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TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study:
Operator Interface Analysis-Phase III

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ABSTRACT

TravInfo is a Field Operational Test of advanced traveler information systems for the San Francisco Bay Area, sponsored by the Federal Highway Administration (FHWA). The project involves a public/private partnership which seeks to compile, integrate and broadly disseminate timely and accurate multi-modal traveler information through commercial products and services. The public sector component centers on the Traveler Information Center (TIC), which collects and integrates both static and dynamic traveler information. The TIC began operations in September 1996 and will operate as an FOT through September of 1998. The evaluation of the TIC consists of four components, system reliability, communications interface, response time, and operator interface. This report focuses on the operator interface element.

The operator interface element investigates the human element by considering the role of the operator in the flow of information through the TIC, the operators' tasks and responsibilities and the operators' physical environment. This report focuses on the physical environment of the TIC operations including the TIC computer interface and the physical surroundings of the operators' workstation environment. The work was accomplished by analyzing the TIC operator interface design and by surveying operators.

Key Words: TravInfo, Field Operational Test, evaluation, traveler information center, advanced traveler information systems, operator interface design, working environment, operator profile

EXECUTIVE SUMMARY

TravInfo is a Field Operational Test (FOT) of advanced traveler information systems (ATIS) for the San Francisco Bay Area, sponsored by the Federal Highway Administration (FHWA). The project involves a public/private partnership which seeks to compile, integrate and broadly disseminate timely and accurate multi-modal traveler information through commercial products and services. The Traveler Information Center (TIC) began operations in September 1996 and will operate as an FOT through September 1998.

The evaluation of TravInfo consists of four major elements: (1) institutional, (2) technology, (3) traveler response and (4) network performance. The Traveler Information Center (TIC) study is part of the technology evaluation and consists of four primary elements: system reliability, communications interface, response time analysis and operator interface. System reliability examines system problems. The communications interface examines TIC data access on the part of both the public and private sectors. The response time element measures the processing time of incidents between their entry into the TIC and their dissemination to the public and private sector. Operator interface investigates the human element by considering the role of the operator in the flow of information through the TIC, the operators' tasks and responsibilities and the operators' physical working environment.

This report focuses on the operator interface element and deals primarily with the TIC's physical environment including the TIC computer interface and the physical surroundings of the operators' workstation environment. The objective of this work is to identify the extent to which the interface and the working environment support the operator in performing his/her job. This will allow better understanding of overall TIC performance and effectiveness and allow evaluators to make recommendations for improvements in overall TIC performance where needed.

The work was accomplished by analyzing the TIC operator interface design, surveying operators, and analyzing the results of that survey. This phase builds upon previous work involving the information flow and task analysis. This earlier work is documented in :

> M. A. Miller and D. Loukakos, "TravInfo Evaluation (Technology Element) Traveler Information Center (TIC) Study (September 1996 - June 1997)", California PATH Working Paper, UCB-ITS-PWP-98-7, California PATH, University of California Berkeley, (1998).

The TIC operator interface design evaluation has three components: 1. understanding the operator interface design features, 2. describing the objectives of the user interface design and measuring the extent to which they are satisfied, and 3. determining operator profile characteristics and their relationship with the interface design.

The TIC operator interface design integrates three distinct interface styles: menus, fill-in forms, and direct manipulation. A menu is a list of options from which the operator selects a desired choice. A fill-in form interface is similar to a paper fill-in form though it is presented on a computer screen rather than on paper. It is a structured, formatted form containing a number of fields in which the operator is expected to type in data. With the direct manipulation interface operators perform actions directly on visible objects often referred to as a "point-and-select" interface. Among the objectives of operator interface design are: compatibility with the needs of the operator, consistency, familiarity, simplicity, and ease of learning and use. The operator compatibility objective refers to the designer's need to know the operator and be able to construct an interface compatible with the operator's job-related needs. The operators were surveyed to develop such a profile.

Overall, the interface design serves its general purpose of allowing operators to perform their data monitoring and entry tasks relatively quickly. However, the general computer interface does not support the tasks of the operators as much as it could. The chief problems are: 1. The organization and layout of fill-in forms do not reflect designer consideration of operator tasks and the nature of potential operator form use; 2. Some of the most commonly used windows have several shortcomings; 3. The two most important menus are poorly ordered. They are filled with rarely-used or unneeded items and yet are not ordered by frequency of use or by categories to assist the operator in quickly finding needed information; 4. There is no grouping of related items on forms which, if done, would improve the overall interface design. Moreover, there are ambiguous terms and non-mutually exclusive attributes within certain fields; 5. There is a lack of consistent organization across all windows.

Overall, the operator interface objectives are generally satisfied. There are, however, three areas of weakness:

- User compatibility: There should have been more consideration of specific operator duties.
- Consistency: The fill-in form formatting is not always consistent
- Responsiveness: There is no feedback on the progress of system processing, and the system is often slow due to lack of processing power.

These design weaknesses likely result in a loss of operator time. It is difficult to quantify this time loss because there is no readily identifiable baseline against which the present system can be compared and it is difficult to break down the time loss into separate components one of which would be ascribed to poor interface design. While the operators have adapted and learned to circumvent some of the design shortcomings, nevertheless, there are likely still time delays. Design weaknesses have also caused a certain level of frustration among the operators and this is reflected in the relatively low overall rating of the interface design by the operators. On the positive side, the window system used is flexible and allows customization of the windows environment to suit the task at hand and/or operator preferences.

The second part of the evaluation consists of an assessment of the operator's working environment based on a survey of operators and evaluator visits to the TIC. The objective of this work was to understand the level of operator acceptability with the different aspects of the TIC working environment. The working environment may contribute to or hinder the operator's ability to do his/her job effectively. A checklist of working environment characteristics was used to help identify those that may contribute to or hinder the TIC operator's job performance. This checklist includes: 1. illumination, noise levels, and thermal characteristics of the working environment, 2. visual display elements of the computer screen, 3. keyboard characteristics, 4. furniture, 5. worksurface, 6. seating, and 7. accessories.

There were only three characteristics where work environmental changes would lead to a more productive TIC working environment: 1) thermal and air quality, 2) general layout of work surface, and 3) cubicle height or sense of connectedness with other operators. Other characteristics were found to be generally acceptable to the operators.

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1. INTRODUCTION

This report documents Phase III of the Operator Interface component of the Traveler Information Center (TIC) evaluation as described in the TIC evaluation plan (1). This TIC evaluation component focuses on the following two primary areas:

- Design of the operator interface
- Operator working environment

The specific objectives for this part of the evaluation are detailed below. This is followed by background material on the study design upon which this evaluation was based.

1.1 Objectives

The objective of the work reported in this document is to evaluate the operator interface and the working environment in order to identify the extent to which the interface and the working environment support the operator in performing his/her job. This will allow better understanding of overall TIC performance and effectiveness. It will also allow evaluators to make recommendations for improvements in overall TIC performance. This part of the evaluation investigates:

- How the operator relates to his/her working environment.
- How the computer interface design and the overall working environment support the operator in performing his/her job.
- What recommendations can be made for improvement.

This phase builds upon previous work (Phases I and II) involving the information flow and task analysis (2), which explored the range of tasks operators perform in the course of their daily activities including monitoring and retrieving incident-related information from the California Highway Patrol Computer Aided Dispatch System (CHP CAD), entering and processing information within the TransView system, and disseminating information via the Landline Data System (LDS) and the Traveler Advisory Telephone System (TATS).

1.2 Study Design

The operator workstation linking the operator to the TIC computers and databases, referred to as the TIC/operator interface, is the focus of analysis documented in this report[1]. The working environment consists of all aspects of the physical setting in which the operator performs his/her job. The evaluation of both the operator interface and the working environment was conducted through both 1) on-site research and visits by the evaluation team and 2) interviews with the

[1] This work does not include an analysis of the underlying operating system or an assessment of the Octel/Voice Processing System TATS system.

operations' staff, i.e. operators and their supervisors. Interviews enabled the evaluator to probe into the operators' appraisals of the interface and the surrounding working environment.

Interviews were conducted with fourteen operators and two supervisors, all TIC staff directly involved in the handling of information. The interviews were conducted from November 1997 to January 1998. Each interview was divided into two sections consisting of checklists for a 1. user profile and 2. working environment characteristics (Appendix A and B, respectively). Interviews typically lasted 45-60 minutes. The interview data were analyzed by developing aggregate statistics to derive profiles for both user attributes and working environment characteristics.

In the following sections, the word "operators" is used to describe both the operators and the two supervisors who perform operator duties. There were only occasional and minor differences in responses between these two groups[2].

2. OPERATOR INTERFACE DESIGN EVALUATION

The purpose of this evaluation is to understand the extent to which the TIC interface design serves and supports the TIC operations' staff in performing their job. The evaluation was conducted through both 1. on-site research and inspections by the evaluation team and 2. interviews with the operations' staff, i.e. operators and their supervisors.

The TIC/operator interface structure is the X-Windows/Motif graphical user interface running on a UNIX operating system. Each window consists of a frame, a toolbar of pull-down menu items, a resizing corner, a closure button, a full screen button, and an optional scroll bar (3, 4).

Effective software interfaces are ones that serve and support their users. They should be designed either by directly involving intended users in the design process, or if this is not possible because specific individuals are not available[3], then by developing and utilizing a profile of user characteristics and tasks to be executed. Such a profile would include attributes such as level of education, knowledge, and experience with computer systems. The TRW-led TIC design and development team used TravInfo Management Board[4] review comments on the TIC interface design and incorporated prior operator experience from a similarly deployed system in Atlanta. The following input on operator qualifications is taken from the TRW's System Requirements document (5):

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[2] During the supervisor interviews, in addition to obtaining their individual own profile and working environment assessment, aggregated operator response data were also discussed. Only the aggregated results of the operator interviews were discussed in order to preserve individual operator confidentiality. Such discussions were conducted to obtain the supervisors' opinions of the operators' overall responses, that is, were such responses as expected or surprising? Moreover, the supervisors know very well operator qualifications and could readily and accurately comment on operator responses. Operator interview results matched supervisor expectations.

[3] Such was the case for TravInfo because the operations contractor had not been selected during this phase of the computer interface design.

[4] The Management Board is TravInfo's public sector governing body led by TravInfo Project partners: Caltrans (District 4), Metropolitan Transportation Commission, and the CHP (Golden Gate Division).

"Operator personnel shall be experienced in the 'hands on' operation of computer based, console operated, communication and information processing systems. Skill sets of personnel to staff the TravInfo/TIC, found in CHP Operations Centers, or similar centers of other agencies, are appropriate for operating the TravInfo/TIC."

The evaluation of the computer interface design has three primary components discussed in Sections 2.1-2.3:

- Objectives of the operator interface design
- User profile characteristics
- User interface design features

2.1 Objectives Of User Interface Design

There are numerous general objectives to consider when designing a computer user interface. These are briefly discussed below. A more thorough discussion of these characteristics may be found in (6,7). The computer interface designer should strive to satisfy these objectives when making design decisions. However, these objectives are sometimes in conflict with each other, and so design tradeoffs must be made with the user population kept in mind.

- <u>User Compatibility</u>—The computer interface design needs *to know the user*, that is, to be compatible with the needs of the user, in this case, the TIC operator. A very common mistake of computer interface designers is to assume that all users are alike and that all users are like the designer. The designer should know and understand the individuals in the relevant user population and the specifics of their jobs.

- <u>Product Compatibility</u>—The system design should be compatible with other systems having common features with the product under design. The user who is familiar with similarly used products will have invested time in learning the previous system and will be able to take advantage of this invested time when learning the new system.

- <u>Task Compatibility</u>—The structure and flow of a system should match and support the task that is being implemented. In particular, the system design should offer the user a choice among *tasks* and not a choice among alternative *data types*. Data types are not a meaningful organizational unit for the user. The user should be able to readily move among data types for each task rather than be forced by system design to navigate back and forth between different applications in order to complete a task. For example, tasks, such as documenting reports, could include graphical, word processing, database, and spreadsheet applications. If system design were organized by application and not by task, then to finish a report would require moving back and forth among all appropriate applications.

- Work Flow Compatibility—The system should be structured so as to facilitate transitions among tasks. Certain users' job responsibilities involve frequent transitioning among alternative tasks. Such transitioning should not be slow and tedious.

- Consistency—Similar operations in different parts of an application or in different applications of a system should have similar interfaces or even the same interface. That is, there should be uniformity within the system, in features such as formatting, menu types, and wording.

- Familiarity—Concepts, terminology, and spatial arrangements that the user is already familiar with should be incorporated into the interface. This will allow the user to take advantage of a natural tendency to learn and reason by analogy with examples of situations with which the user is already familiar. For example, using objects and terms from manual filing systems to bridge the gap to automated filing systems will help the user. Words such as file cabinets, folders, and documents should be used instead of volumes, libraries, and indexes. The former may be used to present the same objects and functions in a form already familiar to the user and so would require little or no learning of new ideas and terms. Whereas the latter are computer jargon and may be less familiar to the intended user population.

- Simplicity—The interface should not be so complex as to overwhelm and confuse the new user and to be boring to navigate for the experienced user. Providing all the "bells and whistles", while complete, would likely result in an interface that is far too complex. A typical user would not necessarily need to know every aspect of the system's functionality. Such extra system capabilities may remain in the background for use when and if needed by the expert user.

- Direct Manipulation—A direct manipulation interface is one in which users directly perform actions on visible objects as opposed to an interface in which users specify actions, parameters, and objects indirectly through language. For example, old-fashioned text editors versus modern word processors illustrate these two methods of interface manipulation. The former requires the user to enter commands to modify text. The latter allows the user to manipulate directly the words of a document when text needs to be inserted, deleted, or otherwise modified. Such an interface is much more direct and easy to learn and use.

- Flexibility—The system should be flexible enough to support and allow more user control and to accommodate variability in user skill and choices. Interfaces that allow the user to tailor and make choices offer this kind of flexibility.

