity digital samples of the participant's voices, required 65K (Kilobytes) of memory space for each sample. At that size a 512K RAM card could not hold more than ten messages. It would require an internal memory card, compression/ decompression software or at least two 1 MB (megabyte) cards to hold enough speech data to handle the entire message assembly list in the Crusader software.

Indikta
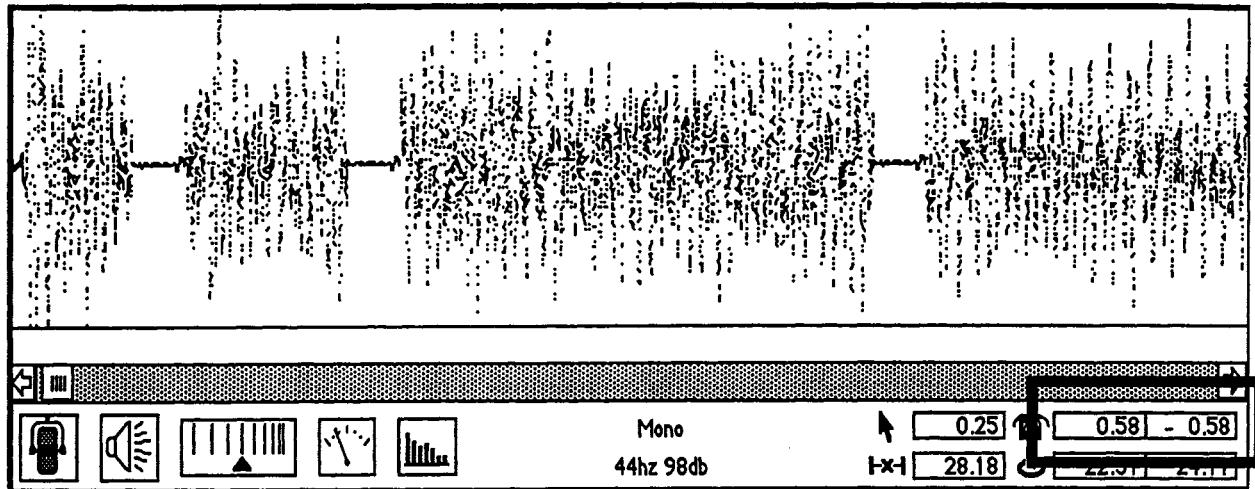
Participant #1
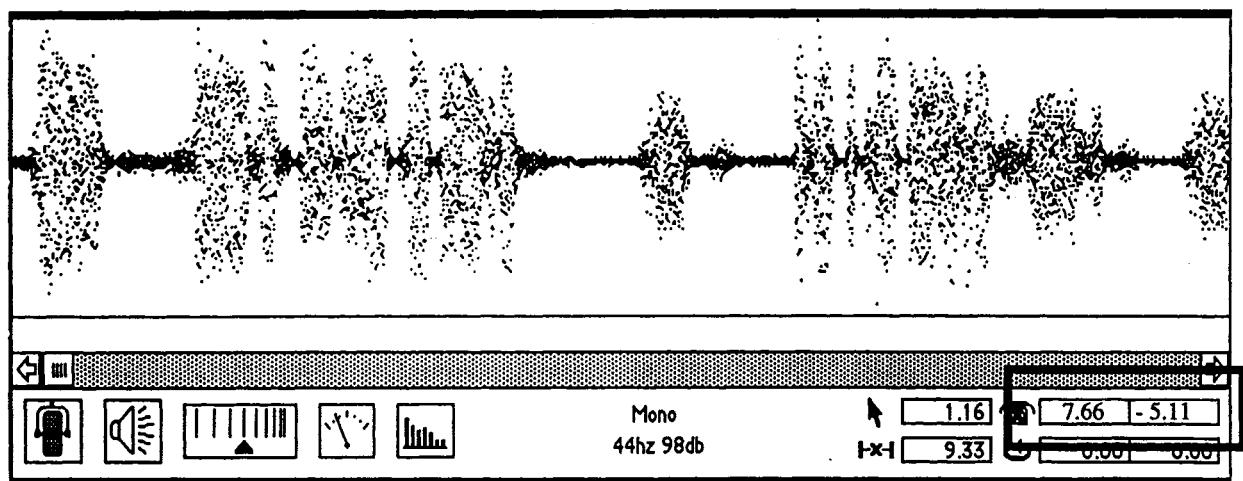
Figure 19. *Comparison of Indikta to Participant #1*
Note the differences in inflection and diction patterns,
and the value of the inflection difference value.

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CHAPTER 2

TASK TWO
SIMULATION STUDY OF THE DYNAGUIDE AND INDIKTA DEVICES AS MESSAGE DELIVERY SYSTEMS

INTRODUCTION:

The purpose of Task Two's simulation study was divided into two areas of interest. One part was to measure the effectiveness of sending messages to participants who were driving in the dynamic simulator, and secondly, to vary the message content and driving scenarios to provide a measure of how the participants reacted to and interacted with the devices. This was accomplished by assembling identical messages with the Crusader software package to send to each of the devices while participants were driving in the dynamic driving simulator. We decided to determined what measures would provide a means of assessing trust in the two devices as a function of driving conditions and message content. We measured if what a driver saw visually, congestion or free flowing traffic, could be over-ridden by receiving a message contradicting or confirming this visual information. If a driver saw congestion on the road ahead, and was told "no traffic problems exist", which type of information (their own eyes or technology) did they believe? If they observe that traffic is flowing freely and they are told that there is congestion ahead, how do they react?

METHODS OF EVALUATION

The Dynamic Driving Simulator

In the simulator we can measure the driver's reaction to information received from the devices. The driving simulator allows an experimenter to be seated behind the simulation vehicle where they can view the driving worlds and record the driver's reactions to the conditions presented. We can, therefore, see how a participant reacts to a message about congestion or an accident ahead. They might brake or decelerate, they might turn off on an alternate route, or they might choose to ignore the message based on what they visualize of the road conditions ahead or based on their personal experiences. To do this we employed the dynamic driving simulator at the HFRL (see Figure 20.) and used a simulated driving world. This driving world can be programmed to include up to three driving segments ranging from single lane roadway to two lane roadway with bi-directional traffic flow to a three lane single traffic flow highway. This allows the experimenter to use a variety of driving scenarios to assess the participant's driving behavior and decision making process.
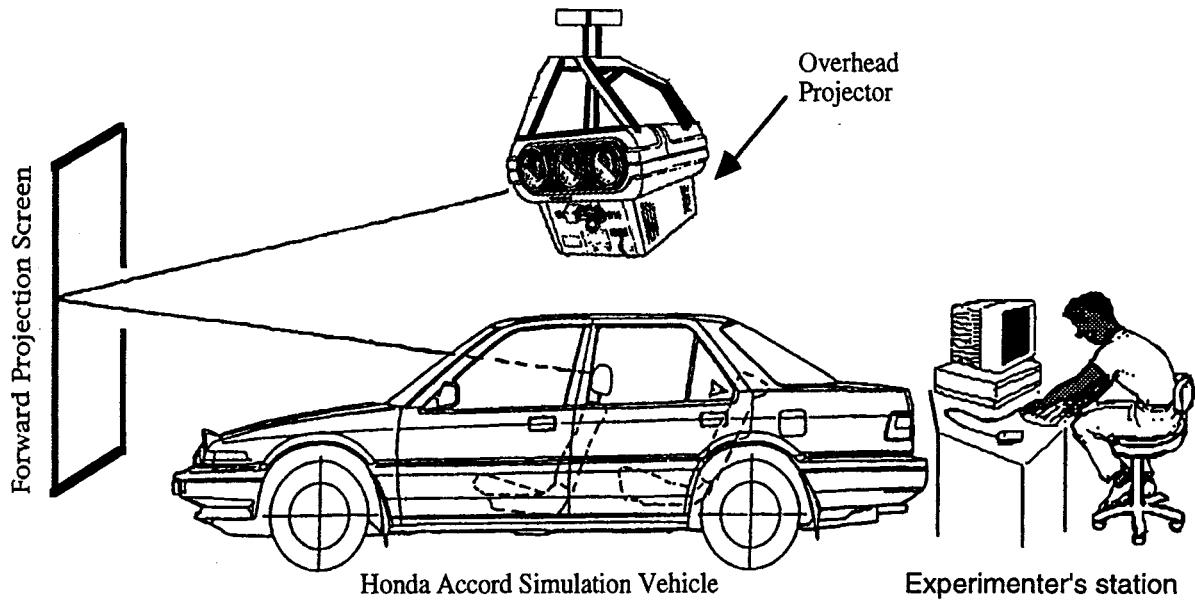
Figure 20. *Side projection view of the simulation facility illustrating the 1990*
Honda fixed-position vehicle, the overhead projection system, the
screen orientation and driver visual viewing angle.

The HFRL's driving simulation facility is based upon a fixed-based Honda 1990 Accord. Inputs from the driver, in terms of accelerator, brake activation and steering are converted from analog to digital inputs. These are used as information which is fed to a computer model which approximates the equations of motion for the actual vehicle. Outputs from this model are then used to adjust the eye point of the driver in the environment in accordance with the inputs given. The simulation changes to fit the orientation of the driver based on their driving actions. These changes are then displayed in real-time, constituting the dynamic driving world observed by the driver of the car.

This simulated driving world was programmed to be representative of the Twin Cities Metropolitan roadways, including driving with and against traffic and maneuvers typical of driving: merging into traffic, making a left turn across traffic, and passing cars in front of the drivers. To facilitate the driver's recognition of the routes they were driving, we programmed the driving worlds to represent roadways traveling from the south side of Minneapolis into downtown. We called Segment One "Cedar Avenue" (State Highway 77) due to its representation of two lane bi-directional traffic. Segment Two we called "the Crosstown" (State Highway 62) due to its two lane roadway and single direction traffic flow.

By using common roadways we were able to generate scenarios based on the messages we could send with the Crusader software. For example, we could send any messages that had a location on Cedar Avenue, the Crosstown, or on the Crosstown's most used freeway connector I-35W. This gave the drivers a frame of reference for where they were driving and what types of conditions they were likely to encounter. (See Figure 21).
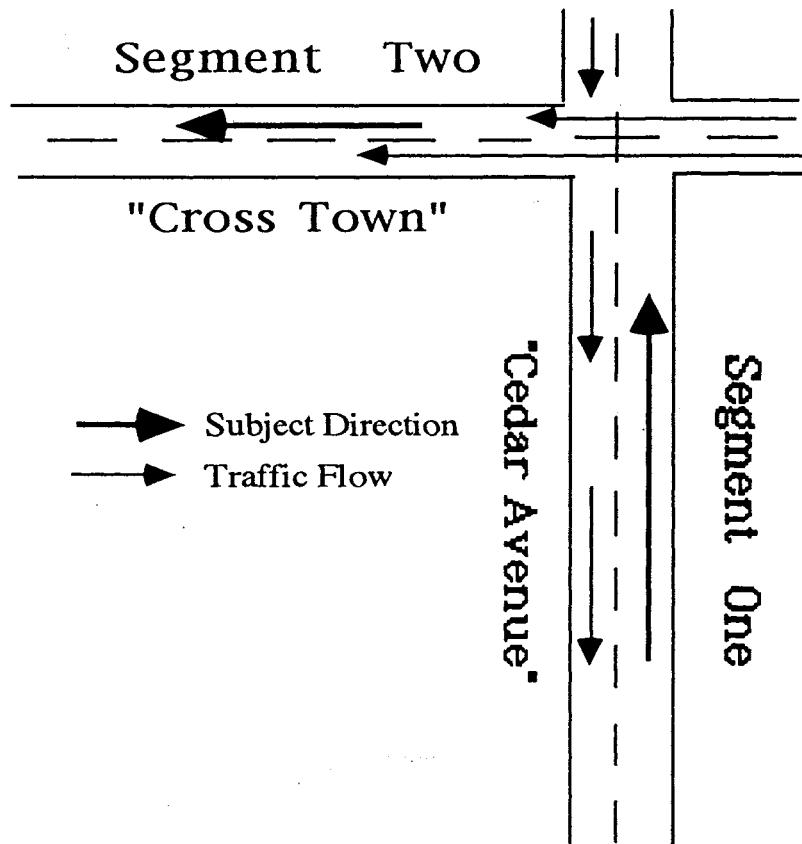
Figure 21. *Simulated driving world containing two segments of differing driving conditions. You will note that drivers cross traffic at the end of Segment One and flow into traffic on Segment Two.*

We used an XTAR hardware platform to generate the driving worlds. This is a medium level graphics generation system based in a 33MHz 386 PC that attaches to an Electrohome ECP-3000 projection system. Also contained in this loop is the actual vehicle itself, the 1990 Honda Accord and the associated analog to digital conversion peripherals that allow interactive driving responses. As noted below, the software package used in the present project for the generation of objects for this system is the AUTOCAD design aid system.

The XTAR system has been used extensively at HFRL for experiments in which look-ahead driving maneuvers predominate (e.g., left-turns). In terms of computational power, the XTAR system can calculate 2,000 flat-shaded polygons per second, where polygons are the currency of simulation fidelity. This represents a maximum refresh or re-draw rate of thirty screens per second. This approximates a motion picture which shows a frame rate of twenty-five frames per second

Object creation in XTAR is performed in a number of steps, as illustrated in the following diagram (Figure 22).

```
┌──────────────┐
│ Autocad Tool │
│  (dxf file)  │
└──────────────┘
        │  dxftool program
        ▼
┌──────────────┐
│ Xtar Assembly│
│   (dl file)  │
└──────────────┘
        │  bsptree program
        ▼
┌──────────────┐
│ Xtar Machine │
│     Code     │
│ (dlo program)│
└──────────────┘
        │  pdl program
        ▼
┌──────────────┐
│ Xtar Object  │
│  Generation  │
│ (C++ program)│
└──────────────┘
```
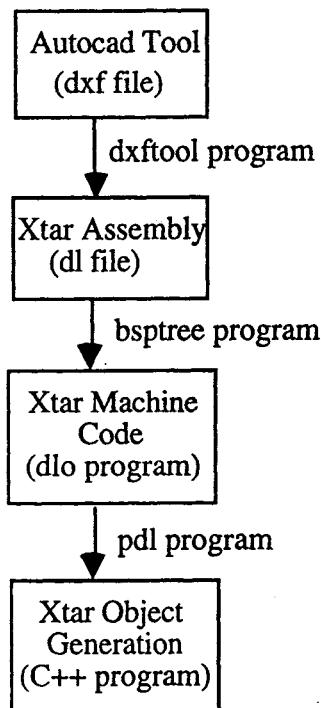
Figure 22. *Object creation procedure in the*
XTAR graphics simulation system.

Once the AUTOCAD file for a object is created, the file is saved in the "dxf" format. XTAR has its own series of translation tools that convert this dxf file into a format that allows the object to be loaded at runtime.

To send messages, we hardwired our simulation vehicle with both the Volvo Dynaguide and the Indikta receivers simultaneously installed in the dashboard. We then wired both antennas directly to our signal generator and RE531 RBDS encoder. Finally, a terminal connection was made between a 486 PC computer which ran the Crusader message assembly software and the RE531 encoder. This meant that messages could be relayed directly to the car by the experimenter without being broadcast.

The receivers in the simulator were tuned to 89.7 MHz which was our "broadcast" frequency. We chose several representative messages (Table 6) of various states of traffic conditions including serious accidents, lanes closed, traffic flowing freely, or problems occurring in an area that the driver had previously driven past. These messages were entered into Crusader in a random order depending upon the differing scenarios. In this way we were able to control exactly which messages were sent and when they were sent. This allowed us to ensure that participants could not anticipate what messages would be sent.

Table 6. *Messages sent to the participants.*

Incident	Location	Cross Street
1) Serious Accident	At I-35W Northbound	Junction I-94
2) Stop & Go Traffic	At State Highway 62	Junction of Penn Avenue
3) Traffic Flowing Freely	At I-35W Northbound	Junction of 60th. Street
4) Center Lane Closed	At I-35W Northbound	Junction of Lake Street
5) Traffic Flowing Freely	At State Highway 62	Junction of France Avenue
6) Expect Delays	At State Highway 77	Junction of I-494
7) Major Road Construction	At State Highway 62	Junction of I-35W
8) Expect Heavy Traffic	At State Highway 77	Junction of Old Shakopee Rd

EXPERIMENTAL DESIGN

The purpose of this study was to assess how helpful the two RBDS-TMC devices were to users driving on a simulated roadway. We assessed both the ability to receive complex information from the systems (user interaction) and the driver's decision-making based upon the information given (user reaction). The objectives were to find out how the public would rate the usefulness and the extent to which they would trust in these radio devices. To study this the participants drove in the Dynamic Driving Simulator and operated both radios as they reacted to driving worlds. We gave them traffic messages and varied traffic states and observed how they reacted to the information given to them.

The subjects were all licensed drivers in the Minnesota. They included forty total subjects divided into two age groups. Twenty subjects were in the young age group, consisting of nine males and eleven females ranging in age from 23-35 years old. The older age group consisted of twenty subjects with twelve males and eight females ranging in age from 51 to 72. Further the older group was divided into three age groups: 51-59 (ten subjects), 60-68 (six subjects), and >69 (four subjects). See Appendix F for a copy of the instructions given to each subject.

We needed to examine the effectiveness of both the graphical display of the Dynaguide and the speech synthesis of Indikta, while at the same time establishing a measure of comparison. We decided to compare two other methods of receiving information. The first was a text screen display, showing the identical messages on four lines of twenty four characters. The second comparison was traffic radio information. This was done by sending a recorded message through the normal radio of the car. A tape player was attached to the signal generator which played an audio cassette containing music which was interrupted by a radio disc jockey reading the current traffic report for the Twin Cities Metropolitan area. This "traffic report" contained the same information that the Crusader software would send to the other devices. This enabled us to send identical messages to the Indikta, the Dynaguide, to a text screen, and through the radio via a radio traffic report. To compare these four systems we decided upon two trials in the simulator using each system.

All subjects completed eight, five-minute trials in the simulator. These trials consisted of driving the car at 55 mph northbound on State Highway 77 (Cedar Avenue North) toward the Twin Cities. Traffic moved in the other lane towards them on this two way street. They approached an intersection with a stop sign. This intersection was State Highway 62 (The Crosstown Highway) which heads east/west. They were told to reach downtown as quickly as possible. If they remained on Cedar Avenue North it would take them 25 minutes. If they took the Crosstown and then went north on I-35W it would take them 16 minutes. They were instructed that congestion or accidents could slow them down on I-35W and it could take 30 minutes or longer with bad traffic. They were instructed to decide whether to make a left turn onto the Crosstown towards I-35W or to stay on cross the street and remain on Cedar Avenue North based on whichever route they felt was the best way to travel.

The key to being able to determine the best route, was the drivers using their visual observations and the information given to them by the four information sources. They were able to see if the Crosstown was congested or free flowing as they approached the intersection (visual information). The Crusader messages would state whether traffic was backed up on I-35W, that the Crosstown was congested, or if traffic was flowing freely (radio information). The participants were instructed to try to reach downtown as quickly as possible. If they were stuck in traffic it would increase their travel time tremendously. They were told that if the Crosstown was congested, they should consider driving straight through the intersection and continuing on Cedar Avenue North. However, the Crusader message might indicate that traffic was flowing freely or that there were no reports of incidents on the Crosstown or I-35W. In that case they were instructed to make a decision on whether they should turn left turn onto the Crosstown or to go straight. Likewise, they might see free flowing traffic and be told that it was congested. Again, they would have to make a decision whether to go straight or turn.

Their main task was to drive the car, observe the traffic, listen or look for traffic messages and then decide whether to turn onto the Crosstown Highway or to continue on Cedar Avenue.

This allowed us to establish our first goal of assessing the user interaction with the devices.

To complete the second goal of assessing the user reaction to messages and the trust they placed in the devices, we devised conflicting traffic scenarios. When the subjects arrived at the Crosstown Highway they would observe one of two driving scenarios:

1) Free flowing traffic (cars were whizzing by on the Crosstown at 55 mph)
2) Congestion (cars appeared parked on the Crosstown or were traveling at 10 mph).

To asses their trust in the devices, the messages received on the radios were not always the same as what was observed on the Crosstown. For example, the Indikta system would say traffic was flowing freely on the Crosstown, however, as the participant approached the intersection they would see stop and go traffic. The Dynaguide would indicate Congestion on I-35W but as they approached the Crosstown, traffic would be moving freely. The participants were instructed to remember that cars might be traveling freely on the Crosstown where they were, but might be backed up several miles ahead or on I-35W. They were told to make a decision whether to turn or not based on what they felt would save them the greatest amount of time. They were asked to make up their minds whether they trusted the radio's information (messages) or their own eyes (visual observations).

After the participant made a turn or went straight, the trial was over and the experimenter would record the decision and begin the next trial. There were two trials using each of the four types of system messages: map, voice, text, and radio announcer.

After the participants had completed all trails, we asked them how they felt about the radios and what their impressions were of the ways of receiving information (See Chapter 3).

RELIABILITY

To ensure reliability, each subject received a random order of presentations for each device. They operated each of the devices twice with the order of the four devices within each of the two trials presented randomly. They received the eight messages in a fixed order but were never given the same message twice. Whether the Crosstown was congested or free flowing was also randomized. This allowed us to have complete randomness as to messages sent, devices used, state of the traffic on the Crosstown, and whether the information received by the participant was accurate or false. No set of trails was the same for any subject. As such it was possible for a subject to receive eight trials where all of the messages were accurate or all were false, as well as, any combination in any order. Table 7. shows the representative trials of one subject.

