THE ADVANCE PROJECT:
Formal Evaluation of the Targeted Deployment

Volume II

NOTE TO READER:

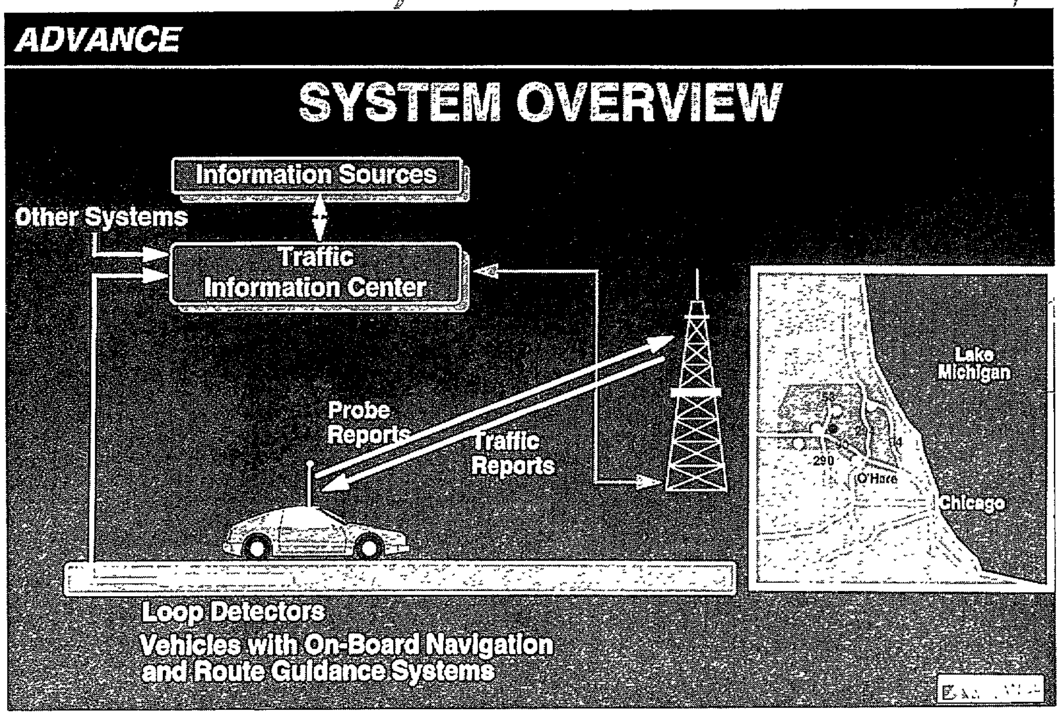
THIS IS A LARGE DOCUMENT

Due to its large size, this document has been segmented into multiple files. All files separate from this main document file are accessible from links (blue type) in the table of contents or the body of the document.

THE ADVANCE PROJECT:

Formal Evaluation of the Targeted Deployment

Volume 2



ADVANCE

ADVANCED DRIVER AND
VEHICLE ADVISORY
NAVIGATION CONCEPT

DISCLAIMER

PREFACE

This document reports on the formal evaluation of the targeted (limited but highly focused) deployment of the Advanced Driver and Vehicle Advisory Navigation ConcEpt *(ADVANCE)*, an in-vehicle advanced traveler information system designed to provide shortest time route guidance. Argonne National Laboratory (ANL) served as the Evaluation Manager. Organizations that assisted in the evaluations of the various subsystems under test plans developed by Booz-Allen & Hamilton, a support contractor to the Federal Highway Administration's Intelligent Transportation System Field Operations Test program, were the University of Illinois at Chicago Urban Transportation Center (UIC-UTC), Northwestern University Transportation Center (NUTC), and DeLeuw, Cather & Company.

This report contains the results of the targeted evaluation in three volumes. Volume 1 presents the Evaluation Manager's Overview Report prepared by ANL. The overview presents the scope of the evaluation, the data collection protocols, a synopsis of the findings, and a discussion of the validity of the targeted deployment's results. Volume 1 also contains Appendixes A through H. Volume 2 contains Appendixes I, J, and K. Volume 3 contains Appendixes L and M.

The appendixes contain the evaluation test results. The reports of each evaluating organization have been presented in the version received from their respective authors, following completion of the technical and policy reviews conducted according to procedures set by the project's Steering Committee. Appendixes A-G were prepared by UIC-UTC; Appendixes H-J were prepared by NUTC; and Appendixes K and L were prepared by DeLeuw, Cather. Appendix M is a glossary of terms used in these reports, as compiled by ANL.

DOCUMENT CONTENTS

VOLUME 1

DOCUMENT CONTENTS (Cont.)

CONTENTS-VOLUME 2

THE *ADVANCE* PARTICIPANTS

Founding Parties and Members

American Automobile Association
Federal Highway Administration
Illinois Department of Transportation
Illinois Universities Transportation Research Consortium
Motorola

Associates

Ford Motor Company
General Motors Corporation
Sun Microsystems, Inc.
Surface Systems, Inc.

Sponsors

AB Volo Technical Development
Cellular One
DonTech
Etak, Inc.
Honda R&D North America, Inc.
Illinois State Toll Highway Authority
Institute of Transportation, Taiwan, Republic of China
Metro Traffic Control
Mercedes-Benz of North America
National Center for Supercomputing Applications
Navigation Technologies
Nissan Research & Development, Inc.
Pace
Peugot S.A.
Rational
Renault
Toyota Technical Center, Inc.

Contributors

INRO/University of Montreal (CRT)
SAAB
Seagate Technologies
Venkatesh Kambhammettu
Versant Object Technology

Contractors/Technical Support

Aldridge Electric, Inc.
Argonne National Laboratory
Battelle, Inc.
Booz-Allen & Hamilton, Inc.
Castle Rock Corporation, Inc.
De Leuw, Cather & Company
Deborah Gordon Public Relations
Econolite Control Products, Inc.
IBI Group
Metro Transportation Group, Inc.
MITRETEK Systems
National Highway Traffic Safety Administration
Science Applications International Corporation
SEI Information Technology
The Blackstone Group
University of Iowa
Volpe National Transportation Systems Center

FIELD TEST EVALUATION DEVELOPERS, MANAGEMENT, AND STAFF

For Argonne National Laboratory

Project Manager: Adrian Tentner
Evaluation Manager: Christopher Saricks
Associates, Contributors, and Reviewers: Don Rote, Mara Krinke, Greg Chisholm, Bob Baker, Jeffrey Slater, Thomas Taxon, James Boyle, Ulf Hannebute, Yung Liu, Richard Simms, Constantine Tzanos, Arthur Wright

For Northwestern University

Principal Investigators: Frank Koppelman, Joseph L. Schofer
Test Managers: Regina G. Webster, Frank Koppelman, Joseph L. Schofer
On-site Operators and Monitors: William A. Charlton, Michael P. Johnson, Wei-Hsin Lin, Tsai-Shiou Peng, Daniel Schofer, Tanay Shah, Chien-Hua Wen
Test Drivers: Katherine Anderson, Aaron Boucher, Daniel R. Bober, William DiBella, Stephen Donohue, Kenneth Ferro, Warren Gelfand, Joan Joseph, Michael Kenworthy, Joseph Kilgore, Eric Lathrop, Herman Leon, Julius Longshaw, Holly Miner, Kenneth Noga, Robert Oberwetter, Margaret Pasquini, Mari-Ann Pollu, Steve Rago, George Ranallo, Marie Renallo, Lisa Senner, Anne Stapleton, Ernest Stephan, Jason Stobbe, Lance Tiedemann, Ted Tran, Robert Wolf, Wally Wood

For the University of Illinois at Chicago

Principal Investigators: Ashish Sen, Siim Soot
Test Manager: Siim Soot
Field Managers: Stanislaw Berka, Helen Condie, Mark Mathes, Scott Stelzer
Test Drivers (throughout project): Megan Anderson, Kevin Curtin, Margaret Curtin, Douglas Deckert, Robert Donahue, Yevgeniy Dymarskiy, Tamara Haskins, Erik Jalakas, Michael Kenworthy, James Andrew Lee, Arthur R. Miller, Kundan Patel, Mari-Ann Pollu, Ashley Snyder, Marika Soot, Lance Tiedemann, Theodore Tran, Robert Wolfe

For Booz-Allen & Hamilton

Test Co-Developers and Technical Reviewers: Paul Bellela, Michael Klassen, Charles Minehan

For MITRETEK Systems

Technical Reviewer: Richard Bolczak

ABBREVIATIONS AND ACRONYMS

AAA	American Automobile Association
AASHTO	American Association of State Highway Transportation Officials
ACG	Access Control Gateway
ADIS	Advanced Driver Information Systems
ADV	*ADVANCE* System
ADVANCE	Advanced Driver and Vehicle Advisory Navigation ConcEpt
AHAR	Automatic Highway Advisory Radio
AI	Artificial Intelligence
ANR	*ADVANCE* Network Representation
ANSI	American National Standards Institute
APTS	Advanced Public Transportation Systems
ASCII	American Standard Code for Information Interchange
ATC	Automated (electronic) Toll Collection
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management Systems
AVI	Automatic Vehicle Identification
AVL	Automated Vehicle Location system
AVLM	Automatic Vehicle Locating and Monitoring
BD	Base Data
BSC	Base Station Controller
CASE Tools	Computer Aided Software Engineering Tools
CATS	Chicago Area Transportation Study
CCTV	Closed Circuit TV
CCVE	Closed Circuit Video Equipment
CD-ROM	Compact Disk-Read Only Memory
CLSS	Closed Loop Signal System
COM	RF communications subsystem of *ADVANCE*
COM. 1	RF Coverage Component of the RF Communications Network
COM.2	Fixed Communications Interface
COM.3	Mobile Communications Interface
CRC	CRC Corp. Ltd. (Castle Rock Consultants), subconsultants to DeLeuw, Cather & Co.
CRC Bytes	Cyclic Redundancy Check bytes
CSMA	Collision Sense Multiple Access
C-TIC	Corridor Transportation Information Center
CTS	Clear to Send
CVO	Commercial Vehicle Operations

DAT	Digital Audio Tape
DB	Data Base
DBMS	Data Base Management System
DCCO	De Leuw, Cather & Company
DDS	Detail Design Specification Document #8600
DF	Data Fusion
DIME	Dual Incidence Matrix Encoded files
DRGS	Dynamic Route Guidance System
DS	Data Screening
DSR	Data Set Ready
DTE	Data Terminal Equipment
DTR	Data Terminal Ready
DTTC	Detector Travel Time Conversion
ERS	Emergency Response Service
ETC	Electronic Toll Collection
ETTM	Electronic Toll and Traffic Management
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FTP	File Transfer Protocol
GCM	Gary-Chicago-Milwaukee
GDS	General Design Specification, Document #8500
GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphical User Interface
HAR	Highway Advisory Radio
HOV	High Occupancy Vehicle
HTTP	Hypertext Transfer Protocol
HUFSAM	Highway Users Federation for Safety and Mobility
HVAC	Heating, Ventilation, Air Conditioning
IBI	IBI Group, Subconsultants to De Leuw, Cather & Company
ICS	Interface Control Specification, Document #8 110
ID	Incident Detection
IDOT	Illinois Department of Transportation
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
IUTRC	Illinois Universities Transportation Research Consortium

LAN	Local Area Network
LCD	Liquid Crystal Display
LORAN-C	Long range land-based radio navigation system operated by the U.S. Coast Guard
LSB	Least Significant Bit
MIF	Motorola Intermediate File
MM1	Man-Machine Interface
MNA	Mobile Navigation Assistant
MOE	Measure of Effectiveness
MPO	Metropolitan Planning Organization
NavTech	Navigation Technologies Corporation
NCP	Network Control Processor
NCP/IF	Network Control Processor Interface
NDT	Network Display Tool
NFM	Network Flow Model
NFS	Network File System
NHTSA	National Highway Traffic Safety Administration
NU	Northwestern University
NUTC	Northwestern University Transportation Center
NWCD	Northwest Central Dispatch
OAM	Operations Administration and Maintenance
OD	Origin-Destination
OOA	Object Oriented Analysis
OOD	Object Oriented Design
PI	Principal Investigator
PMP	Project Management Plan, Document #8200
PO1	Point of Interest
POP	Project Operations Plan
QA	Quality Assurance
QC	Quality Control
RAM	Random Access Memory
RD-LAP	Radio Data Link Access Procedure
RF	Radio Frequency
RFSRV	RF Server
RISC	Reduced Instruction Set Computer

RNC	Radio Network Controller
ROM	Read Only Memory
RPC	Remote Procedure Call
RPCGEN Tools	Remote Procedure Call Generation utility
RPMIF	Radio Packet Modem Interface
RTS	Request to Send
RXD	Received Data
SAE	Society of Automotive Engineers
SC	Steering Committee
SCADA	Surveillance Control and Data Acquisition
SE	Static Estimates
SIF	Standard Interchange File
SP	Static Profiles
SPU	Static Profile Update
SSI	Surface Systems Incorporated
SVRS	Stolen Vehicle Recovery System
TAC	Technical Advisory Committee
TBD	To Be Determined
TCP/IP	Transmission Control Protocol/Interface Protocol
TFHRC	Turner-Fairbank Highway Research Center
TIC	Traffic Information Center
TIGER	Topologically Integrated Geographic Encoding & Referencing files
TLI	(AT&T) Transport Layer Interface
TRB	Transportation Research Board
TravTek	Travel Technology
TRF	Traffic Related Functions
TSC	Traffic Systems Center
TT	Travel Time
TTL	Transistor-Transistor Logic
TTP	Travel Time Prediction
TXD	Transmitted Data
UDP	Universal Data Protocol
UIC	University of Illinois at Chicago
UIC-EECS	University of Illinois at Chicago - Electrical Engineering and Computer Science Department
UIC-UTC	University of Illinois at Chicago - Urban Transportation Center

V & V	Verification & Validation
V&VPlan	Verification & Validation Plan, Document # 8300
V&VTeam	Verification & Validation Team
VNIS	Vehicle Navigation and Information Systems
YD	Yoked Driver

APPENDIX I

ADVANCE

Advanced Driver and Vehicle
Advisory Navigation Concept

Familiar Driver Perspectives on *ADVANCE*
and Future Dynamic Route Guidance Systems
Evaluation Report
Document # 8462.01

Prepared by
Northwestern University Transportation Center

DISCLAIMER

ADVANCE

Advanced Driver and Vehicle
Advisory Navigation Concept

FAMILIAR DRIVER PERSPECTIVES ON *ADVANCE* AND FUTURE DYNAMIC ROUTE GUIDANCE SYSTEMS

by

Joseph L. Schofer
Frank S. Koppelman
William A. Charlton

Northwestern University
Transportation Center
Evanston, Illinois 60208

ADVANCE Project Document # 8462.01

July 24, 1996

EXECUTIVE SUMMARY

The *ADVANCE* familiar driver test provided a small sample of drivers familiar with their local road network and patterns of recurring congestion with an opportunity to drive a vehicle equipped with the *ADVANCE* dynamic route guidance system for a period of two weeks of normal use. On the basis of this test experience, drivers were asked to evaluate the *ADVANCE* system and to assess the value of features for future in-vehicle route guidance systems.

This test involved 80 volunteer households living in the *ADVANCE* test area in northwest suburban Chicago; 110 drivers from these households used the *ADVANCE* vehicle and responded to both baseline (pre-test) and post-test surveys. Thirty two of these drivers participated in focus groups. Drivers also maintained written logs describing their rerouting experiences with the *ADVANCE* system.

The baseline survey captured driver and household demographics, trip making and driving experience, sources and use of traffic information, experience with common technologies, and personality attributes. The post-test survey asked about the test experience, evaluation of specific *ADVANCE* features, risk factors associated with *ADVANCE,* preferences for features of future systems, and willingness-to-pay for such systems. The focus group results provided a rich qualitative perspective on driver experiences with *ADVANCE* and preferences for design features and performance characteristics of future systems.

This test was limited by several important factors. First, the sample size was small and non-random, and thus the responses reflect the perspectives of a well-educated, higher income population which is not necessarily representative of the study area or the broader driving population. Second, the test period was short. Third, the *ADVANCE* system offered limited functionality, and in particular, very little real-time traffic data was available. Despite these limitations, a number of findings from the surveys, focus groups, and reroute logs provide consistent, logical, and potentially important directions for the development of future in-vehicle route guidance systems.

Drivers reported that routes provided by the *ADVANCE* system were not particularly good and tended to be inferior to their own routes. This is attributable to the facts that (1) drivers knew the network, congestion patterns and routes that best served their routine trips; (2) the *ADVANCE* network and travel time database were imperfect; (3) the *ADVANCE* route planning algorithm, by policy, placed a priority on routes using higher-type roadways rather than the neighborhood streets which familiar drivers commonly used for parts of their trips.

Because of their experience-based knowledge, familiar drivers seemed to prefer and felt they would benefit from a substantial degree of control over their choice of routes and route planning criteria. At the same time these drivers expressed a high level of interest in real-time traffic information, particularly information which will tell them about non-recurring congestion. They were interested in blending such real-time information with their own knowledge to plan their routes.

Thus familiar drivers in this test seemed to define a different role for the in-vehicle route guidance system than that underlying the design of *ADVANCE:* they envisioned an on-board computer guidance system as an intelligent assistant. They were less interested in giving routing control to the computer. Instead, they seemed to envision using the technology to acquire and process real-time data, and to use those data to evaluate driver-provided routes and, where appropriate, to recommend alternatives to those routes.

Drivers perceived and evaluated route guidance systems in two principal dimensions: the route guidance function and its performance; and the driver interface, including data input and information output functions.

Both focus group and survey results revealed patterns of gender and personality differences in both responses to *ADVANCE* and preferences for future system attributes; these help define the breadth of capabilities that should be considered for future route guidance systems.

Responses to questions about willingness-to-pay for future systems, in both the focus groups and the post-test surveys, suggested that drivers were willing to pay realistic amounts for such systems, and they seem likely to pay modest fees for incremental information services, such as real-time and multi-city data. Willingness-to-pay was more closely associated with driver characteristics and experiences than with driver assessment of the *ADVANCE* system.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION AND OBJECTIVE

The *ADVANCE* Project developed, implemented, and tested an in-vehicle route guidance system intended to provide drivers with navigation and real-time traffic congestion information. The target market for *ADVANCE* was "familiar" drivers, drivers traveling in their own communities, who are highly experienced and therefore familiar with the structure of the road network and patterns of recurring congestion. The challenge of providing useful information to such knowledgeable drivers is substantial, since they (presumably) already have a lot of experiential information about the transportation systems they use.

The *ADVANCE* familiar driver test was designed to measure the perceptions and behavioral reactions of such drivers to an extended experience driving an *ADVANCE*-equipped vehicle. The original deployment plan was to equip 3,000-5,000 privately-owned vehicles with *ADVANCE* route guidance systems, and to allow the owners of those vehicles to use that system for a period of 12-18 months. This would have provided an opportunity to gather a large data set, covering a diversity of people, extending over a period of time sufficiently long to allow driver learning and adaptation to this new technology. Because *ADVANCE* is a probe-vehicle based concept, the large deployed fleet was designed to generate a large quantity of real-time traffic data to support dynamic route guidance.

The targeted deployment scheme ultimately adopted by *ADVANCE* reduced both the scale and time period of field testing so that only 80 households were provided with the opportunity to drive *ADVANCE* vehicles; these were project-owned, not the participants' own vehicles. The driving period was shortened to two weeks. Thus, the scope of the familiar driver evaluation was limited by two factors:

1. Because of the small size of the vehicle fleet, there were very few probe vehicles in operation at any one time; thus, there was little real-time traffic data available to support the dynamic route guidance system. Drivers could experience the operations and feel of *ADVANCE* but they could not test the full capabilities for dynamic route guidance.
2. The two-week driving period gave drivers a limited time to learn to operate the system and to use it in their daily travel.

Rather than serving as a full-blown test of dynamic route guidance, the familiar driver test as implemented under the targeted deployment scheme provided drivers with a limited opportunity to use and evaluate the *ADVANCE* system. Based on this short period of utilization of the limited system, data collection tools were used to explore drivers' reactions to *ADVANCE,* and to invite them to use their experience with this system to express their interests in and preferences for features of future in-vehicle dynamic route guidance systems.

The objective of the familiar driver test, then, was to provide a small sample of drivers familiar with the road network with an opportunity to test and evaluate the *ADVANCE* system and on the basis of their test experience, to provide a speculative evaluation of the features of future in-vehicle navigation systems.