- Responsiveness—The computer and its interface should respond as soon as possible, if not immediately to a user's input. While the computer is working, the users should be provided with feedback on the progress the system is making toward completing the task. Examples of feedback include "Working ...", "Please wait ...". An improved message would be a status report on how much work has been completed or needs to be completed in terms of a measure that counts up or down relative to some meaningful unit, for example, number of files processed, or number of pages printed.

- Invisible Technology— What is actually happening within the system can remain invisible to the user. He/she does not need to know about the technical details of how the system is implemented and operated in order to use it effectively. Technical jargon, obscure error messages, and unfamiliar concepts require users to have a technical background above and beyond what is necessary for purposes of carrying out task responsibilities effectively.
- Robustness—The interface should permit common and unavoidable user errors. A system that crashes because it is too sensitive to erroneous user input would inevitably discourage a user from exploring and taking new steps in carrying out his/her job responsibilities. Learning would thus be inhibited and productivity would suffer as users would work overly carefully and slowly to avoid the types of common errors that cause crashes.

- Protection—The system interface should be designed so as to protect the user against the catastrophic results of frequently occurring human error. It should always be difficult for the user to perform actions that have negative results. There should be recovery steps that are simple to understand and easy to implement when needed. Error prevention methods, such as warning displays and confirmation/verification options, can assist in making it very difficult to perform errors with dire consequences.

- Ease of Learning and Ease of Use—Systems should be both easy to learn and easy to use. Easy to learn systems may be ready to use immediately, but maybe structured in form and cumbersome for frequent use. Easy to use systems usually require time before users learn to fully utilize its capabilities, but once learned there is a payoff with respect to speed, ease of use, and user productivity. The user profile assists the designer in making necessary trade-off decisions relative to these two characteristics.

2.2 User Profile Characteristics

The user profile characteristics are representative of the user needs and help form the basis for a well-designed interface. Assessment of these characteristics plays a crucial role in the evaluation of the interface design. Consideration of potential operator characteristics was, however, limited during the TIC interface design. To obtain user profile characteristics, a checklist was developed based on work from (7) and (8) modified to fit the specific case of the TIC system (Appendix A).

General Information

The checklist consists of two types of general information: first, job-related information such as type of job training, level of experience in the traveler information provider business, and type and length of TIC employment; secondly, psychological characteristics such as attitude and motivation. Attitude refers to a person's feeling or outlook about his/her work and motivation refers to how stimulated a user is to perform his/her job.

Knowledge and Experience (General)

This category includes reading level, typing style and skill (low, medium, high), education level, computer literacy, use of maps, and experience with 1. the Windows Operating System, 2. system applications similar to but not necessarily the same as the TransView application, 3. the TransView system specifically, and 4. use of other systems.

Knowledge and Experience (Transportation)

This category consists of specific transportation-related areas consisting of familiarity with Bay Area 1. street and freeway network, 2. towns, cities, and counties, and 3. alternative transportation modes.

Physical Characteristics

This category includes level of color blindness, handedness, and gender.

2.3 User Interface Design Features

Interface design features comprise what is usually referred to as the dialog style and reflect the actual design of the interface. A dialog style is a means of interaction between a user and a system. Three dialog styles are used to varying degrees in the TIC computer interface design: menus, fill-in forms, and direct manipulation. The features for each of these three styles are not mutually exclusive across styles and overlaps exist. These dialog styles are used in an integrated fashion and thus care must be applied to account for tradeoffs among them when evaluating these styles.

A menu is a list of options from which the user may choose. In menu-driven user interfaces, the user is repeatedly presented with menus from which to choose. A fill-in form interface is similar to a paper fill-in form though it is presented on a computer screen rather than on paper. It is a structured, formatted form containing a number of fields in which the user is expected to type in data. A direct manipulation interface is one in which users perform actions directly on visible objects. Sometimes these interfaces are called "point-and-select" interfaces and often include a pointing device such as a mouse, trackball, or touch screen and often use graphics to display objects and actions. Several dialog styles are used in the TIC computer interface and are described in more detail in Appendix C and in (7).

The next section presents the overall interface design evaluation framework.

2.4 Evaluation Framework

This framework is based on the text in (6) and (7). The TIC's interface design features are comprised of the merging into a single interface design of the following three dialog styles: 1. menus, 2. fill-in forms, and 3. direct manipulation. The framework (Figure 1) depicts diagramatically the relationships among the three components described in Sections 2.1-2.3. These relationships are discussed in this section. In general, A_1, B_1, and C_1 deal with inputs used in the development of the operator interface and A_2, B_2, and C_2 deal with the evaluation of the operator interface design.

A_1 = The objectives listed are building blocks to be used in the development of the operator interface, that is, any operator interface should have these.

A_2 = The TIC interface design, a combination of the Menu, Fill-in Form, and Direct Manipulation dialog styles, is evaluated against the objectives listed to determine the extent to which each of these objectives is satisfied.

B_1 = The objectives help determine the operator profile.

B_2 = The first objective, "User Compatibility", is the one most closely connected to the user profile in the evaluation of the operator interface . The computer interface design needs *to know the user*, that is, to be compatible with the needs of the user. The designer should know and understand the individuals in the relevant user population and the specifics of their jobs.

C_1 = The operator profile characteristics serve as input to be used in the development of the operator interface.

C_2 = Each of the dialog styles individually is associated with a particular operator profile that would be most appropriate for or best matched to it based on input from (7). There may be conflicting operator profile attribute values when compared across the three dialog styles. A comparison, i.e. evaluation, should be made between the determined operator profile and the actual operator profile that exists.

2.5 Evaluation Of Operator Interface Design

This section presents the results of the evaluation of the TIC interface design including an analysis of:

- The Operator profile
- Operator usage of the TransView windows environment
- The features of the interface dialog styles that comprise the TIC interface
- The degree to which the operator interface design objectives are met and, in particular, its connection with the operator profile.

2.5.1 Operator Profile: Interview Results and Analysis

This section presents the results of the assessment of the operator profile. The sample size consisted of fourteen operators and two supervisors at the TIC.

Table 1 summarizes the findings regarding operator characteristics in the "General Information" category. The typical operator works full time, has had mandatory and formal training to use the system, and has worked at the TIC for approximately 1 to 2 years (which is close to the total time the TIC has been operational), without much previous experience in the traveler information provider business. The operator's attitude is positive and his/her motivation to do the job is also moderate to high.

Figure 1: Evaluation Framework

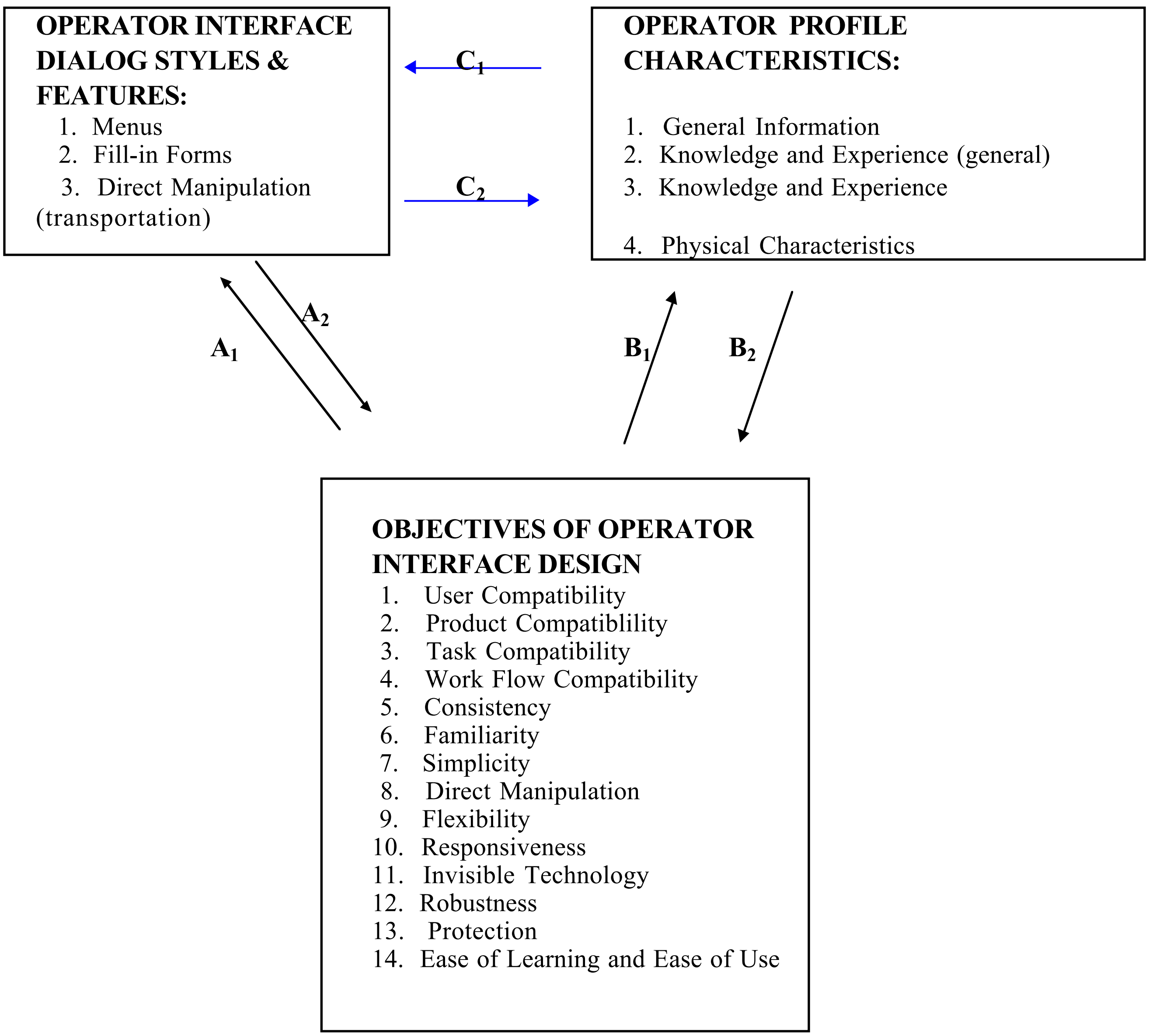


Table 2 summarizes the findings regarding operator characteristics in the "General Knowledge and Experience" category. The typical operator has an above 12th grade reading level, a fairly high typing skill, and a college education. He/she has several years of Windows-specific experience and, based on his/her tenure at the TIC, has had at least a moderate level of experience with the TRW-developed system[5]. The operator is fairly familiar with the use of maps and feels moderately computer literate.

Table 1
Results for General Information Category

GENERAL INFORMATION	SUMMARY STATISTICS
Shift	31% part time; 69% full time
Employment Length (years)	Average = 1.4 years; 75% 1-2 years
Primary Training	100% mandatory and formal
Experience (years)	62.5% have had no experience in traveler information provider business
Attitude	68.7% positive; 12.5% negative
Motivation	All but one are high or moderate

Table 3 summarizes the findings regarding operator characteristics in the "Transportation Knowledge and Experience" category. The typical operator is familiar or very familiar with the geography of the Bay Area including its street and freeway network as well as alternative transportation modes that are available to the traveling public.

Table 2
Results for General Knowledge and Experience Category

GENERAL KNOWLEDGE AND EXPERIENCE	SUMMARY STATISTICS
Reading Level	93.7% above 12th grade level
Typing Skill	56.2% high; 43.8 moderate
Education	93.7% at least college
Experience:	
Windows	Average = 4.3 years
TRW System	18.7% novice; 81.3% at least moderate with 25% expert[6]
Task	6.3% novice; 93.7% at least moderate with 43.7% expert
Application	87.5% have had no experience with similar applications
Use of Maps	43.7% "sometimes"; 56.3% at least "familiar"
Use of Other Systems	62.5% "no use"; 18.7% "little use"; 18.7% "frequent use"
Computer Literacy	6.3% "low"; 68.7% "moderate"; 25% greater than moderate

[5] This, of course, depended on the timing of this survey and the operator turnover rate.
[6] "Novice", "moderate", and "expert" categories are not based on strictly pre-defined criteria but rather how the operators felt about their level of expertise using the system. The number of years of experience was also obtained and allowed verification, although imperfect, of operator statements regarding level of expertise.

Table 3

Results for Transportation Knowledge and Experience Category

TRANSPORTATION KNOWLEDGE AND EXPERIENCE	**SUMMARY STATISTICS**		
Familiarity with Bay Area	somewhat familiar	familiar	very familiar
Street and Freeway Network	6.2%	25%	68.8%
Towns, Cities, and Counties	6.2%	18.8%	75%
Alternative transportation modes	6.2%	37.5%	56.3%

2.5.2 Operator Usage of TransView Windows Environment

The operators expressed a consistent view about the TransView windows they use most frequently and the importance of these windows relative to operator duties. The "Location Selector", "Traffic Incident Manager (TIM)" are always used by all operators. Operators report that they use the "Location Selector", "TIM", the "Map" and the Instatrack web page (non-TransView) for approximately 90% to 100% of their time while on the TravInfo workstation to perform their job responsibilities. Other windows are used less frequently such as the "Sensor Information Manager", the "County Information Editor", and the "Planned Events Manager".

Operators gave assessments of "fair" to "average" for the level of support provided to them by each of the three most frequently used windows (Location Selector, the TIM, and the Map)[7]. Operators judged the computer interface to be overall slightly better than "fair". See Table 4. The specific questions asked of each operator may be found in Appendix B.

[7] A five-level grading scale consisting of "excellent", "good", "average", "fair", and "poor" was used in the assessment.