Each trial is numbered one through eight. For each trial a random order of devices was selected, with the limitation that once a device had been picked twice it was removed from the selection pool. Next the two traffic conditions, congested and not congested where randomly assigned to each of the eight trials. This was a computer generated random function allowing for each case to have equal probability of being chosen for each trial. The messages presented were constantly presented in the same order. They did not vary by subject but corresponded to the same trial number for each subject. Because the device used and traffic conditions were individually varied, it was not necessary to randomize the messages because no message was ever repeated for a subject and the desired effect of randomizing the true/false nature of the presented message was maintained. The messages were sent regardless of which traffic condition was presented. The message may relay correct or incorrect information. In other words, because of early randomization we have a random table of visible information (congested/not congested) versus message information (true and false messages) giving us a random presentation of corresponding or conflicting information. The true/false column becomes randomized due to the random traffic condition, the random device presentation, and the constant message list.

TABLE 7. *Example of Subject Data .*

SUBJ. #	TRIAL #	DEVICE	CONGESTED NOT CONGESTED	CRUSADER MESSAGES	TRUE / FALSE	DECISION Left or Straight
1	1	Volvo	Not Congested	Serious Accident I-35W	FALSE	Turn Left
	2	Text	Not Congested	Stop & Go Traffic S.H. 62	FALSE	Straight
	3	Indikta	Congested	Traffic Free Flowing : I-35W	FALSE	Turn Left
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight
	5	Radio	Congested	Traffic Free Flowing S.H. 62	FALSE	Turn Left
	6	Text	Congested	Delays : State Highway 77	FALSE	Straight
	7	Radio	Not Congested	Road Construction S.H. 62	FALSE	Turn Left
	8	Indikta	Not Congested	Construction S.H. 77	TRUE	Turn Left

The decision column reflects the participant's choice of either continuing straight on Cedar Avenue North, or turning left onto the Crosstown (and ultimately I-35W). It can be observed from this table how the order of presentation of devices and congested or not congested state taken against a fixed message list will establish a random order of true or false information being presented by the devices. It is this mixture of true and false information that allows the study to

observe the driver's reaction to the devices based upon whether they believe the information on the radios, i.e. turning into congestion because the message from the device says traffic is free flowing or going straight when there is no congestion because the device says congestion ahead. If a participant truly trusted the device, they would take alternate routes because they believe the devices' information over their own observations of traffic levels.

This type of experimental design allows us to present conflicting or confirmatory information. If the road is congested, a person would avoid that road if they wanted to arrive somewhere in the shortest amount of time. These devices provide a means of giving the driver current traffic information that they can use to change their route. Unfortunately, if a device is difficult to use or if the driver does not trust the information they will not head the warnings from the traffic messages. We measure with this study if a driver uses the traffic messages for changing their route, by observing whether they follow their visual observations or if they follow the advice of the messages.

To measure the decisions made, we set forth a criteria that the visual observation is always correct. This may not be the case but it gives us a baseline to do comparisons of the decisions.

CRITERIA:
1) If a driver approaches an intersection and it is congested, going straight will be judged as a correct decision.
2) If a driver approaches the intersection and traffic is free flowing, turning left will be established as a correct decision.
3) If the driver disregards the visual information and turns left into congestion or goes straight when the Crosstown is free flowing, these will be considered incorrect decisions.

What we determined was; if receiving message information that was contradictory to that observed visually caused changes in driving patterns. To do this we presented messages that either confirmed or contradicted what was seen visually and we recorded the decisions made by the drivers. This required using the above criteria as a baseline but not as an absolute measure. If a driver followed the criteria and made a "correct turn" it does not mean that they made the correct decision. It is simply a means a collecting data. We are most interested in those decisions that would be considered incorrect decisions. These incorrect decisions imply that the drivers made a decision based on the information received from the devices not from their visual observations. To balance this study we used two techniques to draw out further information.
1) The first was to include messages that relayed traffic conditions on I-35W, a highway that could not be visually observed but which could drastically change the time to reach downtown if it was congested. This allows us to note when drivers made incorrect decisions based solely on the messages presented. If the Crosstown was free flowing the driver should turn left, but if

they receive information that I-35W was congested and they go straight we know that they made their decision based on the information received. 2) Secondly, we sent messages that confirmed the visual observations. Here we noted any incorrect decisions which would indicate that the driver did not use visual or Crusader message information. The most interesting data, therefore, came from the incorrect decisions made.

RESULTS

Each of the following tables and graphs depicts various factors of traffic conditions, messages sent, and by which device, with the ultimate criterion being whether the participant makes a correct decision or an incorrect decision. It was stressed to the participants that there were no correct/incorrect answers and that they should make up their own minds. This criteria does not reflect whether the decisions are ultimately correct, they are defined here purely to establish a measure of the participant's trust in the messages received from the devices. See Appendix G for results.

Table 8. *Overall decision made by device used.*

Device as a Function of Overall Decision Made

	Correct	Incorrect
Volvo	62	18
Indikta	61	19
Text	69	11
Radio	62	18

OVERALL DECISION MADE
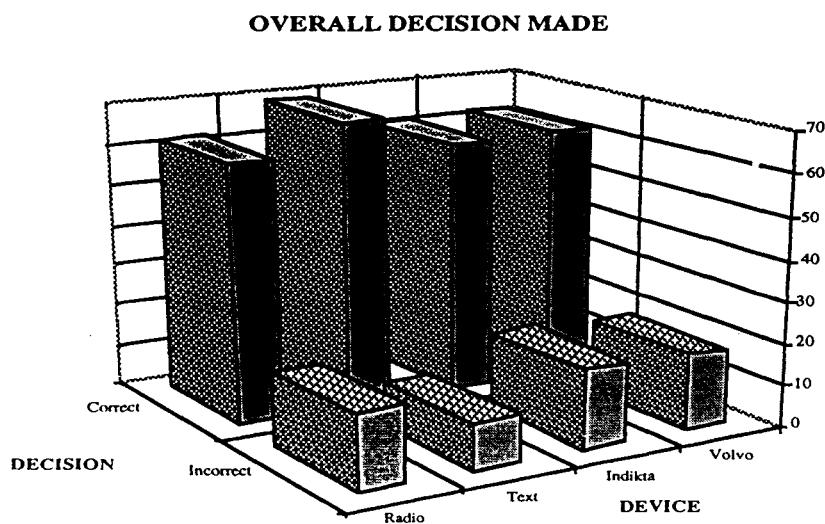
Figure 23. *Total number of decisions graphed against devices used.*

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Table 9. *Decision made compared across devices and age groups.*

Device as a Function of Decision Made

Older Subjects	Correct	Incorrect	InfoBased
Volvo	35	5	2
Indikta	33	7	7
Text	35	5	5
Radio	30	10	9

Younger Subjects	Correct	Incorrect	InfoBased
Volvo	27	13	11
Indikta	28	12	12
Text	34	6	6
Radio	32	8	7

Figure 24. *Subjects graphed by age group as a function of device used against decision made.*

Table 10. *Decisions made as a function of observing congested or not congested states while receiving information from each device separated by age group.*

Device by Traffic State as a Function of Decision Made

	Older Subject			Younger Subjects	
	Correct	Incorrect		Correct	Incorrect
Volvo Congested	18	2	Volvo Congested	15	5
Volvo Not Cong.	17	3	Volvo Not Cong.	12	8
Indikta Congested	18	2	Indikta Congested	15	5
Indikta Not Cong.	15	5	Indikta Not Cong.	13	7
Text Congested	18	2	Text Congested	18	2
Text Not Cong.	17	3	Text Not Cong.	16	4
Radio Congest	17	3	Radio Congest	18	2
Radio Not Cong.	15	5	Radio Not Cong.	14	6
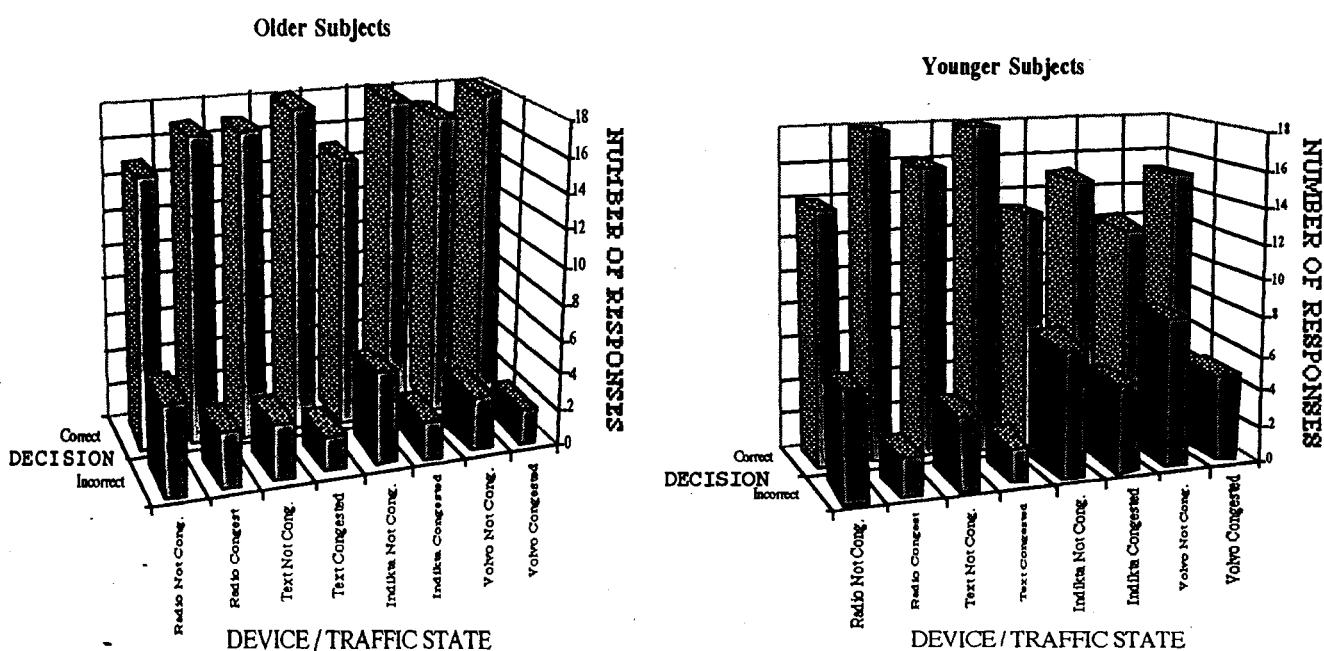
Figure 25. *Subjects by age group as a function of device and traffic condition verses decision made.*

Table 11. *Decisions made as a function of receiving true or false information from the devices separated by age group.*

Device by True/False Information as a Function of Decision Made

| | Older Subject | | | Younger Subjects | |
	Correct	Incorrect		Correct	Incorrect
Volvo True	20	0	**Volvo True**	20	0
Volvo False	16	4	**Volvo False**	7	13
Indikta True	25	1	**Indikta True**	26	0
Indikta False	9	5	**Indikta False**	3	11
Text True	19	0	**Text True**	18	1
Text False	16	5	**Text False**	16	5
Radio True	24	2	**Radio True**	23	3
Radio False	6	8	**Radio False**	9	5
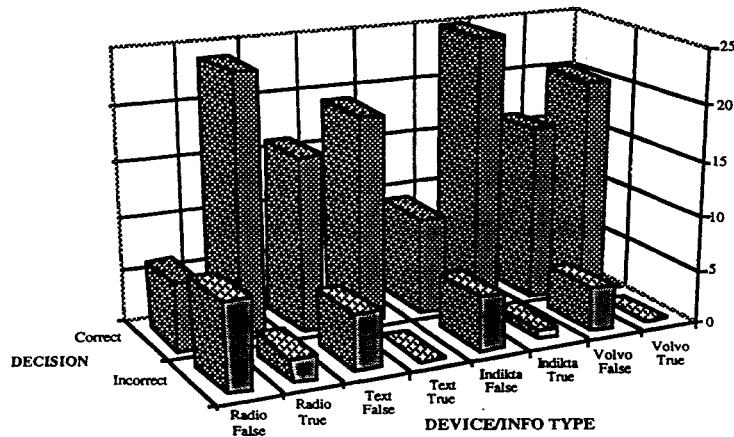
Older Subjects

Younger Subjects
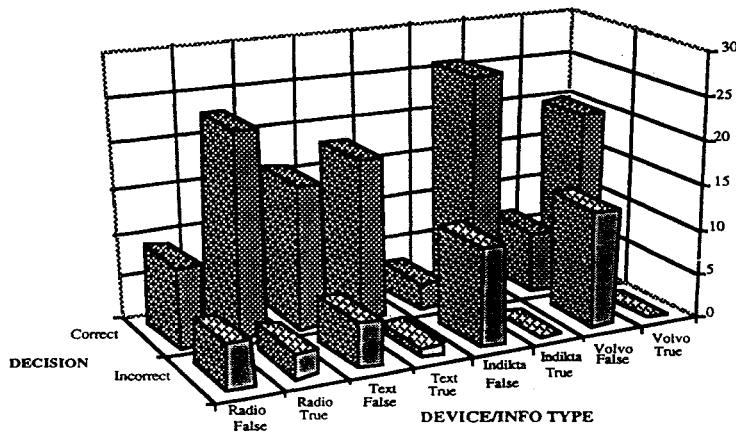
Figure 26. *Subjects by age group graphed as a function of device and truthfulness of message received against decision made.*

FINDINGS

The findings were interpreted using the following baseline:

1) If a driver turned onto the heavily congested Crosstown, or continued on Cedar avenue when the Crosstown was moving freely, they were judged as making an INCORRECT decision. We established that what the driver saw (congestion or no congestion) represented normal driving and turning into heavy traffic was, therefore, an incorrect decision.

2) If a driver believed their eyes and turned during non-congested times on the Crosstown or if they continued on Cedar avenue when the Crosstown was congested represented a CORRECT decision. This is determined regardless of what message was broadcast.

3) The previous two criteria establish a scoring scale, without implying actual quantitative information on what could happen on the roadways when making these decisions. They were an arbitrary starting point for analysis. These determinations of correct/incorrect decisions were independent of what message was sent.

4) It was established that an incorrect decision for a driver was to turn into heavy traffic or to ignore a free flowing Crosstown Highway because both of these situations would increase the participant's driving time.

5) If information was broadcast on any of the four modalities that conflicted with the visual information described above, the messages was recorded as giving false information. This means that the devices received messages that were contradictory to the visual information. It does not mean that the messages were wrong or giving misleading advice. False means contradictory information to the visual observation.

6) Likewise, if a message confirmed the visual information it was deemed true information or confirmatory.

Participants in this study were scored on a simple scale of whether they completed a correct or incorrect decision. This was compared to the actual state of traffic on the Crosstown and the information that they received from the devices. If a driver turned onto the heavily congested Crosstown, the decision was cross checked with what information (message) was sent to them and by which modality. If a participant made several incorrect decisions while receiving false information from a device we assumed that they made that decision based upon the information received. In other words, they trusted the device and the message. If a participant made incorrect decisions while receiving true information from the devices, it indicated that they would rather take their chances by ignoring the information or not trusting the devices. Similarly, if a driver made a correct decision while receiving true information it would indicate that either they believed the messages from the devices, or that they used them to confirm their own decision. It might also indicate that the drivers paid no attention to the devices but made

what they thought was an obvious choice, making a correct turn. It was possible to assume in a controlled study where subjects were asked to use the devices and their information, that the drivers most likely checked the device's information and used it to confirm visual observations. Drivers making correct decisions when receiving false information from the devices were assumed to have decided that their visual observations were more important than the device's information. This would demonstrate a lack of trust in the devices or the messages. Therefore, the most important information from the tables and figures comes from the incorrect decision column which shows drivers making unnatural decisions. If these were made when false information was broadcast it would indicate a strong faith in the devices and their information.

Gender as a function of decisions was examined and produced no significant differences by devices, type of information, or correct/incorrect decisions. Men and women were almost equally divided into groups containing device differences and information differences when compared to decision making. The older subjects produced no significant differences when broken down into smaller age groupings and will be examined here as a single older group.

OVERALL DECISIONS MADE
(Table 8)

Examining the four modalities (devices) as a function of overall correct/incorrect decisions made, provided no outstanding results. Using the text screens produced the greatest amount of correct decisions versus incorrect decisions but this result was not unexpected. Reading a text screen takes a great deal more time than the other three devices and therefore, could lead to greater comprehension of the messages and their meaning. We believe that the actual reason for the higher number of correct response was due to the lack of trust in the text screen or the inability or unwillingness to read the entire messages. The drivers had a greater inclination to believe their visual observations than to believe a text message. They made fewer incorrect decisions based on their observations rather than on a typed message. This will be discussed further in Task Five.

DEVICE AS A FUNCTION OF DEVISION MADE
(Table 9)

Taking the same data from the overall decisions and dividing it among the two age groups tested provided some interesting findings. The Info Based column refers to whether the incorrect decision was recorded when the device provided false information. This was important because incorrect decisions based on false information indicates trust in the device or message. There was a definite bias from the older subjects towards the radio, while the younger subjects preferred the Indikta and Volvo devices.

Older subjects made almost twice as many incorrect decisions when listening to the radio than to the other three devices. This would indicate that they trusted the radio announcer over their own observations of congested or not congested traffic. This was confirmed by the information based results which show the Volvo Dynaguide being the least trusted and the radio receiving the highest marks. It was also interesting to note that the Indikta device was also trusted at a slightly higher rate than the Volvo or the text screen. This would likely relate to the Indikta's voice messages being similar to a radio announcer.

The Younger age group shows almost a two to one preference for the Volvo and Indikta over the text and radio modalities. We would attribute this to the comfort level of younger subjects with using computers or "high tech" devices. This will be discussed in Task Five.

DEVICE BY TRAFFIC STATE AS A FUNCTION OF DECISION MADE (Table 10)

These results further serve to define the decisions made by the participants. It was determined in our criteria that it was a worse scenario to make a turn into heavy traffic or to ignore a clear traffic lane. It was assumed that making an incorrect congested decision (turning onto the congested Crosstown) was more serious and would require greater trust than going straight on Cedar Avenue when the Crosstown was free flowing. These results were borne out in Table 10. For each of the devices fewer incorrect decisions were made when the participants observed congestion on the Crosstown. In all cases there were more incorrect decisions when the Crosstown was free flowing. This was expected. You would have to have a large amount of trust in a device to turn into slow, heavily congested traffic.

DEVICE BY TRUE/FALSE INFORMATION AS A FUNCTION OF DECISION (Table 11)

Finally, the choices made were examined against whether the participants received false misleading information or correct truthful messages. We expected that when receiving truthful messages the participants would use that information to confirm their choice and make a correct decision. When given false information it was assumed that participants would vary in their decision to make correct or incorrect decisions.

The older participants show greater tendencies to make incorrect turns when given false advice with all devices. When given true information they made only one incorrect decision for the Volvo, Indikta, and text screen. This would indicate use of the devices as confirmation tools or possibly that the participants gave reduced attention to these devices. An increase in incorrect decisions when given false information by these three modalities gives an indication that the participants were paying attention and heading the messages. The radio modality again indicates

the strong preference of the older drivers to listen to the radio announcer over the other modalities. Trust was so high in the radio announcer that under the false message scenarios the older subjects made a greater number of incorrect decisions than correct decision. This shows a strong trust in the radio announcer.

Younger participants as expected show the same trends of increase incorrect decisions when given false information, and few incorrect decisions when given true information. The younger group favors the Volvo and Indikta when making incorrect decisions based on false information, and made no incorrect turns when given true information by both devices. This would suggest strong trust in the confirmation of visual observations and in the choices to make incorrect decisions when visual observations were contradicted by the device's messages. It was also interesting that when the radio announcer gave false and true information that similar results were obtained for incorrect decisions. Younger subjects exhibited far less trust in the radio announcers than the older group.

RESULTS

This task found that decisions made by participants depended heavily upon a combination of visual observation, messages received, device used, trust in the device, and age group. When the devices confirmed visual observations they were believed more readily than when drivers were forced to decide between message information and conflicting visual cues. Older subjects preferred the radio announcer and voice messages to the graphic modalities, while the younger subjects made difficult choices more readily with the Volvo and Indikta devices. This points out the need to use a wide age range of subjects for further testing and the need for alternative message delivery systems as comparison guides for the two main devices to be examined.

CHAPTER 3

TASK THREE
COMPARISON OF THE VOLVO DYNAGUIDE AND INDIKTA DEVICES

INTRODUCTION

Thirty-four of Task Two's simulation study participants responded to a post test follow up questionnaire. This questionnaire was designed to assess preferences of one device over another. As with the simulation data the results will be broken down by the same young and old age groups.

METHODS OF EVALUATION

The questions asked consisted of:

1) Which device did you like best and why?

2) Which device did you like least and why?

3) Rank these choices as to which information deliver method you preferred. Use 1 for the highest, 2 for the next highest, and 3 and 4 for the least preferred.

> Radio Announcers   ____
> Text Screen System   ____
> Map System   ____
> Voice System   ____

4) What features did you like on the ____ system? (Voice, Map, and Text)

5) Did you trust the information received on the ____ system? (Radio, Text, Voice, Map)

6) Which did you prefer the voice or the map system? Why?

7) If you received information that conflicted with what you saw on the Crosstown which system would you believe the most? Why?
Which system would you trust the least? Why?

8) Which system would you like to have in your car? (you may choose more than one)
Why?

FINDINGS

Not surprisingly the answers followed many of the observations in Task Two.