2.0 TEST PROCEDURE

Figure 1 summarizes the overall familiar driver test procedure. In this test 80 households were invited to utilize *ADVANCE* project vehicles equipped with in-vehicle navigation and route guidance systems for a period of two weeks each. Prior to receiving the vehicles, participants were required to complete a baseline survey to measure their demographic characteristics,

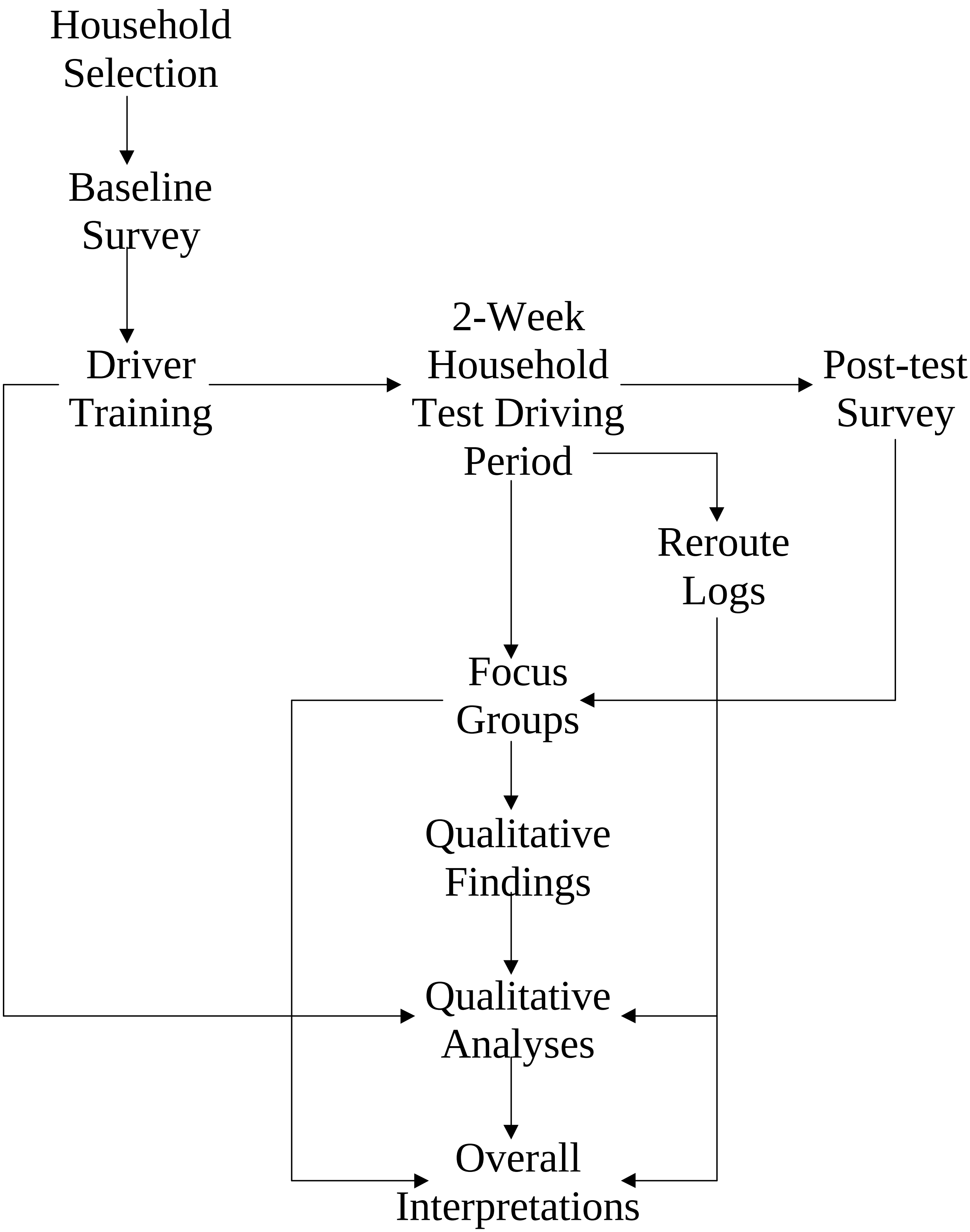


Figure 1: Familiar Driver Study Procedure

driving habits, attitudes, and experience with the road network and electronic technologies. At the end of their usage period, each driver was asked to complete a second, post-test survey, which focused on experiences with and reactions to *ADVANCE*, as well as preferences for features of future route guidance systems. After all of the households finished the driving phase of the test, 32 of the drivers participated in focus groups to explore their perspectives on future route guidance systems in more qualitative detail.

2.1 Sampling

Households were selected to participate in this test from a group of more than *400* persons who volunteered to be *ADVANCE* drivers; thus, persons in the sampling universe were self-selected. Representatives of these households learned about *ADVANCE* through news stories and word-of-mouth: no systematic solicitation of drivers was conducted. Volunteer drivers approached the *ADVANCE* office expressing their willingness to participate in the experiment. Drivers were asked to complete screening forms to provide the basis for their selection. The primary eligibility criteria for participation in this test were:'

1. Residence in the *ADVANCE* test area;.
2. 2.5 years of age or older;
3. Good driving record, certified by checking the files of the Illinois Secretary of State;
4. No driver-reported perceptual or health problems which would threaten driving ability;

---

1. P. Odent, J. Schofer, and F. Koppelman, "Private Driver Rolling Recruitment Procedure for the *ADVANCE* Project," ADV-DR-07, May 2, 1994.

5. Ownership or lease of vehicle which could safely accommodate the *ADVANCE* system (since the original evaluation plan was to equip participants' own vehicles with the on-board unit); and

6. Active trip-making behavior, as reflected in a trip intensity score computed on the basis of descriptions of weekly travel supplied by drivers in the screening form.

Households were eligible to participate if self-designated primary and alternate drivers met the first four criteria. They were selected based on trip intensity scores, and willingness of drivers to schedule their driving period in conformance with the availability of *ADVANCE* test cars.

Most of the primary drivers were males, and most of the alternate drivers females. A few households had no alternate drivers. This designation of primary and alternate drivers reflected the utilization patterns of the *ADVANCE* vehicle. While this did not produce an even utilization of the test vehicles by men and women, it did assure that some testing was done by each gender.

This sampling scheme has two inherent biases. First, all of the drivers were volunteers. This means they were not a random sample of the population, but were in some way special because they chose to be involved in this field experiment. Because all of the drivers volunteered on the basis of having seen or heard news reports about the *ADVANCE* project in the mass media, they were a group whose level of interest in participating in the experiment was sufficiently high that they took active steps to seek out this opportunity.

The bias associated with volunteer participants is characteristic of any experiment of this type; it is not possible to select drivers randomly, because they must volunteer to engage in this experiment, and those who volunteer are likely to be different than the rest of the population. In our case, because these volunteer drivers were not systematically sought out, they might be described as "early adopters," people who were particularly interested in and anxious to test new ideas and technologies. Thus, they were likely to be more favorable to such innovations, and at the same time, more critical in their evaluations of new technologies. Thus, the results of this test should be interpreted in light of this special characteristic of the responding population. Caution should be used in generalizing these outcomes to a substantially different driver population, especially to groups with less bias toward high income and education levels.

However, informal observation of and discussions with drivers in training sessions prior to delivery of the *ADVANCE* vehicles revealed that there were at least some drivers who had no more than a modest interest in the *ADVANCE* technology. These were the spouses, usually female but sometimes male, of the primary driver in the household who had sought out the opportunity to test the *ADVANCE* technology. These drivers participated in the experiment as cooperative spouses rather than as technology buffs or early adopters. While this group represented a minority of the driver population in this experiment, and in many cases they had only limited experience driving the test vehicles, their presence in the sample does serve to provide some balance and therefore may slightly relax the limits on generalizability of results.

2.2 Driver Training

Because the test driving period was only two weeks long, a special effort was made to train drivers in the effective and safe use of the *ADVANCE* system before they received their vehicle. By intensifying training, the learning period was to be shortened, and thus more of the two-week driving period might reflect "normal" operations. Training sessions involved groups of drivers from l0-12 households (as many as 25 individuals), who were given an oral briefing followed by hands-on demonstration of the use of the *ADVANCE* system in the vehicle they were to receive. The briefing covered:

- Description of the *ADVANCE* project, purpose of the test and the role of participating drivers;
- Overview of the *ADVANCE* system and its functions;
- Operation of the in-vehicle system, its features, procedures for use and limitations;
- Driver obligations: safety, return of the vehicle in good condition, completion of surveys, participation in focus groups;
- Procedures to follow in the event of system failure, vehicle failure, and motor vehicle accident.

Hands-on training in the use of *ADVANCE* was done individually for each household by an experienced *ADVANCE* staff member. This involved some time in the vehicle cycling through the functions of the system, followed by a period of driving in which the functioning of the system was demonstrated. In most cases, trainers allowed the volunteer drivers to operate the vehicle and the *ADVANCE* system, while they provided instructions. The overall training and vehicle delivery process took slightly less than two hours; the in-vehicle training lasted *20* to 30 minutes. Post-test survey results confirmed the effectiveness of the training process, as did the fact that there were very few calls to the *ADVANCE* Project Office asking for assistance in the use of the system during the driving period.

2.3 Schedule

All of the procedures used in the familiar driver test were pilot-tested with three volunteer households in early July of 1995. Regular, two-week long familiar driver tests were conducted from the end of July until the end of November of 1995; this extended test period was required because *ADVANCE* vehicles were in demand for many other tests during the same period. Familiar driver tests were conducted when at least five, and as many as 25, test vehicles were available for this activity.

2.4 Data Collection and Analysis

As shown in the process diagram (Figure l), baseline surveys (see Appendix I) were completed by participants before they could get the *ADVANCE* vehicle. Post-test surveys (see Appendix II) were to be completed within one week after the end of the driving period. Most households met this requirement, but a few required follow-up, and the post-test survey was not received from one of the households.

In addition, drivers were asked to maintain reroute logs (see Appendix III), on which they recorded cases where they were offered a reroute by the *ADVANCE* system, or they chose to divert from an *ADVANCE*-guided route. The reroute log asked drivers to explain the reasons for these diversions and their decisions to accept or reject *ADVANCE* route planning. The purpose was to get a clearer indication of the ways in which drivers actually used the *ADVANCE* system.

Focus groups were conducted after all of the field testing was completed, and after the majority of the post-test surveys had been subjected to preliminary analysis. The results of this initial survey analysis guided development of the focus group plans. The qualitative findings of the focus groups, recorded on audio and video tapes and in written summaries, were then used to guide more intensive quantitative analyses of the baseline and post-test survey data,

Analyses conducted and reported here include descriptive statistics on the drivers, their responses to the *ADVANCE* system, and their preferences for features of future systems. In addition, a variety of statistical models were developed to explore the associations among these variables, and, in particular, to get a better sense of relationships between the characteristics and experiences of drivers and their interests in features of future in-vehicle route guidance systems.

2.5 Limitations and Threats to Validity

Results and interpretations of the familiar driver test are based on a small sample of drivers. All statistical results are based on 127 respondents or fewer. Data sets smaller than the maximum number of survey responses received are sometimes used in this report because not all drivers answered all survey questions, and/or because some analyses were conducted on subsets of the total sample. For example, only 110 drivers responded to both the baseline and post-test survey. The statistical validity of results, as well as generalizability to a larger population, are threatened by this small and non-random sample. More specifically, we may identify patterns and relationships which do not reflect a broader reality, and our investigation will fail to identify some important patterns which are only weakly revealed in the data.

Results are also limited in validity because of sampling biases, as discussed above; because of the short driving period for participants; and because the small probe fleet under the targeted deployment (60-70 vehicles, not operating in an organized fashion to collect real-time traffic data) meant that very little real-time traffic data could be provided to drivers. The latter means that we could conduct only a very limited test of dynamic route guidance.

Within these limitations, analyses of data from the familiar driver study suggest some interesting, logical ideas which may guide the development and implementation of future route guidance systems.

3.0 PROFILE OF PARTICIPATING DRIVERS

3.1 Demographics

Eighty households, and thus 80 primary drivers, participated in the familiar driver test. One-hundred twenty-seven drivers completed the baseline survey, 80 primary drivers and 47 alternate drivers. Of these, 110 completed post-test surveys and are the basis for the findings reported here. Table 1 shows that 62% of all drivers were males, while 70% of the primary drivers were males. Thus, while the overall driver sample was reasonably balanced by gender, because of the dominance of males among primary drivers, driving experience and survey responses based on that experience are somewhat biased toward males.

Eighty-seven percent of drivers completing the pre-test also completed the post-test instrument. A primary reason for failure to complete the second survey was that some drivers, especially alternate drivers and females, did not actually get a chance to drive the *ADVANCE* vehicle as a result of household decisions and constraints, and thus could not (and were asked not to) complete the post-test survey. While 96% of primary drivers and 92% of male drivers who completed the baseline survey completed the post-test, only 70% of the alternate drivers and 80% of the females followed this pattern.

Table 1: Drivers by Gender and Type

Driver Type	Male	Female	Total
Primary Driver	54 (70%)	23 (30%)	77 (100%)
Alternate Driver	14 (42%)	19 (58%)	33 (100%)
Total	68 (62%)	42 (38%)	110

Mean age of participants was 44 years, and the range was from 26 to 69 years. Sixty-eight percent of drivers had bachelor's degrees or a higher level of education. Thirty-nine percent of the drivers reported household incomes between $75,000 and $100,000; 95% were over $50,000 per year. Eighty percent of the households had two or three motor vehicles available; only 5 % were single-car households (no participants came from zero-car households, because the original recruitment plan was developed to install *ADVANCE* systems in drivers' own vehicles). Eighty-five percent of the participants were employed full-time (94% of the males, 75% of the females). Sixty-six percent of the drivers described their occupations as management, professional or technical (69% of males, 60% of females). Thus, our sample is biased toward upper income workers with high auto ownership.

Table 2 shows that 86% of the drivers worked outside of the home at least five days per week, and nearly 80% of these drove to work 5 or more days per week; men more commonly worked outside their homes and drove regularly to work. Respondents reported driving an average of 16,000 miles per year (36% drove more than 17,500 miles, 3% more than 32,500 miles). Beyond their work trips, respondents reported an average of 4.4 weekly auto driver trips for shopping, 5.6 for personal business, and 3.7 for social activities.

Table 2: Work Outside Home, Drive to Work

	All Drivers	Males	Females
Work outside home >5 days per week	84 (86% of respondents)	57 (90% of male respondents)	27 (77 % of female respondents)
Drive to work >5 days per week	65 (93 % of respondents)	47 (94 % of male respondents)	18 (90% of female respondents)

3.2 Technology Experience

Because the *ADVANCE* system, and the in-vehicle route guidance concept, are strongly dependent on computers and communications technology, we asked drivers about their perspectives on the use of three common technological systems, computers, automatic tellers, and video cassette recorders. Table 3 summarizes the responses, which were on a 5-point scale, where 1 = strongly disagree and 5 = strong agree. The results suggest that participants in this test are comfortable with the use of electronic technologies, males significantly more so than females (at the 0.05 level for ATMs, and at the 0.005 level for the other technologies).

Table 3: Perspectives on Common Technologies
(Mean Responses)

Question 1 = strongly disagree; 5 = strongly agree	Full Sample	Males	Females
I find computers easy to use	4.13	4.26	3.90
I find a bank ATM easy to use	4.14	4.29	3.90
I can easily program a VCR for recording	4.19	4.35	3.90

Of course we do not know how the general driving population would have responded to these questions, but we expect that the *ADVANCE* volunteer drivers were more favorably inclined toward the use of such technologies.

3.3 Sources of Traffic Information

A series of eight questions were asked about the use of navigation and traffic information from various sources (Appendix I, questions 19-26); the more interesting results are summarized here. Table 4 suggests that the use of maps for navigation is not particularly common among responding drivers, but they do nof find maps difficult to use. Commercial radio is a primary source of current traffic information (Table 5), and it is frequently used, both before and (even more so) during trips. The continuous traffic broadcasts transmitted by the Illinois Department of Transportation are much less frequently used; males reported using radio reports from both sources slightly more often than females. Television is a more frequent source of traffic information than either telephone services (which normally charge a fee) or IDOT radio. Variable message signs are reported to be used about as frequently as commercial radio during trips, but such signs are available only on limited access highways and they are not yet common in the Chicago metropolitan area. This response may mean that drivers used their signs often when they were available.

Table 4: Use of Maps
(Mean Responses)

Question (1 = strongly disagree; 5 = strongly agree)	Full Sample	Males	Females
I rarely use a road map	2.53	2.47	2.63
I find maps easy to use	4.37	4.55	4.08

Table 5: Mean Frequency of Use of Various Sources of Traffic Information

Information Sources (1 = never; 5 = very often)	Before trips			During trips		
	Full sample	Males	Females	Full Sample	Males	Females
Commercial radio	2.63	2.63	2.63	3.54	3.59	3.45
IDOT radio	1.32	1.33	1.30	1.52	1.62	1.37
Telephone	1.28	1.24	1.35	1.45	1.41	1.53
Television	1.97	1.88	2.13			
Variable message signs				3.52	3.45	3.64

Driver assessments of different sources of traffic information are presented in Table 6. The infrequent use of IDOT radio and telephone information is reflected in scores below 1 (= outcome never happens) because respondents could choose "I don't use this source" as a response to any information source, which was coded as zero and which contributed to the reported means. Commercial radio reports and variable message signs are most favorably rated, both seen as reasonably reliable, but neither apparently producing a large effect on trip time, route, or travel time.

Table 6: Assessment of Sources of Traffic Information
(Mean Responses)

1= never 5= always 0=do not use this source	Commercial Radio	IDOT Radio	Telephone	Television	Variable Message Signs
Reliable	3.15	0.73	0.73	1.81	3.45
Save time	2.70	0.64	0.66	1.59	2.59
Reduce anxiety	2.72	0.59	0.59	1.41	2.56
Cause route change pre-tnp	2.81	0.49	0.44	1.74	
Cause route change on trip	3.14	0.67	0.67		3.03
Cause departure time shift	2.71	0.53	0.44	1.73	2.09
Percent of zero responses	5.6%	75.0%	75.9%	37.5%	6.3%

3.4 *ADVANCE* Expectations

The baseline questionnaire asked drivers to describe their expectations for *ADVANCE* prior to their participation in the field tests. Respondents answered these questions based on limited public informxtion about the *ADVANCE* system. The responses are summarized in Table 7. Both males and females revealed highly favorable expectations for their *ADVANCE* experience: they felt it would be helpful for navigation and congestion avoidance, and they were slightly less positive about *ADVANCE* reducing their driving anxiety. Drivers were not concerned about the *ADVANCE* system distracting them from the driving task.

Table 7: Mean Expectations for *ADVANCE*

Question (1 = strongly disagree; 5 = strongly agree)	Full Sample	Males	Females
Distract me from driving	1.75	1.74	1.78
Reduce anxiety while driving	3.53	3.47	3.63
Help get to new destinations	4.38	4.28	4.55
Save time	4.46	4.40	4.58
Be useful	4.59	4.56	4.65
Be fun to use	4.65	4.59	4.75

4.0 CLUSTER ANALYSIS OF PERSONALITY CHARACTERISTICS

We expected that a number of the characteristics of the drivers themselves would be useful in explaining reactions to the *ADVANCE* system and preferences for features of future systems. These characteristics include basic demographic measures as well as personality descriptors. To make efficient use of the personality measures, we used cluster analysis to develop simple classifications of personality types. Cluster analysis is a statistical method used to classify data into relatively homogeneous subsets based on similarity of selected variables or measures of each data point. In this application, cluster analysis was used to group drivers in terms of similarity of responses to survey questions about personality (question 17 in the baseline survey):

I like discovering new routes to get someplace.

If I get lost I ask people for directions.

I can give precise directions to others.

I get impatient if I have to wait in traffic.

I am not a nervous person.

I am an assertive driver.

Responses were selected from a 5-point scale ranging from strongly disagree to strongly agree. Two, three and four cluster solutions were produced and evaluated primarily in terms of the logic with which clusters could be named and described. Two of these three solutions are shown in Tables 8 and 9 in terms of the centers of each cluster in each of the dimensions defined by the components of Question 17. Because all scales are from 1 = strongly disagree to 5 = strongly agree, high average scores on a question indicate personality characteristics which drivers strongly attribute to themselves, while low scores indicate characteristics drivers do not think are self-descriptive. Patterns of high scores, highlighted in boldface in Tables 8 and 9, were used to name clusters judgmentally.

Table 8: Personality Cluster Centers: 2 Cluster Solution

	Self-Reported Personality Characteristic (1 = strongly disagree; 5 = strongly agree)					
Cluster Description and Membership	Like discovering new routes	Ask for directions	Can give precise directions	Get impatient waiting in traffic	Not nervous	Assertive driver
Cautious (35 members)	2.57	3.20	3.18	2.89	3.29	2.89
Confident (73 members)	4.44	3.31	4.32	3.39	4.18	3.82

Table 9: Personality Cluster Centers: 3 Cluster Solution

	Self-Reported Personality Characteristic (1 = strongly disagree; 5 = strongly agree)					
Cluster Description and Membership	Like discovering new routes	Ask for directions	Can give precise directions	Get impatient waiting in traffic	Not nervous	Assertive driver
Cautious (20 members)	2.30	3.30	2.90	2.35	3.40	2.50
Confident (46 members)	4.35	4.17	**4.29**	2.80	4.33	3.70
Impatient (42 members)	4.00	2.29	4.10	**4.12**	3.64	3.81

The two cluster solution divides drivers into groups called "cautious" and "confident." The three cluster solution further divides the sample to produce a third category which we call "impatient," made up mainly of drivers from the confident group in the two-cluster solution. Both of these results can be described as good solutions to the clustering problem because the names of the clusters are easily derived and logical, and because no cluster is extraordinarily different from the others in terms of size (none is very small or very large). The four cluster solution is more difficult to interpret and will not be used in further analyses. In later sections of this report we use the two-cluster solution to test cluster membership, which is an indication of personality types as a variable for describing and exploring responses to *ADVANCE* and preferences for various features of future in-vehicle route guidance systems.