Table 4

Operator Assessment of Most Frequently Use Windows

TRANSVIEW WINDOW	OVERALL RATING	IDENTIFIED PROBLEMS
Location Selector	Almost "fair"	Incomplete or missing data, lack of consistent terminology, some items difficult to locate
TIM	Between "fair" and "average"	poor design, some choices within pop-up windows are not useful or complete, no ability to write macros, some fields are not needed, too labor intensive
Area Map	Between "fair" and "average"	does not always use terms, e.g. streets names, at freeway off-ramps or other locations, that are most familiar to the driving public, not up to date, needs to be made more precise and accurate when clicked

2.5.3 Interface Features for Dialog Styles

The interface design serves its general purpose of allowing operators to quickly perform their data monitoring and entry tasks. However, the general computer interface does not support the tasks of the operators as much as it could. The chief problem areas, in summary, are the following, with details to follow in subsequent sections:

- The organization and layout of fill-in forms (among which is the TIM, the most used window in the entire system) does not reflect designer consideration of operator tasks and the nature of potential operator form use.
- Some of the most commonly used windows, particularly the "Location Selector" and "TIM", have several shortcomings (See Section 2.5.3.2).
- The two most important menus, the "Information" and "Application" menus, are poorly ordered. They are filled with rarely-used or unneeded items and yet are not ordered by frequency of use or by categories to assist the operator in speedily arriving at needed information.
- There is no grouping of related items on forms which, if done, would improve the overall interface design. Moreover, there are ambiguous terms and non-mutually exclusive attributes within certain fields.
- Lack of consistent organization across all windows. (See Figures 1-9 and Appendix E).

These design weaknesses likely result in a loss of operator time. It is difficult to quantify this time loss because there is no readily identifiable baseline against which the present system can be compared and it is difficult to breakdown the time loss into separate components one of which would be ascribed to poor interface design. While the operators have adapted and learned to circumvent some of the design shortcomings, nevertheless, there are likely still time delays. Design weaknesses have also caused a certain level of frustration among the operators and this is reflected in the relatively low overall rating of the interface design by the operators (Section 2.5.2). On the positive side, the window system used is flexible and allows customization of the windows environment to suit the task at hand and/or operator preferences.

2.5.3.1 Menus

Menu Structure:

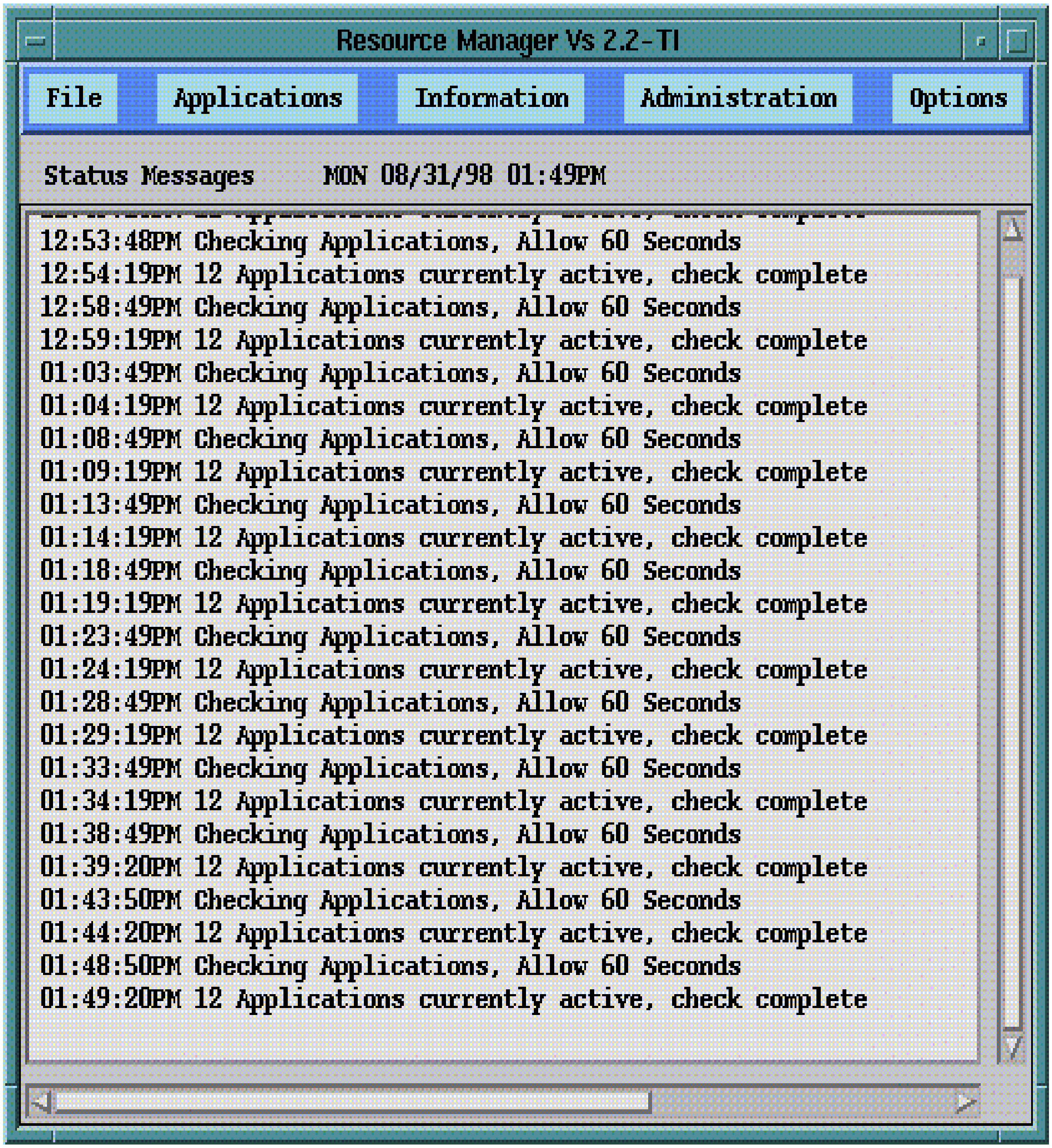
1. *Match Menu Structure to Task Structure:* The overall menu structure is not organized to allow the most efficient sequence of steps to accomplish the most frequent user goals. The menu structure could better match the task structure, particularly in terms of semantics. However, the fact that multiple windows from different menus can be open at the same time, allows users to "customize" the system to match their task structures.

The main top-level system window for all TravInfo applications, the "Resource Manager," has five permanent pull-down menu options (Figure 2): "File," "Applications," "Information," "Administration," and "Options." The "File" menu is for general file manipulation. The "Applications" menu holds traveler information applications such as a window that allows quick selection of a location (referred to as the "Location Selector"), information viewers such as maps for the location of incidents or "events," and a window to view traffic backups (the "Traffic Congestion Backup Manager"). The "Information" menu contains all the main traveler information windows used for data entry chief among which is the "Traffic Incident Manager" or TIM window. The "Administration" menu is for system administration and the "Options" menu contains system options.

The operators mainly use the "Applications" and "Information" menus. These two menus are not entirely semantically distinct. Indeed, there are many items in the "Applications" menu which are information viewers and which semantically could belong in the "Information" menu. This is a source of potential confusion for inexperienced users and does not facilitate ease of learning of the system. Another problem with the menu structure is that the two most used windows, the TIM and the "Location Selector," are not located in the same menu.

Another menu structure that matched the task structure better could have been envisioned. For example, the menu structure could have been organized by the "timeliness" of the data: one menu could be for static data, one for periodic data and one for dynamic data. However, the fact that the user interface is a window system that allows windows from different menus to be open at the same time mitigates this problem considerably. It offers flexibility and the capacity to customize the windows working environment.

Figure 2: TransView Screen: Resource Manager



2. *Depth Versus Breadth*: The menu structure contains primarily breadth. The top-level window, the "Resource Manager," has five menus only two of which go beyond the first level (the "File" and "Options" menus). The two main menus used by operators, the "Applications" and "Information" menus, have no submenus. Two factors are important in determining the depth/breadth relationship for a particular menu structure: user decision-making time and user execution time. In general, when user decision-making times are short, and user execution times are long, more breadth is desirable (user execution times depend on system response time and selection mechanisms available). In the case of TravInfo, where user decision-making times are short and user execution times can at times be long (due to slow system response) choice of breadth seems appropriate.

3. *Easy Way for Users to Tailor Menu Structure to Task Structure:* The default menu structure cannot be tailored to suit the needs of the user and/or of changing tasks. In this sense, the TransView or TIC menu structure does not offer additional flexibility and usability compared to traditional menu systems. On the positive side, the windows system allows users to invoke and keep open the windows they choose. This allows users to tailor their windows' environment according to their preferences or to the task at hand.

4. *Graying Out Versus Deletion of Inactive Menu Items:* Inactive menu items are mostly deleted. For icon invocation (opening, closing, minimization or maximization) inactive menus are grayed out. When users are at the moderate to expert level, as in the case of the TravInfo operators, and menus are keyboard-driven, deletion seems to provide an advantage. For mouse driven systems though, graying out is often preferable. However, given that the operators are high-frequency users and that response time should be as quick as possible, having mostly deletion of inactive menus seems appropriate.

5. *Semantics (Clear, Logical, Mutually Exclusive and Exhaustive):* Categories of items for the "Applications" menu are logically separated from one another. In general, items are organized so as to *maximize* the similarity of items *within* a category and *minimize* the similarity of items *across* categories.

Menu Choice Ordering:

1. *Appropriate Menu Choice Label Ordering:* Different ordering schemes are applied to the five different top-level menus of the "Resource Manager." The "File" menu is organized by convention, i.e. common usage. The "Applications" menu is organized functionally and within each category items are listed alphabetically. The "Information" menu is organized alphabetically as is the "Administration" menu. Finally, the "Options" menu is organized by convention.

   Menu ordering for the most important menus, "Applications" and "Information," was poorly chosen reflecting insufficient consideration of operator tasks and pre-launch system testing. These menus are "cluttered" with many rarely-used items and yet are not ordered by frequency of use or by categories. An example is the "Information" menu that is organized alphabetically which generally applies when no other ordering scheme fits the menu choices. However, in this case other ordering schemes clearly apply. This menu should be organized either functionally (i.e. traffic, transit etc.) or by frequency of use. There is a clear difference in the frequency of use of items within this menu, with the TIM window being used the most often. Ordering the items by frequency of use, or functionally, would minimize search and selection time and better support the operator in his or her tasks.

Menu Choice Selection:

1. *Cursors, Mnemonic Letters, and Pointers:* Menu selection is overwhelmingly mouse driven with the presence of some keyboard commands (mainly for icon invocation). Since all other tasks can be performed using the mouse, it is an appropriate menu selection device.

2. *One Choice Versus Many Choices:* All menus present mutually exclusive choices, and users can only select one at a time ("choose one" menu) so there are no issues related to distinguishing the two choice modes.

3. *Menu Feedback:* Users are provided with visual feedback indicating which options are selectable (see Graying Out and Deletion of Inactive Menu Structure), which window the mouse is currently pointing to, and which windows are currently selected. There is no visual feedback within menus, in the form of a checkmark or change in color, when an item has been selected.

Menu Invocation:

1. *User-invoked (pop-up) Versus Permanent:* The TravInfo TIC interface has mostly permanent pull-down menus. There are a few user-invoked menus mainly at the "Resource Manager" level. This use of menu styles is quite appropriate given that the operators 1. have moderate to expert level expertise, 2. are very frequent users of the system, 3. receive formal training and 4. hence are aware of the location of pop-up menus.

Menu Navigation:

1. *Degree of Consistency in Design and Layout:* Menu design conventions (general window design, title location and format, button locations) have been established and are applied consistently on almost all menu screens within the system.

2. *Navigational Aids:* Navigational aids are not provided. However, given that the menu system is not deep and not complex and that the operators are high-frequency users, navigational aids are not really needed.
3. *Direct Access Methods:* There are no direct access methods such as type-ahead and user-created macros to facilitate navigation and data entry. However, given that the operators use few windows and keep them open throughout their shift, and that the menu structure is not

deep, the absence of direct access methods does not significantly affect operator response time.

2.5.3.2 Fill-in Forms

Fill-in Form Organization and Layout:

1. *Support the Task:* The organization and layout of fill-in forms could have been designed and organized to better support operator tasks. The chief problems for all the fill-in forms, such as the TIM, are that: there is no grouping of related items, useful items are sometimes missing and pop-up lists from within fields are not always complete and do not always contain useful items (Figures 3-8).

2. *Item organization:* There is no grouping of items whether that be semantically, by sequence of use, by frequency of use, and/or by relative importance. Items related to the location of an incident in the TIM window (Figure 4) are an example of this. This results in forms that are harder to learn and scan through and thus slows operator response time, even for experienced operators.

3. *Use of Space:* There is no use of space, whether white or gray, for symmetry and balance and to help lead the eye in the appropriate direction. This results in forms that are harder to learn and scan through and could slow operator response time.

4. *Needs of High-Frequency and Infrequent Users:* The number of screens is minimized (all menu items lead to single windows). This allows speedier processing given that the operators are high-frequency users and hence can navigate well through single screens that contain more information than would several screens. Also when system response is slow, as happens sometimes with the TIC system, it is better to minimize the number of screens and put more information per screen.

Fill-in Form Caption and Field Design:

1. *Placement:* Captions are not placed to the left of input fields but above. Also captions are not left justified for text fields and right justified for numeric fields as is standard. This likely has no significant impact, but proper caption placement and justification would allow quicker learning of the forms and better visual distinction of alphabetic and numeric fields.
2. *Separation:* The caption is separated vertically from its field by approximately one space.

3. *Distinctive Headings:* The forms do not have item grouping, however there are section headings. The section headings, however, are not very distinct from caption titles. In fact, the font style and number for the section headings and caption titles are exactly the same (see TIM form in Figures 4-8). This does not facilitate scanning and ease of learning.

4. *Captions Versus Fields:* Captions are well distinguished from fields.

5. *Caption Language:* Captions are brief, familiar and descriptive.