Question One: Which device did you like best and why? Older subjects choose the radio 3 : 1 over the other devices. Their reasons ranged from being comfortable with a radio announcer, (as opposed to the gadgets), to being afraid to operate the map and to look down at the text because they would swerve on the road.

Younger subjects embraced the map 2 : 1 over the other modalities. Most cited the ability to look at the map and see exactly where the accidents were as their major plus to the Dynaguide. Most were annoyed by the Indikta's tonal quality with five different subjects mentioning that it was like listening to Darth Vader or asking what the difference was from the radio announcer except that messages were more specific.

Question Two: Which device did you like least and why? Both the Younger and the Older Subjects chose the Text screen as their least favorite modality. The main reason being the amount of time necessary to read the message and scroll between lines of text. Older subjects also noted dislike of the map due to its bright distracting light and the voice because they could not understand it. Several subjects mentioned disliking "Warning" before every Indikta message.

Question Three: Rank these choices as to which information deliver method you preferred. As with questions One and Two the Older subjects ranked the radio first, Indikta second, Dynaguide third and the text screen last. Younger subjects ranked the Dynaguide first followed by a tie between the Indikta and the radio with the text screen last.

Question Four: What features did you like on the ____ system? The majority of subjects expressed a strong affinity for the ability to see where the accidents were on the Dynaguide screen. Most liked the ability to get different levels of information on the Dynaguide system. Most younger subjects liked having a map right on the dashboard for directional purposes, (not necessarily for information delivery). They liked the idea of voice messages that were specific to the area traveled. (It should be noted that no excessive messages were sent to increase clutter as we decided to assess system preference without over burdening the subjects). Several older subjects cited liking the Indikta because it was similar to a radio announcer. Several subjects liked that the Indikta paused the music playing to inform them of the approaching situation.

Question Five: Did you trust the information received on the ____ system? Older subjects stated that they trusted the radio announcer because they were usually right. They trusted the Indikta device slightly because it was similar to a radio announcer. Finally, they split evenly on the Dynaguide and the text screen citing inability to see the icons and text clearly and hesitancy to use these two devices while driving a car. The younger subjects trusted the Dynaguide 2 : 1 over all other devices, noting that there was so much detail that it had to be correct. Several younger subjects rated radio the worst due to personal experiences when trusting the radio announcers.

Question Six: Which did you prefer the voice or the map system? Older subjects, when given two choices, picked the Indikta system 4 : 1 because they were afraid to push all of the buttons on the Dynaguide. Younger subjects chose the Dynaguide 6 : 1 mainly due to it's graphical map and a strong dislike of the Indikta voice .

Question Seven: If you received information that conflicted with what you saw on the Crosstown which system would you believe the most or trust the least? The responses followed Questions One and Two's ratios exactly. Interestingly, several older subjects mentioned that they would believe the radio announcers above all others because they could see the accidents and the radio announcers would give them alternate route information.

Question Eight: Which system would you like to have in your car? The older subjects did not see a need for the new systems but some did mention the Indikta as a possible radio for their car. Younger subjects chose the Dynaguide almost exclusively due to the map screen.

RESULTS

The abilities of older drivers to accept these devices should be carefully examined in future tests. Even though they represent a group of individuals that will probably not purchase these devices, there will be an explosion of older baby-boomer drivers in the next ten years who might purchase them.

Older drivers appear set in their ways preferring the simple radio announcer, yet it is interesting to note the acceptance of a voice system by this age group.

The younger age group liked the Dynaguide, mainly for it's graphic map as much as for the information it provided.

The Indikta system should improve it's voice quality as it was cited as being hard to understand by the older participants and annoying by the young group.

Alternative route information was noted by participant's in both groups as lacking for both systems. The older subjects liked hearing different routes to take to avoid the incident, while younger subjects expected the radios to show or explain how to get around the incidents quickly.

CHAPTER 4

TASK FOUR
EVALUATION OF CRUSADER SOFTWARE PACKAGE

INTRODUCTION

The purpose of this task was to catalog the outputs of both devices using all possible messages and locations from the Crusader software database. This required individual data entry of each message and location and recording of the Dynaguide screen output (icons and text), and Indikta voice and screen (text). An Excel and a Lotus 1-2-3 database of the results of this task were delivered to Gary Hallgren of Mn/DOT in December. Copies can be obtained from the HFRL upon request.

METHODS OF EVALUATION

All possible locations and messages were identified and cataloged. The diagrams that follow this section show the progression of software data entry from locations to the possible messages (Figures 27 and 28). These figures show the progression of locations from State to Highway to Segments and points and the messages from the seven categories down to the sub categories. Each message sub category contains any number from 1 to 121 different messages. The locations include all points in the Twin Cities metropolitan area. These were individually entered into the Crusader software and transmitted to the Dynamic Driving Simulator vehicle which had both devices installed. A researcher cataloged all outputs into the database file.

FINDINGS

Several messages were not received by either device, we were told that this might be due to Mn/DOT instructing the manufactures to ignore certain messages. However, the messages ignored included several very important combinations of traffic conditions and events. This is especially prevalent with the Indikta device which decoded less than half of all potential messages.

Most location codes were identified accurately by both devices except those few exception noted in the database. It is worthy to note that the Dynaguide system had nearly 100% correct locations of icons on the Dynaguide maps, while Indikta identified the correct corresponding locations with near 100% accuracy with voice and text.

Small discrepancies exist between the database and the actual Highways and State Roads. there are exits that do not exist, or roads that do not go by the names established in the database.

RECOMMENDATIONS

- Re-examine the database to determine the most practical and useful messages and require their output from the devices.

- Include the combination messages i.e. Accident, stop and go traffic, next 2 hours. This message relays three important points of information. That there is an accident, that traffic is stop and go, and that it will last for two hours (Duration will also be entered in the original message assembly). It can be very important to a driver to know that an accident is ahead and traffic is stop and go, as opposed to an accident ahead, yet traffic is flowing freely.

- Require the manufactures to submit a record of output from the devices to assure quality control and communication between Mn/DOT and the companies from whom they purchase these expensive devices. This will allow the devices to be debugged before installation in test vehicles.

- Re-examine the naming of State Roads and highways in the database to reflect their "alternative" names. For example, most people recognize Cedar Avenue not State Highway 77, or they know where "The Crosstown" is located but not S.H. 62. Perhaps these common names can be incorporated with their database names. Indikta would probably be able to establish a duel database which has a pop down menu for street names and one for colloquial names or common names. A button press could toggle between the two types of location databases.

- Incorporate alternate route information. Participants commonly cited receiving alternative route information as the main advantage of radio over all other devices. All participants wanted to know if the route they were going to turn on to was free flowing or if incidents and slow downs were occurring. Traffic radio often lists alternative ways to go around accidents, or gives information on which alternatives routes are best. Participants stated that they wanted this information.
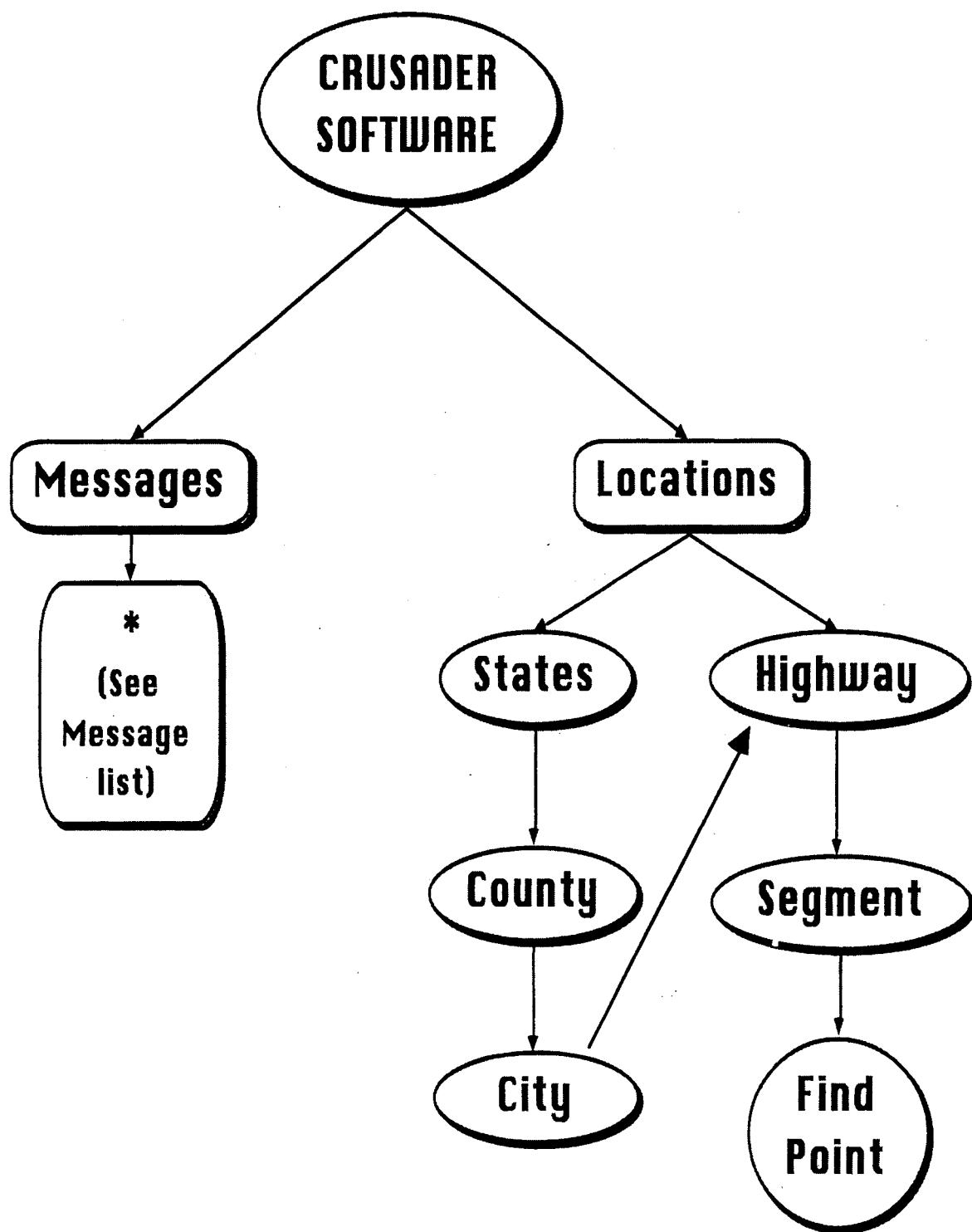
Figure 27. *Crusader Menus.*

Events

Traffic Conditions

Dangerous Vehicle

Equipment Failures

Abnormal Loads

Width Limits

Traffic Density

Warnings

Height Limits

Other Causes

Winds expected

Skid Hazards

Weight Limits

Weather Outlook

Length Limits

CRUSADER SOFTWARE

Weather

Weather Situation

Maximum Temperature

Minimum Temperature

Effects

Obstruction Hazard

Reduced Visibility

Recommendations

Incidents

Wind Conditions

Delays

Road Causes

Roadworks

Information

Advice

Road Closures

Lane Closures

Figure 28. *Crusader message database selections.*

CHAPTER 5

TASK FIVE : DATA COLLECTION AND EVALUATION FEASIBILITY STUDY FOR AN ON-ROAD VEHICLE.

INTRODUCTION

Task four was designed as an action plan and cost estimate analysis to outfit an on-road vehicle(s) for data collection involving the use of in-vehicle measuring and recording devices. These devices would aid in the on-road evaluation of automobile subsystems, outside the car driving aids, such as signs and procedures which involve automation, and for in-vehicle navigational or informational systems. The results from this task can be used as a guideline in developing measures of evaluation for general public usability studies of devices or procedures other than just using questionnaires, focus groups, or other similar subjective measures. The goal of this task was to define measures of evaluation possible in on-road vehicles and the associated costs and resources needed.

DRIVING PERFORMANCE MEASURES

In the simulation study we use a stripped down Honda vehicle which has had potentiometers adapted to the steering wheel, accelerator, and braking mechanisms. These potentiometers measure lane deviation (wanderings), acceleration / deceleration and speed maintenance changes, and response time changes when braking. This data is saved in computer files. These data files can be analyzed to formulate an individual driving model for each driver (control data) which can be compared to their performance when completing tasks (such as operating an in-vehicle information system).

This can be duplicated in an on-road vehicle with relative low costs. The ease of establishing this type of data collection can be enhance by newer model cars which include digital speedometers and "car computers" which measure driving performance. The 1994 model Saturn automobiles included a central processor which constantly measured driver speed maintenance, braking characteristics, anti-lock braking, individual wheel traction coefficients, and optimum engine performance during various driving conditions and temperatures (Saturn Automobile Corporation, 1994). These central processors have downloading and monitor outputs used during engine diagnostics and could be easily adapted to send data directly to a computer located in the trunk of the car. This would, however, require several logistical problems to be solved including getting data in a usable format related to the driver's performance rather than the vehicle's performance.

To outfit an existing older car would require the same potentiometers as those used in simulation study vehicles. This can be done without interfering with the performance of the automobile. A standard adaptation would require:

- Three potentiometers ($125 each) attached to the steering, brake, and speedometer;
- An eight channel analog to digital converter board ($300) for collecting and converting data bits;
- A low cost computer, at the minimum a 286 processor with a 150 megabyte hard drive($450). (See Figure 29). The data would be downloaded every day from the central processor for data analysis.
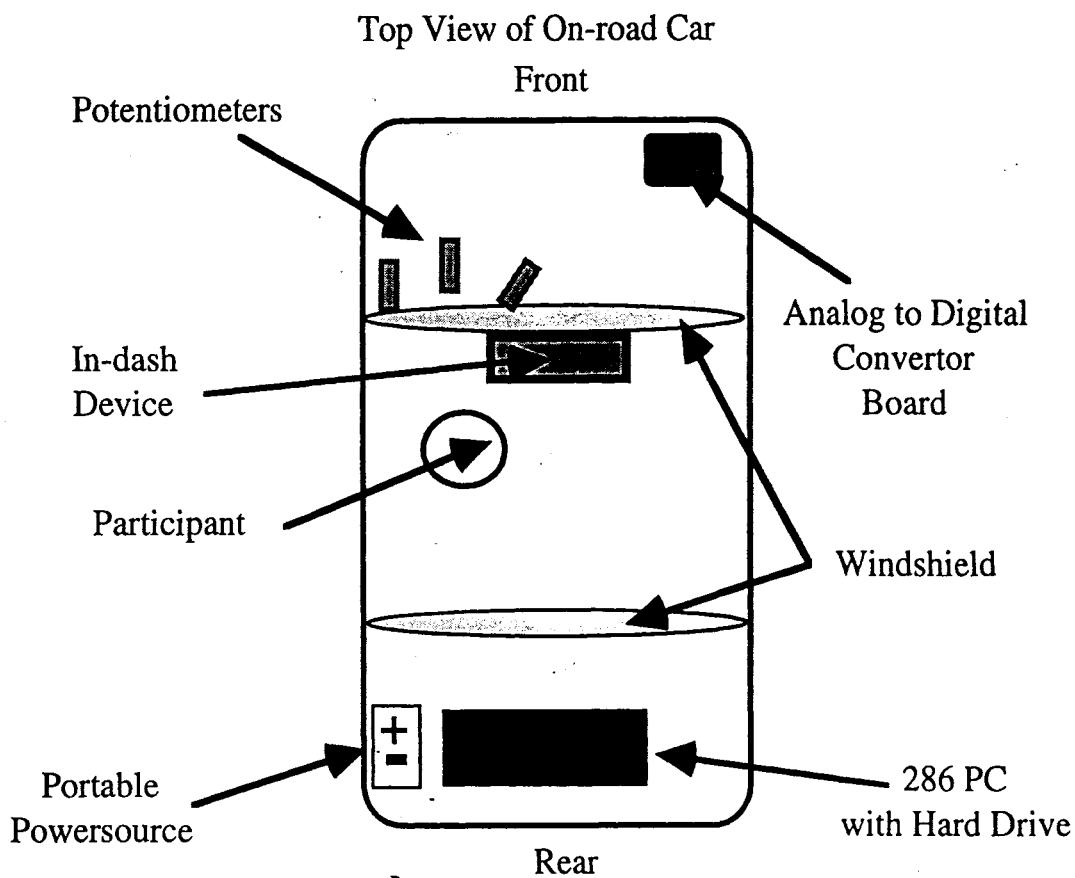
Figure 29. *On-road vehicle outfitted with potentiometers and central processor.*

Therefore, this would require a one-time cost of $1225 per vehicle. It is possible to reduce the cost significantly when: using a newer vehicle with an engine performance monitor (only equipment needed would be the 286 PC to collect data); using volume purchasing for multiple cars; using the University of Minnesota's Central Stores or Mn/DOT's departments, which can purchase reduced price equipment based on their overall purchase volume; or when buying used parts, for instance acquiring the 286 PCs from the University's Inventory Warehouse where surplus PCs would cost the HFRL $150 each. This would reduce the overall cost to closer to $700 per vehicle.

VIDEO PERFORMANCE MEASURES

We have noted in previous HFRL studies that more data may be collected than is necessary since the measures used are mainly for safety evaluation. The more common method of evaluation used with in-vehicle devices focuses on the driver's interaction with the devices. Recent studies on ATIS and ATNS used video data collection from multiple vantage points. (Bossi, Ward, & Parkes, 1994; McCauley, Clarke, Sharkey, & Dingus, 1994; Akamatsu, Yoshioka, Imacho, & Kawashima, 1994; Srinivasan, Jovanis, Yang & Kitamura, 1994; and Sperling & Reeves, 1980).

The most common positions of video cameras correlate to the actions of the driver with the device. Cameras are mounted to observe the driver's eye, head movements, interaction (hands) with the devices, and the overall driving scene from behind the driver and looking down the road. This arrangement of cameras produced interesting data (See Figure 30). However, we can not infer the driver's actual attention to devices or focus points while driving from these videos. (Sperling & Reeves, 1980). With four cameras mounted in this way, the experimenter is collecting video data of the possible interactions with the devices and the simulated roadway. The camera mounted on the eyes is used to gauge attention away from the driving field of vision. This has the drawback of not knowing what the driver is looking at or attending to, but it does reveal times of divided attention. The head camera, is used to correlate with the eye camera to determine times of diverted attention. The hand and body camera provides synchronous viewing of actions of the driver with devices, controls, or vehicle systems. Finally, the rear view camera can be used to visually correlate these actions with the driving scene projected in front of the driver.

Unfortunately, these views, in and of themselves, can not provide adequate data to determine the effect of the devices on driving performance, nor can they be used to infer driver attention to devices. To correct this the drivers are asked to read aloud or narrate their actions to provide a soundtrack to match their observed movements. In this way a data stream or narrative stream is created which helps focus in on the actions and attention of the participant when driving.

Top View of On-road Car   Sightlines of the Four Cameras
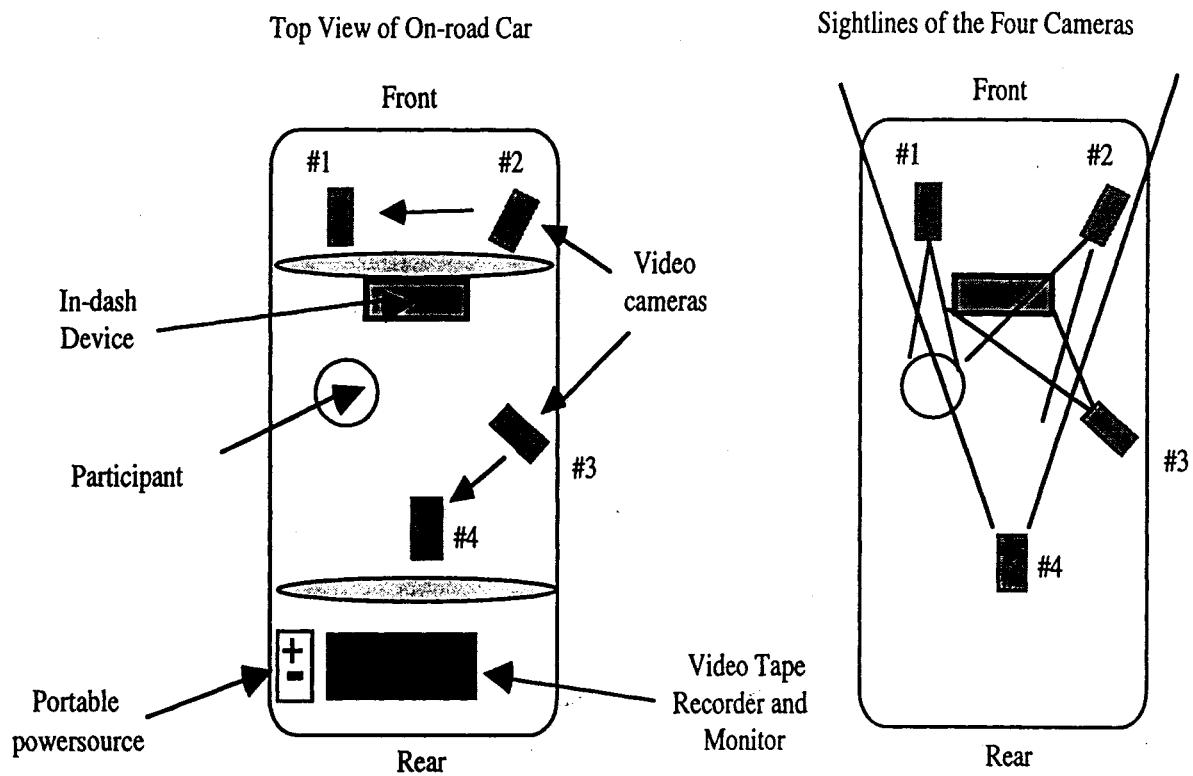
Figure 30. *Video camera placement in an on-road vehicle and the associated sight lines from each camera.*

Eye gaze data taken from front mounted video units showed that drivers glance at various automobile functions at an average rate of one glance per five seconds. When using in-vehicle devices it was assumed that longer glances at the direction of the devices correlated with attention to the device. This was found to be a false assumption as driver performance data did not correlate with the longer glances. Drivers were also required to press a button when using the device. This triggered a marking of the video tape. Interestingly, these presses did not happen at times that the experimenter would assume that the driver was attending to the devices.