5.0 *ADVANCE* TEST EXPERIENCE

Interactions with drivers in training sessions and discussions in focus groups revealed that in many households the male driver made dominant use of the *ADVANCE* vehicles, despite our expectations that gender usage would be more balanced in two-person (male-female) households. As indicated in Section 3.1, in some cases female drivers who registered as alternates in the baseline survey did not drive the *ADVANCE* car at all, and therefore did not respond to the post-test survey. Clearly experimenters cannot directly control the way households choose to use test vehicles in such field studies. While the occurrence of this within-household male dominance was not a surprise, more balanced gender usage might have been achieved by direct instructions from test managers in the driver training sessions.

The post-test survey (Appendix II) included several questions to assess the experience drivers had in the field test. Because the vehicles were all project-supplied, driver experience could also have been be affected by differences between their regular vehicle and the *ADVANCE* vehicle. In the driver scheduling process, efforts were made to match broad characteristics of *ADVANCE* vehicles with the participant's normal vehicle, e.g., in terms of luxury cars, vans, small cars. Ninety-one percent of respondents (94% of the males, 86% of the females) reported that the *ADVANCE* vehicle met their travel needs during the test.

There was some concern that the two-week driving period might be too short for drivers to get a reasonable impression of the *ADVANCE* system. Table 10 shows that drivers generally felt that the driving period was sufficient. They were particularly positive about the training effort, which is important because the short test period did not leave much time for in-vehicle learning. The moderately high confidence level reported at the start of the test confirms the effectiveness of the training. Another measure of the effectiveness of driver training was the small number of responses to questions about "help" calls to the *ADVANCE* Office (very few calls were made) and usefulness of the User's Manual and visor card (also not much used by test participants). Driver confidence increased substantially over the test period. Males were more confident in their use of the *ADVANCE* vehicles before and after the driving period than were females.

Table 10: Mean Participants' Assessment of Test Experience

Question (1 = strongly disagree; 5 = strongly agree)	Full Sample (n)	Males (n)	Females (n)
Driving period long enough to test *ADVANCE*	3.29 (108)	3.30 (67)	3.27 (41)
Training was sufficient	4.42 (106)	4.36 (67)	4.54 (39)
Personnel were helpful	4.71 (104)	4.73 (66)	4.68 (38)
User's manual, visor card answered questions	4.02 (46)	3.90 (30)	4.25 (16)
Calls to *ADVANCE* answered questions	4.10 (21)	4.27 (15)	3.67 (6)
Questionnaires were clear and appropriate	4.01 (105)	3.90 (67)	4.21 (38)
Felt confident when first drove car	3.88 (107)	3.94 (66)	3.78 (41)
Felt confident at end of test	4.60 (108)	4.72 (67)	4.41 (41)
Wanted to continue using vehicle at end of test	4.29 (107)	4.38 (66)	4.15 (41)

5.1 Reroute Logs

Drivers were asked to maintain a paper record (Appendix III) of situations in which, when using *ADVANCE* route guidance, either (1) the *ADVANCE* unit recommended a reroute; or (2) the driver elected to reroute for any reason. This information was collected to get a more detailed sense of drivers' experiences with *ADVANCE*. It was originally expected that such reroutes would be automatically recorded on the memory card installed in the *ADVANCE* unit for evaluation data collection. Under the targeted deployment, route plans and reroutes were not written to the memory card, so there was no objective record of reroutes. Of course even with data from the memory card, the reasons for reroutes could only come from driver records.

Reroute logs were received from 74 of the 80 households; they contained reports of 665 reroutes, 8.99 per household. We have no assurance that all reroutes were recorded; it is likely that some information was lost because, for safety reasons, drivers were asked to complete their reroute logs after the trip, or at least when the vehicle was stopped. There was no follow-up during the tests to remind drivers to record their reroutes. Because these data represent a sample of unknown proportions, they will not be related to other measures collected in this evaluation study. It is possible to examine reported reroutes alone to get a general sense of driver experience with *ADVANCE*.

About 20% of all reroutes were recommended by the *ADVANCE* system; 64% were driver-initiated; no reason was offered for the remaining 16%. Fifty-six percent of reroutes recommended by *ADVANCE* were accepted by drivers. Drivers estimated that they saved time on 44% of these (25% of *ADVANCE*-offered reroutes); the estimated mean time savings was just under 7 minutes per reroute, or 46% of the total trip time as reported by the drivers (implied trip length of 15 minutes).

Of the 64% of reroutes initiated by drivers, about 5.5 % were in cases where drivers claimed to have better real-time information: they saw congestion or an incident ahead and rerouted to avoid it. In 64% of the cases where drivers initiated a reroute, drivers claimed to know a route which was somehow better than the *ADVANCE* route: faster (23%); more direct (27%); easier or simpler (11%); safer *(4%);* or the *ADVANCE* route involved an impossible or illegal maneuver (5%). In 10% of the cases in which drivers rerouted on their own, they had either gone off route and were recovering or they simply switched their destination in mid-trip. The reasons for 14% of the driver reroutes were not reported. Drivers estimated that they saved time in 55% of their own reroutes; the mean estimate of time saved was 7.7 minutes, or 32.5% of trip time (implied trip length 23.5 minutes). The difference in implied trip length for trips involving *ADVANCE* vs. driver reroutes (15 vs.23.5 minutes) is probably a reporting anomaly and indicates the uncertainty in this data source.

These results suggest that (1) drivers experienced a number of reroutes during their two-week test period; (2) about one-fifth of these were commanded by *ADVANCE;* (3) drivers rejected just under half of the *ADVANCE* reroutes, and they initiated nearly two-thirds of the reroutes they experienced, in nearly 70% of the cases because they felt they knew a better route; (4) drivers perceived that they saved time by reroutes, whether due to *ADVANCE* or their own volition. The third finding provides insight into the perceived quality of *ADVANCE* route planning and real-time information, issues which are addressed in more detail in the next section of this report.

6.0 FOCUS GROUPS

6.1 Background

Focus groups are structured discussions for qualitative exploration of attitudes and perceptions. Because sample sizes are small and the content and directions of discussions are affected by the participants themselves, the results cannot be subjected to quantitative analyses and statistical testing. On the other hand, focus groups are powerful tools for exploring the ways in which people perceive products, services, and concepts. They are ideal for formulating the questions to be asked in statistical analyses. They are especially valuable for understanding consumer reactions to products and services, as differentiated from the preconceived, and perhaps biased, perspectives of those people directly involved in system and service development.

For these reasons, we conducted a series of focus groups with *ADVANCE* familiar drivers shortly after their driving experience. These drivers completed the post-test surveys prior to the focus groups, a necessary sequence to assure that we got the questionnaire responses before we lost contact with the drivers. It would have been desirable, had we had a substantially larger sample of drivers, to conduct focus groups to guide development of the post-test surveys. This would have allowed us to build the post-test survey instruments on a better understanding of the ways in which drivers perceived and experienced *ADVANCE.* However, our small sample and short time frame for the familiar driver tests demanded that we distribute and collect post-test instruments very quickly after the driving period. There were not enough drivers to use some for focus groups and others for the post-test survey.

Thus, the focus groups we conducted provided another, important way to absorb the reactions and ideas of participating drivers, rather than serving as a basis for instrument development. A preliminary analysis of a subset of post-test instruments was conducted prior to developing the focus group plan to assure that we were responsive to driver issues in these discussions. However, the main post-test analyses, all analyses reported here, were performed after the focus groups were conducted. In this way, the focus groups informed the quantitative analyses.

6.2 Discussion Outline

A detailed outline for the focus group discussions was prepared in advance, based on partial post-test survey results, the evaluation test plan, and general knowledge of travel behavior and market research. This discussion outline is included as Appendix IV. The major points covered were: review and evaluation of experience with the *ADVANCE* system; interests in and preferences for features of future route guidance systems; willingness to pay for future systems; and perspectives on what kinds of drivers would be interested in such future systems. Target times were set for each component of this discussion to keep the sessions within 2 hours.

6.3 Approach

Based on the gender-vehicle usage patterns we observed in the training sessions and preliminary post-test surveys, we decided to conduct one focus group with only female participants. It was expected that within-household gender influences would be reduced in such a discussion, so that a better notion of the perceptions and preferences of women and men would be developed. This was balanced by an all-male group. A third. and final, focus group comprised a mixture of male and female members.

A market research contractor was hired to recruit and schedule focus group participants from the list of *ADVANCE* familiar drivers We confirmed from the post-test surveys that all candidates for focus groups had actually driven the *ADVANCE* vehicle. The contractor filled the groups from the candidate lists to create a female, male, and mixed group with l0-14 people each. The 12-person male group met on a Thursday evening and the g-member female group and the 1 l-person mixed group met (separately) on a Saturday morning.

Groups met in the focus group rooms of the market research contractor, at a location roughly in the center of the *ADVANCE* test area. They were moderated by the senior member of the test team. Other test team members and project representatives observed behind a one-way mirror, keeping written notes on the discussion. The focus groups were recorded on audio and video tapes. The moderator prepared a summary of each group session within a day after the meeting was conducted; these findings were shared and discussed among the test team, and an integrated, written summary of results of each group was prepared.

Focus group members were given a $35 incentive for their participation. Although all *ADVANCE* drivers were told in the training sessions that focus groups were a part of their obligation to the project, a few declined to attend the focus groups because they felt the incentive was too small.

6.4 Focus Groups Results

This section presents an integrated summary of all three focus groups.

6.4.1 Real-time information: Real-time information was more appealing to familiar drivers than route planning based on static information (e.g., maps). Such drivers can plan their own routes well based on their knowledge of the network and recurrent congestion patterns. While there was a value associated with information about (static) network structure - an electronic map and perhaps a simple, static route planner for occasional new trips, or for out of town visitors - there was a stronger preference for real-time traffic information, even without route guidance: just traffic information, perhaps on a color-coded, synoptic map. Some wanted customized traffic reports, focusing on their routes or communities.

Drivers were interested in more timely traffic information to provide a basis for making their own route plans; and, they wanted more detailed information than that received from the

ADVANCE system, information which would support their own choices: why propose the reroute? What is happening on the network? What is the cause of the congestion? Exactly where is it located? Some suggested that such detailed information would allow them to use expressways until they got close to the congested point, then divert to arterial streets.

Participants recognized that they need and do not have real-time data for arterial streets, though such information is generally available for expressways in the Chicago area.

Some were willing to buy real-time information on a per trip or per month basis. They saw the possibility that not all users would want and need (and be willing to buy) real-time information all the time. A range of $20-30 per month for real-time information was acceptable.

6.4.2 Route planning: There was general agreement among focus group participants that the quality of *ADVANCE* route plans was not very good. Some routes were longer, sometimes much longer, in time and distance than users' preferred routes. Many drivers were frustrated because the *ADVANCE* unit did not give them what they felt were the best routes. Some of this was probably due to database errors, either in the network map or the estimated travel times; but some inferior routes were caused by the structure of the route planner and its path selection criteria, which put people onto higher type facilities quickly, avoiding local streets. Such routes were often not the most direct and logical, and familiar drivers recognized this quickly. In the face of this situation, drivers often reverted to their preferred routes.

Drivers in all of the focus groups were clearly interested in having more control over route planning. Self-routing was preferred especially where real-time information is lacking or poor. When it becomes better, drivers anticipated that they would develop more confidence in the quality of routes provided by the system, and would then be more willing to follow the route guidance.

Many drivers wanted to be able to set own route planning criteria: minimum time, minimum distance, keep moving, avoid a particular street, avoid a general street type (e.g., tollways, expressways), use certain streets, avoid railroad grade crossings, etc.

There was interest in seeing routing options, not merely a single recommended route, which would allow drivers more choice. Driver choice of routes would be facilitated by showing alternative routes on map, not with text or link-by-link arrow displays as in the *ADVANCE* route preview feature. For those who are comfortable with maps, this would be faster and would facilitate user choice of route.

There was considerable enthusiasm in all three focus groups for a route planner that can learn drivers' favorite routes and especially their local shortcuts. Drivers envisioned real-time data being used by the on-board system to evaluate their own routes in terms of predicted travel time and current congestion, proposing alternatives when those might be faster. It should be noted that the *ADVANCE* route planner is based on the notion that neither government nor a private company can direct vehicles through sensitive, residential neighborhoods, although individual drivers do this all the time. If the route planning system learns, individually, from individual drivers, then the policy problem of exacerbating neighborhood traffic impacts may be reduced.

Focus group participants offered a variety of ideas for this route learning function. It would be like "writing a macro... like telling the computer to 'learn this script (route)'. .." It should be possible to drive the route and have the computer learn it. Drivers should be able to tell the unit: "...learn this . . . . and not that route..." Some suggested the capability to enter the preferred route in a home computer, from which it would be downloaded into the vehicle's route planner. Others did not have home computers or did not want to depend on them.

These creative suggestions offer a different perspective on route planning than what has been implemented in *ADVANCE* and other on-board route planning systems: use the computer as an intelligent assistant to driver-as-expert. Both driver and computer bring unique information and skills to the route planning process. Familiar drivers know their route planning criteria, of course, and these may vary across trips and perhaps even within a single trip. They know the network and its recurrent congestion patterns. They are inherently self-serving, and thus unfettered by public policies about route selection. Computers can process information very rapidly, they can receive and analyze large quantities of information about current network conditions, and they can quickly compare proposed routes against real-time conditions. Where appropriate they can plan and propose alternative routes.

Such a route planning model would be a learning, artificial intelligence system, founded on a partnership between driver and computer, rather than a static computer software package which merely presents directives to the driver. While such a route guidance system is likely to be substantially more complex to develop, it may provide drivers with better routes and a higher level of individual control and customization. Such a product may be more likely to improve drivers' travel experience and thus it may be more marketable.

<u>6.4.3 Other functions:</u> Some participants were interested in an electronic business directory which will help them find and travel to the nearest establishment of a particular type. Some suggested a roadside assistance, or panic, call button, which would notify tow services or emergency responders of a problem; this would be especially valuable if it would report current

vehicle position, something a driver does not always know. Others felt that this function currently is provided by cellular phones.

A number of drivers were interested in a multi-city, multi-state database - and they expected this might be an add-on capability at extra cost. This was appealing to regular out-of-town travelers as well as to several people who make only occasional long-distance trips (e.g., a mother who annually takes her child to college). Some also wanted real-time data for other cities, based on the arguments that (1) saving time was often important during such trips; and (2) travelers do not know (even) recurrent congestion patterns in other cities. Some participants suggested selecting the database for a specific area by entering its area code; others proposed downloading map databases for other areas by modem to avoid carrying a pack of CD-ROM maps.

6.4.4 Operating features and user interface: Participants suggested a wide variety of operating feature enhancements, primarily aimed at improving the driver interface and overall system useability. These ideas include the following:

- Faster system start-up, route planning, and replanning, because drivers are unwilling to wait for the route guidance system to "catch up" to their trip. If route planning is fast enough, and destination entry is easier, drivers would sacrifice some capacity for storing destinations (because re-entering and re-planning would be easier). Faster (more timely) tracking of current vehicle position was also desired.
- Ability to save more destinations *(ADVANCE* saved only 7).
- Capability to store destinations by common name (e.g., store, bank, school) rather than by a list of street addresses.

- Automatically save current trip, like the telephone "redial" feature.
- Easier and more flexible destination entry; the *ADVANCE* touch screen keyboard was hard for many to use, especially for persons with long fingernails; ideas for easier destination entry included: selection from a list of points of interest or from a business listing, by entering the telephone number (drivers often know the phone number; perhaps numbers could be transferred directly from the cellular telephone to the route guidance system), and using voice recognition (to safely allow in-motion destination en try}.
- Sometimes drivers do not know the name of the town, or the exact address of the destination *(ADVANCE* required these for defining destinations); therefore, some drivers desired "point and shoot" destination selection on zooming map display, using a touch screen or an attached pointing device. Selecting a destination by pointing to a general area, rather than defining a specific address, is often sufficient, because when they are near the destination, many familiar drivers do not need route guidance for the last few blocks.
- Bigger map (larger display and especially a map with more detail covering a larger area).
- Map display with more or all street names.
- User-adjustable display colors.
- Route guidance from the map display as well as or instead of from arrow display.
- Show full route on map, especially for route preview; preview in current turn-by-turn form takes too long, too many steps.
- Show both expected travel times and mileage for planned routes *(ADVANCE* only showed

mileage).

- Heading-up as well as north-up display options.
- More reliable and timely advance warning of route guidance maneuvers.
- Built-in unit, more centrally located on the instrument panel; however, some were interested in various forms of portability for the system, the ability to move it from car to car, or to use at home or work. Home, office or kiosk (e.g., in shopping mall) service was of interest for reviewing current traffic conditions prior to making the trip. This would probably produce a larger effect on shifting trip departure time and destination for congestion avoidance.
- A number of database problems were cited. It appeared that, based on the driver training briefing (where participants were warned of this problem), and their own experience with the *ADVANCE* system, drivers seemed to be forgiving of database errors, but they wanted them eliminated.
- Drivers found names for places and streets in the database were different from posted and/or commonly-accepted names. Differences between the network database and driver knowledge was frustrating, and therefore some proposed that users should have the ability to fix, update, and customize the database in their vehicles.
- Some drivers wanted automatic rerouting when vehicle goes "off route." That is, they did not want to be asked the question "do you want a reroute?" They want to be informed, but they want the reroute guidance.
- Drivers also wanted to be able to customize the information presented, selecting both content and format. There was a strong consensus on a preference for real-time

congestion information; most participants liked map displays; the voice messages were viewed as good, not distracting; text was the less-preferred option. The format and detail of information presented might vary by location, with more detail in complex places or where drivers request it.

- Drivers want simplicity of usage, especially for data input and extracting desired output.

6.4.5 Willingness-to-pay: The focus groups briefly touched on willingness-to-pay for future real-time route guidance systems and services. Some participants were willing to pay from $750 to $1,000 to acquire an in-vehicle system, and from $2 to $30 per month for "single area" coverage of real-time data. Some participants wanted the ability to buy real time data for shorter or longer time periods (as needed). It was suggested that the needs of occasional users, or people unwilling to subscribe to on-going information services, might be met by charging for real-time data per trip or per *call* e.g., 25-50 cents per call, like cellular phone charges. Some would accept advertising on the display to reduce costs.

6.4.6 Gender perspectives A comparison of the women-only focus group with the others suggests that men were more inclined to see the route guidance system unit more as a technical "toy"; they tended to follow its advice more literally, and were more discouraged by its failures and shortcomings. Women were more pragmatic. They were more inclined to temper their response to guidance from *ADVANCE* with their own network knowledge. They focused their assessment on functionality and potential, and were more willing to forgive occasional shortcomings.

The women were as eager for information as the men, and most of them liked the maps. Yet they preferred simple presentations and were willing to turn over some decision making to the computer. It is possible that women were more willing to say this -- they were much more outspoken and creative than men in their single-gender focus group -- and that the preference extends to men as well.