Figure 3: TransView Screen: Location Selector

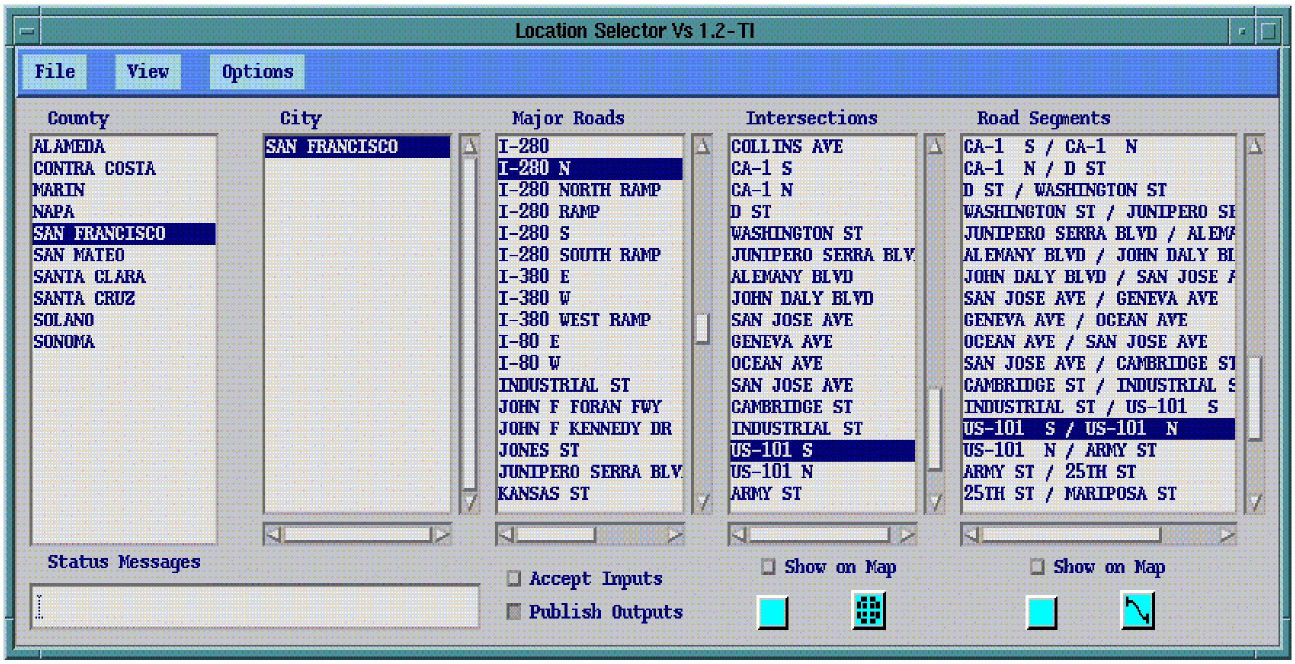


Figure 4: TransView Screen: Traffic Incident Manager for Incident Type—Road Work

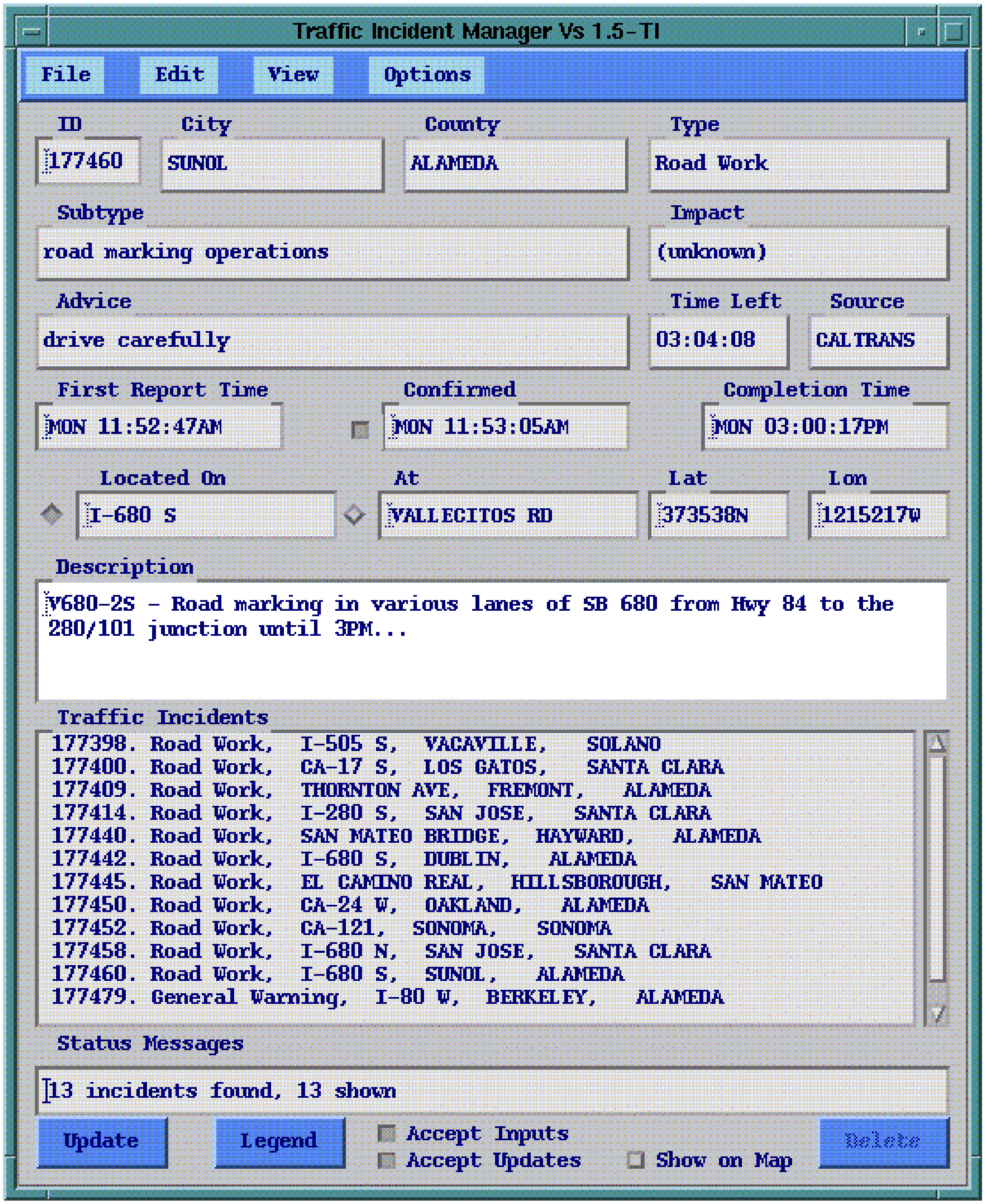


Figure 5: TransView Screen: Traffic Incident Manager for Incident Type—Accident

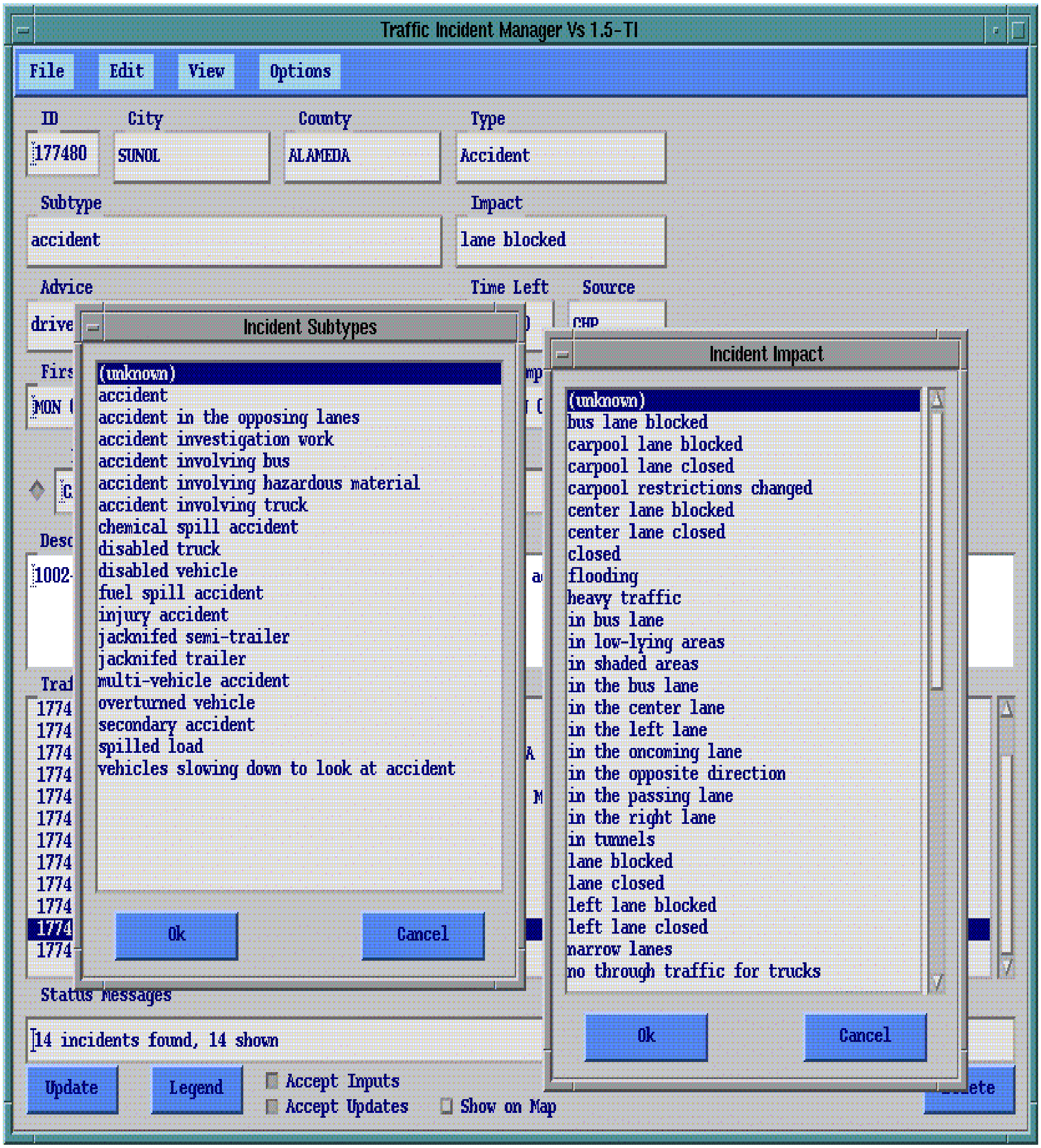


Figure 6: TransView Screen: Traffic Incident Manager for Incident Type—Lane Closure