However, correlation was found when audio was incorporated with video and the drivers were required to read out loud the device messages or narrate what they were doing while driving. These times of device attention corresponded to the driving performance measures observed. (Akamatsu, et al, 1994). In a previous study of an ITS prototype text receiver at the HFRL, data collection was facilitated by having the participants read the text messages from the device out loud. It would, therefore, be advantageous to have a method of indicating when attention is diverted towards the in-vehicle devices.

At least two methods could be instituted :

- The first would use a microphone attached to the video tape recorder used to collect the video data. This normal soundtrack would then record the driver reading out loud the information, the voice synthesis of the Indikta, or the driver would use a narrative similar to the methods of Akamatsu, et al.
- The second method would be for the driver to press a button mounted on the steering wheel when they were attending to the device. This button would activate a light behind the driver which could be seen by the rear mounted camera and recorded on the data tape. (Triggs & Drummond, 1992).

To set up video for on-road study would require using four compact closed circuit digital cameras which could be mounted in an unobtrusive way. (See Figure 31). These cameras can be mounted without interfering with the driver's line of sight. These are connected to an attached monitor and video cassette recorder (See Figure 32) which record the video data as a four way simultaneous split screen image. The cost for the first camera, monitor, and wiring would be $299.00, with each additional camera costing $150.00. To allow for recording of the video data a low cost video cassette recorder would be purchased and placed with the monitor in the rear of the car. This would allow for six hours of continuos data collection per session. It would, of course, be necessary to purchase a system that allows for a video signal out, which most newer CCD systems incorporate. To purchase all necessary equipment, and wiring would cost a total of $900.00 per vehicle. Again this cost might be reduced by multiple purchases or using University and Mn/DOT resources.

Video could be used instead of a lane deviation (steering) potentiometer by placing a CCD at the outside wheel well of the forward driver side tire. A visual record would be made of the vehicle's tire wandering in relation to the center line. This is dependent upon there being a well drawn visible center line or broken center line. This would be purely subjective on the part of the analyst and would have to be correlated with the four inside cameras and a triggering mechanism to determine device attention. Use of video digitizing equipment such as the PEAK™ digitizing system used in biomechanical study, would allow frame by frame analysis of the driving pattern. This software allows for determination of velocity and acceleration data as well as simple distance calculation. This is dependent upon proper calibration and the ability to use the center line. Unfortunately the center painted lane on most roads is inconsistent in quality and distance between broken lines. This software usage would, therefore, be limited A normal pattern would have to be established and compared to the pattern when attending to the devices.
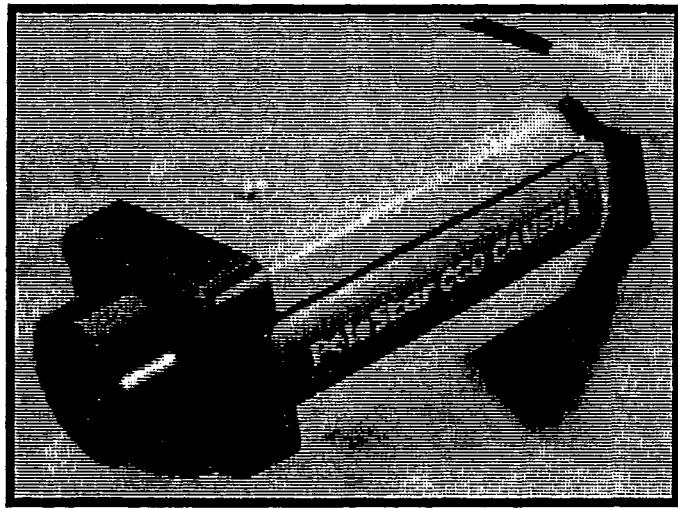
Figure 3.1 *Compact CCD Camera*
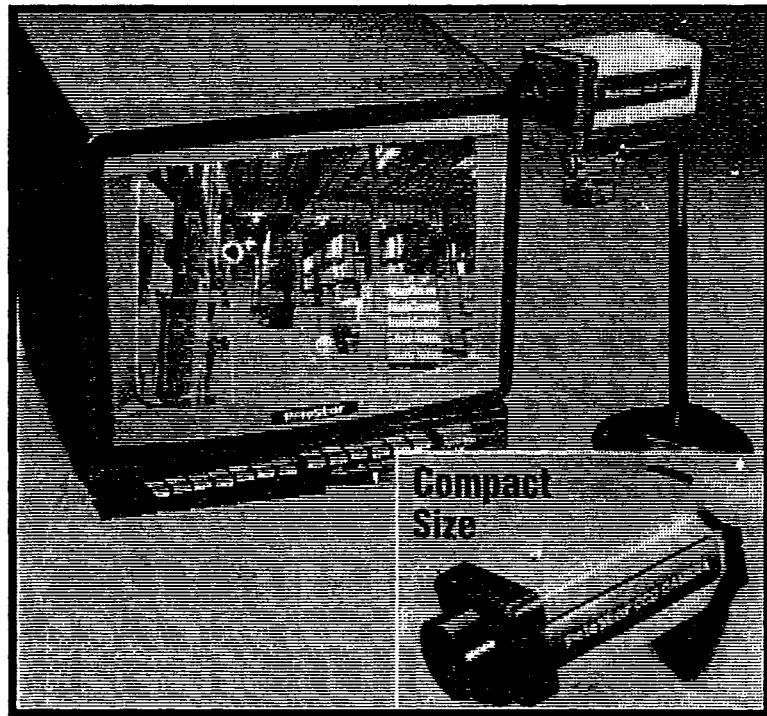
Figure 32. *CCD Camera and Monitor Set-up.*

A fully equipped car for both video and driving performance measures could be outfitted for a total cost of $1600.00. Measures of evaluation still need to be assessed and assigned for on-road study, however, in our opinion this type of measuring system would surpass current research which looks at only one type of measure at a time. This type of in-vehicle system would provide excellent data for any type of research objective.

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CHAPTER SIX

TASK SIX
TRAFFIC MANAGEMENT CENTER EVALUATION

INTRODUCTION

The traffic control room at the Traffic Management Center (TMC) is responsible for monitoring traffic information and relaying this information to the public. We developed a questionnaire to assess how the work stations, work areas and computer systems (hardware and software) are perceived by the operators who use them at the TMC control room in Minneapolis. There are five work stations with differing functions, within the traffic control room; the Information Officer (I.O.), the Crusader Operator (C.O.), the Radio Announcer (R.A.), and the North and South Stations. A full description of the duties of each work station and the layout of the TMC traffic control room are presented in Chapter Six of the Human Factors Evaluation of the Delco Prototype RDS System available from the HFRL or Mn/DOT. During the peak periods (6-9 a.m. and 3-6:30 p.m.), these five operators are present.

The questionnaire addressed four of the five operators in the traffic control room; 1) The I.O.s, who's responsibilities include coordinating, gathering and disseminating daily real-time traffic information for broadcast by the Twin Cities' traffic reporting media, (e.g. WCCO, KSTP, Metro Traffic) including KBEM, Mn/DOT's Traffic Radio Station. They communicate with the traffic reporters and other news media and assist with coordination, dissemination and implementation of major incident information. 2) The C.O.s, who are responsible for sending out traffic information via computer to RBDS devices. Finally, the 3) North and the 4) South Station operators, the primary operators of traffic control and informational devices from within the TMC.

The eighty-one question survey consisted of two major sections: The first part contained questions relating to the work stations, work area and environmental issues; such as comfort, ease of use, health factors, lighting, temperature and noise; while the second part contained specific questions relating to the systems (ramp meters, or changeable message signs) that the North and South Station operators use. The survey contained open-ended, yes/no, and 5-point Likert scale questions. These questions were designed to elicit responses over a wide range of topics including: the physical work station, health issues, work areas, and specific equipment as well as issues related specifically to the North and South Station operators.

Administration of the surveys took place at the TMC over a two week period. Questionnaires were distributed to twenty operators with sixteen completed questionnaires being returned. The information was compiled and tabulated. Not all questions were answered by all

respondents. Some respondents felt certain questions did not pertain to them or they did not know the answer. The average seniority of the respondents was 3.3 years. The following summary includes the results of the survey, key problem areas, and recommendations for the future.

FINDINGS

The numerical values found below and in Appendix H were calculated using the number of respondents answering each question, not by the total number of respondents (sixteen). These calculations were done after the questionnaire were collected and thus not seen by the respondents.

PART ONE OF THE QUESTIONNAIRE

Part One of the survey consisted of twenty-eight questions regarding the general work area conditions of the traffic control room operators. An assessment of the work stations, health factors, work area and environment of the traffic control room was completed and the answers are summarized below. When operators were asked to rate their overall work area (on a scale, 1 = bad and 5 = good), the average was 3.75. Table 12 shows specific responses regarding operators work areas. See Appendix H for all responses.

Table 12. *Some Yes/No questions asked of the respondents.*

QUESTION	RESPONSE	
	% YES	% NO
Are the chairs comfortable	50	50
Table height is right height for respondent	71	29
Monitors comfortable and easy to look at	43	57
Lighting in the control room was adequate	63	37
Comfortable and at ease working encoder message assembly system	87	13
Comfortable and at ease with the system for changing cameras/monitors	72	28
Comfortable and at ease with the ramp meter system	93	7

Most operators reported no health problems related to working in the traffic monitoring area. When asked if they had ever had headaches, neckaches, blurred vision, sore wrist or sore back, all the average responses were between 1 = never and 2 = occasionally. Very few operators reported feeling "cramped or closed in" at their work area, averaging 1.38 on the scale 1 = never

and 5 = always. However, if they did respond positively to feeling cramped or closed in, it was associated with too many extra and unauthorized people in the control room. This was also the major complaint related to the noise in the control room. The respondents reported that the traffic monitoring area was noisy with a mean response of 2.56 which falls between 2 = occasionally and 3 = sometimes.

Sixty-two percent of the respondents reported that there were distractions in the control room monitoring area. When asked to specify what these distractions were, the most frequent response was unauthorized individuals in the control room. Other responses included having a major incident at the other station, side conversations, and boredom. When asked where and when the greatest distractions occurred, the main response was during the peak periods either in the beginning of a shift or when there were frequent incidents.

The operators reported a mean of 3.63 for their individual comfort with their traffic monitoring tasks in the control room, (where 1 = not at all, and 5 = very much). The area of the traffic control room which was reported as having the least adequate design layout was the I.O.'s work area. Sixty-four percent felt this area should be reorganized. The R.A.'s station was reported as having a good design layout, with 67% of all respondents listing it as the best designed work area.

The operators were asked to report their likes and dislikes of the control room. The following are some of the commonly cited responses:

Likes:
- Equipment easy to operate.
- Providing a valued important service, can make a difference.

Dislikes:
- Poor ventilation.
- Too many interruptions and inconsistent operational procedures.
- Too many unauthorized individuals wandering through control room.
- Difficult to work efficiently from the North and South Station with the I.O., because the operators' backs are turned to the I.O. when operating the stations.

The operators were also asked to report on what they would like to see done differently in the control room and where improvements could be made. Operators frequently reported that consistency in monitoring (operating) from one operator to another was very important for uniformity in control. Having a separate viewing area for groups tours was also cited more than

once. Further improvements were to have better relationships with everyone who was in contact with the control room, for example; the patrol, media, I.O.s, North and South Station operators, C.O.s, and R.A.s.

When asked how familiar the operators were with the metro highway system, they responded with a 3.63 on a scale of 1 = not very familiar to 5 = very familiar. Meaning that most of the operators felt that they were familiar with the metro highway system.

Some operators felt too much operator discretion was allowed in operating the ramp meter system. Interestingly, 92% of the operators reported having a certain method or special routine to turn off the ramp meters. These individual "methods" to turn off ramp meters would lead to inconsistencies in the way the system was run and thus the way the drivers on the road were affected.

PART TWO OF THE QUESTIONNAIRE

The second part of the questionnaire employed more specific questions related to the systems used by the North and South Station operators. This part was completed by the North and South Station operators only. Part two consisted of Likert scale questions. There were seven sections in Part Two, which were: Ramp meters, Cameras, Turning off Ramp meters, Dealing with Incidents, Time and Workload, and Changeable Message Signs (CMS). Within each section questions were asked and answered using a scale: 5 = strongly agree to 1 = strongly disagree.

Operators reported that monitoring the ramp meter values is an important part of their job (4.09). When asked more specifically about the color coding used on the ramp meter displays, they reported that the color coding helped them identify traffic areas (4.63), that the color coding system was not confusing, and that the display provided a good overview of traffic flow at their station (4.18). Overall, the color coding system for the ramp meters was a useful display that provided easy recognition of traffic areas.

The responses in the Camera sections were slightly lower suggesting less comfort in operation and emphasis on the importance of these systems. They ranged between 2.00 and 3.73 for the Camera section and between 2.00 and 3.64 for the Barco section.

The "Turning off the Ramp Meters section", provided the finding that turning off meters did not start one hour before the peak period ended (2.18). (Respondents were not asked to respond to when the ramp meter turn off procedure was started). The ramp meters were also reported as being overridden more often than just five minutes before a shift ended (1.55). This implies simply that the meters are more constantly monitored throughout the peak shift with no set times established with each respondent as to when they turn the meters off or override the meters. In other words, we have not asked for specific procedures but have found that operators in general use daily situations to determine when to override or shut down the meters.

When dealing with incidents, operators reported that they decided upon their own rate for the affected ramp meters (4.00). Most responded that they informed the I.O. of an incident immediately after it occurred (4.36). Operators reported that they had no problem completing their duties during their work periods in the control room. Almost zero percent reported that their work load was too heavy, implying that all had sufficient time and ability to complete their work efficiently.

Finally, most operators rated the questions regarding the Changeable Message Sign (CMS) system highly. These questions were designed to see if the operators felt the CMS were easy to use and if they could find the necessary messages to display. A high rating here suggest an overall satisfaction with the ability of the CMS system to deliver accurate and timely messages in the opinion of the respondents. The responses ranged between 3.36 and 3.91.

DISCUSSION

This questionnaire attempted to discover the opinions of the respondents to distractions, the activity level in the control room, their feelings about the traffic monitoring tasks, the design layout of the control room and their stations, and finally likes and dislikes of aspects of the control room. The results of this limited survey showed there were no major problems associated with the traffic control room and that there were many aspects of the control room that actually enhance the operators tasks. An example was the color coding system for the ramp meters providing an easy recognition of traffic problems. However, certain things could be improved. Prohibiting unauthorized individuals in the control room during peak periods and major incidents, would reduce the control room distractions and noise. Also, a redesign of the control room should incorporate a viewing area for guests while improving the work area for all operators. Several respondents made other suggested work area improvements including:

- Move the monitors so they are not obscured by other objects.
- Provide enough space at each work station for work to be done (papers to be laid flat).
- Provide built in shelves at the I.O. work station (room for props).
- Raise the I.O.'s table so the operators need not lean to use the microphone.
- Put carpeting on the floor to reduce the noise in the control room.

The traffic control room consists of five different work stations. Each work station has its own needs and devices. When designing each work station the tasks of the operator must be incorporated into the design. When the control room layout is redesigned, the relationships between the workstations needs to be examined. Perhaps all tasks should be incorporated into one station. Hopefully, shared devices could be located between the stations sharing them or limited to one station. All monitors should be easily seen and unobscured.

Currently, there are approximately twenty North and South station operators working in the control room. Some work one shift per week or several mixed A.M./P.M. shifts. Having so many operators that work for limited amounts of time can lead to inconsistencies in the monitoring and ramp meter tasks. It is usually advisable to have full time operators who would develop a sense of the traffic flows and who would use the same procedures (albeit their own) every day for over-riding and shutting down meters. This would be cited as a major plus to commuters who reach the same ramp each day at the same time and who would love the consistency of knowing that this or that ramp meter is shut off depending upon incidents ahead. It is shallow for us to think that this is a cure all. Having a full time operator does not ensure consistency, because traffic is dynamic and changing. The only thing that full time staff provides is consistency in their own behavior and procedures. A more practical approach is attempting to establish a guideline or procedure statement that is followed by all operators to enhance this consistency. The point being made is that a system of training of all operators, regardless of the amount of shifts worked, with guidelines for operation and procedures to follow could improve the consistency of ramp meter operation.

It was noted by a few of the part time operators that working in the control room enhanced their other job tasks. For example, one respondent responded that working in the control room made them a better designer in their other tasks at the TMC.

RECOMMENDATIONS

The recommendations are presented as possible implementations for the traffic control room with its present equipment. Information gathered from the surveys represented a general assessment of the issues related to the control room area. Therefore, the following recommendations are also presented in a format following the questionnaire's organization. A further investigation should examine the key issues of concern for the traffic control room operators. Future investigation should address the work area along with work stations of the operators and the overall design of the control room. The consistency of operator monitoring and the presence of unauthorized individuals in the control room also should be addressed.

- Create or emphasize a systematic way (guidelines) to turn ramp meters on and off. Incorporate focus groups or brain storming sessions with the operators, so that all opinions and suggestions are examined. This should create more consistency in the control room which in turn should aid in the reduction of congestion.
- Move the monitors so they are not obscured by other objects. Operators should be able to comfortably see all monitors and equipment needed for their task(s).
- Make sure there is enough space at each work station for everything that is needed to perform required tasks. Cluttered work areas reduce productivity.

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- The most frequent complaint relating to the noise in the control room is associated with the extra, unauthorized individuals. Only the authorized controllers (for the period) should be allowed in the control room. A stricter policy should be enforced regarding unauthorized individuals.

- Organize the I.O.'s work station to better utilize the work space and area. An example cited by the I.O.s was to providing built in shelves.

- Raise the I.O.'s table so the operator need not lean to use the microphone.

- When redesigning the control room, position the work stations so that the I.O. or North or South operators do not have to walk around the desks to reach each station.

- For the North and South work stations, design curved work areas (similar to the I.O. work station). This will increase the ease of reaching for controls. Distribution of controls should place the most frequently operated controls directly in front of the operators, with less frequent controls placed on the outside range of the operator's reach.

- Provide the I.O. with access to the ramp meters and CMS's during non-peak times to provide better accessibility.

- Several respondents reported noise from the I.O.'s radios and patrol monitors. The radio's buzzing noise should be quieted to increase the comfort level within the room.

- Use sound dampening tile on the floor to help quiet the control room or employ sound dampers to the walls.

- If the traffic management control room is to be redesigned, there should be a joint effort by the design engineers and control room operators to ensure that job quality and productivity is enhanced. The redesign of the control room should focus on the workstations for all operators, equipment placement, and a viewing area for guests and visitors. A co-ordinated effort employing all persons associated with the control room and the designers of the workstations should be employed to increase the ability of providing an adequate work area.

- Management should address issues concerning staffing levels for the North and South Station operators to ensure a consistency for the monitoring of traffic incidents and ramp meter control. This can include establishing a handbook or procedural guidelines for ramp meter operation, or simply reducing the staff. This is a complex problem due to individual variation and the ability or desire of management to monitor the following of procedures. An effort is underway to correct this inconsistency that will hopefully eliminate this problem.

- More training sessions are needed to allow new operators time to gain a better understanding of their task, thus gaining more consistency within each task.

Appendix A

Linkage Diagrams

APPENDIX A. Linkage Diagrams.