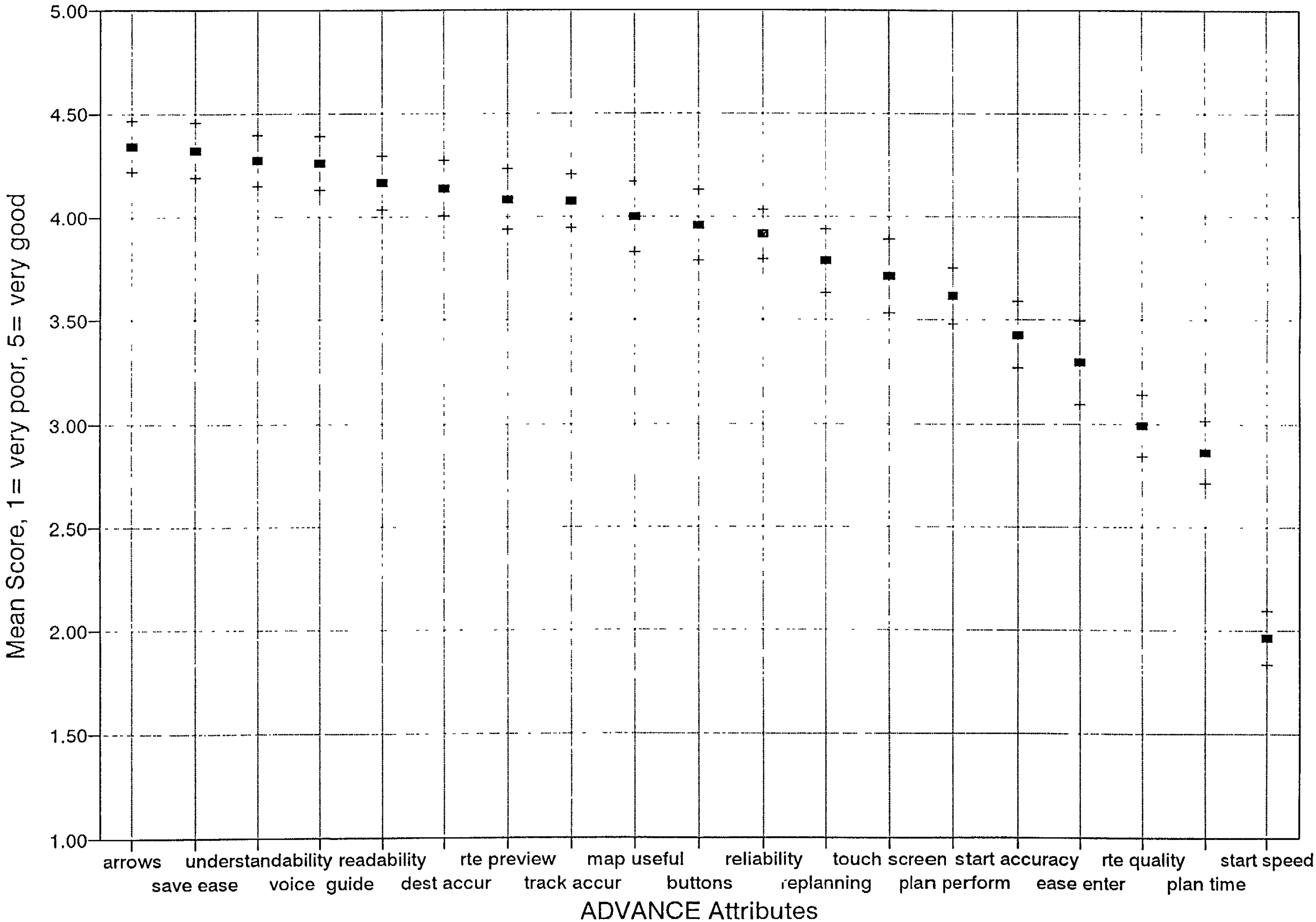
7.0 RESPONSES TO THE *ADVANCE* SYSTEM

7.1 Assessment of Feature Performance

The post-test survey asked participants to evaluate 19 aspects of the *ADVANCE* system on a scale from 1 = very poor to 5 = very good (Appendix II, question 10). Figure 2 shows the mean scores and the 90% confidence intervals for the full sample across all 19 features. The features have been ordered from best to worst rated. Most of the listed features are well-rated, that is, the mean score is above 3.5. The highest rated aspects of *ADVANCE* are in the driver interface: route guidance arrows, ease of saving destinations, display understandability, route guidance voice messages, and display readability. On the other hand, ease of destination entry is rated quite low, which confirms the criticisms made in the focus groups. The next group of features in the rating hierarchy include accuracy of destination finding, vehicle tracking accuracy, the route preview feature, and usefulness of the map display.

Overall reliability of the *ADVANCE* system is rated significantly lower than the top-rated features (Figure 2). Overall route planning performance was rated significantly lower than overall reliability. Similarly, quality of planned routes was rated significantly lower than route planning performance.

Figure 2: Mean Performance Scores of ADVANCE Attributes
With 90% Confidence Limits



This series of comparisons suggests that, while selected features of *ADVANCE* were viewed very favorably, some of the key performance characteristics related to route planning were much less positively rated: overall reliability, route planning, and quality of planned routes. Because all features except speed of system startup were rated on the favorable side of the scale, it is reasonable to interpret these results as positively biased, perhaps because of the self-selected participants and their desire to present a positive assessment. For example, rankings falling below 4.00 on the scale might be interpreted as increasingly unfavorable. These lower ratings of key overall performance characteristics are quite consistent with focus group findings, and underscore the notion that familiar drivers are logically very demanding when it comes to route planning and quality.

There were no important differences between the ratings on the features given by men and women, as illustrated in Figure 3. When the ratings are disaggregated by personality cluster membership, as shown in Figure 4, it appears that members of the cautious cluster tend to rate many of the features more favorably than do members of the confident cluster. These differences are not statistically significant but they appear from Figure 4 to be systematic. This is a logical pattern because participants self-described as having cautious personalities might be expected to be more accepting of an imperfect route guidance system than more confident people.

The mean overall rating respondents gave to *ADVANCE* on the same 1 to 5 scale (Post-test question 9) was 3.93 (3.73 for women, significantly less that the 4.05 mean score for men).

Figure 3: ADVANCE Performance Scores by Gender

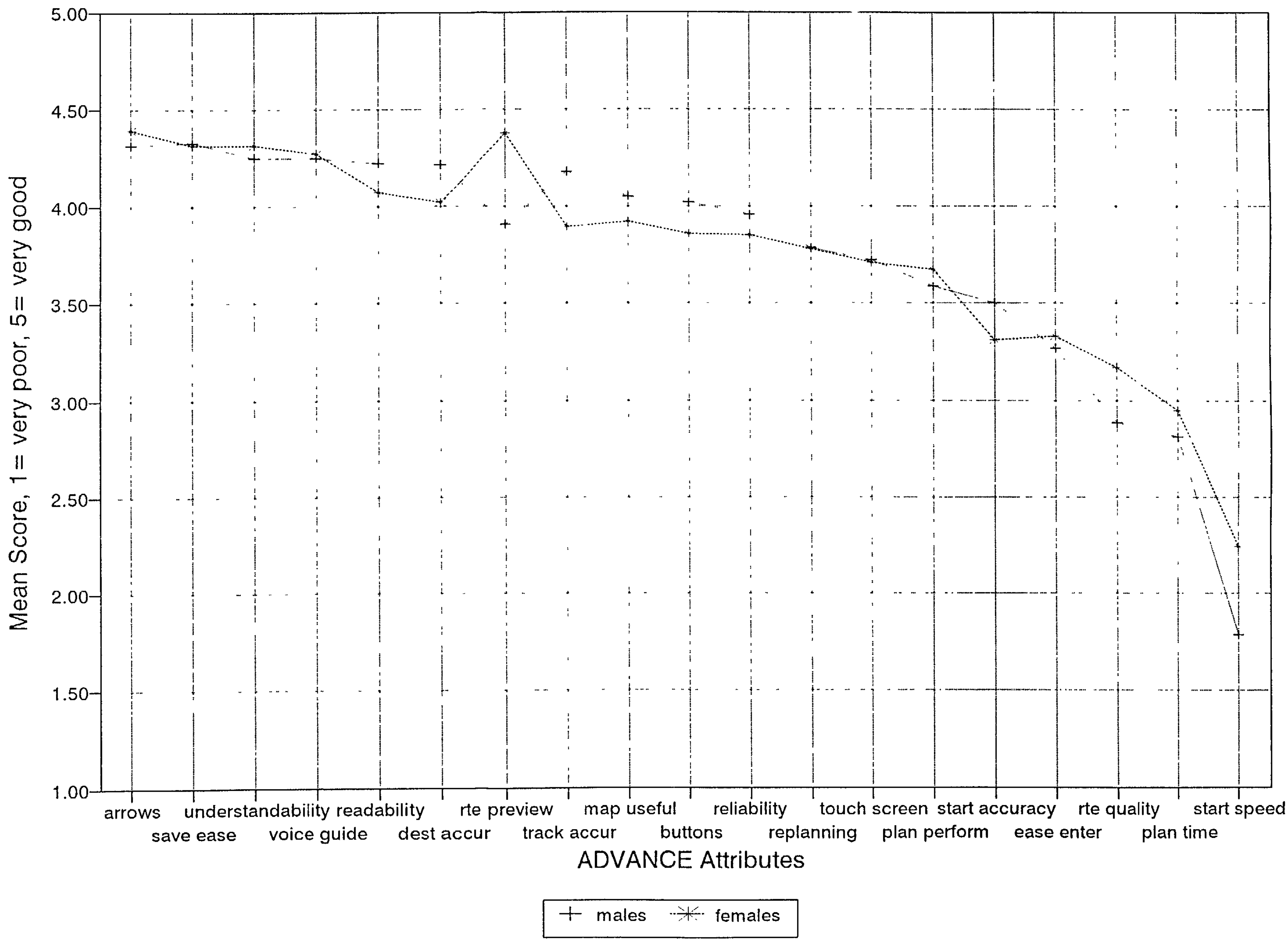
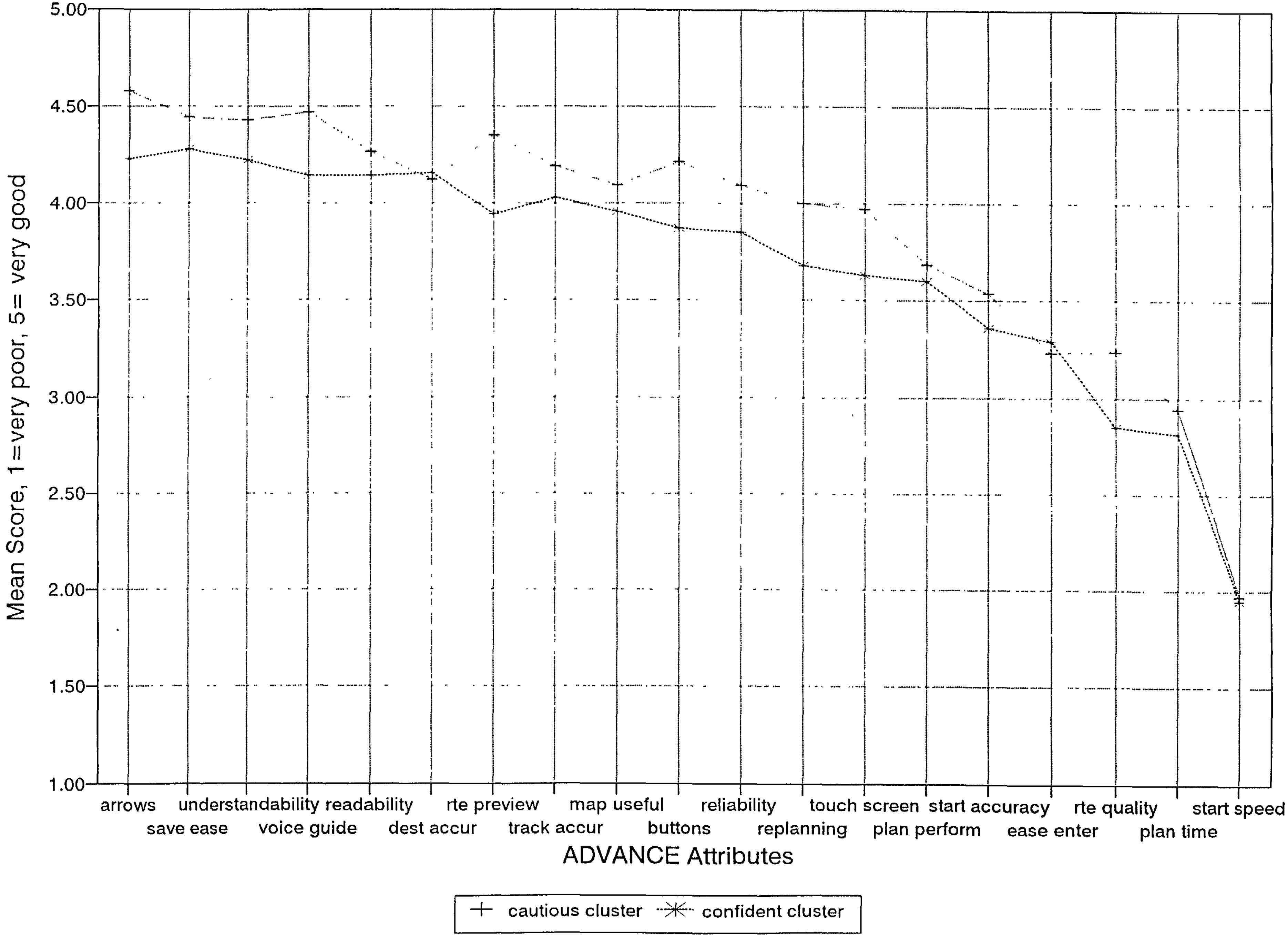


Figure 4: ADVANCE Performance Scores by Personality Cluster



7.2 Importance of Features

Respondents were asked to rate the importance of these features on a scale from 1 = not at all important to 5 = very important. Figure 5 shows the mean ratings of importance of the same 19 *ADVANCE* features for both personality clusters. Personality has no effect here, nor does gender (not shown). It is interesting to observe that several key features rated among those judged most important, overall route planning performance and quality of planned routes, were rated in the lower third of the features in terms of performance; route quality was the third lowest rated feature. This suggests that the relatively low overall rating of *ADVANCE* may be due, at least in part, to the fact that the performance of these important features was not highly-rated. These importance ratings also suggest that a primary avenue for improvement of future route guidance systems is to enhance the route planning capability. The focus groups provided some directions for such enhancements.

7.3 Comparative Route Quality

Respondents were asked to compare *ADVANCE*-provided routes with their own routes on 5 dimensions. The mean scores on a scale from 1 = strongly disagree to 5 = strongly agree are shown in Table 11. Compared with other ratings of *ADVANCE* features, these scores are quite low. *ADVANCE* routes compared particularly unfavorably with familiar drivers' routes on short travel times and distances. This again confirms the focus group results, where participants reported they often knew, and used, better, quicker, more direct routes than the *ADVANCE* route planner gave them. These response patterns were the same across genders and personality clusters.

Figure 5: ADVANCE Importance Scores by Personality Cluster

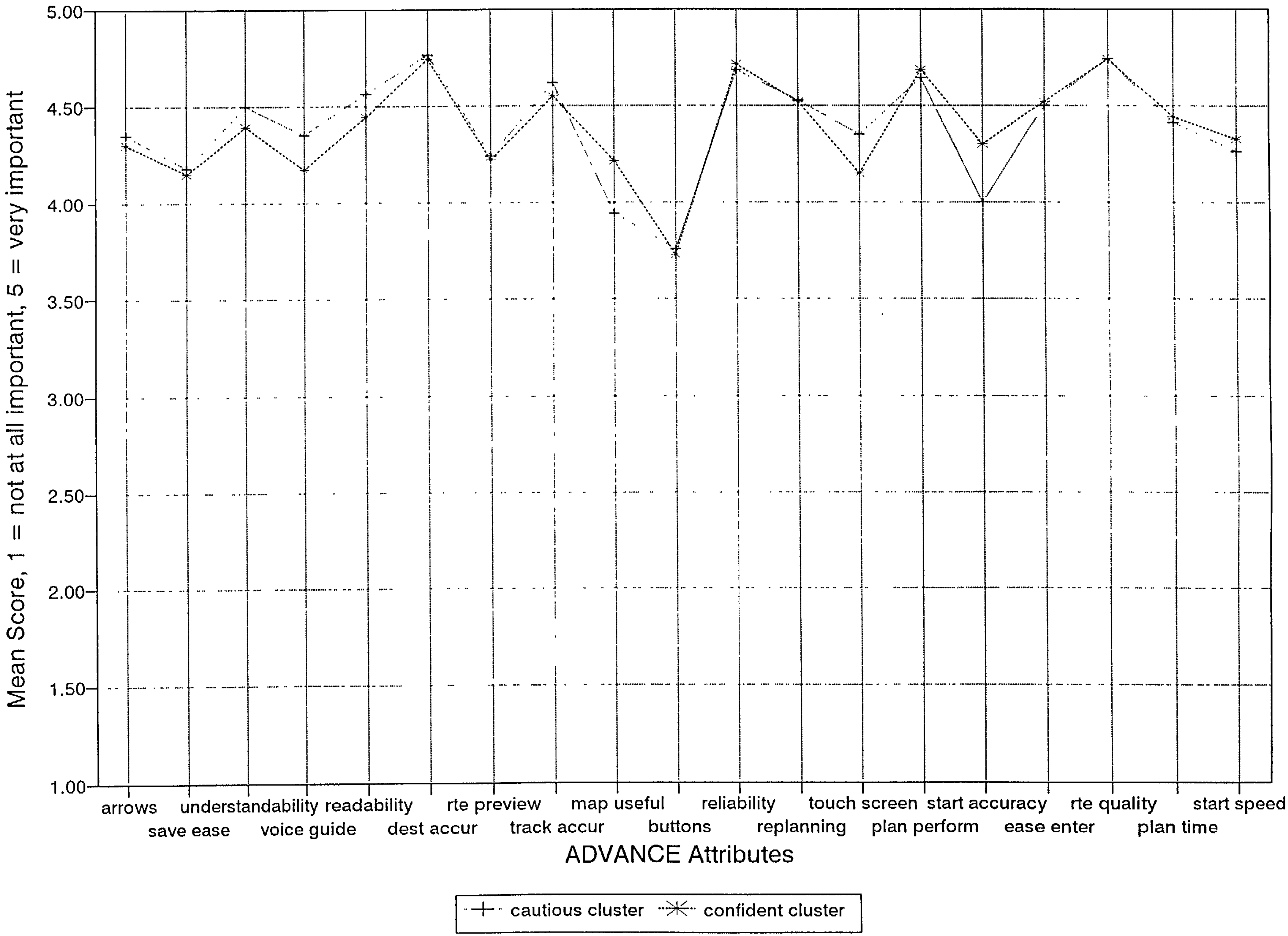


Table 11: *ADVANCE* Route Quality Compared with Driver's Own Routes

Compared with driver's routes, *ADVANCE* routes were.. .	Mean responses full sample
direct	3.25
fast, with shortest travel times	2.94
short, no excess distance	2.74
simple, no complex maneuvers	3.54
logical, sensible	3.14

7.4 Safety Risks

Questions about 27 possible safety risks associated with the presence and use of the *ADVANCE* system were included on the post-test survey to determine if drivers felt that the route guidance system posed a hazard to them (Appendix II, Question 17). They were asked about the frequency of occurrence of certain hazardous events, and the perceived level of risk associated with those events. Table 12 presents the mean responses for the full sample. The frequency scale ranged for 1 = never to 5 = always; the risk scale ranged from 1 = not serious at all to 5 = very serious. Nearly all respondents answered the frequency question (108 - 110 responses). Many did not answer the risk portion of the question because they did not experience the specific risk (63- 100 responses).

Table 12 shows that both the frequency and risks of certain unsafe conditions were rated very low. The most common risky events were "*ADVANCE* led in wrong direction at start of trip" (2.47) and "pressed wrong control" (2.15). Neither of these was rated as 'particularly risky. The highest risk events, "too complex in heavy traffic" (1 .81) and "drifted out of lane"

(1.86) did not commonly occur (1.61 and 1.53, respectively). These results suggest that *ADVANCE* drivers did not find the system to be a safety hazard. Of course this does not make the system objectively safe. It merely shows that, after two weeks of driving experience, drivers perceived minimal safety hazard from the in-vehicle system.

Table 12: Ratings of Potential Safety Hazards

Hazard	Mean Frequency 1 = never; 5 = always	Mean Risk 1 = not at all serious; 5 = very serious
Interfered with response to emergency	1.06	1.24
Too complex to use in heavy traffic	1.61	1.81
Drifted out of lane while using	1.50	1.86
Stopped vehicle to use feature	1.50	1.48
Couldn't select feature fast enough to use	2.12	1.59
Difficulty shifting attention between outside events and *ADVANCE*	1.40	1.74
Traffic prevented using needed function	1.63	1.67
Pressed wrong control	2.15	1.41
Stopped vehicle to correct error	1.70	1.48
Arrow and voice guidance conflicted	1.76	1.46
Could not hear guidance due to other noise	1.20	1.19
Drove more slowly to use *ADVANCE*	1.57	1.36
Interfered with driving more than using map	1.25	1.23
Missed commanded turns due to traffic	1.62	1.63
Missed commanded turns due to insufficient warning	1.95	1.77

Hazard	Mean Frequency 1 = never; 5 = always	Mean Risk 1 = not at all serious; 5 = very serious
Got lost using *ADVANCE*	1.27	1.19
Felt disoriented using *ADVANCE*	1.42	1.37
Guidance led in wrong direction at start of trip	2.47	1.61
Did not provide guidance in test area	1.35	1.27
Commanded illegal or impossible action	1.61	1.77
Some important geographic features not shown	1.59	1.39
Could not see names or features on display	1.36	1.25
Watching traffic interfered with seeing map display	1.44	1.51
Needed to lean over to see map display	1.17	1.13
Compass directions were confusing	1.27	1.30
Could not see streets or other features on map	1.53	1.44
Glare interfered with seeing display	1.92	1.57

7.5 Factor Analysis of Performance Ratings

To develop a better understanding of the ways in which test participants conceptualize the *ADVANCE* system, we performed factor analyses of the feature performance ratings (Appendix II, question 10). Factor analysis is a statistical technique which takes the values of n variables (here the 19 measures of *ADVANCE* feature performance) across m data points (here the number of responding drivers) and creates a smaller number of composite variables, or factors, made up of weighted combinations of the original n variables. The factors have the property that they are orthogonal to each other in the n-dimensional space of the variables, so each factor conceptually represents an independent aspect of, or perspective on, the *ADVANCE* system. The analyst selects the number of factors, based on the percentage of variation explained and the logic of the variables which “load on” (contribute high or low scores to) each factor.