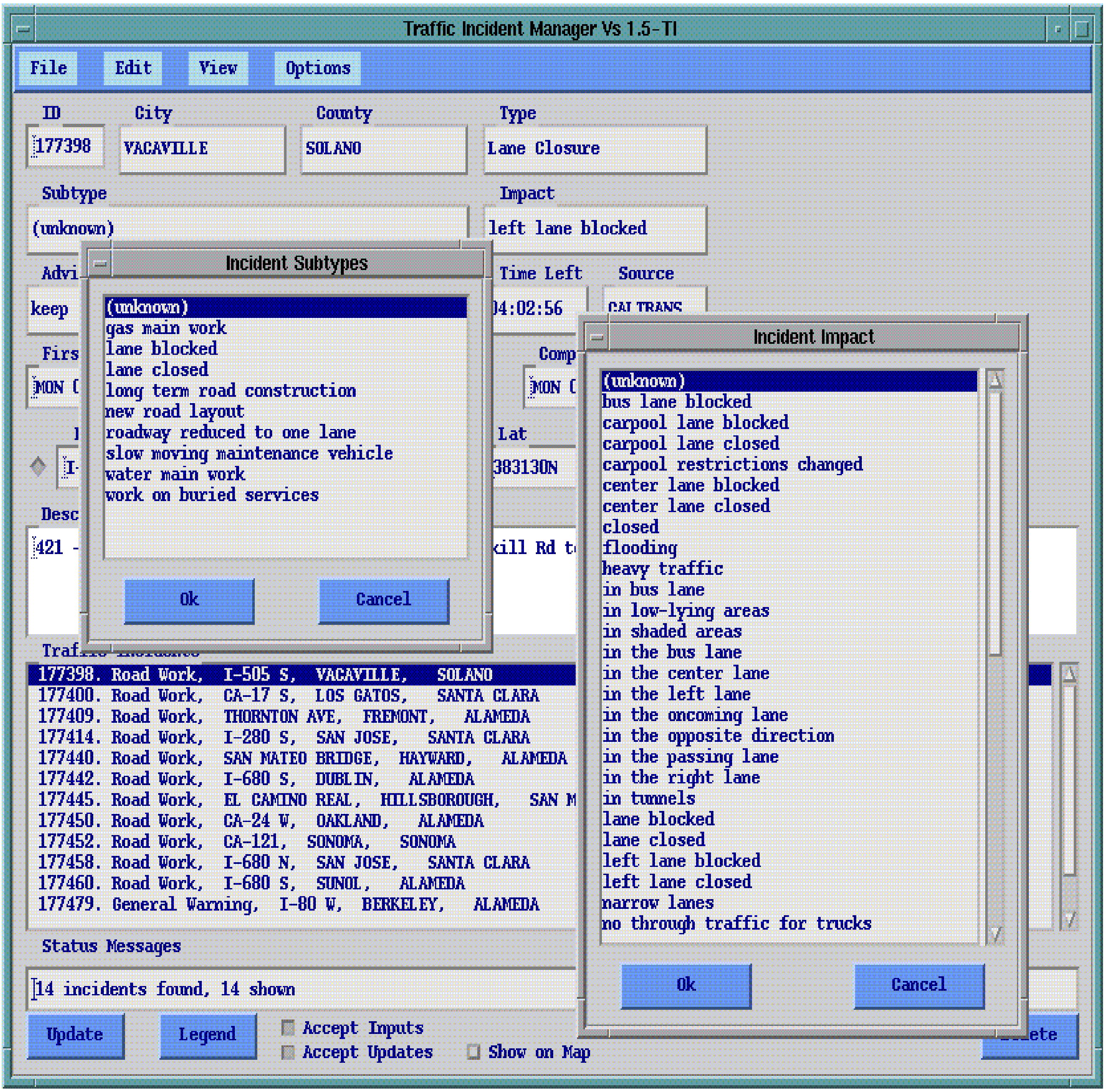


Figure 7: TransView Screen: Traffic Incident Manager for Incident Type—Weather

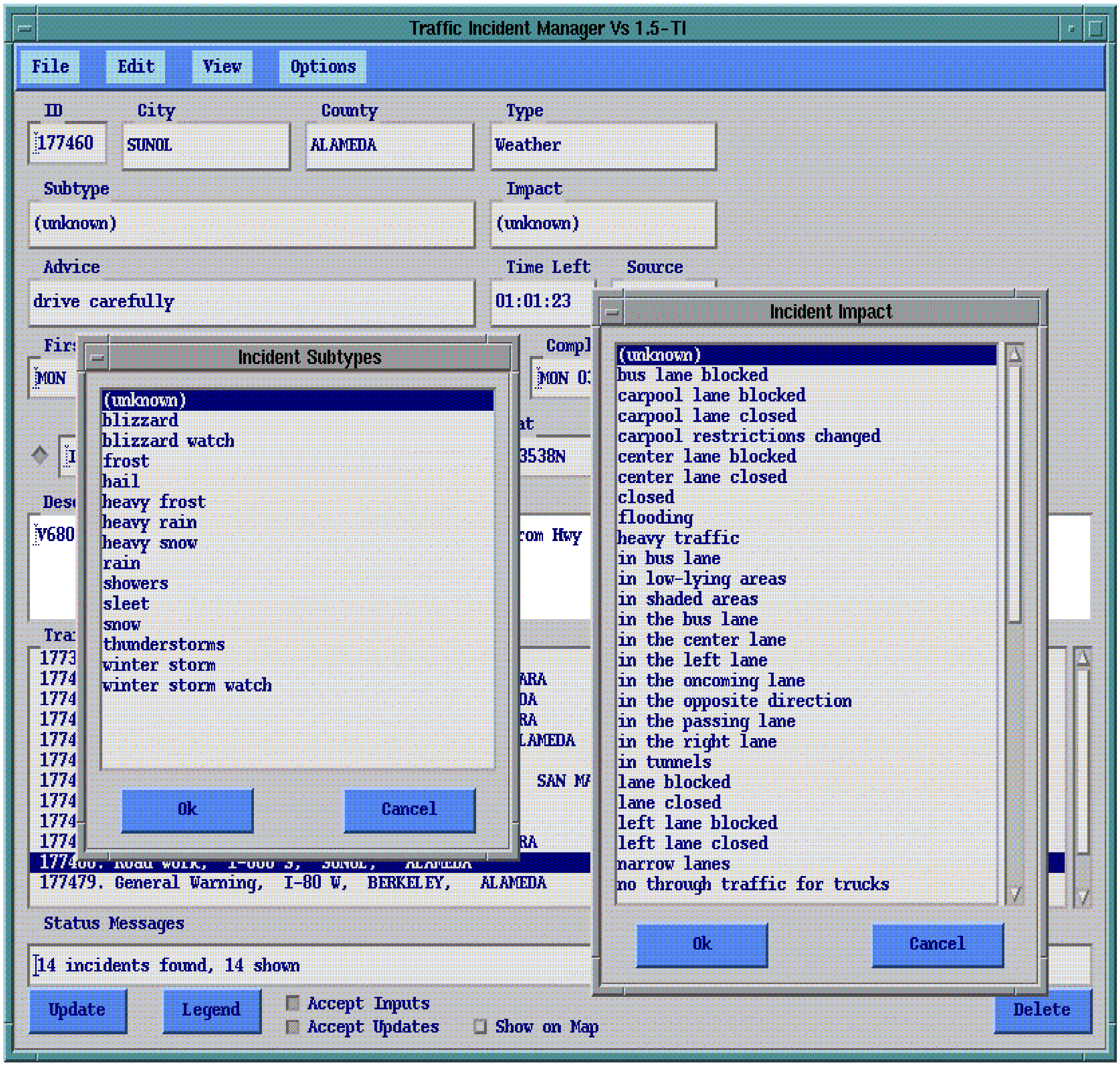
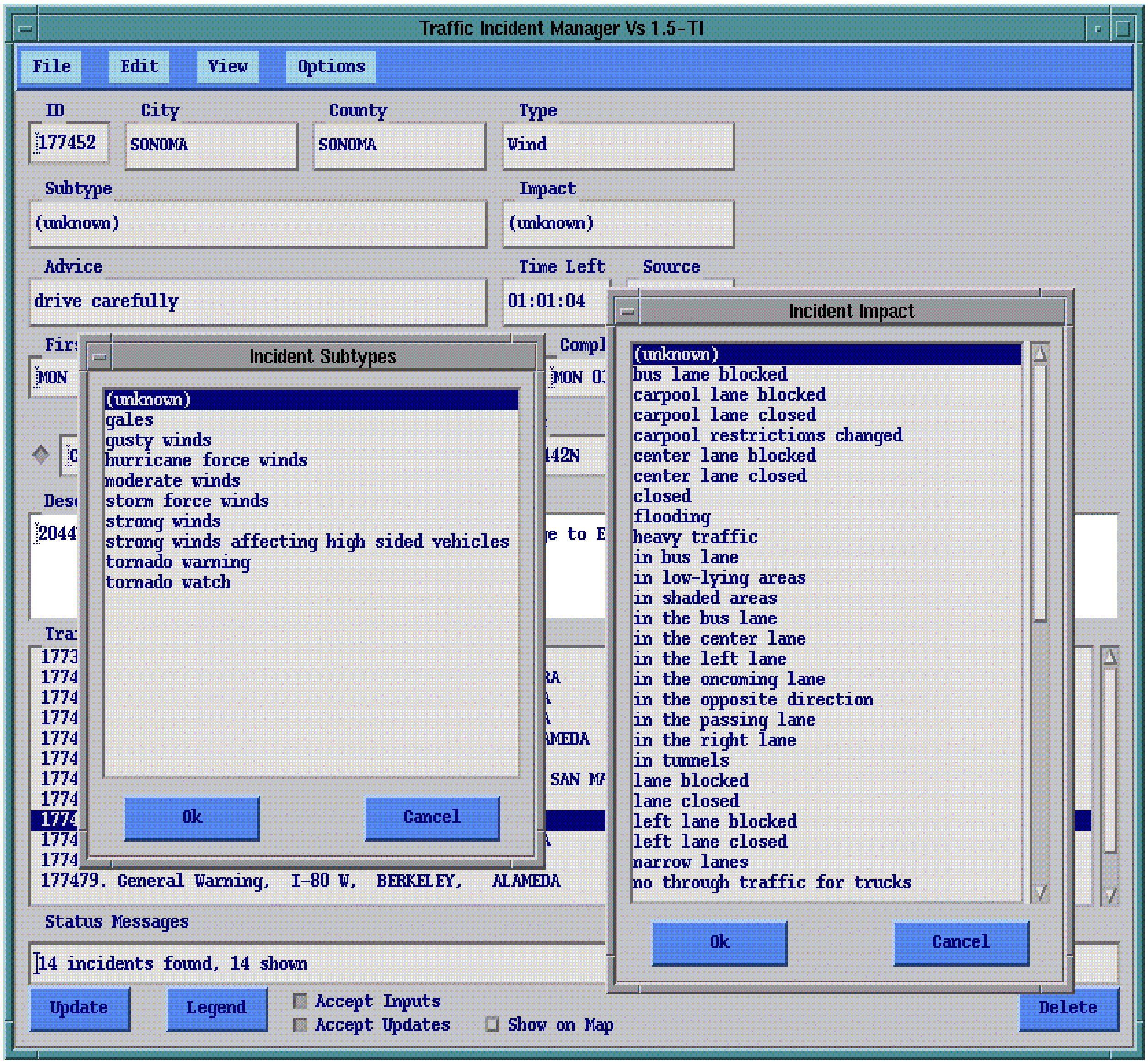


Figure 8: TransView Screen: Traffic Incident Manager for Incident Type—Wind



Fill-in Form Input Formats:

1. *Pop-Up or Pull-Down Menus:* Most forms have pop-up or pull-down menus within fields which saves time for operators. One minor flaw is that fields with pop-up menus are not distinguished from those without by some visual cue.

Fill-in Form Navigation:

1. *Cursor Positioning:* When a form is first entered, there is no cursor placement. This does not really have any consequences since data is entered by invoking pop-up menus with a mouse.

2. *Auto Movement Function:* There is no function that automatically moves the user from one field (once data is input) to the next logical input field. This function could save operator time.

3. *Direct Manipulation:* The mouse pointer selection mechanism is used in all interface dialog styles.

2.5.3.3 Direct Manipulation

Direct Manipulation:

1. *Visual Feedback for Position, Selection, and Movement:* Visual feedback is provided for mouse position, item selection and mouse movement (whether that be simple mouse movement or "dragging" an object). One minor drawback is that when a mouse is positioned above a window it is highlighted but can only be selected by clicking the title bar as opposed to clicking anywhere in the window. This likely results in a minor loss of operator time.
2. *Alternatives for High-Frequency, Expert Users:* There aren't any alternative system interfaces such as command languages, aside from a few command keys for icon invocation. This could be useful given that operators are high-frequency, expert users. However, since few windows are actually used (on average three or four windows) and switching from one window to another is relatively quick, the absence of command keys does not have any significant impact on operator response time.

3. *Icon Design:*

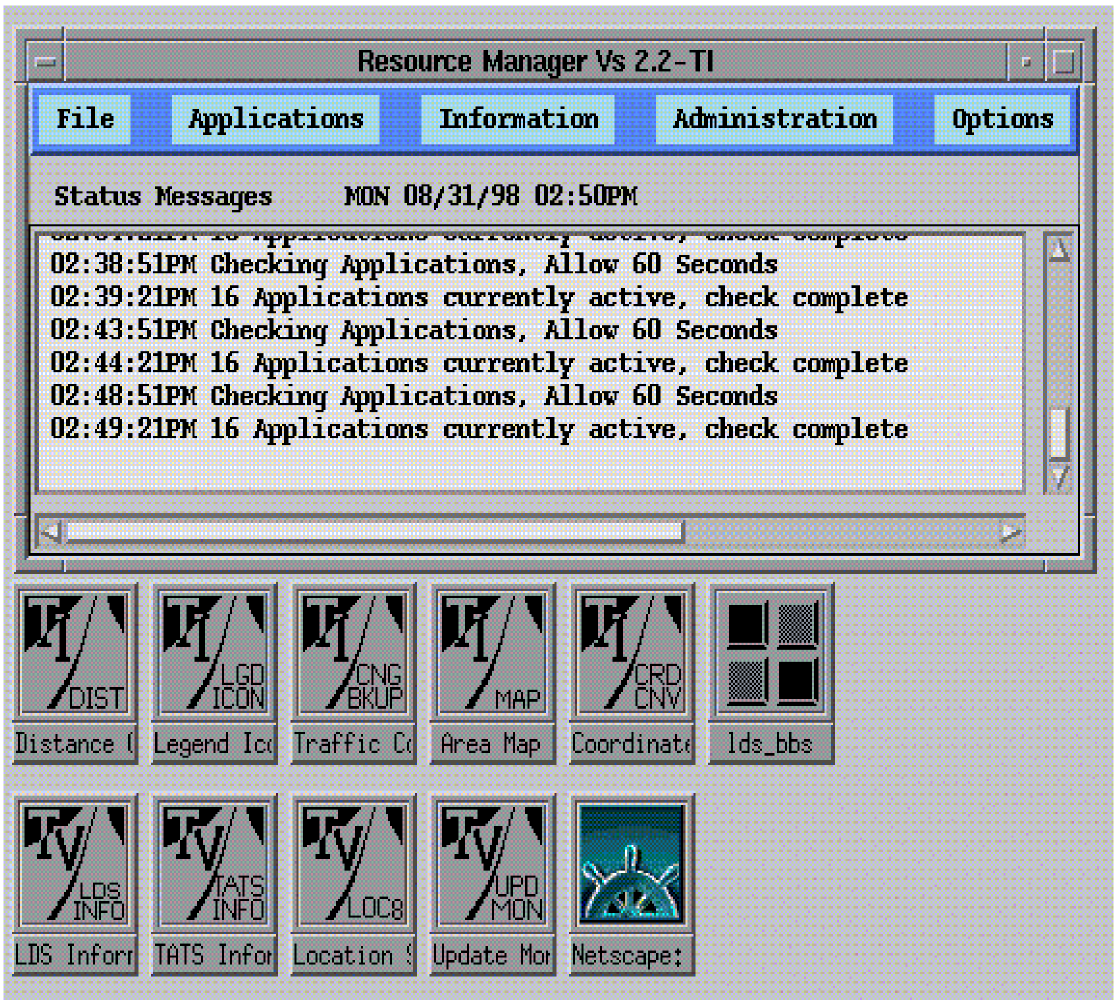
    - *Consistent*: The icon design scheme is consistent.

    - *Concrete and Familiar:* Icons are not designed to be concrete and familiar as compared to abstract and unfamiliar. Icons are poorly distinguished from one another (Figure 9). This likely results in loss of operator time as icon recognition and selection is difficult.

- *Minimize Articulatory Distance:* Icons do a poor job of representing their referents, i.e. to what the icon refers (Figure 9).

- *Visually and Conceptually Distinct:* Icons for items from different menus are not designed to be visually and conceptually distinct. The poor visual design likely results in lost operator time as icon recognition and selection is made more difficult. On the positive side, operators can place the icons where they choose in the "Resource

Figure 9: TransView: Screen Icons



- Manager" window. This allows them to compensate for the poor visual design by assigning a location to each specific icon used and hence facilitating recognition and selection.

- *Amount of Detail:* Excessive detail in icon design is avoided.

- *Linkage with Names:* Icons are accompanied by names but these are not always completely readable (See Figure 9).

- *Number of Icon Types:* The number of icon types is limited to basically three types (See Figure 9) but given the poor visual design, this does not ensure greater visual and conceptual distinctiveness.