Dynaguide : Eject tape, select station to listen to.
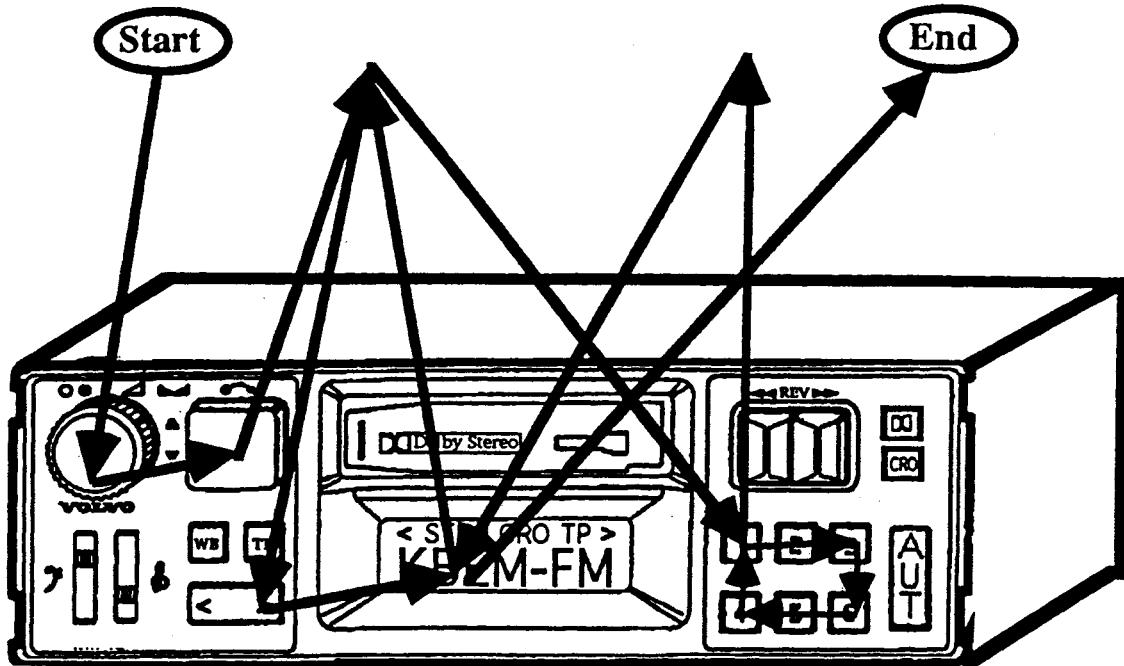
Dynaguide Task : Start TP search / End TP Search
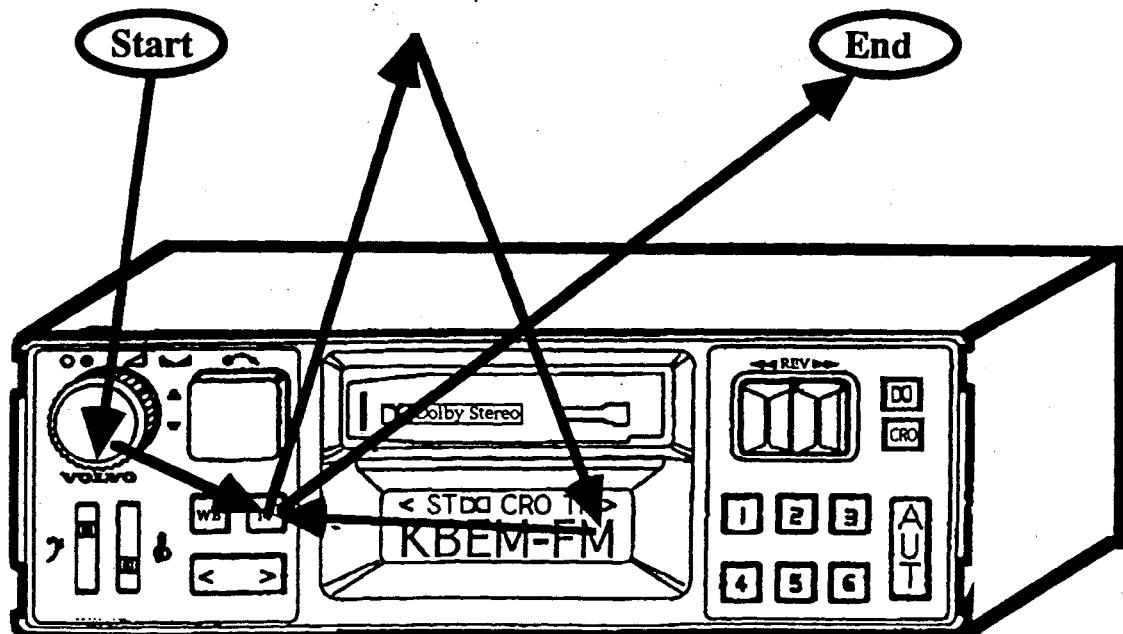
Dynaguide : Filter, select icon, read text
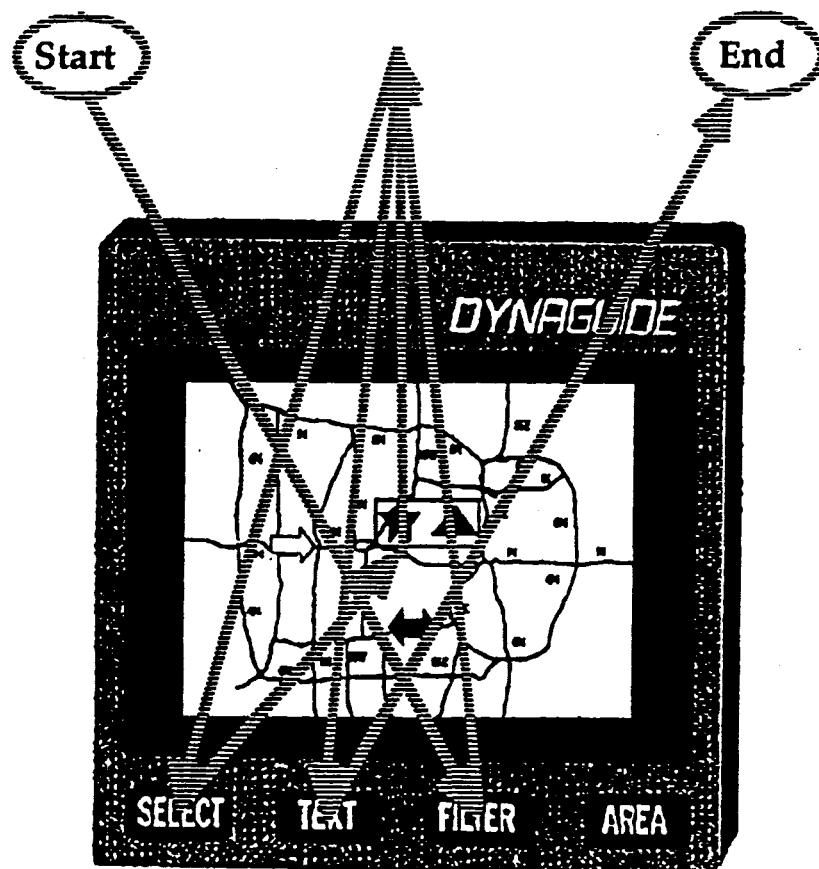
Dynaguide : Select map area, icon, and read text
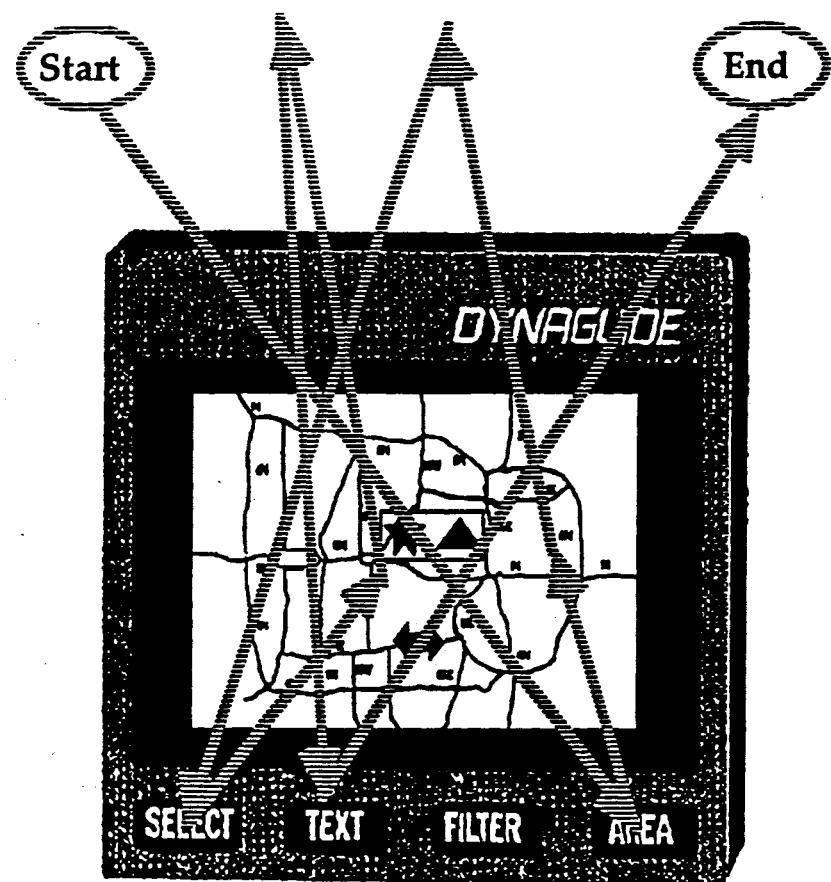
Dynaguide : Use TP function, select icon, read text.
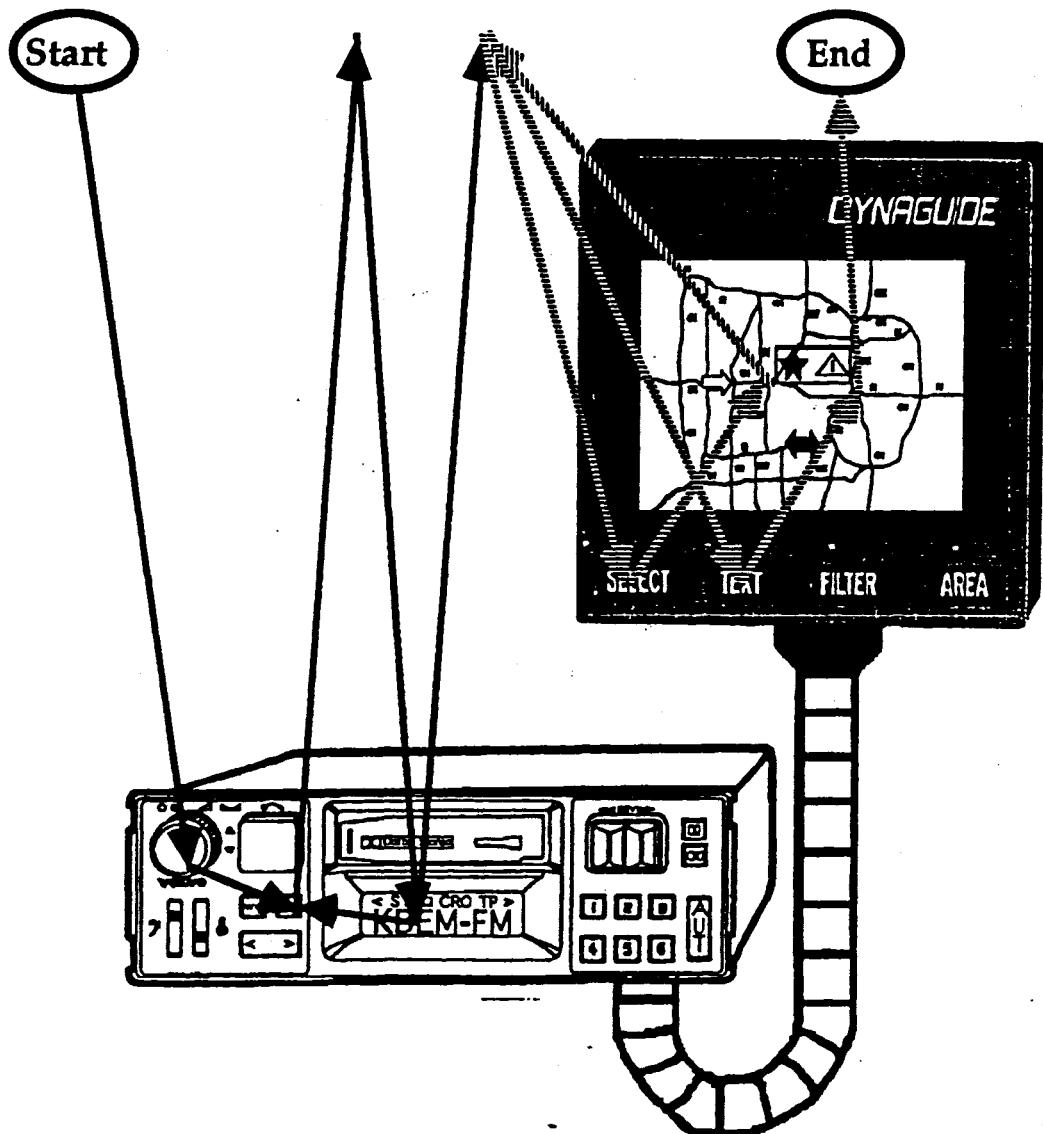
Indikta : Select between menu options.
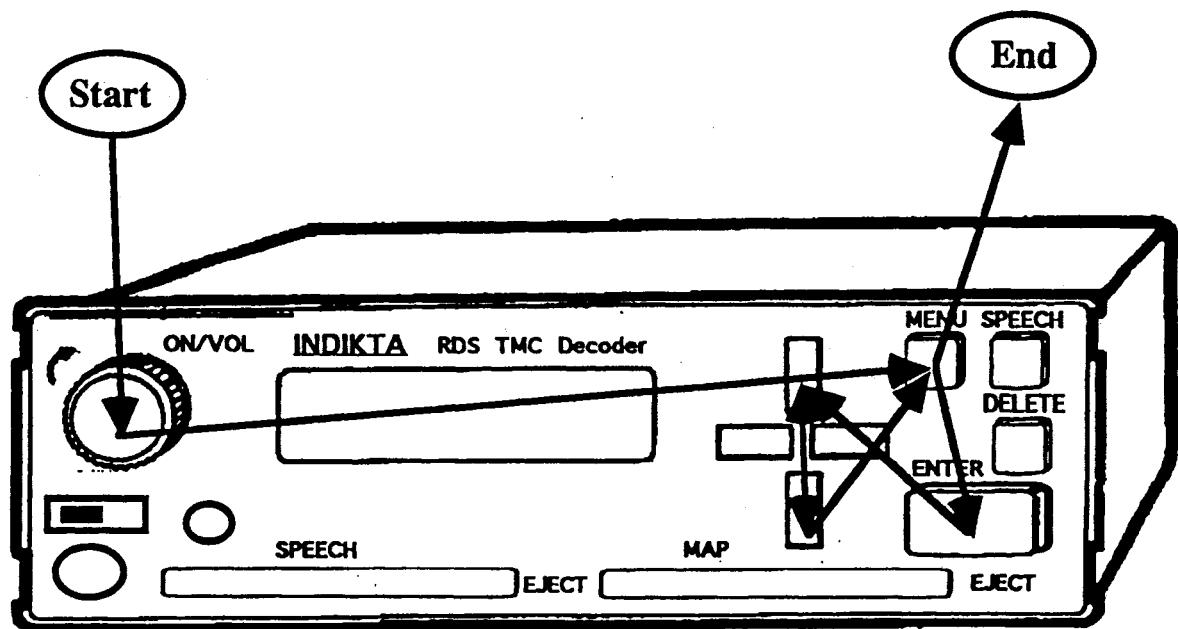
Indikta : Turn on RDS, select route on decoder, confirm warning on display pod, and turn off speech function.
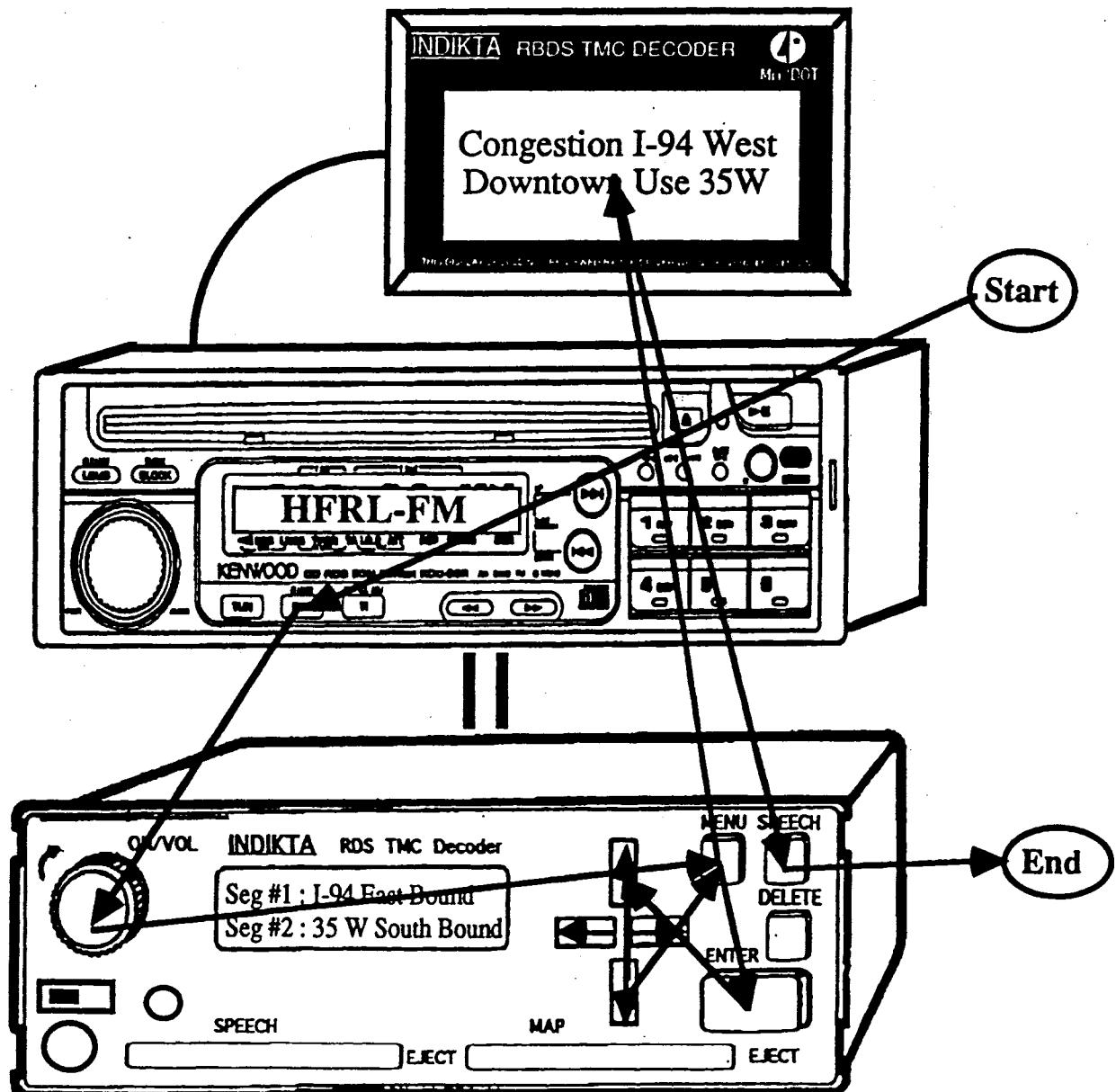
Appendix B

Flow Charts

APPENDIX B.: Flow Diagrams

DYNAGUIDE : Select "TP" button to find traffic information.

```
        ┌─────────┐
        │  Turn   │
        │  Power  │
        │   On.   │
        └────┬────┘
             │
             ▼
         ╱───────╲
        ╱ Use "TP" ╲        Yes      ┌──────────┐
       ╱  Function   ╲───────────────│ Press TP │
       ╲  to Search  ╱               │ Button.  │
        ╲ for Info?  ╱               └────┬─────┘
         ╲─────────╱                      │
             │                            ▼
            No                      ┌──────────┐
             │                      │ Station  │
             ▼                   ┌─▶│  Found   │
      ┌──────────┐               │  └────┬─────┘
      │ Listen to │              │       │
      │ Radio or  │              │       ▼
      │ CD Player │              │   ╱───────╲
      └──────────┘              │  ╱    Is     ╲    Yes   ┌──────────┐
                                │ ╱  Dynaguide  ╲─────────│ Press"TP"│
                                │ ╲   Screen    ╱         │ to Stop  │
                                │  ╲ Displaying╱          │  Search  │
                                │   ╲ Icons?  ╱           └────┬─────┘
                                │    ╲──────╱                  │
                                │       │                      ▼
                                │      No                 ╱────────╲    Yes   ┌─────────┐
                                │       │                ╱ Continue  ╲────────│ Listen  │
                                │       ▼               ╱  Listening  ╲       │ To Radio│
                                │  ┌──────────┐         ╲ to Station? ╱       │ and Read│
                                │  │ Press"TP"│          ╲───────────╱        │Dynaguide│
                                │  │ to Stop  │               │               │ Screens │
                                │  │  Search  │              No               └─────────┘
                                │  └────┬─────┘               │
                                │       ▼                     ▼
                                │  ┌──────────┐
                                └──│ Press"TP"│◀─────────────┘
                                   │ Button to│
                                   │Re-in    │
                                   │ Search   │
                                   └──────────┘
```
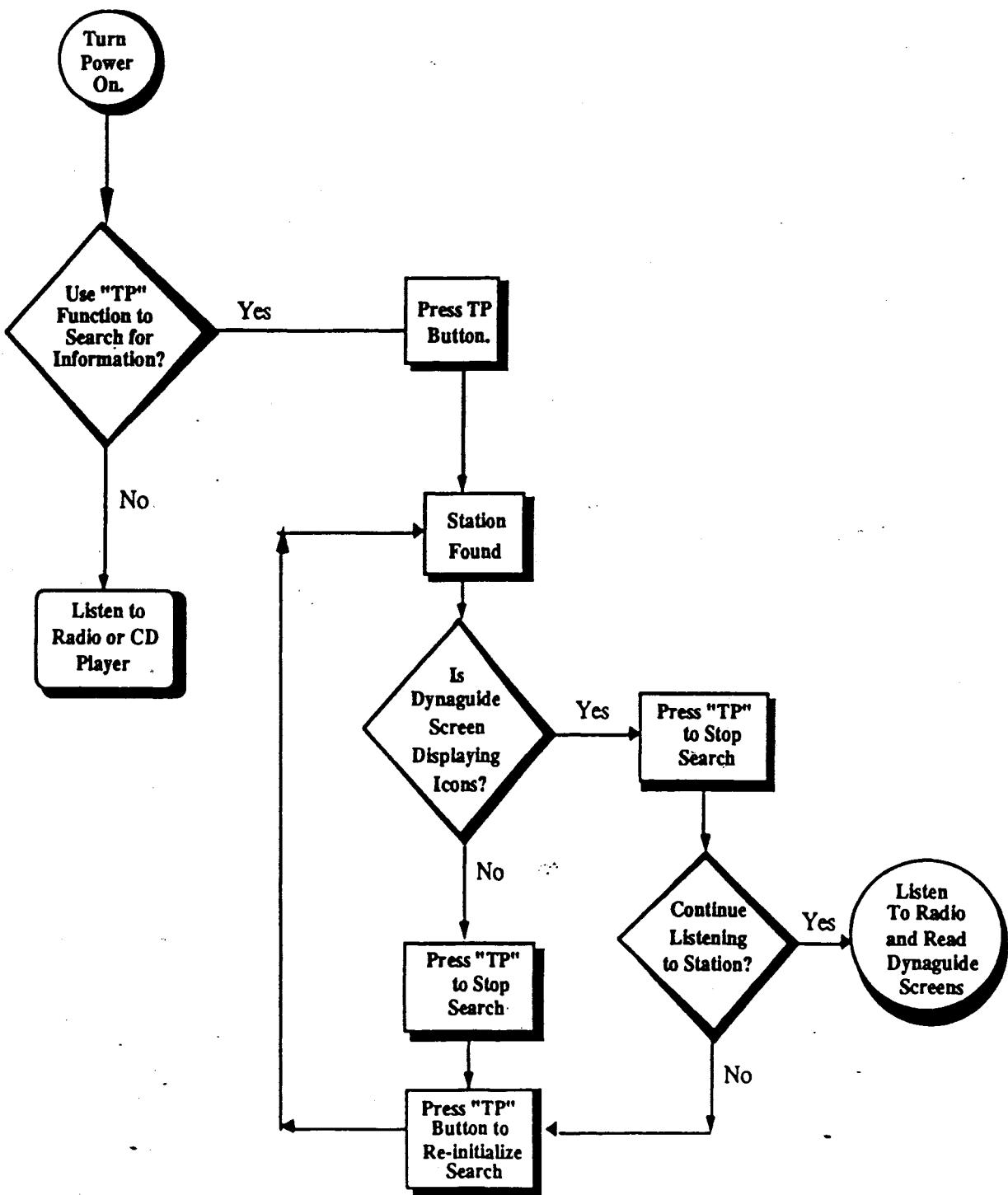
Indikta : Configuring the Decoder.

```
        ┌──────────┐
        │  Turn on │
        │  Power   │
        └────┬─────┘
             │
             ▼
        ╱─────────╲         YES    ┌──────────┐
       ╱ Configure ╲──────────────▶│  Press   │
       ╲ Decoder?  ╱               │  Menu    │
        ╲─────────╱                │  Button  │
             │                     └────┬─────┘
             │ NO                       │
             ▼                          ▼
      ┌──────────────┐            ┌──────────┐
      │  Listen to   │            │  Set-Up  │
      │ CD/Radio, wait│           │  Mode    │
      │for any message.│          └────┬─────┘
      └──────────────┘                 │
                                       ▼
```