Thus, factor analysis served to reduce the dimensionality of the space defining *ADVANCE* system performance from the 19 components of question 10 to a smaller number of composite dimensions. Three, four and five factor solutions were developed; the 3-factor solution was the most interpretable and is shown in Table 13. Factors are named judgmentally based on the contributing variables which load particularly heavily or lightly on each factor (rotated factor scores in Table 13). Factor scores range from -1.0 to + 1.0. Those variables contributing to factor names are highlighted in bold in Table 13; these were judgmentally selected to be around 0.5 or greater.

The three composite dimensions (factors) were named:

1. route guidance (33.5 % of variance explained);
2. driver interface (9.2 % of variance explained);
3. speed of operation (8.4 % of variance explained).

The route guidance factor represents quality of planned routes, en route replanning, overall route planning performance, route guidance information presentation, accuracy and overall reliability (Table 13). The driver interface factor includes destination entry and saving and the push button and touch screen controls on the display head. The start-up and route planning times load heavily on the speed factor, and so does route preview (a time-consuming function).

Table 13: Three Performance Rating Factors

ADVANCE Feature	Factor 1 score	Factor 2 score	Factor 3 score
Start-up speed	-0.03778	-0.09376	0.80122
Accuracy of start-up position	0.49115	-0.40249	0.09613
Display readability	0.42784	0.34321	0.27399
Display understandability	0.41918	0.43188	0.28757
Usefulness of map	0.40517	-0.01003	0.04483
Ease of destination entry	0.07935	0.68039	0.24498
Ease of destination saving	0.18966	0.67735	0.06684
Route planning time	0.17213	0.17775	0.71212
Quality of planned routes	0.48469	0.24870	0.46695
Route preview feature	0.21879	0.20647	0.66812
Route guidance arrows	**0.67847**	0.18446	0.21753
Route guidance voice	0.63543	0.13645	0.30734
En-route replanning	0.69677	0.10535	0.21037
Overall route planning performance	0.68623	0.22144	0.22089
Touch screen controls	0.19203	**0.70597**	0.01618
Button controls	0.23501	0.77523	0.09558
Accuracy of vehicle tracking	**0.67757**	0.22844	-0.10372
Accuracy of destination finding	**0.61912**	0.20382	0.02467
Overall reliability	0.71760	0.40574	-0.00165

These three factors suggest that, in terms of the performance ratings participants assigned to *ADVANCE* features, drivers view the route guidance system in three dimensions, of decreasing importance: the route guidance function including route planning, the driver interface, and the speed of operations. This result parallels the findings of the focus groups, where considerable emphasis was placed on evaluating and proposing enhancements to the route planning feature; and numerous complaints and ideas were directed at the driver interface. Virtually all drivers, in surveys and focus groups, as well as all members of the *ADVANCE* development team, recognized the need for and importance of increasing system speed.

These factors offer a way for developers to understand in-vehicle route guidance systems from the perspective of experienced users. They suggest design and performance categories warranting priority efforts in the design of future route guidance systems.

7.6 Models of Response to *ADVANCE*

We conducted analyses of variance and estimated regression models to explore associations between driver assessments of *ADVANCE* and demographic, experience, and personality measures. We estimated many different models; those discussed here were selected on the basis of statistical significance (F-statistic), logical structure (included variables, signs, magnitudes and significance of variable coefficients), and the insights into driver perspectives they offer.

The most interesting of the dependent variables was overall impression of *ADVMVCE.* The models help explain what variables contribute to the development of that impression. Such results may be helpful in the design of future route guidance systems which produce more favorable user impressions.

Only a few significant correlations were found among many variables tested. Almost all of the associations were weak, and thus the models cannot explain a large proportion of the variation in the dependent variable. This is primarily attributable to the small sample size, which is always less than 110 (the number of valid responses to both the baseline and post-test surveys). Some models were estimated with substantially smaller sample size because only respondents who answered all questions used in a particular model contributed to that sample.

Thus, it is not realistic to use such models as strong predictors of responses to future systems. Instead, the results of this effort may serve as clues about potentially important relationships between overall impression and characteristics of drivers and route guidance systems. These relationships warrant confirmation in future, larger-scale, and more focused market testing. The five most interesting models are shown in Table 14; each column is a different model, and regression coefficients and t-statistics are shown for all variables included in each model (blank cells indicate variables not included in a particular model). These models should be evaluated in terms of significance of the coefficients (t-statistics > 1.5), logic of the signs and magnitudes of those coefficients, and the correlation coefficient and F-statistic for the overall model. Many coefficients are not significant, in which case it is reasonable to assume that the associated variable does not contribute to overall assessment of *ADVANCE*. Of course many models showed very poor fits or were not logical or useful, and these are not presented in this report.

Table 14: Regression Models of "Overall Impression of *ADVANCE*"

Independent Variables	1 coefficient (t)	2 coefficient (t)	3 coefficient (t)	4 "confident" cluster coefficient (t)	5 "cautious" cluster coefficient (t)
Demographics					
male	0.355 (1.3)				

Independent Variables	1 coefficient (t)	2 coefficient (t)	3 coefficient (t)	4 "confident" cluster coefficient (t)	5 "cautious" cluster coefficient (t)
Experience					
trips per day	-0.067 (-2.8)	-0.062 (-2.7)	-0.060 (-2.69)	-0.035 (-0.37)	-0.072 (-3.68)
I often use radio traffic reports during trips	-0.098 (-0.7)				
I find computers easy to use	0.161 (1.1)				
Personality					
I can give precise directions to others	-0.018 (-0.1)				
Confident personality (cluster 2)		-0.14 1 (-0.6)			
Scores on *ADVANCE* performance assessment factors					
route guidance	0.246 (2.04)	0.233 (1.88)	0.235 (1.92)	0.163 (1.21)	0.515 (1.68)
driver interface	0.252 (2.0)	0.288 (2.38)	0.292 (2.43)	0.036 (0.21)	0.466 (2.75)
speed	0.322 (2.2)				
Constant	3.65 (5.2)	4.17 (21.0)	4.09 (27.14)	4.09 (27.14)	4.11 (17.18)
R^2 (F)	0.30 (2.82)	0.20 (3.40)	0.20 (5.01)	0.04 (0.63)	0.64 (8.26)

Model 1 includes variables in all of the major categories. It suggests that males tended to have a more favorable impression of *ADVANCE* than did females, but the effect is small and not significant. Persons who made more trips per day (more experienced drivers) were significantly less favorable to *ADVANCE,* and this may reflect dissatisfaction with route planning. The experiences of using radio traffic reports and computers were not significantly associated with overall impression, though the positive sign for computer use is logical. People who felt they can give precise directions were slightly (but not significantly) less favorable, perhaps because their expectations were higher than those of others.

Not surprisingly, the three performance assessment factors, route guidance, driver interface, and speed of operation, contributed positively and significantly to overall impression. The assessment of speed was slightly more influential in determining overall impression, while route guidance and driver interface contributed about equally.

Model 2 introduces personality cluster membership as a dummy variable, a partial segmentation. Membership in the confident personality cluster did not show a significant influence on impression. The performance factors continue to be major contributors to overall assessment, and heavy travelers rated *ADVANCE* less favorably. The "speed" factor was excluded because it was deemed less interesting from a development perspective, since it was generally agreed that speed was low and required considerable improvement.

Model 3 excludes personality cluster membership but keeps trips per day and the two performance factors; it is no worse than model 2, and of course it continues to show the relative strength of the relationship between the two performance assessment factors and overall impression of *ADVANCE.*

Models 4 and 5 are fully segmented on personality clusters: model 4 is estimated only on members of the "confident" cluster, model 5 only with members of the "cautious" cluster. Model 4 is quite poor; the signs of performance factor coefficients are logical but none of the driver coefficients on the independent variables are statistically significant. Model 5 is better, but it is based on a very small sample, 20 members of the cautious cluster. The coefficient signs are logical and consistent with previous models.

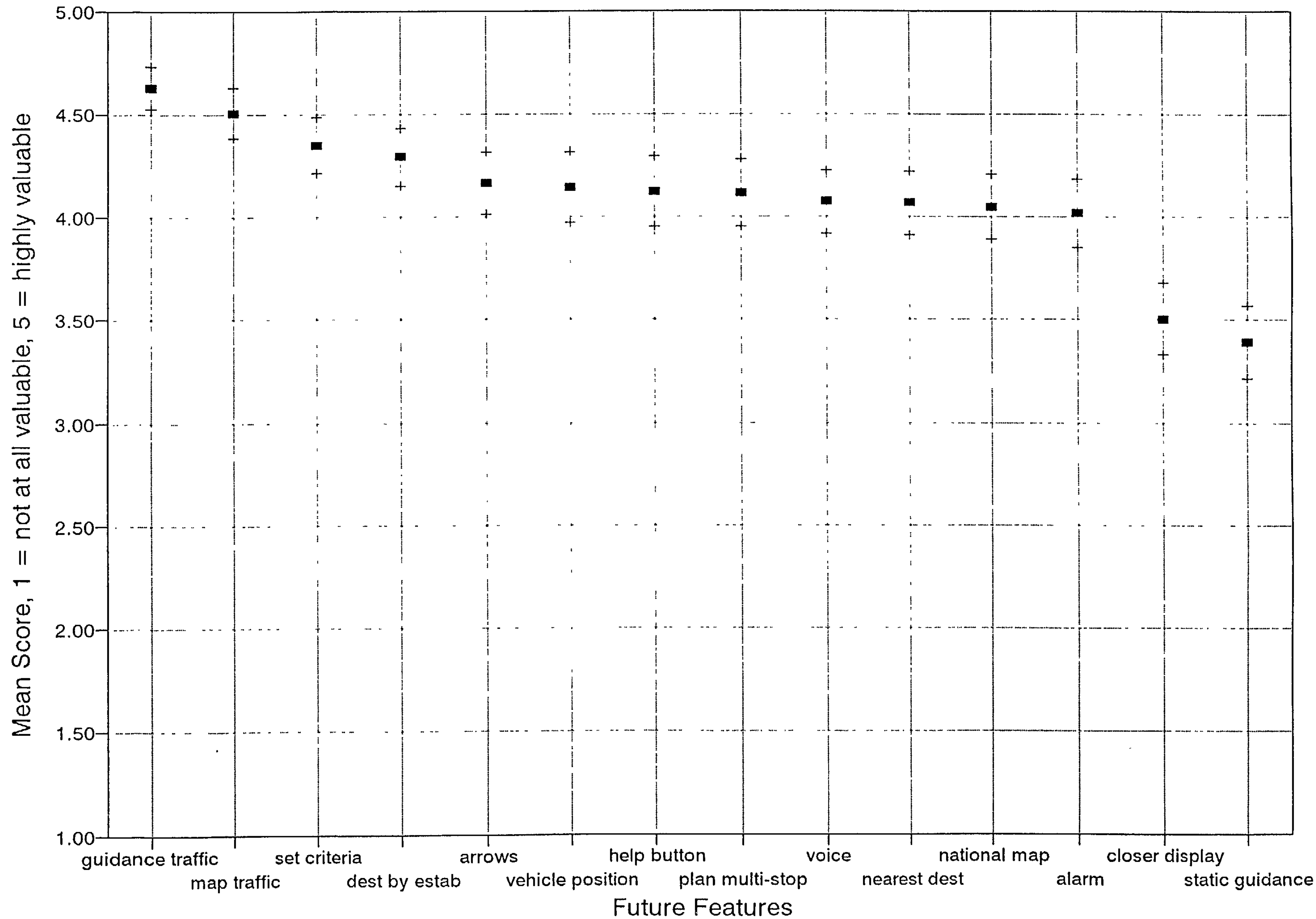
Together these models suggest that driver assessment of route guidance performance is a major contributor to overall impression of *ADVANCE.* More active travelers are more demanding of the route guidance system, perhaps because they are more knowledgeable about network structure and traffic congestion. Thus, it may take a better route guidance system to satisfy experienced travelers, which confirms expectations underlying the familiar driver test. Experience with computers and traffic information were not related to overall impression, nor were measures of driver personality. Of course these and other variables may be important, but their relationship to impression of *ADVANCE* was not revealed in our limited sample.

8.0 PREFERENCES FOR FUTURE ROUTE GUIDANCE SYSTEMS

8.1 Profiles of Values of Future Feature

In the post-test survey, participants were asked a series of questions about their preferences for future route guidance systems (Appendix II, question 18). Figure 6 shows the mean responses to the general question "In a future in-vehicle navigation system, how valuable would each of these features be to you?" The response scale was 1 = not at all valuable to 5 = highly valuable. Features are ordered in Figure 6 by decreasing preference and 90% confidence intervals are shown. All features were rated relatively highly, suggesting that, when respondents

Figure 6: Value of Future Route Guidance System Features
With 90% Confidence Limits



are given an unconstrained "wish list," any and all new features are valued. There are significant differences across responses to specific features.

Dynamic route guidance ("route guidance based on current traffic congestion information") was the most valuable of the future features, followed by "map display of location and intensity of current traffic congestion." These are rated as significantly more valuable than static location information ("map display showing current vehicle position").

Figure 7 shows these future preferences for males and females. Both men and women placed high value on dynamic guidance and real-time traffic information. Women were less interested in a map of current vehicle position, but had stronger preferences than men for the help button, ability to plan multi-stop trips, voice guidance messages and the ability to select the nearest destination of a particular type. That men had stronger preferences for static information may reflect a more independent self-image or simply a greater level of experience with network traffic conditions.

Figure 8 compares future feature preferences for members of the cautious and confident personality clusters. Confident drivers put greater value on congestion map, setting own route planning criteria, and several other features but none of these inter-cluster differences are significant. Differences between the personality clusters were smaller than differences between genders.

Figure 7: Value of Future Route Guidance Features by Gender

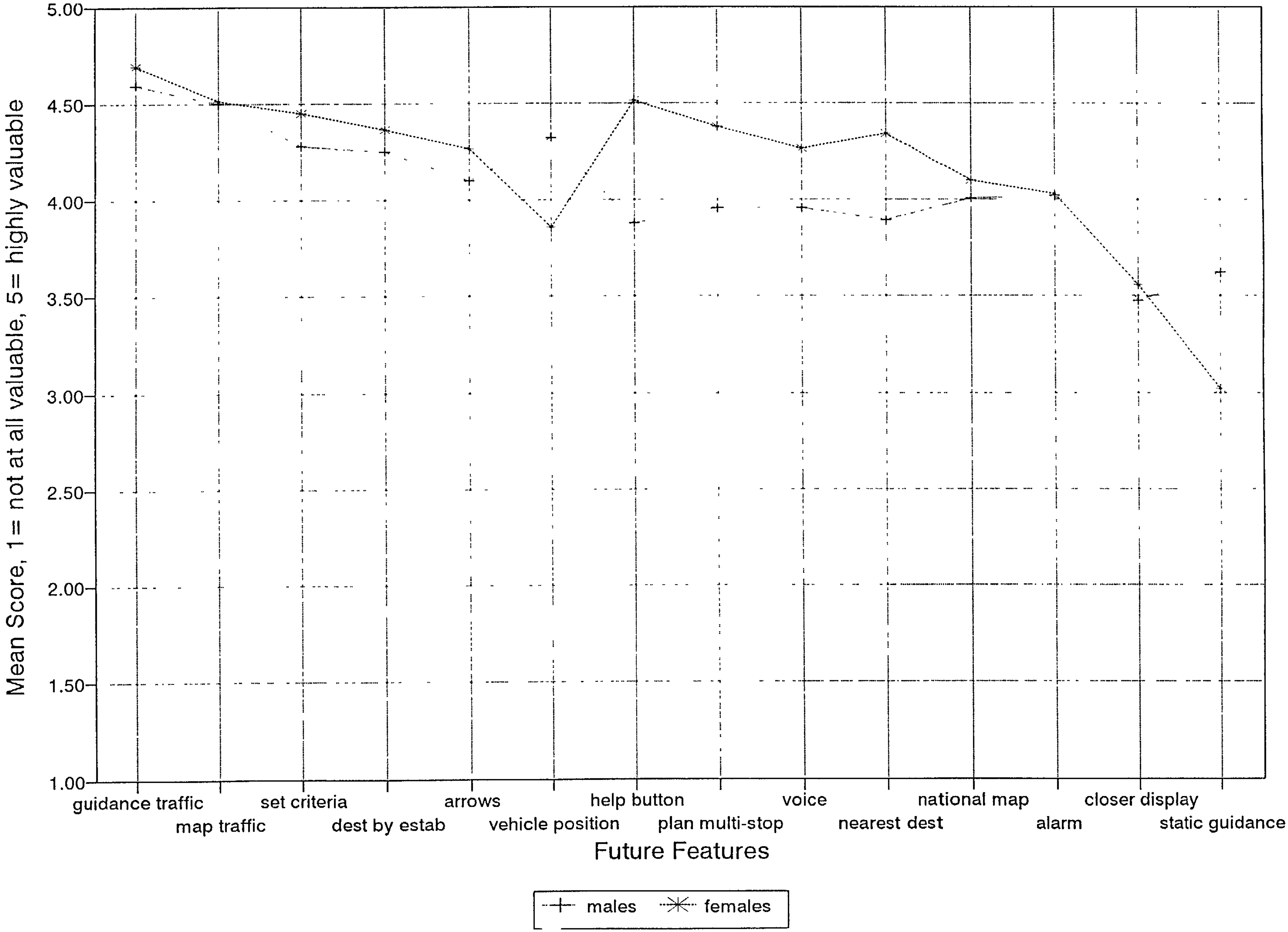
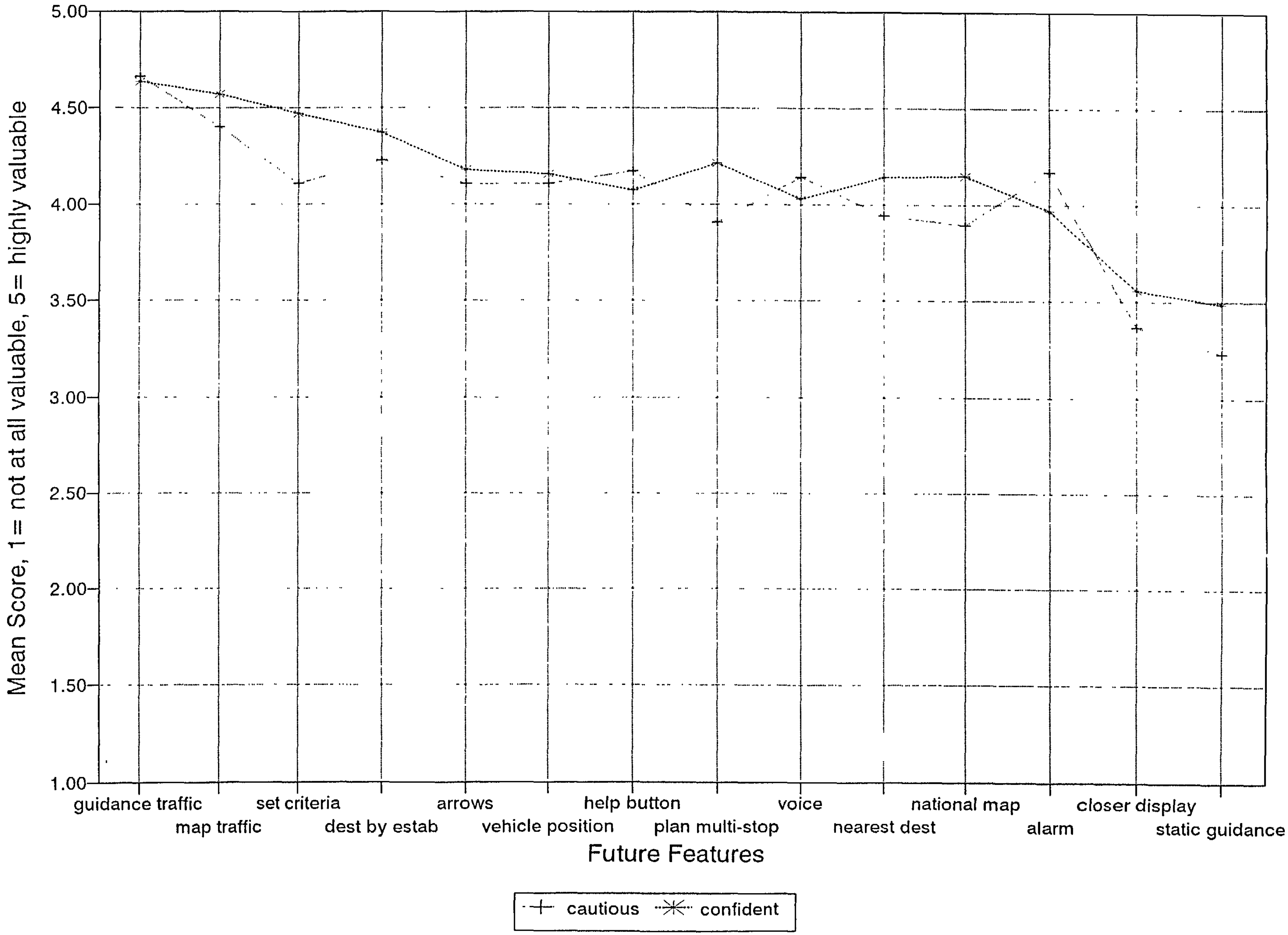


Figure 8: Value of Future Route Guidance Features by Cluster



8.2 Factor Analysis of Future Feature Values

We conducted a factor analysis of participants' stated future feature values to explore how drivers perceive the next generation of route guidance systems. Table 15 shows the rotated factor scores for the four-factor solution. We name the four factors as follows:

Table 15: Four Future Feature Value Factors

Future Feature	Factor 1 score	Factor 2 score	Factor 3 score	Factor 4 score
Map display with current position	-0.11363	0.18011	0.46823	0.47192
Route guidance with static information	-0.16733	-0.07486	-0.03815	0.75111
Route guidance arrow display	-0.00915	0.10888	0.87438	0.06325
Route guidance voice messages	0.18245	0.00761	0.82225	-0.18449
Route guidance using current traffic information	0.06763	**0.85106**	0.05624	-0.06270
Map display of current traffic	0.11153	0.85301	0.12810	0.18885
Select destination by name	0.55550	0.48939	-0.00631	-0.07551
Select nearest destination by type	0.74215	0.33342	0.12137	-0.07287
Push-button help	0.78352	-0.03685	0.12459	-0.03117
National map coverage	0.41799	-0.02663	0.39766	0.43581
Set own planning criteria	0.37451	0.22378	-0.13781	0.30706
Plan multi-stop trips	0.30648	0.29909	0.29417	0.23116
Theft alarm	0.69684	0.02108	0.01252	0.10167
Display closer to driver	0.21974	0.09234	-0.01635	0.72322

1. Driver interface and assistance features (25.4% of variance explained);
2. Dynamic information (12.6 % of variance explained);
3. Route guidance interface (11 .0% of variance explained); and
4. Static map and route guidance (9.8% of variance explained).