2.5.4 Degree of Satisfaction of Interface Objectives

This section discusses the extent to which the computer interface objectives are satisfied (Section 2.1).

User Compatibility—Table 5 presents two sets of values for the operator profile characteristics. These sets of values were compared to assess the extent to which user compatibility was achieved. First, the characteristic values that would be best suited for the TIC interface (column labeled as "Overall TIC Dialog Style") were derived based on information from (7) obtained for each of the three dialog styles of which the TIC interface is composed (menu, fill-in form, and direct manipulation). Second is the input obtained from the operator profile survey (column labeled "Actual Operator Profile").

Table 5

Values of Operator Profile Characteristics for TIC Dialog Style Compared With Actual Operator Profile[8]

CHARACTERISTICS	OVERALL TIC DIALOG STYLE	ACTUAL OPERATOR PROFILE
Motivation	low	moderate to high
Attitude	negative	positive
Typing Skill	low to medium	moderate to high
Computer Literacy	low	at least moderate
Applications Experience	little	little to none
Task Experience	little	at least moderate
(TransView) System Experience	little	at least moderate
Training	little or no	mandatory and formal
Use of Other Systems	frequent	frequent

[8] Only a subset of the operator profile characteristics discussed in Section 2.2 are listed in this table. Such characteristics correspond generally to those for which input was provided in (6) as well as such characteristics not being unique to the TIC environment.

Overall, there is a fairly close match between the actual attribute values and the attribute values that would be best suited for the TIC interface, though there are some notable differences. For example, for the motivation and attitude characteristics, values of "low" and "negative" are associated with the overall TIC dialog style, respectively, yet the actual values from the operator profile are "moderate to high" and "positive". These differences may be due to the fact that the TIC environment is a place of employment and employees need to meet minimum performance requirements. Moreover, the actual operator profile values for these attributes exceed the corresponding values associated with the overall TIC dialog style and this is a positive result.

The relative closeness of actual operator profile characteristics with the ideal overall TIC dialog style characteristics is likely due to good hiring decisions made by TIC operations management.

- Product Compatibility—The system interface design, i.e. windows environment with menus, is compatible with other systems that have features in common with it.

- Task Compatibility—The organizational unit around which each operator focuses his/her tasks is the TIM. Information input into the TIM arrives from various sources, including CHP CAD, the Location Selector, the Instatrack Web page, Area Maps, and other applications. Within this framework, the overall structure and flow of the system supports the task that is being implemented.

- Work Flow Compatibility—Overall, the system is structured to facilitate transitions among tasks. There is, however, an exception with respect to the visual feedback offered to the operator for the position, selection, and movement of the mouse (See Section 2.5.3.3, #1).

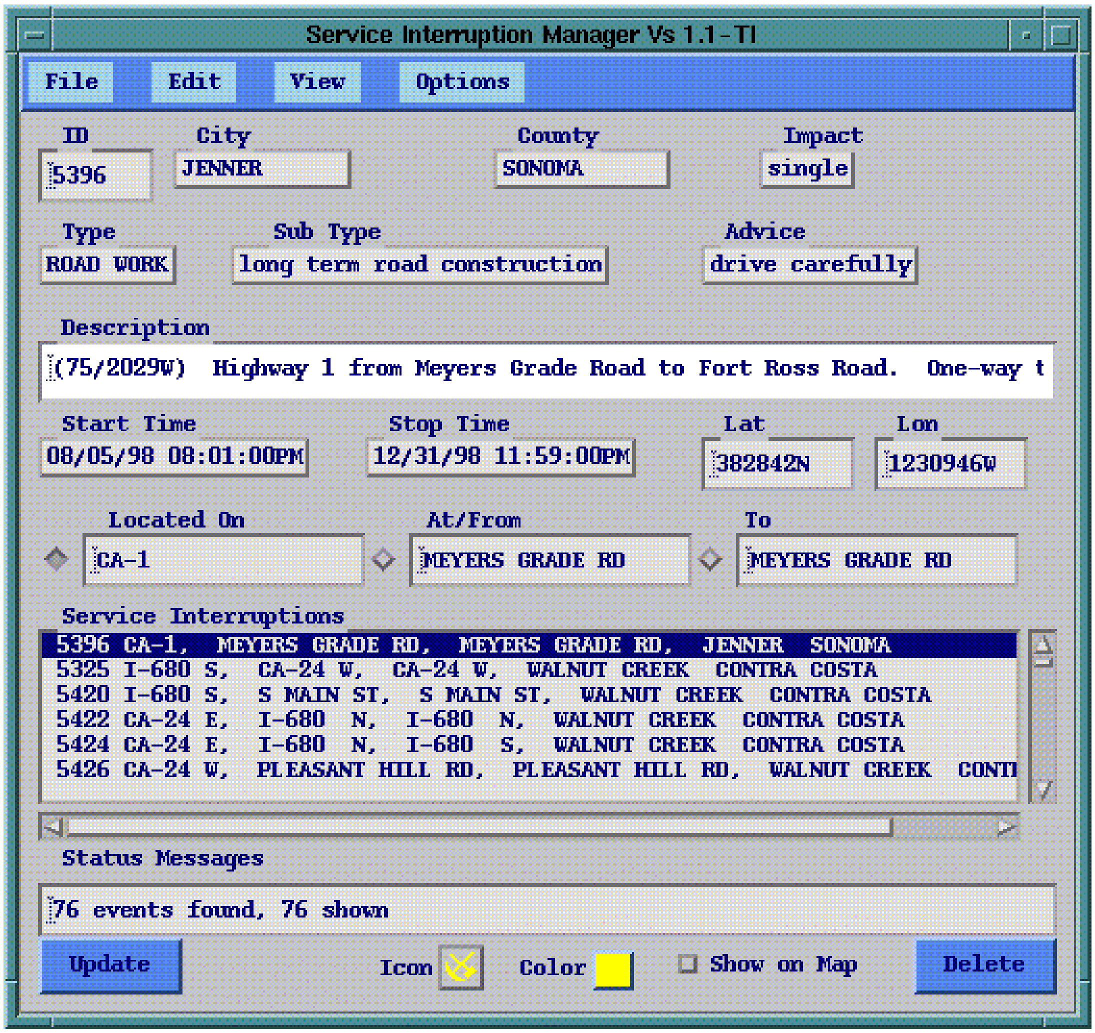
- Consistency—Overall, the level of consistency is satisfactory, in particular given that very few windows are repeatedly used by the operators. There are instances in which the formatting could have benefited from more consistency (Figures 4 and 10).

- Familiarity—The TIC interface uses concepts and terminology that the user is already familiar with, such as "windows", "menus". The interface also displays information both in text and graphical format which are also very familiar to operators.
- Simplicity—The TIC interface is sufficiently simple so as not to overwhelm and confuse a new operator or to be that tedious to navigate for the experienced operator.

- Direct Manipulation—The TIC interface does consist of a direct manipulation dialog style (Section 2.3.3 and 2.5.3.3). Problems associated with this dialog style are discussed in the latter section.

- Flexibility—Data from the operator profile (Section 2.5.1) shows that the TIC operations have employed people with similar backgrounds to perform certain given tasks. Thus there is no strong need for flexibility to accommodate large variations in user skill and preferences. There is, however, flexibility in system use relative to operators being able to work with any windows they choose and keep any selection of windows open at any time. Since operators use primarily four to five windows (Section 2.5.2), the whole issue of tailorability is somewhat moot.

Figure 10: TransView Screen: Service Interruption Manager



- Responsiveness—Based on observations of the evaluators and operator experience, the system is, at times, slow to respond. Moreover, operators are not provided with any feedback on the status of system progress toward task completion, by means of either a simple "Working ..." or "Please wait ..." or more extensive status reports.

- Invisible Technology—The system is not burdened with the technical details of how the system is implemented and operates. Moreover without this information, TIC operators are able to use the system quite constructively.

- Robustness—The TIC system is able to tolerate any kind of input, including errors, without reactions such as system crashes. Operator error, such as inputting incorrect information in the TIM incident description field or inadvertently deleting an incident from the database would, if not corrected, have negative consequences. Each of these actions could, however, be readily corrected.

- Protection—Potentially catastrophic results from operator error, such as all files being deleted, seems to be guarded against.

- Ease of Learning and Ease of Use—The TIC system is relatively easy to learn as well as to use primarily because operators tend to have experience with the Windows Operating System and only four to five individual windows are repeatedly used. The experience of the operators is required to circumvent system problems. The system is easier to use the more familiar an operator is with the Bay Area street and freeway network.

2.5.5 Conclusions

The operator interface objectives are generally satisfied. There are, however, some areas of weakness:

- User compatibility: There should be have been more consideration of specific operator duties.
- Consistency: The fill-in form formatting is not always consistent (See Figures 4 and 10).
- Responsiveness: There is no feedback on the progress of system processing and the system is often slow due to lack of processing power.

Overall, the interface design serves its general purpose of allowing operators to perform relatively speedily their data monitoring and entry tasks. However, the general computer interface could have been better designed and does not support the tasks of the operators as much as it could. The chief problem areas include 1. The organization and layout of fill-in forms do not reflect designer consideration of operator tasks and the nature of potential operator form use; 2. Some of the most commonly used windows have several shortcomings; 3. The two most important menus are poorly ordered. They are filled with rarely-used or unneeded items and yet are not ordered by frequency of use or by categories to assist the operator in speedily arriving at needed information; 4. There is no grouping of related items on forms which, if done, would improve the overall interface design. Moreover, there are ambiguous terms and non-mutually exclusive attributes within certain fields; 5. Lack of consistent organization across all windows.

These design weaknesses likely result in a loss of operator time. It is difficult to quantify this time loss because there is no readily identifiable baseline against which the present system can be compared and it is difficult to breakdown the time loss into separate components one of which would be ascribed to poor interface design. While the operators have adapted and learned to circumvent some of the design shortcomings, nevertheless, there are likely still time delays. Design weaknesses have also caused a certain level of frustration among the operators and this is reflected in the relatively low overall rating of the interface design by the operators. On the positive side, the window system used is flexible and allows customization of the windows environment to suit the task at hand and/or operator preferences.
The system designers should have reflected to a greater degree on the specifics of operator duties, i.e. what operators would be doing and how operators would be using the system. This would have likely led to a more efficient system that would not be cluttered with unneeded windows. In the future, designers should consider more carefully what a system will be used for and how it will be used. Moreover, the presence of a system administrator is highly recommended to fix interface-related problems.

3. OPERATIONS WORKING ENVIRONMENT EVALUATION

The second part of the Operator Interface evaluation consists of an assessment of the operator's working environment. The working environment may contribute to or hinder the operator's ability to do his/her job effectively and thus it was felt important to assess the level of operator acceptability of the TIC working environment. Sources (8, 9) were used as guides to develop a checklist of working environment characteristics to perform this work (Appendix D). The data sources were the stated views of the operators based on their experience. Most of the individual working environment aspects are self-explanatory. For those terms whose meaning was not immediately known, explanations in lay, rather than rigorous and technical, terms were given by the evaluators based on guidance from (9). The analysis was more qualitative, based on operator experience, rather than strictly objective and quantitative in form. For example, with respect to acoustic noise and specifically, ambient sound pressure levels, a maximum of 55 decibels is recommended, excluding noise generated by the user (9)[9]. The evaluators did not take precise measurements with an acoustic detector or sensor and evaluate it against this 55 decibel level upper limit to perform its analysis[10]. There is a tradeoff between the quantitative and technical analytical methods and the more qualitative analytical method based on operator's experience. While the former provides a strict and objective consistency in the analysis, it has the

[9] To put this value in perspective, a library generally has a decibel level of approximately 35 decibels, a heavy truck - 90 decibels, a jack hammer - 105 decibels, and a jet airplane - 125 decibels.
[10] Due to lack of necessary qualifications and resources.

disadvantage that it tends to impose a single "one size fits all" method that may not reflect the variability among the user population[11].

3.1 Characteristics

The working environment checklist was divided into the following four sections: working environment, visual display, keyboard, and furniture.

Working Environment—This section focuses on the illumination, noise levels, and thermal characteristics (heating and cooling) in the TIC environment. The illumination attribute includes office lighting, lighting glare, and the balance in lighting levels among different areas in the user's field of view.

Visual Display—This section focuses on the following attributes of the visual display of the Video Display Terminal, i.e. the computer screen: its resolution, screen glare, color usage , blinking, jitter, flicker, font type, character readability, symbol color contrast, viewing distance, and the adequacy and adjustability of screen controls. The characteristic "blinking" refers to the movement of the individual screen cursor. The characteristics "jitter" and "flicker" refer to the left-and-right and back-and-forth type movements of the screen contents, respectively. The characteristics "color usage", "font type", and "viewing distance" are judged relative to the operator's ability to adjust them to his/her own satisfaction.

Keyboard—This section of the checklist includes the following attributes: height, slope, placement (ease with which keyboard may be repositioned on the worksurface), key force, and stability (steady during normal keying operations).

Furniture—This section of the checklist consists of the following aspects of the worksurface, seating, and accessories and miscellaneous aspects:

Worksurface: general layout of the worksurface, clearances (under the worksurfaces), keyboard support surfaces, and worksurfaces width and height.

Seating: height, depth (permits contact with the seat back in the lumbar area and avoids pressure on the back side of the lower leg), width (at least as wide as the thigh breadth of the seated person), seat pan angle (the seat of the chair is technically called the "seat pan" and the seat pan angle refers to the degree of deviation of the seat from the horizontal or "zero angle" position, seat pan to backrest angle (the angle between the seat back and the seat), backrest (is there one ?), arm rest (are there any ?), casters (are there any ?)

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[11] In the acoustic noise level example, using the 55 decibel level as the boundary between acceptable and unacceptable noise levels, without the subjective component of accounting for differences among the users, this decibel level may in fact be too loud for some and not loud enough for other users.