Use Configure Submenu?   YES → Press Enter Button → Change first selection in Configure Menu?   YES → Press Enter Button

NO

NO

Press down arrow to select next choice

Change Selection Options?   YES → Press enter button until option desired is selected.

NO

Exit Configuration Menu?   YES → Press Menu Button → Listen to CD/Radio in "normal mode"

NO

Indikta : Setting new route and naming the route in "Set-up mode"

```
                              ┌─────────────┐
                             (  Turn on      )
                             (  Power        )
                              └──────┬──────┘
                                     │
                                     ▼
                              ╱─────────────╲                    ┌──────────────┐
                             ╱   Select       ╲      YES          │   Press      │
                            ╱    New           ╲─────────────────▶│   Menu       │
                            ╲    Route?        ╱                  │   Button     │
                             ╲───────┬───────╱                    └──────┬───────┘
                                     │NO                                 │
                                     ▼                                   ▼
                            ┌─────────────────┐               ┌──────────────────┐
                            │  Listen to      │               │   Press          │
                            │  CD/Radio, Wait │               │   Down Arrow     │
                            │  For Messages.  │               │   Until          │
                            └─────────────────┘               │  "Select Route"  │
                                                              │   Displayed.     │
                                                              └────────┬─────────┘
                                                                       │
                                                       NO     ╱────────────────╲
                                              ◀───────────────╲   Select        ╱
                                                              ╲   Route?        ╱
                                                               ╲──────┬────────╱
                                                                      │YES
                                                                      ▼
                                                              ┌──────────────┐
                                                              │   Press      │
                                                              │   Enter      │
                                                              │   Button     │
                                                              │ (Until "New" is│
                                                              │  displayed).  │
                                                              └──────┬───────┘
                                                                     │
         ┌──────────────┐           ╱────────────╲            ┌──────────────┐
         │   Press      │     NO   ╱   Select      ╲          │   Press      │
         │   Menu To Exit│◀───────╲   First        ╱◀─────────│   Enter      │
         └──────────────┘          ╲   Route?      ╱          │   Button     │
                                    ╲─────┬───────╱           │(Route Choices │
                                          │YES                │  displayed).  │
                                          ▼                   └──────────────┘
                                  ┌──────────────┐
                                  │  Use Up/Down │◀───────────────────────┐
                                  │  Arrows To   │                        │
                                  │  Select Route.│                       │
                                  └──────┬───────┘                        │
                                         │YES                             │
                                 ╱────────────╲        ┌──────────────┐   │
                           NO   ╱  Confirm     ╲       │   Press      │   │
                         ◀─────╲   Route?      ╱──────▶│   Enter      │   │
                                ╲─────┬───────╱        │   Button     │   │
                                      │                └──────┬───────┘   │
                                      │                       │           │
                                                       ╱──────────────╲   │        ╱──────────╲    ┌──────────────┐
                           NO                   YES   ╱                ╲──│───────▶╱  Name      ╲  │ Press Menu To│
                         ◀────────────────────────────╲   Continue?    ╱           ╲  Route?     ╱  │   Exit       │
                                                       ╲──────┬───────╱             ╲────┬──────╱   └──────────────┘
                                                              │YES                      │YES    NO
                                                              ▼                         ▼
                                                      ┌──────────────┐          ┌──────────────┐
                                                      │   Press      │          │   Press      │
                                                      │   Enter      │          │   Enter      │
                                                      │   Button     │          │   Button     │
                                                      └──────┬───────┘          └──────┬───────┘
                                                             │                         ▼
                           NO                         ╱────────────╲           ┌──────────────┐
                         ◀─────────────────────────── ╱  Select      ╲          │ Use Right/Left│
                                                      ╲   More        ╱          │ Arrows To    │
                                                      ╲   Routes?     ╱          │ Select Cursor│
                                                       ╲─────┬───────╱           │ Position.    │
                                                             │YES                └──────┬───────┘
                                                             ▼                          ▼
                                                      ┌──────────────┐          ┌──────────────┐
                                                      │   Press      │          │ Use Up/Down  │
                                                      │   Enter      │─────────▶│ Arrows To    │
                                                      │   Button     │   YES    │ Select       │
                                                      └──────────────┘          │ Characters In│
                                                                                │ Route Name   │
                                                                                └──────┬───────┘
                                                                     YES                ▼
                                                                            ╱──────────────╲
                                                                           ╱   Save          ╲
                                                                           ╲   Route          ╱
                                                                           ╲   Name?          ╱
                                                                            ╲───────┬────────╱
                                                            NO                      │
                                                          ◀─────────────────────────┘
```

Appendix C

Redesigns of Each Device

APPENDIX C. : Redesign of the DYNAGUIDE Receiver.

ON / OFF

DELETE

Speech

Menu

INDIKTA RDS TMC Decoder

Warning:
Off Ramp Closed
North I-169
At Betty Crocker Drive
For The Rest Of The
Week

Return

Exit

EJECT
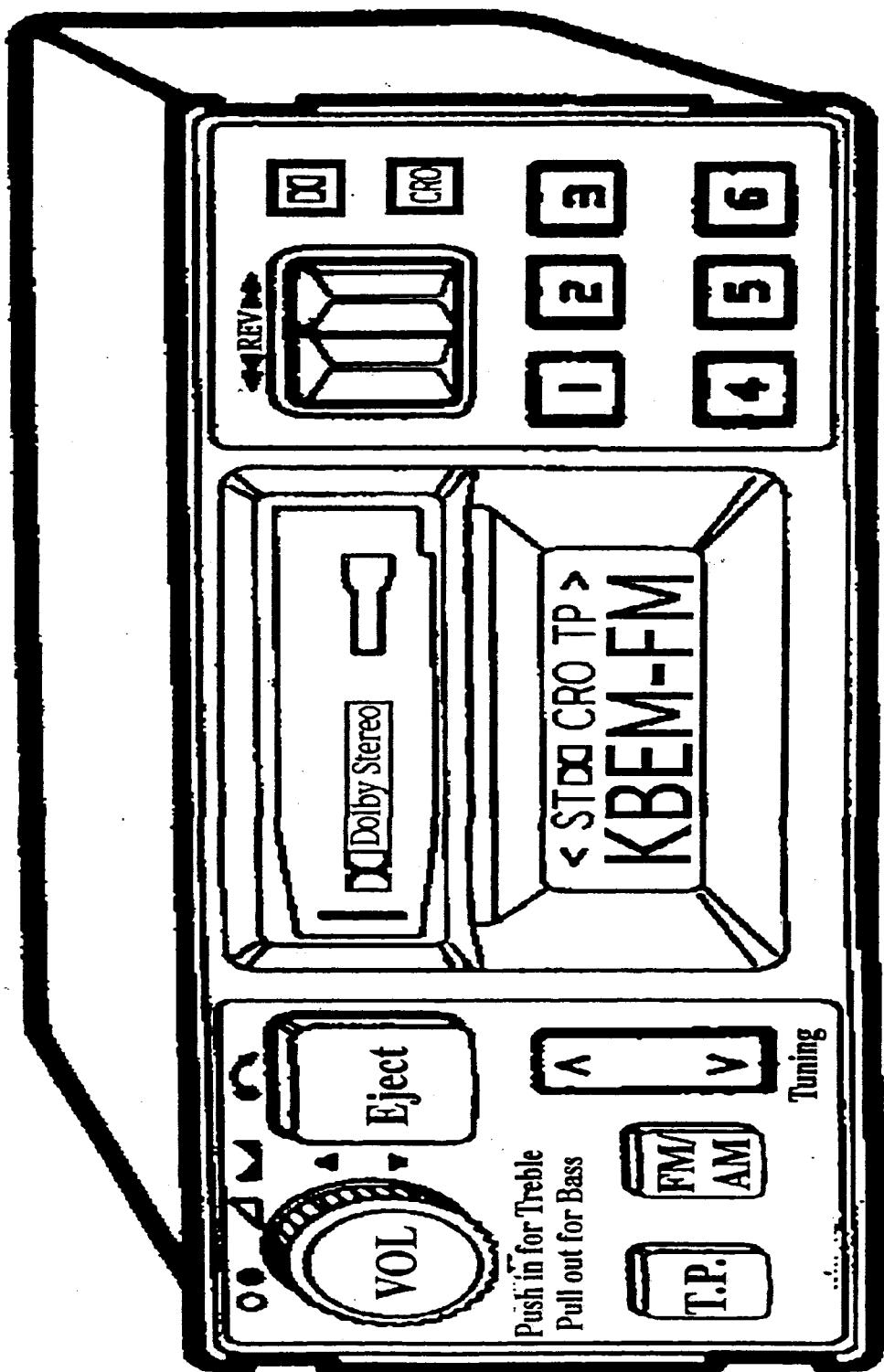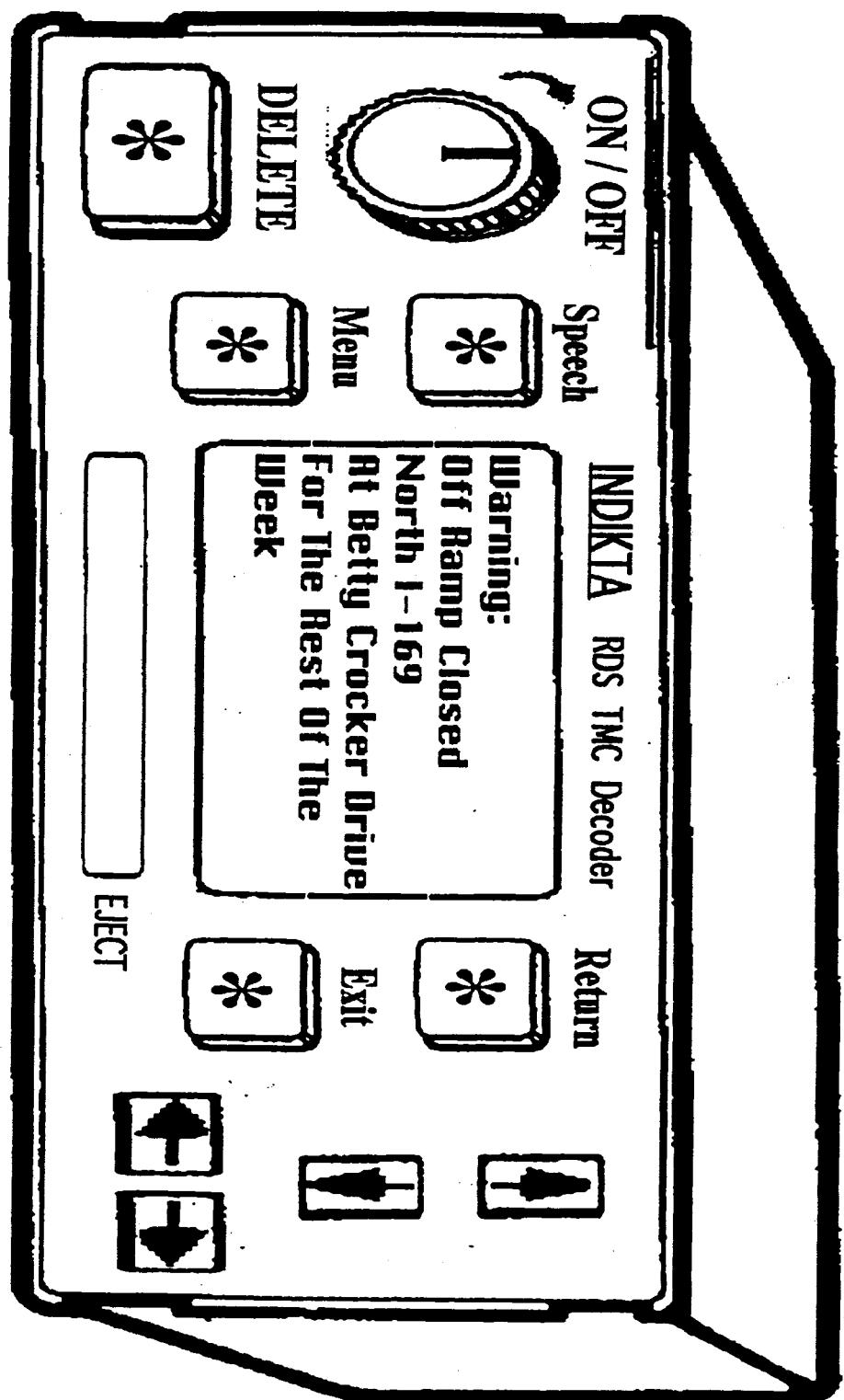
Appendix D

Indikta Menu Screens

APPENDIX D. : Indikta Decoder Menu

Scroll
On / Off

Brightness
100% / 70% / 30%

Sound
On /Off

Reset

Configure

Undelete

Current
Messages

Priority
Speak All / Urgent / Emergency

MENU

Select
Events

Select
Route

Select Category

Route

Region

All
Traffic Incidents
Road Conditions
Weather Conditions
Events
General Warnings

New

Preprogrammed

Anoka
Dakota
Hennepin
Ramsey
Minnesota
United States
Washington

Roadlist

Appendix E

Icon Quiz

APPENDIX E.: *ICON QUIZ*

Dear Participant.

You have volunteered to take a short evaluation quiz of pictures and their meanings. This study is part of a research project that is looking at ICONS (small pictures on a computer that have lots of implied meaning). We are using these icons on a map of the twin cities to represent various traffic problems or advisories.

A driver could look at a map on a computer, and check the roads they would be traveling on. By seeing one of these Icons on their route, they would know if there were traffic problems. In this way, a driver could take an alternate route to work if there is congestion on their normal daily route.
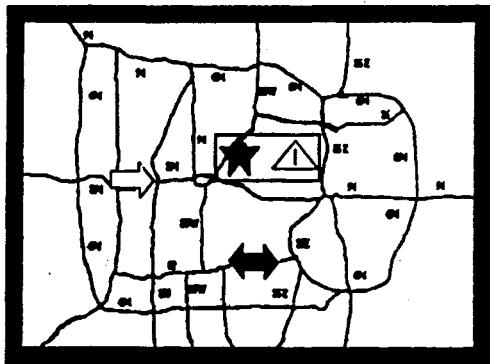
Your computer screen might look like this:

By looking at the highways you want to drive on, you would see the icons we are going to test you on and you could change your route accordingly.

The quiz you will take will show an icon. Next to it is a blank where you will write in what you think it means. There are no right or wrong answers and you can put down as many words as necessary. If you do not recognize a symbol try to write down what you think it represents. After you are done we will ask you some questions.

Here is an Example:

If you were given this Icon.

You would fill in the blank with:

MERGE

Have fun and remember any answer is a good answer!
Thank you for your help !!!!

_____

_____

_____



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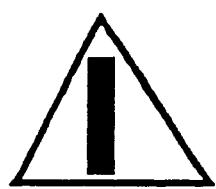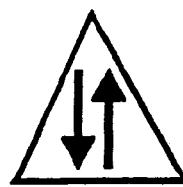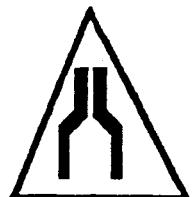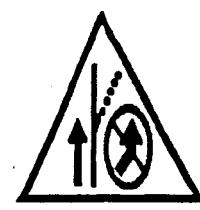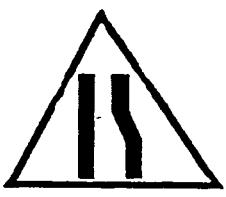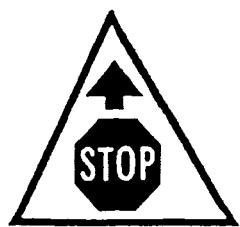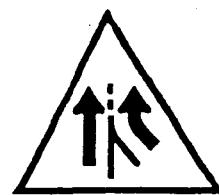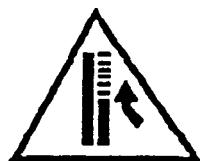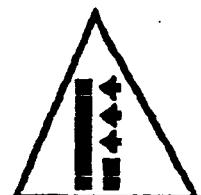
You are finished!!!

The experimentor will now ask you
some brief questions.
Thank you for your time.

Appendix F

Instructions Given To Each Task Two Participants

Appendix F.: Instructions given to Task Two Particpants.

INSTRUCTIONS TO PARTICIPANTS

Welcome to the Human Factors Research Laboratory.

The lab's main area of research is to improve the safety of driving on our roadways. One of the serious causes of accidents is congestion with its fast stops and cars being packed closely together. Congestion adds to other causes of accidents such as: The reduced vision and reflexes of some older drivers, The diminished responsiveness of drivers under the influence of alcohol or drugs, or The general lack of attentiveness produced by the slow movement of congested traffic.

This study, in which you have kindly volunteered to take part in, is related to efforts to reduce congestion. We are looking at several radio devices that give drivers current traffic information while they drive. The Minnesota Department of Transportation can collect current, accurate information on traffic every minute. The problem is how to tell you, the commuter or driver, what is the traffic information. We want to be able to send you traffic information as you drive, so that you can be aware of any delays, accidents, or congestion. One way that this is done is to use a smart car radio which will have a television screen on it that will show you sentences or maps with traffic information on it, or perhaps your smart radio will stop playing music and talk to you with a synthesized voice telling you what is ahead. The Department of Transportation wants to use smart radios like that, so that drivers can manage traffic by being informed drivers. By giving you current information on construction delays, bad weather or incidents such as accidents, you can decide what roads or routes to drive on to avoid these problems. As a driver you would receive information that an accident has occurred ahead of you and because you have this information from your radio, you will avoid the area and take another route.

The purpose of this study is to assess your preferences and how useful you feel these smart radios would be to you. We hope to find out how useful and trustworthy these smart radios are. To study this we will have you drive in the Dynamic Driving Simulator and operate these smart radios as you drive. We will give you a traffic message and you will decide how to use the information given to you.

You are about to receive instructions on the radios and the simulator. You will be given as much time as you like to get familiar with the radio and the simulator before we collect any data. You will practice in the simulator until you feel comfortable driving in it. There is no hurry and at any time during the practice or after a trial we can stop and rest.