This is difficult to interpret, in that only the second and third factors show factor loadings which offer a clear interpretation. These correspond in a limited sense to the focus group results and responses of drivers to *ADVANCE* feature performance, identifying dynamic information and driver interface (the way route guidance information is conveyed - arrows, voice) as key dimensions of *ADVANCE.* The other two dimensions are destination entry and user support features which were not implemented in *ADVANCE,* and static maps. Two- and three-factor solutions were more difficult to interpret.

8.3 Models of Values of Future Features

We estimated a series of linear regression models using values assigned to various future system features as dependent variables (answers to components of question 18 on the post-test instrument), and demographic, experience, personality, and *ADVANCE* performance rating factors (Section 7.5) as independent variables. The purpose of this effort was to explore what driver characteristics and factors best explained future feature preferences.

None of these models was particularly useful, in terms of either goodness-of-fit or insights offered. Table 16 summarizes a few of these models. These suggest that males were more inclined toward maps and route guidance, rather than dynamic traffic information. People who claimed more computer experience found real-time traffic information and route guidance based on it to be more appealing. Respondents who were classified in the confident personality

Table 16: Models of Values of Future Features

Independent variables	Dependent Variable: Future Feature Valued						
	Static map	Static route guidance	Arrow display	Voice messages	Dynamic guidance	Congestion map	Set own routing criteria
Male	0.238 *	0.373 **	-0.209	-0.299 *	-0.208	-0.226	-0.244
Computer experience	0.055	-0.060	-0.036	-0.007	0.148 **	0.209 **	0.030
Confident cluster	-0.030	0.012	-0.102	-0.344 *	-0.126	-0.152	0.317
Route guidance factor score[2]	0.344 **	0.102	0.268 **	0.244 **	-0.014	-0.077	-0.076
Driver interface factor score[2]	0.026	-0.041	0.009	0.085	0.071	0.085 *	-0.091 *
Constant	3.87	3.50	4.52	4.47	4.22	3.94	4.32
R^2	0.142	0.038	0.100	0.128	0.064	0.105	0.102
F	2.54	0.60	1.72	2.26	1.05	1.78	1.75

* t statistic > .5; ** t statistic > 2.0

category (cluster 2) had less interest in getting route guidance through voice messages and were more interested in being able to set their own route planning criteria. Perhaps the strongest and most logical result is that drivers who scored the route guidance of *ADVANCE* higher (route

‘Factor scores are the factor values for each respondent, their performance ratings for each feature weighted by rotated factor scores shown in Table 13.

guidance factor score) were more interested in maps and guidance in future systems.

We explored the differential preferences for more sophisticated features over simpler features by estimating models using as dependent variables differences in answers to paired questions:

Dynamic vs. static map (post-test question 1806 - 1801)

Dynamic vs. static guidance (post-test question 1805 - 1802)

Arrow display vs. voice messages (post-test question 1803-1804)

Dynamic guidance vs. congestion map (post-test question 1805- 1806)

These models are shown in Table 17, and all are poor. They repeat the pattern that men and people who rated *ADVANCE* route guidance better seem to be less interested in dynamic information. This is difficult to explain and it should probably be ignored because of the weakness of these models.

The dependent variables included in the models above, ratings of the desirability of future features, are measured on an ordered five point scale rather than on a continuous, linear scale which is assumed in linear regression. The use of the linear assumption implies that the difference between each pair of rating points is of equal magnitude, an assumption which is not necessarily correct. Ordered probit models take explicit account of the fact that in responding to the questions, individuals are forced to provide ordered, categorical responses (e.g., 1,2, . . .or 5). These models make an explicit transformation (based on the data) between the ordered categorical responses and an implicit underlying linear scale. Thus, they attempt to represent the responses along the scale actually used by the respondent.

Table 17: Models of Differential Values of Future Features

Independent variables	Dependent Variable: Future Feature Valued			
	Map dynamic > static map	Route guidance Dynamic > static	Arrow > voice display	Dynamic guidance > congestion map
Male	-0.336 *	-0.581 **	0.090	0.028
Computer experience	0.147 *	0.207	-0.028	-0.062
Confident cluster	-0.031	-0.137	0.242 *	0.033
Route guidance factor score	-0.416 **	-0.116	0.024	0.063
Driver interface factor score	0.088	0.112 *	-0.076	-0.012
Constant	-0.064	0.725	0.051	0.272
R^2	0.192	0.067	0.036	0.022
F	3.60	1.11	0.57	0.35

* t statistic > 1.5; ** t statistic > 2.0

We estimated models similar to those shown in Table 16 using the ordered probit analysis; the results are reported in Table 18. These models are not substantially different from the linear regression results but they do show somewhat stronger relationships between scores on *ADVANCE* performance factors, both route planning and the driver interface, and values assigned to future features. However, since the differences between ordered probit and linear regression results were small, we did not pursue this methodology further.

Table 18: Ordered Probit Models of Future Feature Values

Independent Variables	Dependent Variable: Future Feature Valued						
	Static map	Static route guidance	Arrow display	Voice messages	Dynamic guidance	Congestion map	Set own routing criteria
Male	0.327 **	0.371 **	-0.290	-0.350 **	-0.352	-0.342	-0.374
Computer experience	0.051	-0.061	-0.043	-0.0007	0.235	0.359 **	-0.0069
Confident cluster	-0.126	-0.002	-0.163	-0.430	-0.323	-0.389	0.453
Route guidance factor score	0.386 **	0.091 *	0.369 *	0.319 **	-0.029	-0.195 *	-0.124 *
Driver interface factor Score	0.023 **	-0.048 *	-0.029	0.101 *	0.095	0.155	-0.151
Constant	2.087	1.840	1.997	2.907	1.494	1.082	2.538
μ_1	0.963	0.904	0.680	0.693	0.466	0.673	1.210
μ_2	1.579	1.793	1.665	1.872	1.481	1.608	2.260
μ_3	2.361	2.679	--	2.690	--	--	--
Log-likelihood At convergence	-92.146	-116.751	-92.943	-97.040	-64.426	-65.091	-76.716
Log-likelihood At zero	-97.752	-120.302	-93.106	-102.842	-64.394	-69.437	-80.699

* t statistic > 1.5; ** t statistic > 2.0

8.4 Willingness-to-Pay for Future Systems

The post-test survey asked participants to estimate the maximum amount of money they would be willing to pay for a future route guidance that had the features they deemed important; their responses were constrained to the range of $500 to 2,000. The mean response was $983 (standard deviation, 0=$305); $991 (0=$333) for males and $969 (0=$251) for females. This gender difference is not significant.

We estimated several linear regression models to explore the relationship between willingness-to-pay and characteristics of respondents and their experiences. The best of these models are shown in Table 19.

These models are relatively good and the results are logical. Their structure suggests that characteristics of the drivers themselves were more important in setting their willingness-to-pay than their experience with the *ADVANCE* field test: the effect of the route guidance performance factor score was only significant in Model 4 and its effect is positive but relatively small. The models reported in Table 19 suggest that mates were willing to pay more for future route guidance systems than women, but the increment is only around $100.[3] More active travelers were willing to pay slightly more. It is surprising to find that people who claimed that computers are easier for them to use expected to pay less for future systems; this is the second-most influential variable of those tested. We might explain this as follows:

- People with more computer experience may have more modest expectations for future computer-based systems, and thus are not as optimistic about the expected returns on their investments.
- People who are knowledgeable about computers may be more aware of the downward

---

3 This differs from the $22 male-female difference described above because the model result isolates the effect of gender difference from all other variables in the model, e.g., computer experience, use of traffic information, etc. The observed $99 l-$969 male-female difference is due not only to gender, but to all other variables associated with gender. The model result is more "pure," al though variables not in the model may contribute to this $100 difference.

trend in prices, and the upward trend in performance capabilities. They may look at the market with a more optimistic expectation of the price-performance trend.

Table 19: Models of Maximum Cost Willing to Pay for Future System

Independent Variables	1 coefficient (t)	2 coefficient (t)	3 coefficient (t)	4 coefficient (t)
Demographics				
male	85.40 (1.15)	89.34 (1.34)	109.76 (1.5 1)	123.17 (1.48)
Experience				
trips per day	8.38 (1.28)		6.76 (1.055)	
I often use radio traffic reports during trips	73.25 (2.19)	82.22 (2.83)	85.26 (2.58)	120.84 (2.80)
I find computers easy to use	-153.89 (-4.16)	-129.09 (-3.74)	-149.47 (-4.14)	-174.48) (-3.70)
Personality				
In cluster 2, *confident*		-136.75 (-2.00)	-156.27 (-2.14)	-69.62 (-0.90)
ADVANCE performance factors				
Route guidance				87.14 (2.21)
Driver interface				-33.98 (-0.81)
Constant	1283.73 (8.335)	1258.87 (8.45)	1320.66 (8.75)	1208.44 (6.03)
R^2 (F)	0.25 (5.4 1)	0.22 (5.63)	0.29 (5.48)	0.28 (3.68)

This result also contrasts with the earlier findings that people with greater computer comfort were more interested in real-time information and route guidance (Table 16). This difference may support the notion that computer-familiar people may be "wiser" buyers in the route guidance market. That segment of the market is likely to be growing rapidly.

Finally, respondents who described themselves as more confident, and who were therefore classified in cluster 2, were willing to pay substantially less than others. This may indicate a lesser feeling of need for in-vehicle route guidance. This is an interesting finding, since our sample of early-adopters is biased toward confident drivers. That these drivers were willing to pay somewhat less than the others may suggest that cautious people are willing to pay more to improve their travel experience. At the same time it may be more difficult to attract cautious drivers to consider future route guidance systems.

8.5 Payment for Extra Features

The post-test survey asked drivers their willingness to pay incremental fees for particular features (question 21). We included this to explore responses to the likely future scenario under which various information services would be sold separately from the on-board system. The responses are summarized in Table 20.

Drivers were willing to pay most for real-time traffic information, and the effect of price seems important. Theft alarm and help call button were less appealing at these prices, although women were more significantly Interested in buying the help feature, a result which mirrors focus group findings.

8.6 Factors Discouraging Purchase

Table 2 1 summarizes responses to a post-test question (22) about the effect of seven discouraging factors on the willingness to purchase a future route guidance system. Moderate annual maintenance costs ($50 per year) and risk of vehicle theft and vandalism due to presence of the on-board unit were most discouraging, but responses were still close to the middle of the scale from 1= very unlikely to 5 = very likely to discourage purchase. Complexity equal to that of *ADVANCE* was least discouraging of the factors tested, though women were significantly more negatively affected than men.

Table 20: Willingness to Pay for Extra Features
(1 = very unlikely to pay; 5 = very likely to pay)

How likely would you be to add features?	Full Sample Mean (standard deviation)	Males Mean (standard deviation)	Females Mean (standard deviation)
Real time traffic information for route guidance @ $20 per month	2.61 (1.27)	2.65 (1.27)	2.54 (1.29)
Real time traffic information for route guidance @ $10 per month	3.50 (1.24)	3.57 (1.21)	3.37 (1.28)
Theft alarm and vehicle tracker @ $10 per month	2.32 (1.11)	2.29 (1.09)	2.37 (1.16)
Push button help call for emergency service @ $10 per month	2.39 (1.31)	2.16 (1.24)	2.78 (1.35)
Combined real-time information, theft alarm and help call @ $30 per month	2.86 (1.34)	2.78 (1.36)	3.00 (1.32)

Table 21: Effect of Discouraging Factors on Willingness to Purchase Future Systems
(1 = very unlikely to discourage; 5 = very likely to discourage)

How likely would these aspects discourage purchase?	Full Sample Mean (Standard Deviation)	Males Mean (Standard Deviation)	Females Mean (Standard Deviation)
Maintenance cost of $50 per year	2.72 (1.19)	2.69 (1.19)	2.78 (1.21)
Complexity equal to *ADVANCE*	1.85 (0.99)	1.74 (0.92)	2.05 (1.07)”
Reliability equal to *ADVANCE*	2.32 (1.14)	2.31 (1.14)	2.54 (1.15)
Installed appearance equal to *ADVANCE*	2.23 (1.13)	2.31 (1.14)	2.10 (1.11)
Potential problems due to electrical loads	2.50 (1.25)	2.31 (1.19)	2.80 (1.31)*
Potential increased risk of vehicle theft, vandalism	2.71 (1.08)	2.60 (1.04)	2.88 (1.14)
Driver distraction while using route guidance system	2.00 (1.13)	1.88 (1.07)	2.20 (1.21)

* Gender difference significant at 0.05 level.

9.0 CONCLUSIONS

9.1 Limits of the Test

The familiar driver experiment gave 110 drivers from 80 households the opportunity to drive cars equipped with prototype dynamic route guidance systems for two week periods and, based on that driving experience, to provide an assessment of the *ADVANCE* system and some perspectives on preferred characteristics of future systems.

This test was necessarily small in scale and scope. The *ADVANCE* system had limited performance capabilities. Its network database was not error-free, and historical travel time data were not particularly accurate. Very little real-time traffic information was available to support dynamic route guidance. These and other limitations constrain our ability to draw inferences about the *ADVANCE* concept and future systems. Still, within these limitations it is possible to identify some useful, potentially important ideas about *ADVANCE* and the design of future, more responsive and successful route guidance systems.

Three sources of information were used in this test: before-and-after surveys of drivers; focus groups involving 30% of the drivers; and reroute logs maintained by most drivers. The focus groups, by their nature, were by far the richest and clearest source of information developed here. Focus group results are not statistical, providing a variety of interesting but qualitative insights into the experiences and perspectives of participating drivers. The surveys were only modestly more quantitative because of the small sample. As a consequence, we put most confidence in focus group results.

The value of the other data sources is reinforced by the fact that we observed good correspondence in the results derived from focus groups, surveys, and even the reroute logs. This consistency in some key results may be interpreted as validation which strengthens the basis for interpretation and extrapolation. The key, more consistently-observed results and interpretations are summarized below.

9.2 Route Quality and Route Planning

The quality of routes planned by *ADVANCE* was not good, and certainly not viewed as favorably as routes planned by our test drivers themselves. Familiar drivers claimed, and apparently had, knowledge of network structure, alternative routes, and even recurrent congestion superior to what *ADVANCE* could off r. This was particularly true for the trips that such drivers take each day and week. While the quality of data in the *ADVANCE* database was one limiting factor, when familiar drivers plan their routes they are not restricted by the policy constraints built into the *ADVANCE* route planning algorithm. This gave familiar driver-planned routes a natural advantage, one not likely to be achieved by future route guidance systems, which will necessarily function under the same or similar routing policies.

As a consequence, our familiar drivers expressed a clear interest in doing their own route planning, setting their own criteria, using their detailed network knowledge, and avoiding routing constraints they viewed as artificial. These are not tasks they are prepared to turn over to computers, at least until those computers can function more like familiar drivers themselves.

At the same time, test participants expressed strong interest in, and willingness-to-pay for, real-time information on traffic conditions. Both directly and by implication drivers indicated their desire for information about non-recurring or incident-based congestion, which their experience cannot anticipate. They wanted dynamic information even without, and perhaps especially without, a constrained route planning capability. This was manifested in their preference for maps showing current congestion rather than turn-by-turn route guidance. That is not to say that drivers were disinterested in the guidance. It was appealing for new trips, and would be more appealing for all trips if it were of better quality.

A key message seems to be that, at least for familiar drivers under current circumstances, the preferred division of labor between computer and driver is probably different than what was designed into *ADVANCE*. Specifically, familiar drivers seem to want the computer. to provide real-time information on which they would base their own route planning process. They expressed interest in having the route guidance system learn their preferred routes, and then evaluate those routes based on current traffic information.

This suggests a concept of the computer as an intelligent assistant to an even more intelligent driver. The computer can process large quantities of information rapidly, a capability that can be effectively used for data acquisition and comparative evaluation of routes. Drivers have the benefit of experience, judgment, the will and ability to change criteria and route plans as circumstances change, and the ability to observe traffic and respond to immediate conditions and trends.

The most successful computer system may be one which is able to learn a driver's routes and perhaps even routing criteria. As positive driver experience with such a system grows, confidence may also increase, and the division of labor might shift back in the direction of more reliance on the computer. This suggests a flexible, artificial intelligence approach that entails a partnership between driver and computer, a relationship in which roles may change with changing circumstances and capabilities.

9.3 Driver Perceptions

Driver perception of route planning systems, present and future, can be defined in two key dimensions: the route guidance capability and the driver interface. Both of these must meet driver needs to warrant a favorable response to the route guidance system, Route guidance includes quality of planned routes, route planning performance, en-route replanning, the format of guidance information, and, for future systems, the availability of real-time information. The driver interface includes the methods for entering data and characteristics of the display.

Drivers did not find the presence or operation of the *ADVANCE* system to be a safety hazard, nor do they fear that aspect of future systems. A system no more complicated than *ADVANCE* is likely to be accepted and used without concern for distractions from the driving tasks.

Different kinds of drivers offered different insights into *ADVANCE* and future systems. Men expressed less willingness to depend on future systems, yet seemed more inclined to follow whatever advice they got from *ADVANCE.* Women were more forgiving of *ADVANCE* failures and more willing to substitute their own good judgment for computer guidance. They expressed more interest in sophisticated trip planning and support features (multi-stop trip planning, help buttons) than men. More confident drivers expressed less need for, and more skepticism of, computer route guidance. Conversely, more cautious drivers had greater interest in computer support for their trip making.

Such gender and personality differences can only suggest the range of features and capabilities which future systems should provide. The small and specialized sample used in this study does not support the idea of developing different systems for different kinds of people, nor can we be confident that these differential reactions and preferences will hold as route guidance system capabilities evolve.

Finally, drivers expect to, and seemed willing to, pay realistic amounts for more capable, future systems, as well as to pay incremental fees for additional services such as real-time information and navigation data for multiple cities. Men were willing to pay more than women, and more active drivers seemed willing to pay a little more. Not surprisingly, more confident drivers, and those with more computer knowledge, were inclined to pay less for future route guidance. Because these groups might be considered among the most likely sales targets, meeting their needs and thereby enticing them to buy future systems is likely to be challenging and important.

9.4 Closure

The results of this evaluation suggest that the route guidance and traffic information needs of familiar drivers are logically different from those of unfamiliar, or visiting drivers. These ideas suggest some directions for the development and marketing of future in-vehicle route guidance systems.

The limitations of the *ADVANCE* targeted deployment restrict our ability to generalize these results. Yet the logic and potential value of these findings serve to support further, larger-scale testing of more advanced real-time traffic information and route guidance systems.

APPENDIX III: REROUTE LOG

DRIVER RE-ROUTE LOG

Instructions: At the end of each trip please record instances when you were following a route planned by the ADVANCE system and you either {I) changed your route during the trip for any reason; or (2) the ADVANCE unit offered you a new route and you rejected *it.*

Date __________ Time___________AM/PM Driver Name ________________________

Trip start location			Initial planned destination		
Street	Cross street	Town	Street	Cross street	Town

Purpose of this trip: ❑ Work ❑ Personal Business ❑ Home ❑ Shop ❑ Social/Recreational ❑ Other

Where re-route occurred: Major Street _______________ Cross Street ___________

Check correct answers and fill in blanks:

❑ Re-route was offered by *ADVANCE* System.