Accessories: wrist support

Miscellaneous: height of cubicles

3.2 Operator Working Environment: Interview Results and Analysis

Operators were asked about their current as well as overall (since they have been working at the TIC) level of acceptability on a scale of 1 (not acceptable) to 5 (very acceptable) relative to each of the working environment attributes. The survey results indicate that there is basically no difference between the operator's rankings of current and overall working environment, that is, there has generally been no change in the TIC working environment since TravInfo went on-line, so the results discussed below reflect both the current and overall operator experience. The following discussion focuses on the average score for the working environment characteristics. The average, however, does not reveal the full distribution of operator scores. To provide more information on the distribution of operator scores, Tables 6 through 11 below display both the average score associated with each characteristic and the percentage of operators who scored each attribute either a "4" or a "5", that is, assigned that attribute a better than average level of acceptability.

The operations' staff is generally satisfied with lighting and sound characteristics, but generally not satisfied with the thermal and air circulatory characteristics of the working environment. Results are shown in Table 6, with the average score relative to lighting and sound characteristics ranging between 3.3 and 4.2 out of a maximum score of 5. People were concerned with the lack of proper ventilation and the extremes in temperature, especially the room being too hot. It should be noted that while such concerns were not unanimously felt by the staff, 75% of the operators scored "Temperature" either a "1" or a "2"; 50% scored both "Air Movement" and "Air Quality" either a "1" or a "2".

Staff is generally satisfied with all aspects of the visual display category. Results are shown in Table 7, with the average score relative to visual display characteristics ranges between 3.9 and 4.8, with all but one characteristic ("Jitter") having an average score between 3.9 and 4.2. For all but one characteristic ("Font Type"), two-thirds of the operators give each of them a score of at least "4".

Staff is again generally satisfied with all aspects of the keyboard category. Results are shown in Table 8, with the average score relative to keyboard characteristics ranges between 3.3 and 4.1. For all but one characteristic ("Placement"), two-thirds of the operators give each of them a score of at least "4".

Table 6

Overall Operator Acceptability Level for Working Environment

WORKING ENVIRONMENT	AVERAGE SCORE	% OF OPERATORS WITH A SCORE OF "4" or "5"
Luminance	3.3	43.8
Glare	4.0	73.3
Balance	3.3	50.1
Visual Display	4.2	81.3
Acoustic Noise	3.9	75.1
Temperature	1.8	0.0
Air Movement	2.6	25.1
Air Quality	2.6	31.3

Table 7

Overall Operator Acceptability Level for Visual Display

VISUAL DISPLAY	AVERAGE SCORE	% OF OPERATORS WITH A SCORE OF "4" or "5"
Resolution	4.0	75.0
Glare	3.9	68.8
Color Usage	4.0	81.3
Blinking	4.2	87.5
Jitter	4.8	100.0
Flicker	4.5	93.8
Font Type	3.8	62.6
Character Readability	4.1	68.8
Contrast	3.9	68.8
Viewing Distance	4.1	87.6
Adequacy of Controls	4.0	87.6
Adjustability of Controls	4.1	87.5

Staff is again generally satisfied with all aspects of the furniture worksurface category, except for the general layout of their own worksurface (See Table 9). There is a lot going on requiring the operator's attention and the "L" shaped layout of their worksurface is not the most conducive for effective work performance over many hours. The average score relative to the other three characteristics ranges between 3.4 and 4.3. The "General Layout" characteristic received an average score of 2.4, with 62.6% of the operators scoring it as either "1" or "2". Frequently expressed comments about the general layout were the following: "too narrow", "ergonomically unfriendly", "layout requires too much twisting and turning to access all the necessary interfaces".

Operations' staff were again generally satisfied with all aspects of the seating characteristics category (See Table 10). The average score relative to seating characteristics ranges between 3.4 and 4.3. From Table 10 for each characteristic, one-half of the operators give each of them a score of at least "4".

Table 8

Overall Operator Acceptability Level for the Keyboard

KEYBOARD	AVERAGE SCORE	% OF OPERATORS WITH A SCORE OF "4" or "5"
Height	3.8	68.8
Slope	3.9	75.0
Placement	3.3	56.3
Key Force	4.1	68.8
Stability	4.0	81.3

Table 9

Overall Operator Acceptability Level for the Furniture Worksurface

FURNITURE WORKSURFACE	AVERAGE SCORE	% OF OPERATORS WITH A SCORE OF "4" or "5"
Clearances	4.3	93.8
Keyboard Support Surface	3.9	87.6
Width/Height	3.4	62.6
General Layout	2.4	25.0

Staff is generally pleased with the wrist support characteristic (average score of 3.1), but score the cubicle height as generally less than acceptable (average score of 2.7) (See Table 11). Approximately 44% of the operators give the "cubicle height" characteristic a score of "1" or "2". The general negative comment about the cubicle height was that the cubicle dividers should be taken down because they interfere with operators trying to communicate with each other.

Having the cubicle dividers naturally reduces the tendency for any communication among operators, both non-work- and work-related. However, the dividers add a sense of privacy to the environment. Removing the dividers could facilitate work-related communication among operators but must be weighed against the tendency for increased non-business related chatter and reduced privacy.

Table 10

Overall Operator Acceptability Level for Seating Characteristics

SEATING	AVERAGE SCORE	% OF OPERATORS WITH A SCORE OF "4" or "5"
Height	4.1	75.0
Depth	4.3	87.5
Width	4.1	81.3
Pan Angle	4.1	81.3
Pan to Backrest Angle	3.6	62.5
Backrest	3.4	50.0
Arm Rest	3.4	50.1
Casters	3.9	68.8

Table 11

Overall Operator Acceptability Level for Accessories and Miscellaneous Items

ACCESSORIES/ MISCELLANEOUS	AVERAGE SCORE	% OF OPERATORS WITH A SCORE OF "4" or "5"
Wrist Support	3.1	50.0
Cubicle Height	2.7	37.6

3.3 Conclusions

There were only three characteristics where work environment changes would lead to a more productive TIC working environment: 1) thermal and air quality, 2) general layout of work surface, and 3) cubicle height or sense of connectedness with other operators. All other characteristics were found to be acceptable by the operators, i.e. these characteristics had an average score of greater than "3". Nevertheless, improvements should at least be considered for these characteristics.

4. RECOMMENDATIONS

The results of the investigation of the TIC operator interface design and the working environment may be used to make recommendations for both the post-FOT deployment setting of TravInfo as well as for future Traveler Information Center projects.

For the post-FOT deployment setting of TravInfo, three alternatives may be considered for the computer interface. First, there is the Do-Nothing or As-Is alternative in which no further changes would be made to the operator interface except regular maintenance. Few modifications have been made since the system was delivered to TravInfo (Spring 1996) and operations began (September 1996). The maintenance contract was signed only a few months ago and a system administrator has been physically located at the TIC and maintaining the system since then. The second alternative, the Fix-It alternative, keeps the TRW-developed system in use today and makes changes to the interface that are consistent with the evaluation results as well as input from knowledgeable TravInfo participants. The third alternative, the New-Interface alternative, would develop a new and different interface. The first alternative is not recommended because it maintains the current system with its problems. Any recommendation between the second and third alternatives would require a cost/benefit analysis to compare alternatives and assess tradeoffs.

The TIC has relocated to another location during the Summer of 1998 and this offers the opportunity to improve the working environment particularly with regard to the general layout of the work surface and the height of the cubicles.

For a new project, such as another Field Operational Test, there are two alternatives to consider on acquiring a TIC computer system. First, an existing software system may be purchased and customized as needed. The second option is to develop an entirely new software system. Any recommendation regarding these alternatives would require a cost/benefit comparative analysis to completely assess differences and trade-offs keeping in mind both the short- and long-term objectives for the project. The following should be kept in mind during this process: 1. Careful consideration of all appropriate operator interface objectives, paying special attention to operator tasks and operator characteristics and 2. Review of similar projects, including lessons learned about successes and failures.

5. REFERENCES

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6. APPENDICES

This section contains the following five appendices

Appendix A	User Profile Checklist
Appendix B	Working Environment Matrix
Appendix C	Details of User Interface Design Features
Appendix D	Operator Computer Interface Evaluation
Appendix E	Additional TransView Screens

APPENDIX A

USER PROFILE CHECKLIST

GENERAL INFORMATION

EMPLOYMENT INFORMATION
Start of employment at TIC?

Shift?
Full-time
Part-time

PRIMARY TRAINING
None
Manual only
Elective formal
Mandatory formal

EXPERIENCE IN TRAVELER INFORMATION PROVIDER BUSINESS PRIOR TIC?
Number of years:

ATTITUDE
Positive
Neutral
Negative

MOTIVATION
High
Moderate
Low
None

KNOWLEDGE AND EXPERIENCE (GENERAL)

READING LEVEL
5th grade
5-12th grade
Above 12th grade

TYPING STYLE AND SKILLS
Low (hunt & peck)
Medium
High (keyboard typist)

EDUCATION
Highschool
College
Advanced degree

WINDOWS EXPERIENCE

Please specify number of years

TRANSVIEW SYSTEM EXPERIENCE
Expert
Moderate
Novice

TASK EXPERIENCE
Expert
Moderate
Novice

APPLICATION EXPERIENCE
No similar systems
One similar system
Some similar systems

USE OF MAPS
Very frequently
Frequently
Sometimes
Not at all

USE OF OTHER SYSTEMS	*COMPUTER LITERACY*
None	Low
Little	Moderate
Frequent	High

***KNOWLEDGE AND EXPERIENCE (TRANSPORTATION)**

FAMILIARITY WITH BAY AREA STREET & FREEWAY NETWORK	*FAMILIARITY WITH BAY AREA TOWNS CITIES, AND COUNTIES,*	*FAMILIARITY WITH BAY AREA ALTERNATIVE MODES OF TRANSPORTATION*
Very familiar	Very familiar	Very familiar
Familiar	Familiar	Familiar
Somewhat familiar	Somewhat familiar	Somewhat familiar
Not at familiar	Not at familiar	Not at familiar

PHYSICAL CHARACTERISTICS

COLOR BLIND	*HANDEDNESS*	*GENDER*
Yes (please specify gradation, e.g. simple red-green)	Right	Female
No	Left	Male
	Ambidextrous	

APPENDIX B

WORKING ENVIRONMENT MATRIX

On a rate from 1 to 5, with 1 being the least acceptable and 5 the most acceptable, please rate your satisfaction with the following elements constituting your working environment.

	NOW	OVERALL
1. Working Environment:		
Office Illuminance		
Office glare		
Luminance balance		
Visual Distractions		
Acoustic Noise		
Temperature Distractions		
Air Movement		
Air Quality (Odors, stuffiness)		
2. Visual Display:		
Resolution		
Screen Glare		
Color Usage		
Blinking		
Jitter		
Flicker		
Font type		
Character Readability		
Symbol Color Contrast		
Viewing Distance		
Controls (luminance, contrast,		
window size and placement):		
Adequacy		
Adjustability		
3. Keyboard:		
Height		
Slope		
Placement		
Key Force		
Stability		

4. Furniture	**NOW**	**OVERALL**
Worksurface:		
Clearances		
Keyboard Support Surface		
Worksurface Width & Height		
General layout		
Seating:		
Height		
Depth		
Width		
Seat Pan Angle		
Seat Pan to Backrest Angle		
Backrest (height, lumbar		
support, width)		
Arm Rest		
Casters (wheels)		
Accessories:		
Wrist Support		
Other:		
Height of cubicles		

APPENDIX C

DETAILS OF USER INTERFACE DESIGN FEATURES

The menu interface design considerations fall into the following categories:

- menu structure
- menu choice ordering
- menu choice selection
- menu invocation
- menu navigation

Menu Structure—The following elements comprise menu structure:

1. *Match Menu Structure to Task Structure:* Menu structure should allow the most efficient sequence of steps to accomplish the most frequent user goals in completing the user's task.

2. *Depth Versus Breadth*: This category concerns the tradeoff between menu depth and breadth. A deep structure has many levels, though few choices at each level. A broad structure has fewer levels, though more choices at each level. Two factors are important in determining the depth/breadth relationship for a particular menu structure: user decision-making time and user execution time. In general, when user decision-making times are long, less breadth is desirable, however, when user execution times are long, more breadth is desirable.

3. *Easy Way for Users to Tailor Menu Structure to Task Structure:* The default menu structure may not be the best for all cases. When a menu structure can be tailored to suit the needs of the user and/or of changing tasks, this offers flexibility and usability not found in simple, traditional menu systems.

4. *Graying Out Versus Deletion of Inactive Menu Items:* Graying out refers to displaying currently inactive menu items, due to temporary and minor changes in system state, in a lighter font and making them unselectable. Deletion refers to deleting or not displaying the currently inactive menu items.

5. *Semantics (Clear, Logical, Mutually Exclusive and Exhaustive):* Categories of items within a menu should have clear labels and be logically separated from one another. In general, items should be organized so as to *maximize* the similarity of items *within* a category and *minimize* the similarity of items *across* categories. This ensures mutually exclusive semantic categories.

Menu Choice Ordering—The following elements comprise menu choice ordering:

1. *Appropriate Menu Choice Label Ordering:* Menu labels can be ordered according to convention, frequency of use, order of use, categorical or functional groups and/or alphabetical order depending on the user and task variables. If any conventional order is relevant it ought to take precedence over any other ordering scheme. If no conventional order applies and if there are more than five or six choices on a menu, these should be grouped in some way to facilitate scanning and searching. If there is a clear difference in anticipated frequency of use of menu items, then ordering them by frequency of use will minimize search and selection time. If there is an order of use inherent in the menu choices, then an order of use organization might be appropriate. For novice or infrequent users, functional or semantic categories of menu items might be desirable if they apply. If no other ordering scheme fits the menu choices, then alphabetic is better than random ordering, especially for high-frequency, expert users.

<u>Menu Choice Selection</u>—The following elements comprise menu choice selection:

1. *Cursors, Mnemonic Letters, and Pointers:* On keyboard-driven menu systems, cursor selection is acceptable for shorter menus, especially if use is casual. For longer menus and/or for high-frequency users, mnemonically lettered selection codes are preferred if practical. If a system has an alternative input device, such as a mouse, and if many other tasks can be accomplished using this alternative device, then it can also be used for menu selection.