You will be asked to complete two to eight five minute trials of the simulator after you have finished practicing. These trails consist of driving the car at 55 M.P.H. northbound on State Highway 77 (Cedar Avenue North) toward the Twin Cities. Traffic will move in the other lane towards you, as this is a two way street. You will approach an intersection with a stop sign. This intersection is State Highway 62 (The Crosstown Highway) which heads east/west. You are trying to get downtown as quickly as possible. If you stay on Cedar Avenue North it will take you 25 minutes. If you take the Crosstown and then go north on I-35W it will take 16 minutes. However, congestions or accidents can slow you down on I-35W and it can take over 30 minutes in bad traffic. You will have to decide whether to make a left turn onto the Crosstown or to stay on Cedar Avenue North based on which route is the best way to travel.

How will you know if it is the best way? It may be congested with rush hour traffic... or I-35W may be backed up due to an accident?

You will be able to determine if it is the best route to take based upon the information given to you by the smart radios. The radios may indicate that traffic is backed up on I-35W or that the Crosstown is congested, if so you can drive straight through the intersection and continue up Cedar Avenue North. If the radios indicate that traffic is flowing freely or that there are no reports on the Crosstown or I-35W, then you can take a left turn onto the Crosstown.

How do the smart radios give me traffic information?

There will three different types of radios and information. You will receive information on a television screen, by hearing one of the radios talk to you, by reading the message off of a text display, and finally, by listening to a traffic information station with a traffic report every ten minutes. We will teach you how to use all of the radios, and give you examples of all of the information that you will receive.

The FIRST SYSTEM is a radio with an attached television screen showing a map.
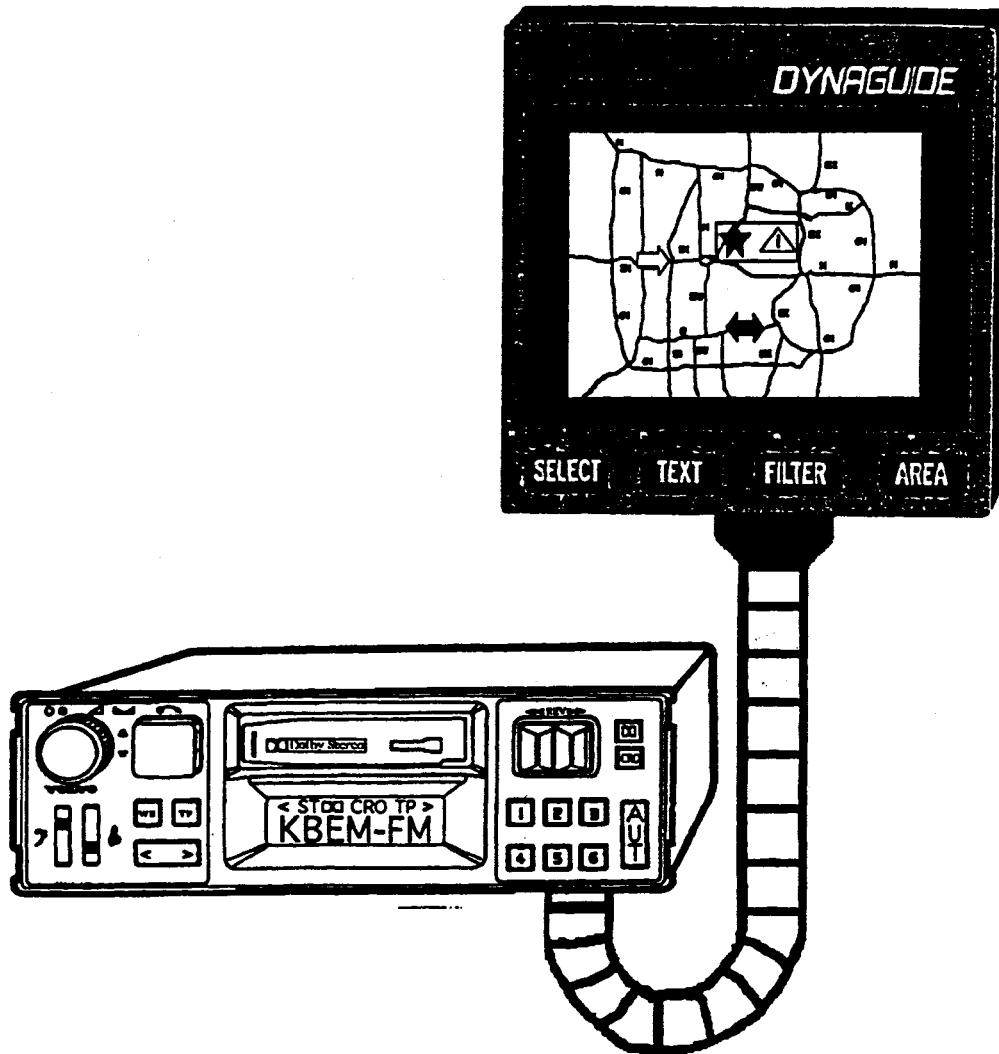
You will see a map of the Twin Cities roadways. On this map icons will appear that tell you about traffic conditions. These icons look like"Stars" or "Arrows" and can be selected to show traffic signs that look like construction workers or merge signs. These icons tell you that there is construction on the road where the "Star" is located. Here is an example:

If you prefer, the screen can display sentences describing the traffic problem. You will have to operate this radio while driving and watch for information on Cedar Avenue or I-35W. The map will look like this:
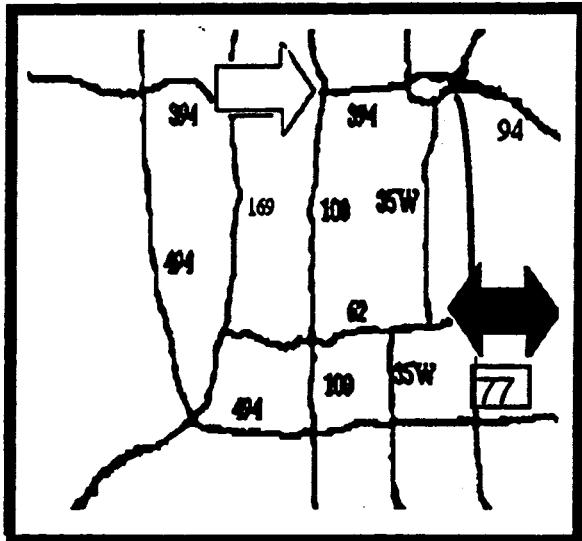
The SECOND SYSTEM has a voice synthesis chip attached and it will turn down your radio automatically and speak to you.

It will say:

"WARNING - ON I-35W AT STATE HIGHWAY 62 - SERIOUS ACCIDENT - SITUATION IS EXPECTED TO CONTINUE FOR THE NEXT FOUR HOURS."

You then will know what is happening on your route.

The THIRD SYSTEM will be text screen which will spell out exactly what the traffic advisors are. It will look like this:
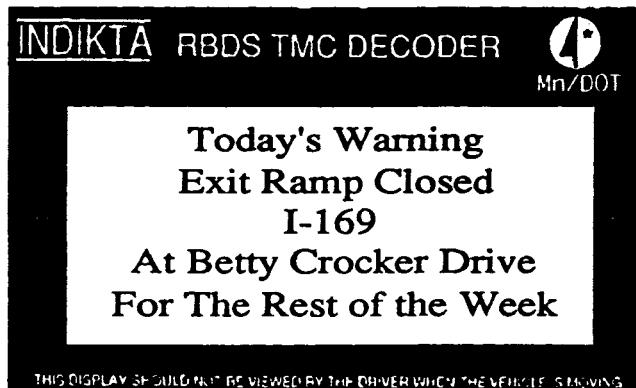
Finally, with the LAST SYSTEM you may not receive any information from the screens, text, or voice chip. In this trail you will receive traffic information from the D.J. on the radio. They will tell you what is happening with rush hour traffic.

* Your task will be to drive the car, listen or look for traffic messages and then decide whether you will turn onto the Crosstown Highway or not. *

One last thing.
When you arrive at the Crosstown intersection there will either be:

1.) Free flowing traffic (cars will be whizzing by on the Crosstown)
or there will be
2.) Congestion (cars appear parked on the Crosstown).

The message you receive on the radios may not be the same as the what the traffic looks like on the Crosstown. For example, the voice system may say traffic flowing freely on the Crosstown, however, as you approach the intersection you might see stop and go traffic. The Map may indicate Congestion on I-35W but as you approach the Crosstown traffic will be moving freely. You should remember that cars may be traveling freely on the Crosstown where you are, but may be backed up several miles ahead or on I-35W. You will still need to make a decision whether to turn or not. You must make up your own mind whether you trust the radios or your own eyes. It is up to you to decide whether to follow the radios advice or not. There are no wrong answers.

After you make the turn or go straight, the trial is over and the experimenter will ask if you are ready for the next trial. It will take a minute ot two to set up for the next trial between each one.

You will have two trials using each type of warning: The map, voice, text, and radio announcer.

During each trial the Crosstown or I-35W will be either Congested or Free Flowing. You will decide based upon the information given in each trial. If you receive information during one trial it does not apply to the next or any other trial.

The simulator road looks like this:
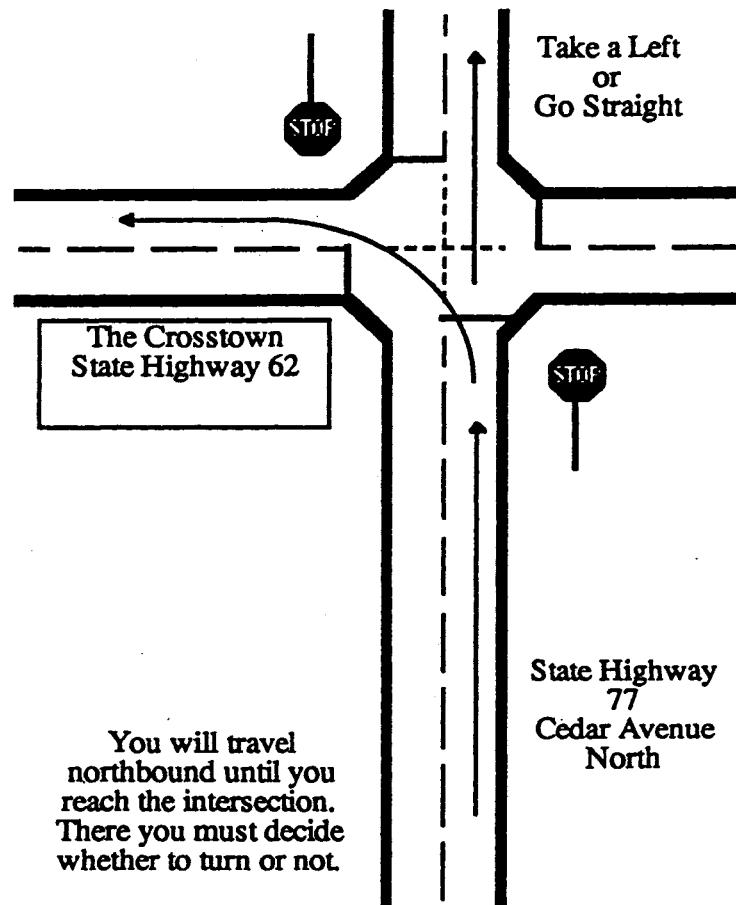
After you have completed all trails, we will ask you to complete a general information questionnaire which we will ask all our participants in the experiment to complete. On this questionnaire we will ask how you felt about the radios and what your impressions were of the ways that they deliver information to you. Your responses to the questionnaire and your driving results will be kept confidential. At the end of these instructions is a consent to participate form, which we will ask you to sign.

Thank you again for volunteering and if you are ready to go ahead, tell the Laboratory person that you are finished and ready to learn about the radios.

DYNAGUIDE MAP DISPLAY INSTRUCTIONS

Selected Symbol with Icon.

Push the Text Button again to return to the map display.

Push the Text Button if you would like to read the text message for what the symbol and icon stand for.

DYNAGUIDE

SELECT   TEXT   FILTER   AREA

Push the Select button until the symbol you have located is surrounded by a box.

Locate if any symbols are on the route you are taking.
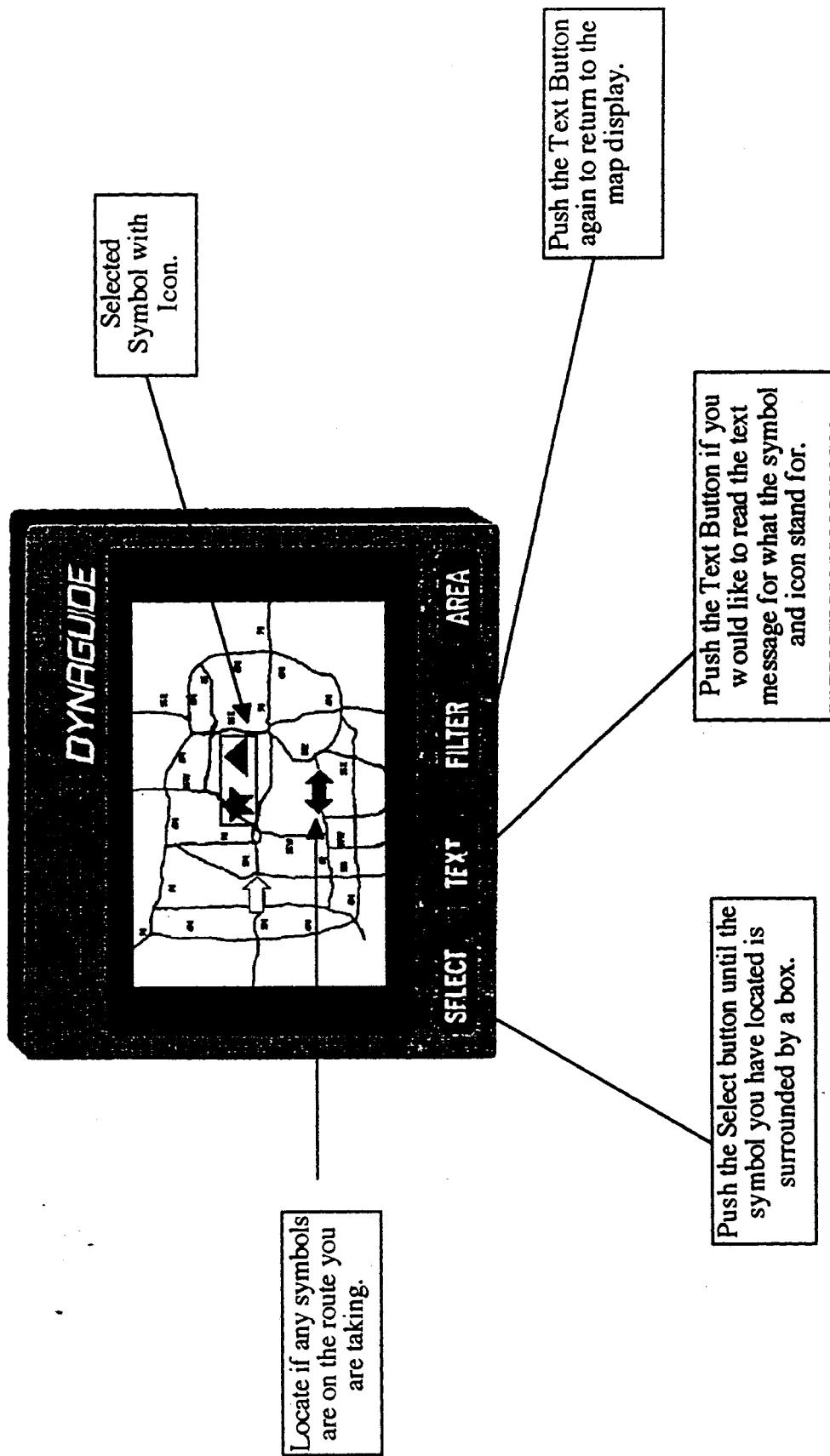
CONSENT TO PARTICIPATE IN SIMULATION RESEARCH

Participant's Name:_____

Date: /   /   1994

I have read the form above and understand the test to be done. The laboratory personnel have explained the simulator and radio to me and informed me that I may stop and rest or quit the study at any time. I fully consent to participate and to have the results of this study used for any purposes the Laboratory or MnDOT see fit. I will tell the experimenter if I have had any discomfort or feel that my driving in the simulator was affected by anything happening around me.

Signed,

_____

Participant's signature

Appendix G

Task Two Data

SUBJECT NUMBER	TRIAL #	DEVICE	CONGESTED NOT CONGESTED	CRUSADER MESSAGES	TRUE/ FALSE	DECISION Left or Straight	CORRECT?
1	1	Volvo	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Indikta	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Text	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Radio	Congested	Congestion I-35W	TRUE	Straight	C
	5	Volvo	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Indikta	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Text	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Radio	Not Congested	Construction State Highway 77	TRUE	Straight	NOT C
2	1	Indikta	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Text	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Radio	Not Congested	Traffic Free Flowing : I-35W	TRUE	Straight	NOT C
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight	C
	5	Indikta	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	C
	6	Text	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Radio	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Volvo	Not Congested	Construction State Highway 77	TRUE	Straight	NOT C
3	1	Radio	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Indikta	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Text	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight	C
	5	Radio	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Indikta	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Text	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Volvo	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
4	1	Text	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Indikta	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Volvo	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	C
	4	Radio	Not Congested	Congestion I-35W	FALSE	Turn Left	C
	5	Text	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	C
	6	Indikta	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Volvo	Not Congested	Road Construction State Highway 62	FALSE	Turn Left	C
	8	Radio	Congested	Construction State Highway 77	FALSE	Straight	C
5	1	Indikta	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Volvo	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Radio	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Text	Not Congested	Congestion I-35W	FALSE	Turn Left	C
	5	Indikta	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Volvo	Congested	Delays : State Highway 77	FALSE	Turn Left	NOT C
	7	Radio	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Text	Congested	Construction State Highway 77	FALSE	Turn Left	NOT C
6	1	Volvo	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Text	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Indikta	Congested	Traffic Free Flowing : I-35W	FALSE	Turn Left	NOT C
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight	C
	5	Radio	Congested	Traffic Free Flowing State Hwy 62	FALSE	Turn Left	NOT C
	6	Text	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Radio	Not Congested	Road Construction State Highway 62	FALSE	Turn Left	C
	8	Indikta	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
7	1	Indikta	Congested	Serious Accident I-35W	TRUE	Turn Left	NOT C
	2	Text	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Radio	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	C
	4	Indikta	Not Congested	Congestion I-35W	FALSE	Turn Left	C
	5	Volvo	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Text	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Radio	Not Congested	Road Construction State Highway 62	FALSE	Straight	NOT C
	8	Volvo	Congested	Construction State Highway 77	FALSE	Straight	C

SUBJECT NUMBER	TRIAL #	DEVICE	CONGESTED NOT CONGESTED	CRUSADER MESSAGES	TRUE/ FALSE	DECISION Left or Straight	CORRECT?
8	1	Text	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Radio	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Indikta	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Indikta	Congested	Congestion I-35W	TRUE	Straight	C
	5	Radio	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Volvo	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Text	Not Congested	Road Construction State Highway 62	FALSE	Turn Left	C
	8	Volvo	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
9	1	Volvo	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Radio	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Text	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Radio	Congested	Congestion I-35W	TRUE	Straight	C
	5	Indikta	Congested	Traffic Free Flowing State Hwy 62	FALSE	Turn Left	NOT C
	6	Text	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Volvo	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Indikta	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
10	1	Text	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Indikta	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Volvo	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	C
	4	Radio	Congested	Congestion I-35W	TRUE	Straight	C
	5	Text	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Indikta	Congested	Delays : State Highway 77	TRUE	Straight	C
	7	Volvo	Not Congested	Road Construction State Highway 62	FALSE	Turn Left	C
	8	Radio	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
11	1	Text	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Volvo	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Turn Left	C
	3	Volvo	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	C
	4	Radio	Not Congested	Congestion I-35W	FALSE	Straight	NOT C
	5	Text	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	C
	6	Indikta	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Indikta	Not Congested	Road Construction State Highway 62	FALSE	Straight	NOT C
	8	Radio	Congested	Construction State Highway 77	FALSE	Straight	C
12	1	Indikta	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Text	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Indikta	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight	C
	5	Radio	Congested	Traffic Free Flowing State Hwy 62	FALSE	Turn Left	NOT C
	6	Text	Congested	Delays : State Highway 77	FALSE	Turn Left	NOT C
	7	Radio	Not Congested	Road Construction State Highway 62	FALSE	Straight	NOT C
	8	Volvo	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
13	1	Radio	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Indikta	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Turn Left	C
	3	Text	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Radio	Not Congested	Congestion I-35W	FALSE	Straight	NOT C
	5	Volvo	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	C
	6	Text	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Indikta	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Volvo	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
14	1	Text	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Radio	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Volvo	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Text	Not Congested	Congestion I-35W	FALSE	Turn Left	C
	5	Indikta	Congested	Traffic Free Flowing State Hwy 62	TRUE	Straight	C
	6	Indikta	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Volvo	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Radio	Not Congested	Construction State Highway 77	TRUE	Turn Left	C