- ❑ Accepted the route
- ❑ Rejected re-route (check reasons below:
  - ❑ Saw no reason to re-route
  - ❑ New route seemed worse
  - ❑ Too close to destination to bother re-routing
  - ❑ Other ____

❑ Re-route was initiated by driver (check reasons below)

- ❑ Heard radio traffic report of incident (accident, construction) or congestion
- ❑ Saw congestion ahead
- ❑ Saw roadway incident ‘accident, construction) ahead
- ❑ My own route is faster
- ❑ My own route is more direct
- ❑ My own route is easier or simpler to follow
- ❑ My own route is safer
- ❑ *ADVANCE* unit directed me to perform an illegal or impossible maneuver
- ❑ Went off-route, needed to recover
- ❑ Decided to switch destinations or add or eliminate a stop
- ❑ Other __________________________

Whatever led to your re-route, do you think this this re-route saved you time? ❑ Yes ❑ No

If so, how many minutes do you think it saved? ______

How long does this trip normally take? _____ minutes.

APPENDIX IV: FOCUS GROUP DISCUSSION OUTLINE

Time	TOPIC	QUESTIONS	PROMPTS
A. 2 min.	Introduction	Purpose: ideas for design and development of future systems based on your experiences with ADVANCE	Observers are present
B: 10 min.	Warm up	How did you like using the ADVANCE system?	What was especially good about your experience? What was especially bad? EVERYBODY

Time	TOPIC	QUESTIONS	PROMPTS
C. 5 min.	Future design features and attributes	Help us define the features provided in future systems. First, should we or anyone else continue development of in-vehicle navigation systems?	 Why? Keep this focused, brief.
D: 20 min.	Future design features and attributes (continued)	What features (services) should be included, excluded? (see attached table for flip chart model). Relate features to makrets, users BREAK	current location (map tracking) route guidance current traffic real time guidance dynamic yellow pages emergency service call roadside assistance out-of vehicle: home, work portable theft alarm others... Important feature for almost all users Important to some users (which?) Important to few or no users Different features for different users?

Time	TOPIC	QUESTIONS	PROMPTS
E. 15 min.	Congestion information	Should new systems include current congestion and incident information? In what form?	maps colors numbers text voice others... , compare with broadcast radio on-demand; continuous
F: 15 min.	Route planning capability	We expect future systems to include a computer route planning capability; what should it be like?	minimum time routes? minimum cost routes? most direct route avoid certain road types (toll roads, expressways.. .) use local streets avoid certain areas learn my preferred routes (intelligent assistant) system-optimal routing Format: maps; arrows; voice

Time	TOPIC	QUESTIONS	PROMPTS
G. 10 min	Attributes	Now that we have identified some important features for in-vehicle route guidance systems, let us define what the attributes or characteristics of future system should be.	ease of data entry speed of operation readability north up, heading up, heads up distractions reliability installation effort and appearance.
H: 15 min.	Willingness to pay	How much people are willing to pay for these features?	New purchase of full dynamic system Monthly fee for dynamic data
I: 10 min.	Who will buy and use such systems	What kind of people will be the first buyers of such systems Will some people use these systems more than others?	intensive travelers insecure/secure travelers men, women older, younger people technology-oriented people technology buffs others... Who?

Time	TOPIC	QUESTIONS	PROMPTS
J: 10 min.	Risks	Do you see any major risks to drivers coming from these systems?	Distractions? How dangerous? How Ii kely? What can we do about this?
K: 5 min.	Do you have any other guidance for us?		
L: 2 min.	Wrap up	Thank you Compensation	

1. Total projected time: 2:00 hours

What features (services) and attributes should be included, excluded? (flip chart model)

	Important for All Users	Important to Some Users	Important to Few Users
Features			
Attributes			

APPENDIX J

ADVANCE

Advanced Driver and Vehicle Advisory Navigation Concept

Field Test of the Effectiveness of
ADVANCE Dynamic Route Guidance
on a Suburban Arterial Street Network
Evaluation Report
Document # 8463.01

Prepared by
Northwestern University Transportation Center

DISCLAIMER

ADVANCE

Advanced Driver and Vehicle
Advisory Navigation Concept

Field Test of the Effectiveness of *ADVANCE* Dynamic Route Guidance on a Suburban Arterial Street Network

ADVANCE Project Document # 8463.01

by

Joseph L. Schofer
Frank S. Koppelman
Regina G. Webster
Stanislaw Berka
Tsia-shiou Peng

Northwestern University
Transportation Center
Evanston, Illinois 60208

Executive Summary

The objective of this test was to determine the extent to which dynamic route guidance (DRG) as implemented *in ADVANCE* could provide useful route guidance to drivers based on information about current travel times which differ from historic travel times due to recurrent or non-recurrent (incident-induced) congestion. The test involved two components: (1) assessment of route quality benefits due to dynamic data under recurrent congestion; and (2) tests of the ability of *ADVANCE* DRG to detect and avoid simulated non-recurring congestion (incidents).

The primary test deployed three yoked vehicles traveling between 5 predefined origins and destinations (O-D pairs) in a congested part of the *ADVANCE* test area, a suburban region served only by arterial streets. Drivers of two of the vehicles (the dynamic vehicles) followed routes planned by the *ADVANCE* Mobile Navigation Assistants (MNAs) based on historic and limited real-time traffic information. The driver of the third (static) vehicle followed MNA-provided routes based only on historical, or static travel time information. Real-time traffic information was generated by a fleet of 18 *ADVANCE*-equipped probe vehicles, driven on routes designed to provide coverage of all reasonable arterial street links which might comprise alternative O-D paths for the dynamic vehicles.

Outcome measures were travel times and routes followed for static and dynamic vehicles, which were recorded by drivers and were written to memory cards in the vehicles. The expectation was that DRG would be successful if it could save time for the dynamic relative to the static vehicle by guiding the driver to a faster route.

Seventy-three origin-to-destination test runs were conducted on 5 O-D pairs; 19 incident simulation runs were also conducted, in which probe drivers were instructed to slow to minimum safe speeds on defined links to simulate roadway incidents. All three yoked vehicles in the simulation tests had real-time traffic information, and the outcome of interest was diversion from the incident links.

More data were available from driver reports than from computer records because of data losses due to equipment malfunctions and other factors. Based on driver reports, dynamic vehicles experienced statistically significantly shorter mean travel times than static vehicles for 2 of 5 O-D pairs; mean dynamic times were greater than or equal to static times for the other 3 pairs, but only one of these comparisons

was weakly significant. Qualitative analysis of individual test runs revealed cases where dynamically-guided vehicles saved substantial travel time; there were also cases where paths used by these vehicles took more time than paths based on static data.

Analysis of the more limited computer database showed significant time advantages for the dynamic cars for 1 of 5 O-D pairs. Because computer data often included only parts of O-D trips, a subset of data was extracted representing static-dynamic comparisons for at least 50% of the O-D travel time. In this case 3 of 5 O-D pairs showed significant mean travel time advantages for dynamically-guided vehicles. Finally, this reduced data set was further limited to only those cases where static and dynamic routes were different, since a routing difference would be expected to be the primary mechanism through which DRG produces an advantage. In this most stringent test, 4 of 5 O-D pairs showed mean time advantages for the dynamic cars, and one of these was statistically significant. Pooled results from all runs across all O-D pairs produced a time ratio of 0.963, a 4% time saving for the dynamic cars which was statistically significant.

The data used for the incident simulation tests came primarily from driver records of routes planned by the *ADVANCE* MNA, because few of the computer records could be retrieved. Diversions off the incident links occurred in a substantial proportion of trials (76%) only for one O-D pair. The other pairs showed little or no effect from the incident simulation. Analysis of the travel time updates (changes from static travel times) generated on the simulated incident links showed that these were on the order of 1 minute, which is too small to impact route planning.

These results suggest that route diversions and travel time savings are sometimes associated with the use of real-time data for route planning, but time savings, especially large savings, were not the typical outcome in these tests. Occasionally substantial time savings resulted from diversions. Such cases seemed to have occurred on highly congested routes in places where considerably longer, and less congested, links were nearby. Qualitative assessment of these diversion routes suggests that they were counter-intuitive (Le., orthogonal to the direction of O-D travel) and perhaps difficult to find without a computer-based route planner using real-time data. There were also cases where the dynamically-guided vehicles experienced longer travel times than the static cars.

That time saving diversions happened only occasionally in both the normal and incident simulation tests reported here might be explained by the network structure (availability of alternative routes) and travel times: there may have been few opportunities for saving substantial travel time on the short (-5 mile) test trips on this suburban arterial street network. On small, sparse networks the preferred route(s) may be quite superior to alternatives, unless there is some major disturbance which radically changes the time topology. It does appear that the DRG concept, as implemented in *ADVANCE,* can detect some larger delays and help drivers avoid them. The natural variability of network performance and data processing and transfer delays can be expected to produce some cases in which the DRG system provides inferior routes and travel times.

Among the other factors limiting the inferences which can be drawn for this test are:

Experimental process - limited probe vehicle coverage; data losses due to equipment malfunctions and data handling errors; insufficient real-time monitoring of data quality during the experiment; and variability in behavior of test drivers.

ADVANCE system - delays in collecting, processing, broadcasting, and utilizing real-time data; the route planning algorithm may have missed opportunities for time savings; and the travel time data fusion and forecasting algorithms may have provided inaccurate data.

Table of Contents

List of Figures

List of Tables

1.0 Introduction and Objective

Creating an effective way to provide dynamic route guidance (DRG), the use of real-time travel time information to support in-vehicle route planning, was a fundamental objective of *ADVANCE*. While other evaluation tasks have addressed the effectiveness of various components of the *ADVANCE* system, this report presents an empirical test of the *end-to-end* implementation of dynamic route guidance in *ADVANCE*. The results may provide guidance to others pursuing the development of DRG, suggesting potential benefits and limitations. This will complement the results of the assessment of driver response to the DRG concept [1].

The objective of this test is to determine whether, and the extent to which, dynamic route guidance (DRG), as implemented *in ADVANCE*, can provide useful route guidance to drivers based on information about current travel times which differ from historic travel times due to recurrent or non-recurrent (incident-induced) congestion. The test involves two components: (1) assessment of route quality benefits due to dynamic data under recurrent congestion; and (2) tests of the ability of DRG as implemented *in ADVANCE* to detect and avoid simulated non-recurring congestion (incidents).

ADVANCE was a probe-based route guidance system, *i.e.*, it relied almost entirely on probe vehicles as its source of real-time traffic information. In this test only 18 probe vehicles were used to collect real-time data. The *ADVANCE* test area was served primarily by arterial streets rather than freeways. The subnetwork used in this test included no limited access highways. Therefore, this is a limited test of a probe-based DRG on an arterial network. The generalizability of the results presented in this report to different settings, e.g., heavily detectorized freeways or very large probe fleets, is thus limited.

2.0 Organization of This Report

The next section of this report describes the test procedures actually followed and identifies some of the main threats to validity encountered. Section 4 presents results of the DRG tests in the context of normal or recurring congestion; results based on driver reports are presented first, followed by results derived from computer data. Section 5 reports results of tests in the context of non-recurring or incident-based congestion, using incident simulation experiments. Again, driver reports are analyzed first, followed by analysis of computer records. The last section of the report presents conclusions and interpretations of importance to future DRG development.

3.0 Approach

3.1 General Design of the Test

This test deployed a triad of yoked vehicles traveling between predefined origins and destinations (O-D pairs) in a congested part of the *ADVANCE* test area [2]. In the recurring congestion phase of this test, drivers of two of the vehicles (the dynamic vehicles) followed route plans offered by the *ADVANCE* Mobile Navigation Assistants (MNAs), which received real-time traffic information updates from the Traffic Information Center (TIC). The driver of the third vehicle (the static vehicle) followed MNA-provided route plans based only on historical, or static travel time information; this was accomplished by disconnecting the radio frequency (RF) modem in the static car so that no real-time data could be received.

Two dynamic cars were used in each O-D test to assure that all data from a particular test would not be lost if a single sole dynamic car failed due to high outside air temperatures or other factors, which was not improbable. Experience showed that the static car was less susceptible to malfunctions, perhaps because it did not rely on RF communications.

Real-time traffic information was generated by a fleet of 18 probe vehicles, also equipped with *ADVANCE* MNAs, driven on pre-designed routes in each of five test networks. The networks were defined to provide a set of logical alternative paths for the yoked cars to follow between origins and destinations. The 18 probe vehicles, in six groups of three vehicles each, followed routes designed to provide coverage of all reasonable arterial street links which might comprise alternative origin-to-destination paths for the dynamic vehicles. Probe coverage was designed to generate at least three probe travel time reports per link within a fifteen minute interval to assure that a representative travel time would be estimated in the TIC and transmitted to the dynamic vehicles'.

---

1 This frequency of probe reports was determined to be sufficient in Traffic Related Functions evaluation test performed by the University of Illinois at Chicago.

3.2 O-D Pairs and Probe Routes

O-D pairs were selected to be in the more congested part of the *ADVANCE* test area, to be separated by about five miles so that some routing alternatives might exist and so that at least three O-D pair tests could be run during a typical 4-5 hour afternoon work shift The set of O-D pairs was designed so that each destination for one test run was an origin for the next run; this facilitated conducting a sequence of tests during each work shift while limiting deadheading (non-productive travel). Locations of origins and destinations were fine-tuned to move them to or near retail establishments where drivers could make refreshment and rest stops. Specific staging areas for the drivers were selected based on field reconnaissance to assure a safe and adequate place to park 21 vehicles, as well as nearness to rest facilities. Sketch maps of the 5 O-D pairs and the primary arterial street test networks are in Appendix A.

At the start of each work shift, probe drivers each received a map book showing their routes for the day; a single map book included routes for all O-D pairs for one of the six probe run groups. Appendix B shows an example of all probe routes for a single O-D pair. During a given shift, each set of three drivers was assigned to a single run group (one through six); a run captain was selected for each group to assist in dispatching. A field coordinator, selected from among the drivers at the beginning of the test program, was responsible for dispatching the entire test fleet for each O-D test. This was done through cellular telephone coordination with the test manager in the TIC.

Probe vehicles were dispatched in advance of the yoked triad to generate travel time reports. Dispatch times, measured in minutes after the start of each test, were defined to assure probe coverage of the relevant links in the networks, including the far downstream links, before drivers of the dynamic cars planned their routes and began their trips to the destinations. The dispatch times were different for each probe vehicle, based on the route to be covered and the need to generate at least three passes per link per 15 minutes. These times were estimated from route maps prior to the start of tests, and then refined based on actual probe route completion times measured during a week of pilot testing at the start of the field effort. An example of the dispatch times is shown in Appendix C,

Yoked vehicles departed the staging areas only after the probe fleet had an opportunity to disperse across the test network, always at least 20 minutes after the initial probe vehicle began its run. Yoked triad drivers departed at l-2 minute intervals and were instructed not to follow each other, but to use the route provided by the MNA.

3.3 Driver Operations

All drivers were paid on an hourly basis. At the start of the test program, drivers were trained in a two-hour briefing followed by four days of pilot testing to work out test procedures and enhance driver skills. Once the test was underway, subsequent to a minor collision not the fault of the test driver, all drivers were given four hours of defensive driving instructions. No other crashes were experienced.

All vehicles were equipped with cellular telephones, which were used for communication with the test manager in the TIC and among cars as necessary for coordination. Drivers reported to the Project Office at the start of each shift (2:00 p.m. each weekday), where they were given instructions, told which O-D pairs would be run that day, issued their map books and run assignments, after which they signed out their test vehicles. Tests were initiated by the field coordinator upon instructions from the test manager in the TIC; tests began when all vehicles reached the staging area and their drivers were ready to proceed. Drivers called in by telephone to report arrival at the destination staging area. These times were systematically recorded by test personnel in the TIC, using the TIC computer clock for timing.

3.4 Test Management and Troubleshooting

A staff of 2-3 persons operated the TIC for these tests, initiating tests, recording test start and vehicle finish times, monitoring probe reports on the TIC computer, and helping drivers troubleshoot MNA and route finding problems via cellular telephone. By monitoring probe reports, the TIC staff could identify MNAs which were not reporting and contact drivers to resolve problems.

Because the test period, August and September of 1995, was one of the hottest summers on record in Chicago, many MNA malfunctions were experienced, and data to be collected at the time of such failures were lost. In some cases simply rebooting the MNA resolved the problem. In others, the units needed to be cooled by stopping the vehicle at the next staging area and opening the trunk where the primary electronic components were installed. Occasionally, it was necessary to contact the Motorola service representative, who would meet the problem vehicle at the next staging area to resolve the trouble. In a few cases, a test assistant in the TIC would take a replacement vehicle to the field to exchange it for the nonfunctioning unit.

TIC reports from probe vehicles, as well as calls from the drivers themselves and the run captains, sometimes identified cases where probe drivers went off route, and thus failed to generate needed data. Such occurrences declined as the tests proceeded because drivers were following repetitive routes and learned them well. Drivers who failed to follow the correct routes were instructed by telephone and in debriefings at the end of each work shift. One driver who could not follow the routes was released at the start of the test period.

3.5 Data Collection

Primary data collected for this test described routes (links traveled) and link travel times experienced by the yoked triad. Both routes and travel times were recorded on PCMCIA memory cards in the MNAs in these vehicles. These were downloaded from the cards on a weekly basis and assembled into a memory card database. The dynamic vehicles also transmitted their link traversals and travel times to the TIC as each link was completed. These were recorded in the TIC database of MNA reports. The static car operated with RF modem shut off, and did not transmit reports to the TIC. As a result, the memory card records, which included data from dynamic and static vehicles, were used in these analyses.

In addition, drivers of the yoked vehicles were instructed to record their routes on paper. These were turned in to the test manager on a daily basis. Good correspondence between routes reported by drivers and recorded on memory cards was observed. Test start times were recorded based on the TIC clock, as were run completion times both for probe vehicles and the yoked triad. Since these times were recorded between staging areas*, which were 2 or 3 blocks from the respective origins and destinations, they differ from times recorded on the memory cards between actual origins and destinations. While driver-reported times are less precise than computer-record times, we experienced no cases of lost data from the drivers, while there were numerous instances where link reports were missing from computer data.

---

2 Drivers could accurately and safely report staging area arrival and departure in their records; it was more difficult for them to consistently detect arrival at the origin or destination intersection while in motion.

3.4 Incident Simulation

Five days of testing at the end of the field work period were devoted to incident simulations. While the original plan was to divert the test fleet to nearby real incidents of substantial magnitude to determine if the DRG system could detect and avoid them, no appropriate incidents occurred during the first four weeks of field work. Specifically, no incidents were near enough to the fleet location to permit diversion to provide timely probe coverage and to dispatch the yoked triad through the incident site.

Instead incidents were simulated as follows:

(1) For each O-D pair, a path frequently followed by dynamic vehicles was identified based on previous test results.

(2) One link on each of these frequently-used paths was identified on which probe drivers could be instructed to travel slowly in a safe manner. This determination was made based on field observation. These were the simulated incident links.

(3) On the days of incident tests, all probe drivers whose routes were on these simulated incident links were instructed to drive on these links as slowly as safety permitted. They were told to turn on their hazard lights, move to the right lane, and reduce speeds to 10 mph or less. Where possible and safe, drivers were instructed to pull to the parking lane or shoulder and wait for periods of l0-15 seconds.

(4) A minimum of three probe vehicles simulated each incident; in most cases several probe routes traversed the incident links; each route through the incident link added three more slow probe vehicle reports. All other probe operations and procedures remained unchanged from the normal, recurring congestion tests described above.

(5) There was no static car; all vehicles in the yoked triad had powered RF modems and followed MNA-planned routes. The reason for this is that the real travel time experienced by a static car would not have reflected incident conditions, since there was no true incident. The outcome measure of interest in these simulations tests was not travel time, but whether or not the dynamically-guided vehicles would be diverted off the simulated incident link.

(6) The driver of one of the three dynamic vehicles remained at the origin staging area while the two others proceeded ahead on MNA-provided routes. The driver remaining at the staging area replanned the O-D route repeatedly throughout the test to take advantage of the developing travel time database generated by the probe runs. Only after the other two dynamic cars reached the destination staging area did the third dynamic car depart the origin staging area. The useful results from this stationary vehicle were in the repeated route plans recorded by the driver, not in the O-D traversal itself. Through this procedure, rather than having the results of only 3 route planning attempts, in some incident simulation runs the route was planned as many as 35 times.

3.7 Number of Test Runs

A total of 92 O-D pair tests were conducted, each using the fleet of 21 vehicles. These included one week of pilot testing and training in the middle of August of 1995, four weeks of normal (recurring congestion) tests beginning in the last week of August, and one week of incident simulation tests at the end of September. The distribution of these runs across the O-D pairs is shown in Table 1. The table shows that the productivity of the field test crew increased as the test proceeded; during pilot testing, only 2 or 3 O-D pairs were run in a single shift; eventually the drivers could reliably perform four tests per day. The third week was less productive because it included Labor Day. An average of 18.4 test runs were completed per O-D pair. Seventy-three normal (recurring congestion) runs and 19 incident simulation runs were accomplished.