2. *One Choice Versus Many Choices:* Some menus present mutually exclusive choices, and users can only select one at a time ("choose one" menu). Others present a list of options that may be selected in combination simultaneously. Both these styles of menus are used frequently in most systems.

3. *Menu Feedback:* Provide users with visual feedback indicating which options are selectable, which option the pointer is currently pointing to, and which options are currently selected.

<u>Menu Invocation</u>—The following element comprises menu invocation:

1. *User-invoked (pop-up) Versus Permanent:* User-invoked (pop-up) menus are menus that appear when the user presses a mouse button or key to bring up a menu that relates to the current screen. A "permanent menu" is permanently displayed across the top of the screen. User-invoked menus should only be used for high-frequency users and when screen space is scarce. Permanent menus are generally preferred.

<u>Menu Navigation</u>—The following elements comprise menu navigation:

1. *Degree of Consistency in Design and Layout:* Conventions for menu design should be established and applied consistently on all menu screens within a system.

2. *Navigational aids:* In complex menu systems, navigational aids (context labels, menu maps and place markers) should be used.

3. *Direct Access Methods:* Direct access methods such as type-ahead and user-created macros should be used to facilitate navigation for expert users.

The fill-in form interface design considerations are initially grouped in the following categories:

- fill-in form organization and layout
- fill-in form caption and field design
- fill-in form input formats
- fill-in form navigation
- fill-in form error handling

Fill-in Form Organization and Layout—The following elements comprise fill-in form organization and layout:

1. *Support the Task:* The form should be designed and organized to support the task. It is crucial to consider how a user will use an on-line form.

2. *Item organization:* Items should be grouped semantically, by sequence of use, by frequency of use, and/or by relative importance. Grouping by semantic categories should be the overriding organizing principle for most fill-in form screens.

3. *Use of Space:* Space, whether white or gray, should be used for symmetry and balance and to lead the eye in the appropriate direction.

4. *Needs of High-Frequency and Infrequent Users:* The number of screens should be minimized (and contain more information) for high-frequency users and when system response is slow in order to speed-up processing. When system response is fast and use is infrequent, more screens with greater clarity may allow faster work.

Fill-in Form Caption and Field Design—The following elements comprise fill-in form caption and field design:

1. *Placement:* In western cultures, for single fields, the caption should be to the left. For list fields, the caption should be placed above, left justified above alphabetical lists and right justified above numeric lists.

2. *Separation:* The caption (in a left-justified group) should be separated from its field by no more than one or two spaces. Caption-field groups should be separated from another by three or more spaces horizontally or by one or more lines vertically.

3. *Distinctive Headings:* Complex forms should have distinct field group and section headings.

4. *Captions Versus Fields:* Captions should be distinguished from fields.
5. *Caption Language:* Captions should be brief, familiar and descriptive.

Fill-in Form Input Formats—The following elements comprise fill-in form input formats:

1. *Pop-Up or Pull-Down Menus:* These should be considered when use is casual, users are inexperienced, the number of valid inputs is large and/or inputs are difficult to spell or remember. Fields with pop-up menus should be distinguished from those without by some visual cue.

Fill-in Form Navigation—The following elements comprise fill-in form navigation:

1. *Cursor Positioning:* When a form is first entered, the cursor should be placed in the most likely default position. For forms where all fields are edited, the cursor should be positioned in the top-left field.

2. *Auto Movement Function:* Functions that automatically move the user from one field (once data is input) to the next logical input field are desirable in that they save operator time.

3. *Direct Manipulation:* Direct manipulation, as with a mouse, increases flexibility, speed and ease of learning for navigation through fields.

Direct Manipulation—The following elements comprise the direct manipulation dialog style:

1. *Visual Feedback for Position, Selection, and Movement:* Visual feedback should be provided for mouse position, item selection and mouse movement (whether that be simple mouse movement or "dragging" an object).

2. *Alternatives for High-Frequency, Expert Users:* Alternative interfaces (such as command languages) should be considered for high-frequency, expert users.

3. *Icon Design:*
   - *Consistent:* The icon design scheme needs to be consistent.

- *Concrete and Familiar:* Icons should be designed to be concrete and familiar as compared to abstract and unfamiliar.

- *Minimize Articulatory Distance:* The more directly the icon relates to its referent (i.e. what the icon refers to or represents), the less articulatory distance there is between them and this is a preferred situation.

- *Visually and Conceptually Distinct:* Icons should be designed to be visually and conceptually distinct.
- *Amount of Detail:* Excessive detail in icon design should be avoided.

- *Object relations:* Icons should be designed to communicate object relations and attributes. When icons take on important attributes (such as an icon displaying a job in progress), the icon design should reflect these attributes in a meaningful way. For example, for an icon displaying a job in progress, if the job is half done then half the icon could be gray, the other half white. When the job is completed, the icon could be all gray to display the changed state.

- *Linkage with Names:* Because icons are not necessarily easy to recognize, it is recommended that they be accompanied by names.

- *Number of Icon Types:* The number of icon types should be limited to ensure greater visual and conceptual distinctiveness.

APPENDIX D

OPERATOR COMPUTER INTERFACE EVALUATION

1. What windows do you use most frequently? What percent of your TransView or TIC computer time (i.e. the time you spend on the TravInfo workstation, not on the CAD) do you spend on these windows? Please rank these windows in order of importance (relative to your operator duties).

#1
#2
#3
#4
#5

2. How would you rate the level of support provided to you by each of these windows in executing your tasks?

	1	2	3	4	5	6
Excellent						
Good						
Average						
Fair						
Poor						

Problems associated with each window:

	Problems
1	
2	
3	
4	
5	
6	

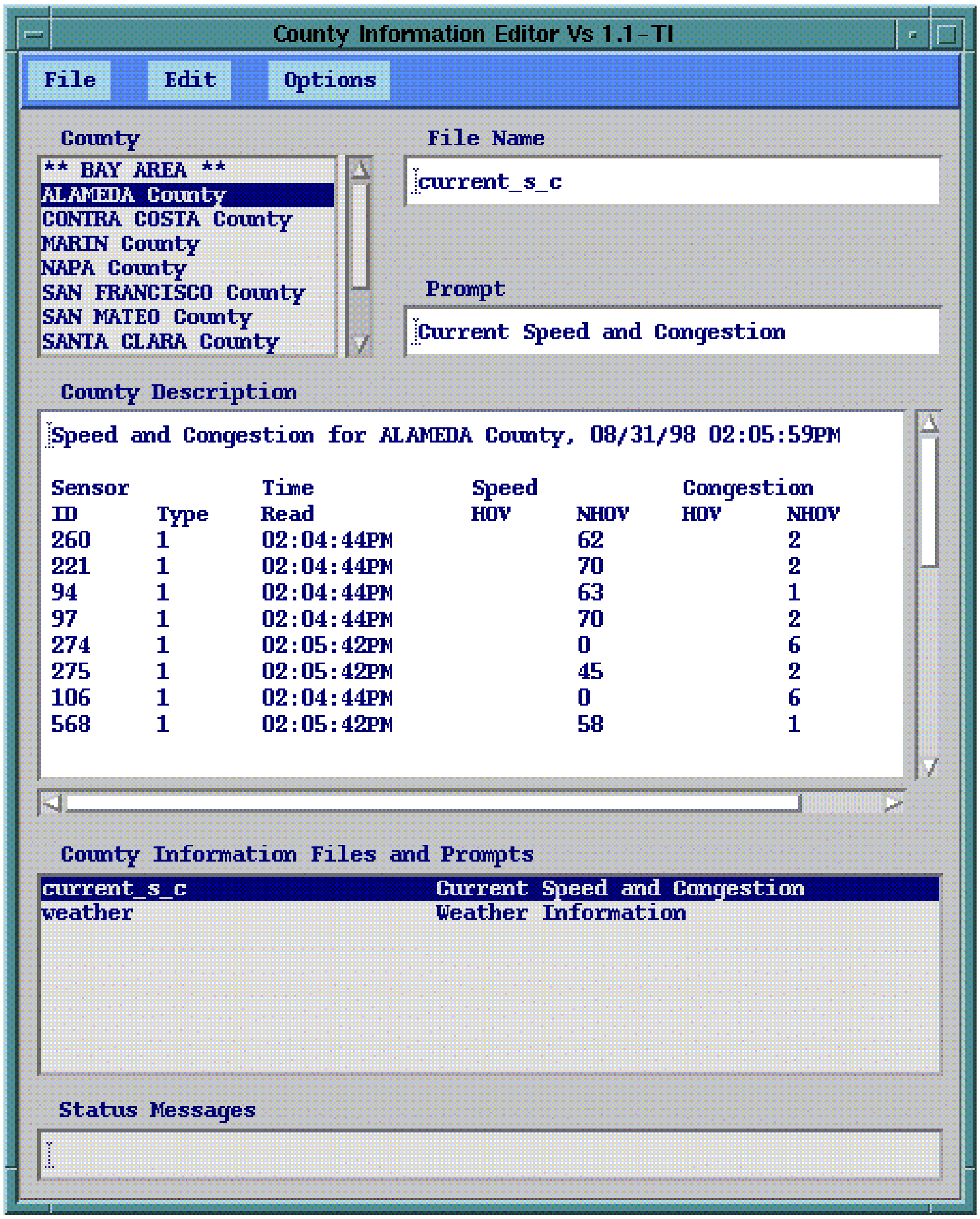
3. Overall, how would you rate the TravInfo computer interface (explain if necessary)?

- ☐ Excellent
- ☐ Good
- ☐ Average
- ☐ Fair
- ☐ Poor

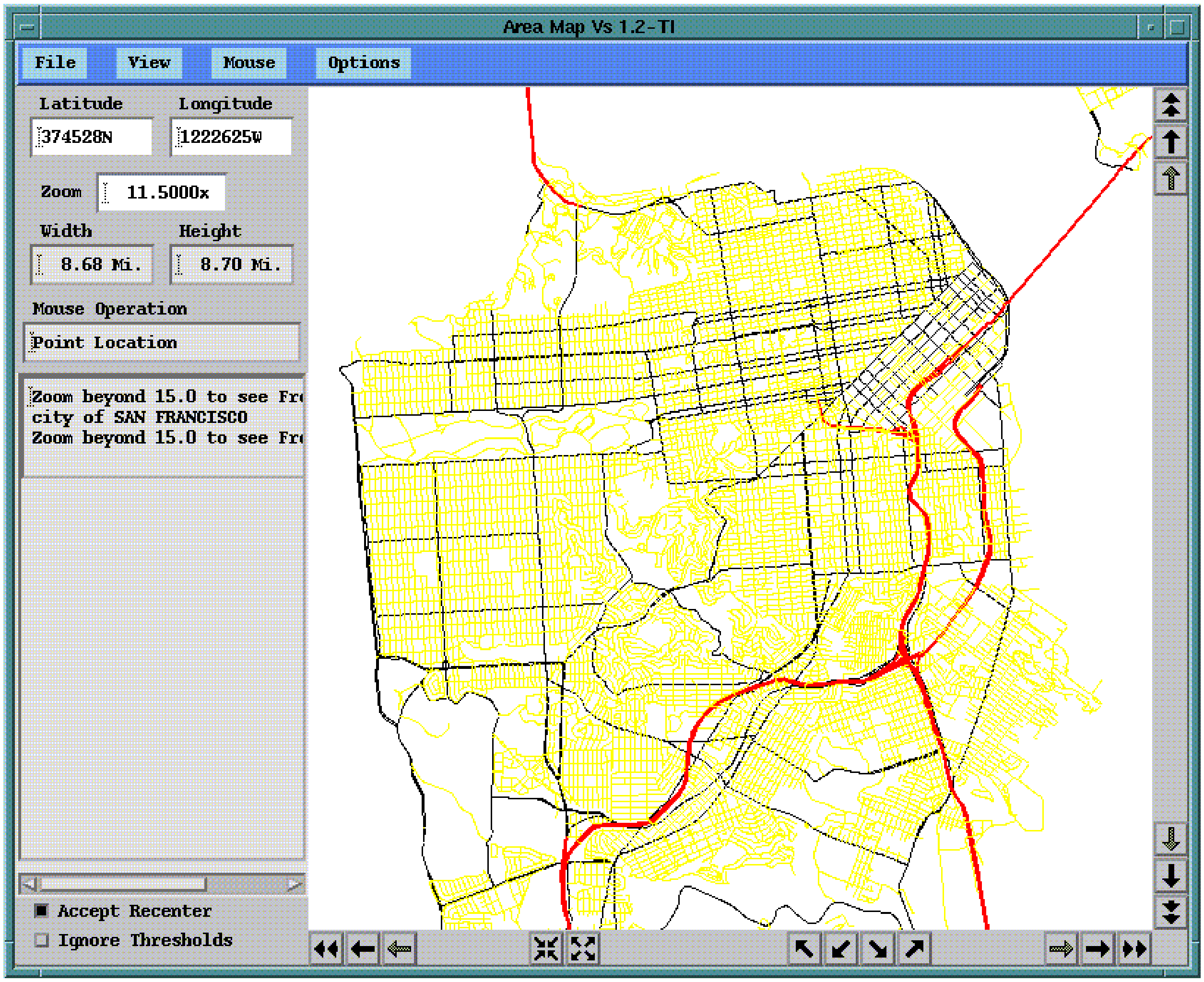
APPENDIX E

ADDITIONAL TRANSVIEW SCREENS

County Information Editor



Area Map


Area Map Vs 1.2-TI
File
View
Mouse
Options
Latitude
Longitude
374528N
1222625W
Zoom
11.5000x
Width
Height
8.68 Mi.
8.70 Mi.
Mouse Operation
Point Location
Zoom beyond 15.0 to see Fr
city of SAN FRANCISCO
Zoom beyond 15.0 to see Fr
Accept Recenter
Ignore Thresholds