SUBJECT NUMBER	TRIAL #	DEVICE	CONGESTED NOT CONGESTED	CRUSADER MESSAGES	TRUE/ FALSE	DECISION Left or Straight	CORRECT?
15	1	Volvo	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Indikta	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Turn Left	C
	3	Text	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	C
	4	Radio	Congested	Congestion I-35W	TRUE	Straight	C
	5	Text	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Radio	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Volvo	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Indikta	Congested	Construction State Highway 77	FALSE	Straight	C
16	1	Radio	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Volvo	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Indikta	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Text	Not Congested	Congestion I-35W	FALSE	Turn Left	C
	5	Radio	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	C
	6	Volvo	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Indikta	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Text	Congested	Construction State Highway 77	FALSE	Straight	C
17	1	Indikta	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Volvo	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Radio	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Volvo	Not Congested	Congestion I-35W	FALSE	Turn Left	C
	5	Text	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	C
	6	Indikta	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Radio	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Text	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
18	1	Indikta	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Indikta	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Radio	Congested	Traffic Free Flowing : I-35W	FALSE	Turn Left	NOT C
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight	C
	5	Text	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Volvo	Not Congested	Delays : State Highway 77	FALSE	Turn Left	C
	7	Text	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Radio	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
19	1	Indikta	Not Congested	Serious Accident I-35W	FALSE	Straight	NOT C
	2	Radio	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Text	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	C
	4	Indikta	Congested	Congestion I-35W	TRUE	Straight	C
	5	Volvo	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	C
	6	Radio	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Volvo	Not Congested	Road Construction State Highway 62	FALSE	Turn Left	C
	8	Text	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
20	1	Radio	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Volvo	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	C
	3	Text	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Text	Congested	Congestion I-35W	TRUE	Straight	C
	5	Indikta	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Radio	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Volvo	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Indikta	Congested	Construction State Highway 77	FALSE	Straight	C
21	1	Volvo	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Indikta	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Text	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Radio	Congested	Congestion I-35W	TRUE	Straight	C
	5	Volvo	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Indikta	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Text	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Radio	Not Congested	Construction State Highway 77	TRUE	Straight	C

SUBJECT NUMBER	TRIAL #	DEVICE	CONGESTED / NOT CONGESTED	CRUSADER MESSAGES	TRUE / FALSE	DECISION Left or Straight	CORRECT?
22	1	Indikta	Not Congested	Serious Accident I-35W	FALSE	Turn Left	NOT C
	2	Text	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Radio	Not Congested	Traffic Free Flowing : I-35W	TRUE	Straight	C
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight	C
	5	Indikta	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	NOT C
	6	Text	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Radio	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Volvo	Not Congested	Construction State Highway 77	TRUE	Straight	NOT C
23	1	Radio	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Indikta	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Text	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight	C
	5	Radio	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Indikta	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Text	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Volvo	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
24	1	Text	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Indikta	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Volvo	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	C
	4	Radio	Not Congested	Congestion I-35W	FALSE	Turn Left	NOT C
	5	Text	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	C
	6	Indikta	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Volvo	Not Congested	Road Construction State Highway 62	FALSE	Turn Left	C
	8	Radio	Congested	Construction State Highway 77	FALSE	Straight	NOT C
25	1	Indikta	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Volvo	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Radio	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Text	Not Congested	Congestion I-35W	FALSE	Turn Left	C
	5	Indikta	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Volvo	Congested	Delays : State Highway 77	FALSE	Turn Left	C
	7	Radio	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Text	Congested	Construction State Highway 77	FALSE	Turn Left	C
26	1	Volvo	Not Congested	Serious Accident I-35W	FALSE	Turn Left	NOT C
	2	Text	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	C
	3	Indikta	Congested	Traffic Free Flowing : I-35W	FALSE	Turn Left	NOT C
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight	C
	5	Radio	Congested	Traffic Free Flowing State Hwy 62	FALSE	Turn Left	NOT C
	6	Text	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Radio	Not Congested	Road Construction State Highway 62	FALSE	Turn Left	NOT C
	8	Indikta	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
27	1	Indikta	Congested	Serious Accident I-35W	TRUE	Turn Left	C
	2	Text	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Radio	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	NOT C
	4	Indikta	Not Congested	Congestion I-35W	FALSE	Turn Left	NOT C
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	6	Text	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Radio	Not Congested	Road Construction State Highway 62	FALSE	Straight	NOT C
	8	Volvo	Congested	Construction State Highway 77	FALSE	Straight	C
28	1	Text	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Radio	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Indikta	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Indikta	Congested	Congestion I-35W	TRUE	Straight	C
	5	Radio	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Volvo	Congested	Delays : State Highway 77	FALSE	Straight	NOT C
	7	Text	Not Congested	Road Construction State Highway 62	FALSE	Turn Left	C
	8	Volvo	Not Congested	Construction State Highway 77	TRUE	Turn Left	C

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SUBJECT NUMBER	TRIAL #	DEVICE	CONGESTED NOT CONGESTED	CRUSADER MESSAGES	TRUE/ FALSE	DECISION Left or Straight	CORRECT?
29	1	Volvo	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Radio	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Text	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Radio	Congested	Congestion I-35W	TRUE	Straight	C
	5	Indikta	Congested	Traffic Free Flowing State Hwy 62	FALSE	Turn Left	C
	6	Text	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Volvo	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Indikta	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
30	1	Text	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Indikta	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Volvo	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	NOT C
	4	Radio	Congested	Congestion I-35W	TRUE	Straight	C
	5	Text	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Indikta	Congested	Delays : State Highway 77	TRUE	Straight	C
	7	Volvo	Not Congested	Road Construction State Highway 62	FALSE	Turn Left	C
	8	Radio	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
31	1	Text	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Volvo	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Turn Left	C
	3	Volvo	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	NOT C
	4	Radio	Not Congested	Congestion I-35W	FALSE	Straight	NOT C
	5	Text	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	C
	6	Indikta	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Indikta	Not Congested	Road Construction State Highway 62	FALSE	Straight	NOT C
	8	Radio	Congested	Construction State Highway 77	FALSE	Straight	NOT C
32	1	Indikta	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Text	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	C
	3	Indikta	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight	C
	5	Radio	Congested	Traffic Free Flowing State Hwy 62	FALSE	Turn Left	NOT C
	6	Text	Congested	Delays : State Highway 77	FALSE	Turn Left	NOT C
	7	Radio	Not Congested	Road Construction State Highway 62	FALSE	Straight	NOT C
	8	Volvo	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
33	1	Radio	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Indikta	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Turn Left	NOT C
	3	Text	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Radio	Not Congested	Congestion I-35W	FALSE	Straight	NOT C
	5	Volvo	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	NOT C
	6	Text	Congested	Delays : State Highway 77	FALSE	Straight	C
	7	Indikta	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Volvo	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
34	1	Text	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Radio	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Volvo	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Text	Not Congested	Congestion I-35W	FALSE	Turn Left	C
	5	Indikta	Congested	Traffic Free Flowing State Hwy 62	TRUE	Straight	C
	6	Indikta	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Volvo	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Radio	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
35	1	Volvo	Not Congested	Serious Accident I-35W	FALSE	Turn Left	C
	2	Indikta	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Turn Left	NOT C
	3	Text	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	C
	4	Radio	Congested	Congestion I-35W	TRUE	Straight	C
	5	Text	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Radio	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Volvo	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Indikta	Congested	Construction State Highway 77	FALSE	Straight	NOT C

SUBJECT NUMBER	TRIAL #	DEVICE	CONGESTED NOT CONGESTED	CRUSADER MESSAGES	TRUE/ FALSE	DECISION Left or Straight	CORRECT?
36	1	Radio	Not Congested	Serious Accident I-35W	FALSE	Turn Left	NOT C
	2	Volvo	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Indikta	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Text	Not Congested	Congestion I-35W	FALSE	Turn Left	C
	5	Radio	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	NOT C
	6	Volvo	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Indikta	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Text	Congested	Construction State Highway 77	FALSE	Straight	NOT C
37	1	Indikta	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Volvo	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Radio	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Volvo	Not Congested	Congestion I-35W	FALSE	Turn Left	NOT C
	5	Text	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	C
	6	Indikta	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Radio	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Text	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
38	1	Indikta	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Indikta	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Radio	Congested	Traffic Free Flowing : I-35W	FALSE	Turn Left	NOT C
	4	Volvo	Congested	Congestion I-35W	TRUE	Straight	C
	5	Text	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Volvo	Not Congested	Delays : State Highway 77	FALSE	Turn Left	C
	7	Text	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Radio	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
39	1	Indikta	Not Congested	Serious Accident I-35W	FALSE	Straight	NOT C
	2	Radio	Congested	Stop & Go Traffic State Highway 62	TRUE	Straight	C
	3	Text	Congested	Traffic Free Flowing : I-35W	FALSE	Straight	C
	4	Indikta	Congested	Congestion I-35W	TRUE	Straight	C
	5	Volvo	Congested	Traffic Free Flowing State Hwy 62	FALSE	Straight	NOT C
	6	Radio	Not Congested	Delays : State Highway 77	TRUE	Turn Left	C
	7	Volvo	Not Congested	Road Construction State Highway 62	FALSE	Turn Left	NOT C
	8	Text	Not Congested	Construction State Highway 77	TRUE	Turn Left	C
40	1	Radio	Congested	Serious Accident I-35W	TRUE	Straight	C
	2	Volvo	Not Congested	Stop & Go Traffic State Highway 62	FALSE	Straight	NOT C
	3	Text	Not Congested	Traffic Free Flowing : I-35W	TRUE	Turn Left	C
	4	Text	Congested	Congestion I-35W	TRUE	Straight	C
	5	Indikta	Not Congested	Traffic Free Flowing State Hwy 62	TRUE	Turn Left	C
	6	Radio	Not Congested	Delays : State Highway 77	TRUE	Turn Left	NOT C
	7	Volvo	Congested	Road Construction State Highway 62	TRUE	Straight	C
	8	Indikta	Congested	Construction State Highway 77	FALSE	Straight	NOT C

Appendix H

Questionnaires Given To TMC Control Room Staff Including Results

TRAFFIC MANAGEMENT CENTER QUESTIONNAIRE

Sara Johnson   June 20, 1994
Human Factors Research Lab
626-7521

     I am a graduate student at the University of Minnesota attempting to determine ways to improve the Traffic Management Center control room and the equipment that is used within the control room. I would appreciate your honesty in responding to the following questions. Please note:

     Your name WILL NOT be associated with this questionnaire or any summary data at anytime.

     Management will not have access to specific responses for these questionnaires. Any reporting of information will be in summary form.

     This questionnaire will be handed out at the Traffic Management Center. Please return the questionnaire, by **Thursday, June 30,** in the envelope provided, seal it and place it in my basket in John Hiebel and Joe Gladkes' office. Thank you.

General Information

(1) How many shifts per week do you monitor traffic at the Traffic Management Center?___**2.75**___.

(2) What station do you work at?

           Crusader   IO   South   **3.5** North   Combination of

        If you answered "combination of," please explain:

* Off peak operator and Information Officer
* Of peak Information Officer and peak south station operator

Work Station

(3) Overall, how would you rate the work station you work at?

                                  3.75

    bad   **1**   **2**   **3**   **4**   **5**   **good**

    Is the chair comfortable? No **50%**   Yes **50%**
    explain.

* Too small
* Does not provide adequate back support
* Information Officer chair should have arms

    Is the table the right height for you? No **29%**   Yes **71%**
    explain.

* Can reach controls easily
* Should be higher
* Information Officer station set up for right handed

    Are the monitors comfortable to look at? No **57%**   Yes **43%**
    explain.

* Monitors are too bright
* Use color monitors
* Angle the top monitors
* Monitors too low and too close up

    Is the lighting in the control room comfortable?(too dark, too light)
                                               No **37%** Yes **63%**
    explain.

* Too dark
* Too light
* Option to turn on certain work areas would be nice

(4) Do you feel comfortable with using the overall computer system?
              no 13%   **yes 87%**
    explain.

* Integration of seperate hardware systems into one; more efficient
* Training hit or miss; word of mouth about new equipment

(5) Do you feel comfortable with the system for ramp meters?

> no 23%   yes 77%
>   explain.

• No, because I do not run them every day
• No, I do not use them
• Too much operator discretion allowed in system

(6) Do you feel comfortable with the system for changing cameras/monitors?
>   no 7%   yes 93%
>   explain.

• Yes, I use it all the time
• Too much operator discretion, people change the salvo tours to meet individual needs, instead of standards
• Salvo information sheet is goo layout

(7) Can you see all the monitors for your station while sitting comfortably at your work station? (In other words, answer no if you have to lean over to see some monitors)

> no 67%   yes 23%

(8) Do you have a certain way to turn off meters during/after peak periods?

> no 8%   yes 92%
> explain in detail.
>   *during low traffic flow?
>   • When computer calling for "2" and mainline is free flowing in that zone, flash whole zone at the same time
>   *time of day?
>   • After 8:00 a.m. for a.m. peak and 5:30 p. m. for p.m. peak, meters are turned off when mainline is free flowing
>   *5 minutes before shift ends?
>   • Metering maybe discontinued beacuse most of volume has already passed through the meter

Health

(9) Do you suffer from headaches during a shift?

> never   occasionally   sometimes   frequently   always
>   1.56

(10) Do you suffer from headaches after a shift?
>   1.56
> never   occasionally   sometimes   frequently   always

(11) Have you ever had any health problems resulting from working in the traffic monitoring area?

neckache	never 1.31	occasionally	sometimes	frequently	always
headache	never 1.44	occasionally	sometimes	frequently	always
blurred vision	never 1.19	occasionally	sometimes	frequently	always
sore wrist	never 1.13	occasionally	sometimes	frequently	always
sore back	never 1.31	occasionally	sometimes	frequently	always

othersDried eye irritation, stress never .38 occasionally sometimes frequently always

(12) Is the traffic monitoring area noisy?

never   occasionally 2.56 sometimes   frequently   always

If so under what circumstances (when)?
explain.
• Too many people doing other things in the area
• Major incident 4 or 5 people talking at once
• Radio buzzing because of a lot of incidents and Radio braodcast going on
• Unauthorized personal in the control room; inappropriate conversations that could be held elsewhere
• Peak period, continuous coverage/incident management situation
• Criticism about how an incident is being managed by authority in the field
• Need carpeted floor tile
• One or more major traffic incidents

(13) Do you feel cramped/closed in when working?

never 1.38 occasionally   sometimes   frequently   always

If so under what circumstances (when)?
explain.
• Too many unauthorized personnel in the control room during peak period
• A lot of staff wondering in control room, stand around and gauk and talk during major incidents
• Room filled with extra people

Work Area

(14) Are there a lot of distractions in the traffic monitoring area?

no 38%   yes 62%

(15) What causes the greatest amount of distraction?
    explain.
- Side conversations
- Unauthorized personal in the control room
- Phone calls, radio, people that should not be there
- Extraneous visitors in the control room
- People walking in when they are not scheduled
- Major incident on opposite work station
- Boredom

(16) Where and when does the greatest amount of distraction most frequently occur?
    explain.
- Operator area during beginning of a.m. off peak and at the end of p.m. peak period
- During peak periods
- Center of room when groups come in
- Control room beginning and end of a.m. peak; beginning of p.m. peak
- Control room; busy peak period
- Can not hear the patrol scanner
- Two hours into a shift (boredom)

(17) How many different things are going on in the traffic monitoring area at the same time? __18__ .
    List them:

- IO radios
- Broadcast
- Ramp meters
- Phones ringing
- Side talk
- Incident monitoring
- Highway helper dispatch /logging

- Traffic reporting
- CMS activation
- LCS activation
- Systems evaluation
- Trilogy dispatching
- Answer questions for duty technician

- Cable TV updating
- HAR activation
- Relaese front door
- Patrol notification

(18) How comfortable do you feel with the traffic monitoring task in the control room?

    not at all   some what   neutral   a lot   very much
                                  3.63

(19) Do you think the design layout of the Traffic Control room is adequate for all stations?

        Radio announcer   no 33%   yes 67%   why?
- Better chair, headset and microphone needed
- Cameras are behind work station
- Can not control monitors infront of him/her
- Not enough room for all props

        Information Officer   no 64%   yes 36%   why?
Off peak operator has to walk around desk to get to operator stations
- Made for right handed individual
- Have to lean over too much
- Should have CMS/ Ramp control for non peak
- Should have control over ramp meters
- Not enough room for euipment needed
- Need better integration of computer hardware devices
- Need built in features to organize things

        Crusader operator   no 33%   yes 67%   why?
- Can not se all monitors
- After thought (just lumped)

        North station   no 29%   yes 71%   why?
- Information sheets should be more organized
- Not enough room for all reference materials and workspace
- Monitors are too close up

        South station   no 31%   yes 69%   why?
- Same as North station

(20) What areas do you believe need a better design layout?
        explain.
- Crusader station; space is too small
- Put IO microphone up higher so do not have to lean over to talk
- IO station needs better use of the space available; poorly organized
- More space and an area for viewing the control room
- Off peak area when IO is an operator too
- IO; too much clutter; too many computers, radios, phones for small area
- Control room too small

(21) What areas do you believe incorporate a good design layout?
        explain.
- Operator stations
- Radio announcer
- IO station curves nicely but is too small

(22) What would you like to see done differently in the control room?
     explain.
* More consistency with operating from one operator to another
* More versatile; operators and IO station should be able to help eachother (CMS, ramp meters accessed from all stations)
* Privacy from unrelated traffic in area
* Compasses on cameras
* More procedures and uniformity in controlling
* Incorporate traffic radio with CMS
* Have the north and south stations curve like the IO station does
* For Crusader station: add monitor that can clearly see what happening; telephone for large scale testing; bigger table; Barco back on

(23) Please list your likes of the control room.
* Valued important service, like my job, can make a difference
* Equipment easy to operate
* Interesting; helps me design better by being an operator
* The new computer system

(24) Please list your dislikes of the control room.
* Hard to get around IO desk to operators station
* Poor chairs; poor ventilation
* Too hot or too cold
* Too many interruptions (phone calls, visitors, contractors)
* Too many operators and inconsistent operational procedures; no decision makers
* Too many computer systems
* Too many monitors in front of each operator
* Too many people wandering through room
* Difficult to work from the north and south station with the IO (effeciently) when backs are turned
* Ventilation poor
* Radio hard to understand from the north and south stations

(25) How familiar are you with the metro highway system?

    not very familiar   some what   neutral   a lot   very familiar
                                                        3.63

(26) How long have you worked at the Traffic Management Center?
     3 years 4 months.

(27) What are your other duties at the Traffic Management Center besides the control room?
     explain.
* Trilogy evaluation
* Public Relations/Braodcast, news releas, brochures, etc.
* Write news releases, produce/record MnDot minute stories
* Communications, Public Relations, Media Relations

(28) If you feel an area of improvement could be made to the traffic control room that has not been covered by this questionnaire, please make comments for improvements below.
- No telephone calls transeferred to control room
- Redesign conference room to include media viewing area/tour
- Policy enforcement/guidance issues
- Less operators in control room
- Key into IO when on phones
- Three station layout
- Relationships; with eachother, with patrol, with media (it is not always productive and useful)

*The next portion of this questionnaire is for the North and South station operators and relates to more specific areas within the Traffic Control Room.

RAMP METERS

How frequently do operators check the ramp meters?

I glance at the ramp meter display at least once a minute
Strongly agree   Agree   Neutral   Disagree   Strongly disagree
3.17

I look at the ramp meter display only when I see poor traffic flow on the monitors
Strongly agree   Agree   Neutral   Disagree   Strongly disagree
1.42

I concentrate all my attention on the ramp meters.
Strongly agree . Agree   Neutral   Disagree   Strongly disagree
1.83

Monitoring the ramp meter values is an important part of my job.
Strongly agree   Agree   Neutral   Disagree   Strongly disagree
3.75

How useful is the color coding that is used in the ramp meter displays?

I think the color coding for the ramp meter values helps in identifying heavy traffic.
Strongly agree   Agree   Neutral   Disagree   Strongly disagree
4.25

The color coding of the ramp meter display confuses me.
Strongly agree   Agree   Neutral   Disagree   Strongly disagree
1.25

The display provides me with a good overview of traffic flow at my station.
Strongly agree   Agree   Neutral   Disagree   Strongly disagree
3.83

The colors used on the ramp meter display correspond to those used on the BARCO.
Strongly agree   Agree   Neutral   Disagree   Strongly disagree
2.92

How often and in what situations do operators override ramp meters?

I very rarely override the computer's ramp meter selection
Strongly agree   Agree   Neutral   Disagree   Strongly disagree
2.50

If there is an incident I let the computer operate the ramp meters.
Strongly agree   Agree   Neutral   Disagree   Strongly disagree
2.08

When I start a shift I regularly over ride some ramp meters straight away.

Strongly agree   Agree   Neutral   Disagree   Strongly disagree

1.67

I use the information from cameras to decide what meter to run the ramp in.

Strongly agree   Agree   Neutral   Disagree   Strongly disagree

3.25

If one camera can see one ramp meter - I use only this information to change the ramp meter code.

Strongly agree   Agree   Neutral   Disagree   Strongly disagree

2.25

Does the coding of the ramp meters help the operators?

When an incident occurs I always know exactly which ramp meters may be effected.

Strongly agree   Agree   Neutral   Disagree   Strongly disagree

2.67

It is easy to identify meters from the coding system used.

Strongly agree   Agree   Neutral   Disagree   Strongly disagree

2.75

I am sometimes confused by the code of the ramp meter and its location.

Strongly agree   Agree   Neutral   Disagree   Strongly disagree

2.92

I can identify more than half of the ramp meter codes and their actual road locations.

Strongly agree   Agree   Neutral   Disagree   Strongly disagree

3.42

CAMERAS

How important is it for the users to scan the monitors?

I spend most of my shift scanning the bank of monitors.

Strongly agree   Agree   Neutral   Disagree   Strongly disagree

3.00

Scanning monitors is the most important aspect of an operators job.

Strongly agree   Agree   Neutral   Disagree   Strongly disagree

2.83

When the cameras are being rotated on the salvo it is easy to identify the locations of each camera.

Strongly agree   Agree   Neutral   Disagree   Strongly disagree

3.08