3.8 Threats and Problems

A number of factors limit the results of this test. The primary limitation was the fact that much data were missing from the files. This is probably because data were not recorded to memory cards due to MNA malfunctions. General problems of reliability associated with the in-vehicle system were greatly exacerbated by high heat conditions during the tests. When an MNA malfunctioned, which occurred as often as 3-5 times during a 4+ hour works shift with 21 vehicles, this might not be discovered for 5-10 minutes when it was noticed that no report had been received at the TIC. At this point the driver was called, the problems discussed, and most commonly the MNA was rebooted. In the meantime the test proceeded. This could result in the loss of l0-20 minutes worth of data. There was no mechanism to provide rapid identification of malfunctioning units.

Table 1: DRG Yoked Driver Test Run Count Summary

Week	Task	O-D 1	O-D 2	O-D 3	O-D 4	O-D 5	Total
1	pilot testing	1	1	2	2	2	8
2	recurring congestion	3	3	5	2	2	15
3	recurring congestion	2	2	2	2	2	10
4	recurring congestion	4	4	4	4	4	20
5	recurring congestion	4	4	4	4	4	20
Total runs, recurring congestion		14	14	17	14	14	73
6	incident simulation	4	4	4	3	4	19
Grand Total		18	18	21	17	18	92

In some cases data were lost in the transfer from TIC files and memory cards to the project database maintained by Argonne National Laboratory, the evaluation manager. In a few cases data recorded under a modem identification number which should have been one of the yoked triad vehicles actually described the travel of a probe vehicle; this was an irrecoverable labeling error.

There were numerous instances where there was simply no record of a link traversal in the memory card file. It was clear from driver records, and from partial memory card records, that a link was traversed, but no record of the travel time was found. This forced much greater reliance on driver records than had been planned.

There were also limitations attributable to the design of the test. In the case of O-D pair 3, some of the dynamic routes actually used Palatine Road, a higher speed arterial 0.5 mile outside of the test network for this pair, and therefore for which there was no probe coverage. This problem might have been avoided had the routes actually traveled been downloaded and traced on a daily basis; however, attempts were made to extract and review data from the database quickly (e.g., overnight) but this process did prove to be practical.

Probe coverage was limited by the size of the available fleet initially and later by the number of available drivers. Because of congestion and traffic signals, probe vehicles sometimes “bunched,” which resulted in fewer independent measures of travel times, and thus a poorer sample. While probe dispatch times were carefully planned and adjusted early in the test, occasionally probes covered downstream links too early (so that the probe report “timed out” before the yoked triad could use it), or too late (so the dynamic vehicles could not avoid a congested link). This might have been solved with a substantially larger probe fleet (e.g., 50% larger) or with more finely adjusted dispatch times (e.g., changing the probe dispatch times by time of day as well as by O-D pair).

In some cases drivers made errors in their routes or dispatch times, which reduced probe coverage and data timeliness. Systematic and egregious errors were caught and used to instruct drivers; smaller errors may not have been detected.

Finally, the driving behavior of both probe and yoked triad drivers influenced experienced and reported travel times. Drivers normally drive at different speeds; a slow driver will generate long probe travel times or produce triad travel times which are long. The test management team in the TIC observed arrival times and watched for fast and slow drivers. When they were observed, they were reminded to drive at the speed of traffic around them. Driver assignments were shifted on a daily basis, but because the task for yoked drivers was more complex (involving more record keeping), the best drivers were kept on this assignment. Drivers were rotated between static and dynamic cars to diffuse some of the individual effects.

Because there is much variation in traffic flows and driver behavior, as well as functioning of the route guidance system, it was difficult to detect real effects, especially relatively small differences between dynamic and static cars. As a result, added emphasis was placed on “clues,” anecdotal indications that the DRG system may or may not be working.

4.0 Analysis of Normal O-D Pair Tests

4.1 Analysis of Data from Driver Reports

Table 2 summarizes results from driver reports, cellular telephone calls to the TIC defining times departing and arriving at staging areas at the start and end of O-D runs, respectively. Means and variances of O-D times for static and dynamic cars are reported, along with ratios of times (dynamic/static). Because two dynamic cars were used in almost all of the yoked tests, two ratios were usually available, dynamic-l/static and dynamic-2/static. This increased the number of available dynamic-static paired tests, denoted by values of "n" in the table, by almost a factor of 2.[3] The ratio of times was used as the outcome measure rather than the difference so that data from all O-D pairs could be combined for an overall evaluation.

When the dynamic vehicle experienced a shorter travel time than the static car, the time ratio is less than 1.0. This occurred only for O-D pairs 4 and 5; O-D pairs 1 and 3 showed time ratios greater than 1.0, meaning the static vehicles experienced shorter travel times. The 0.90 time ratio reported for O-D pair 5, generally the most congested of the pairs, was highly significantly different from 1.0 (significance level approximately 0.006).[4] Since there were many sources of variation in this test, it is not unreasonable to assess results at a lower level of significance. At the level of 0.15,[5] both O-D pairs 1 and 4 show significant differences from 1.0, but pair 1 produced shorter static times, a result counter to expectations.

Yoked drivers recorded their routes on paper; these were compared for static-dynamic pairings to determine route similarity. If static and dynamic routes are the same (given that vehicles depart within about a 3 minute interval), the travel times are

---

3 Values of n in Table 2 are not exactly 2 times the number of O-D runs for each pair because of driver errors, equipment malfunctions and data losses.

4 "Significant" means statistical significance; if static and dynamic travel times are significantly different, there is a high probability that this difference is real, not due to random variation. Significance was determined using a t-test of the difference between the ratio of static:dynamic time and 1.0, in which a test statistic, t, was compared with a critical value oft, t*, from a statistical table. The observed difference is significant if $|t| > |t^*|$.

5 That is, there is a 15% chance that a ratio which is less than 1.0 is really from a distribution with true mean > 1.0.

less likely to be different than if the routes are different. Table 2 shows the number of paired tests (dynamic-static) in which the routes were different by at least one link. For O-D pair 4, static and dynamic routes differed in only 20% of the cases. For O-D pair 1, routes differed in nearly 79% of the cases. These results are contrary to expectations: where travel times differ most, routes would be expected to differ most.

One explanation for this is that travel time for a small number of trials (static-dynamic pairings) may have important effects on the mean values of the time ratios. Figures l-5 show actual driver-reported travel times for static and dynamic cars for O-D pairs 1 through 5. From these, several outcomes of interest were selected; these were cases where the static time was substantially greater than the dynamic time, or vice versa. Table 3 shows 13 such cases. In the first 8 cases, static times were substantially longer than dynamic times. In all but one of these instances, dynamic and static routes were different. In some cases, notably for the highly congested O-D pair 5, the dynamic routes were substantially different and longer in terms of distance. This additional length avoided the most congested part of the trip (westbound along Lake Cook Road). Time savings, measured as static time less fastest dynamic time, ranged from about 30 to 50% of the static times.

This suggests that real-time traffic information may occasionally produce substantial travel time savings, although in these experiments it did not produce regular and repeatable savings. Table 3 also shows five cases in which at least one of the dynamic vehicles experienced longer travel times than the static cars. The potential contributing factors, which may cause or discourage time savings based on dynamic route guidance, are several, and the conditions of this experiment do not permit us to sort out causality. These factors include:

- The conditions of the experiment may have infrequently produced enough real-time information to identify opportunities for time savings ***(i.e.,*** insufficient probe coverage).

- High trip time variability, due to such factors as traffic signals, may have caused vehicles following each other at intervals of only a minute or two initially to experience substantially different travel times.

- Variations in driver behavior and report may have affected results.

Table 2: Driver-Reported DRG Travel Time Results

Measures		O-D Pair 1	O-D Pair 2	O-D Pair 3	O-D Pair 4	O-D Pair 5	Overall
static travel time	mean	17.36	21.92	12.8	21.57	29.31	20.33
	variance	12.80	17.76	3.36	18.96	76.21	54.98
dynamic travel time	mean	19.04	21.36	13.0	20.35	25.85	19.68
	variance	21.81	20.73	6.56	22.38	51.76	42.26
ratio: dynamic/ static	mean	1.11	1.00	1.04	0.956	0.90	1.00
	variance	0.14	0.02	0.04	0.02	0.03	0.06
	n	27	26	29	26	25	133
difference: static-dynamic	mean	-1.37	0.19	-0.77	1.04	3.48	0.44
	variance	21.49	9.92	10.85	11.96	33.93	20.13
	n	27	26	29	26	25	133
static, dynamic routes different	# paired tests	28	28	31	25	27	139
	# different	(7 8 . 6 ;	14 (50.0%)	20 (64.5%)	5 (20.0%)	(40.72)	72 (51.8%)
t-value, static/dynamic times Significance level of difference, if any		-1.51 0.15	0.31	-1.23	1.50 0.15	2.92 0.006	0.20
% tests dynamic faster		40.74%	42.31%	24.14%	50.00%	60.00%	42.86%

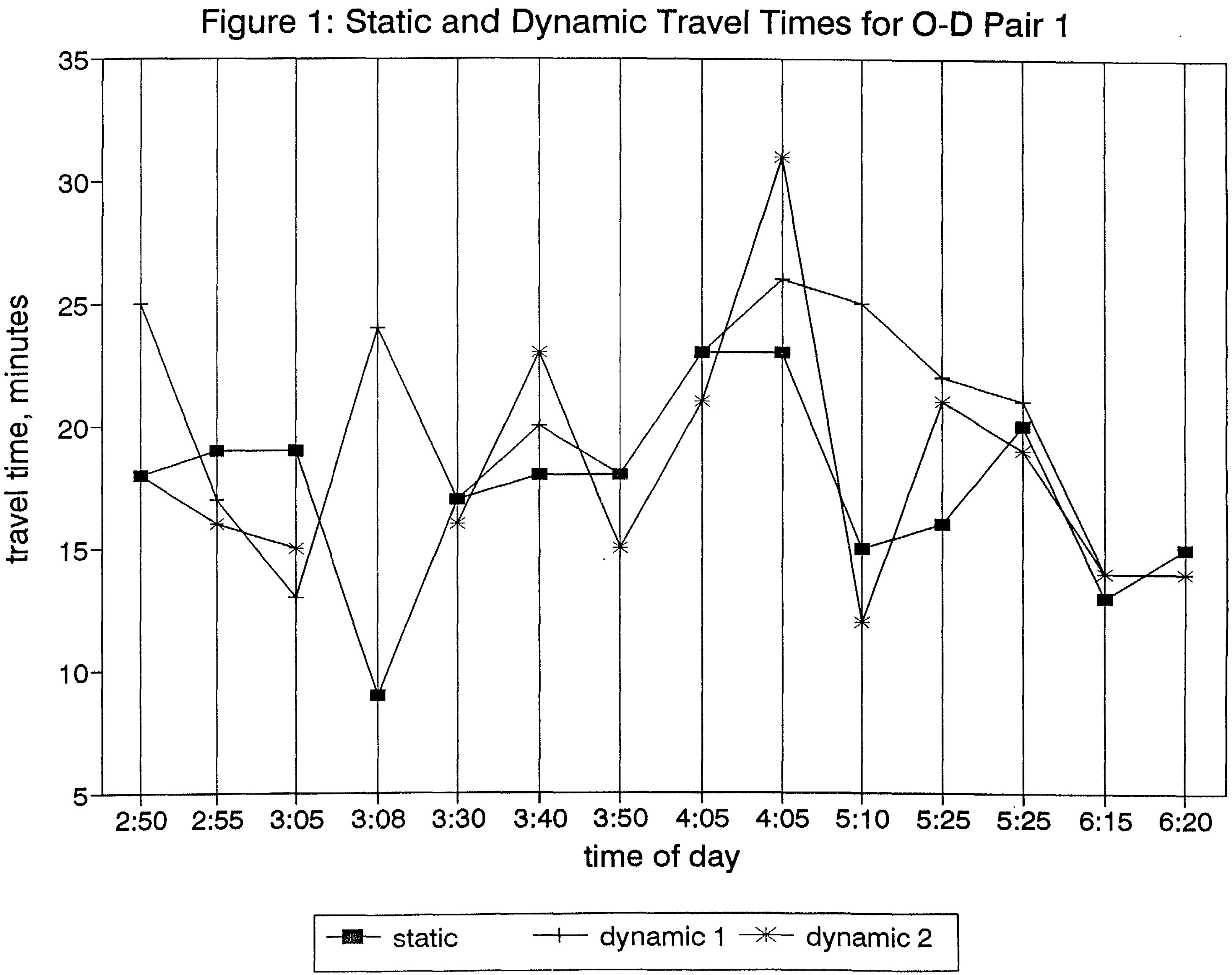


Figure 1: Static and Dynamic Travel Times for O-D Pair 1
35
30
25
20
15
10
5
travel time, minutes
2:50
2:55
3:05
3:08
3:30
3:40
3:50
4:05
4:05
5:10
5:25
5:25
6:15
6:20
time of day
static
dynamic 1
dynamic 2

Figure 2: Static and Dynamic Travel Times for O-D Pair 2

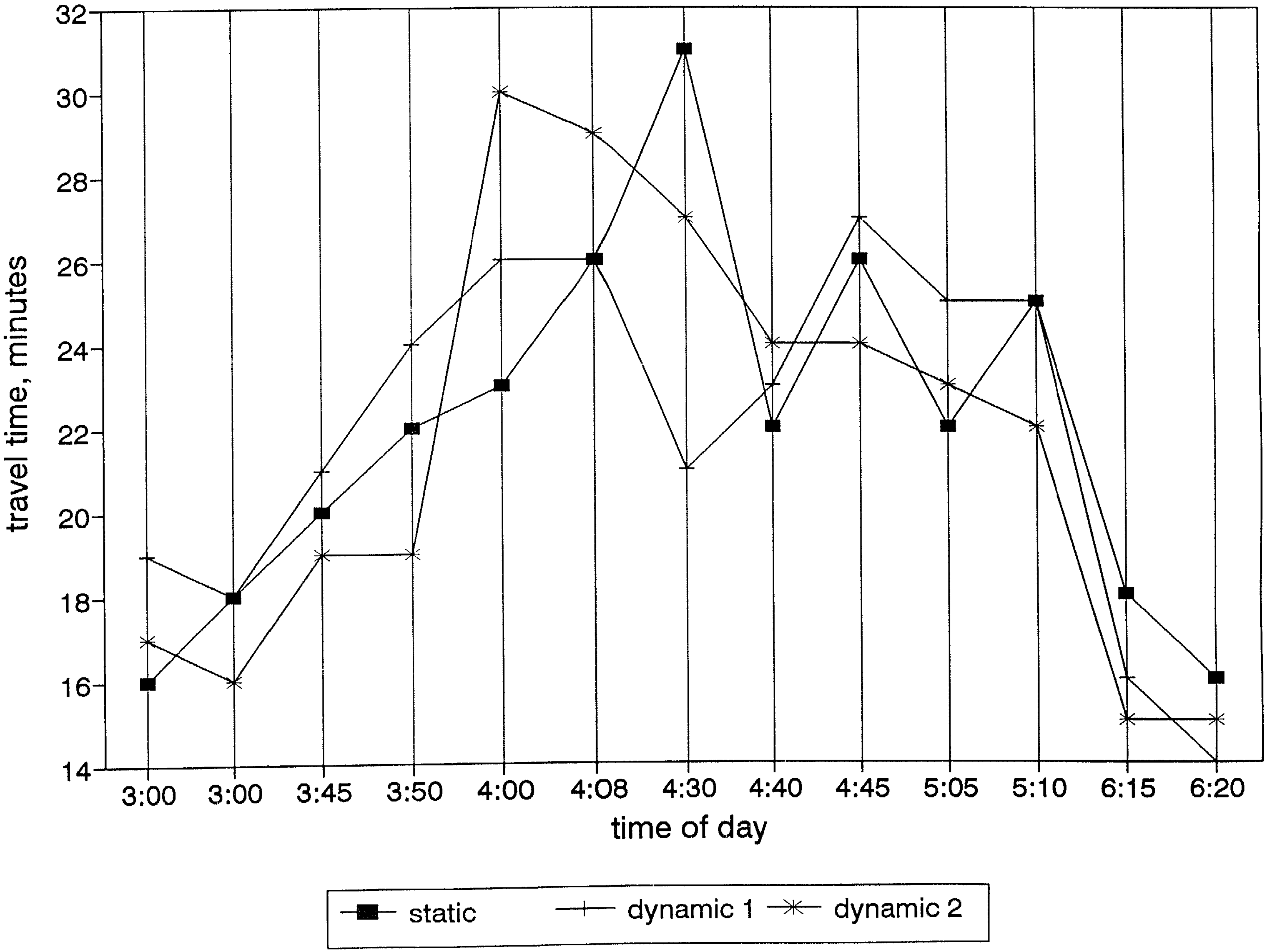


Figure 3: Static and Dynamic Travel Times for O-D Pair 3

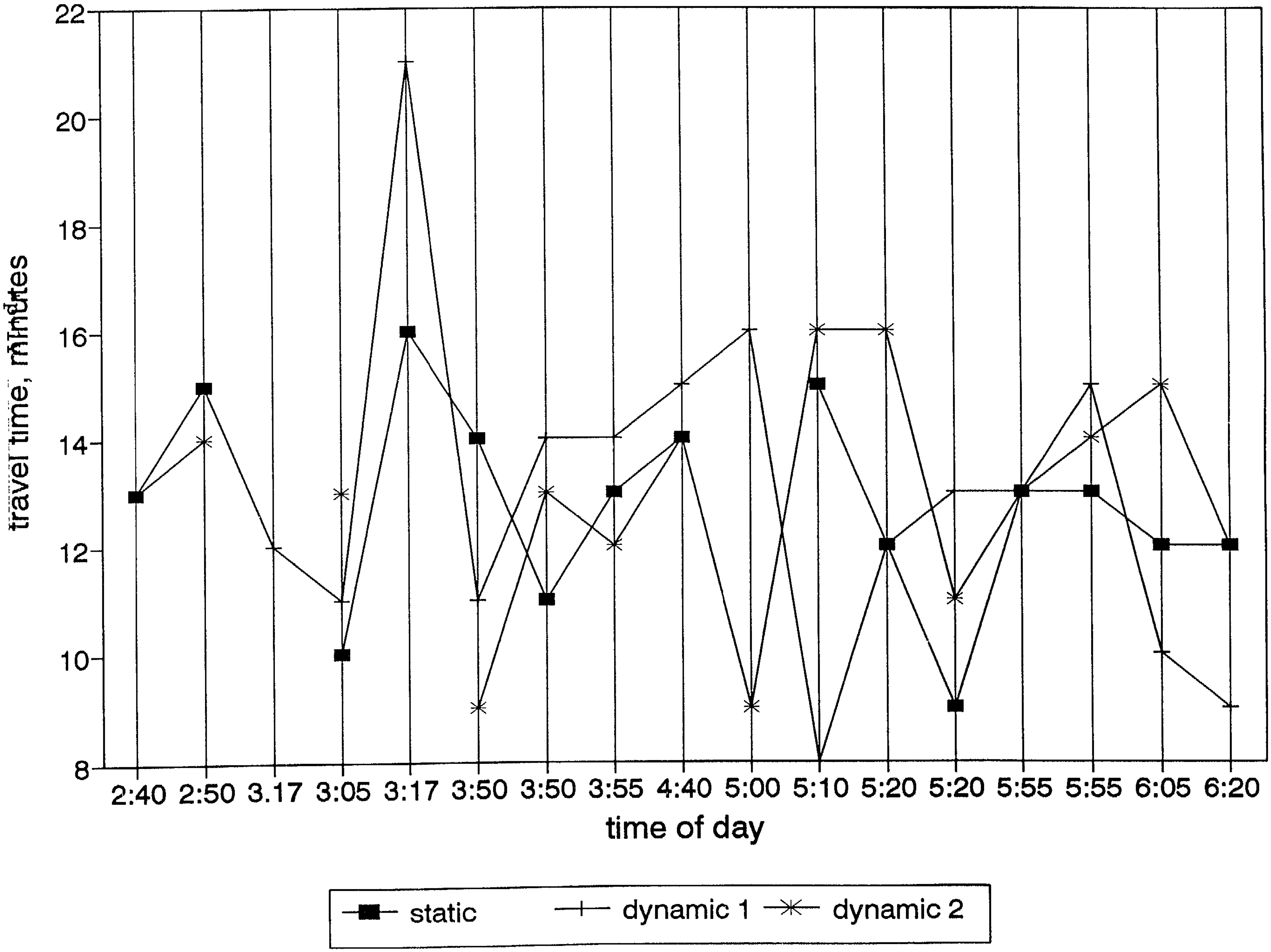


Figure 4: Static and Dynamic Travel Times for O-D Pair 4

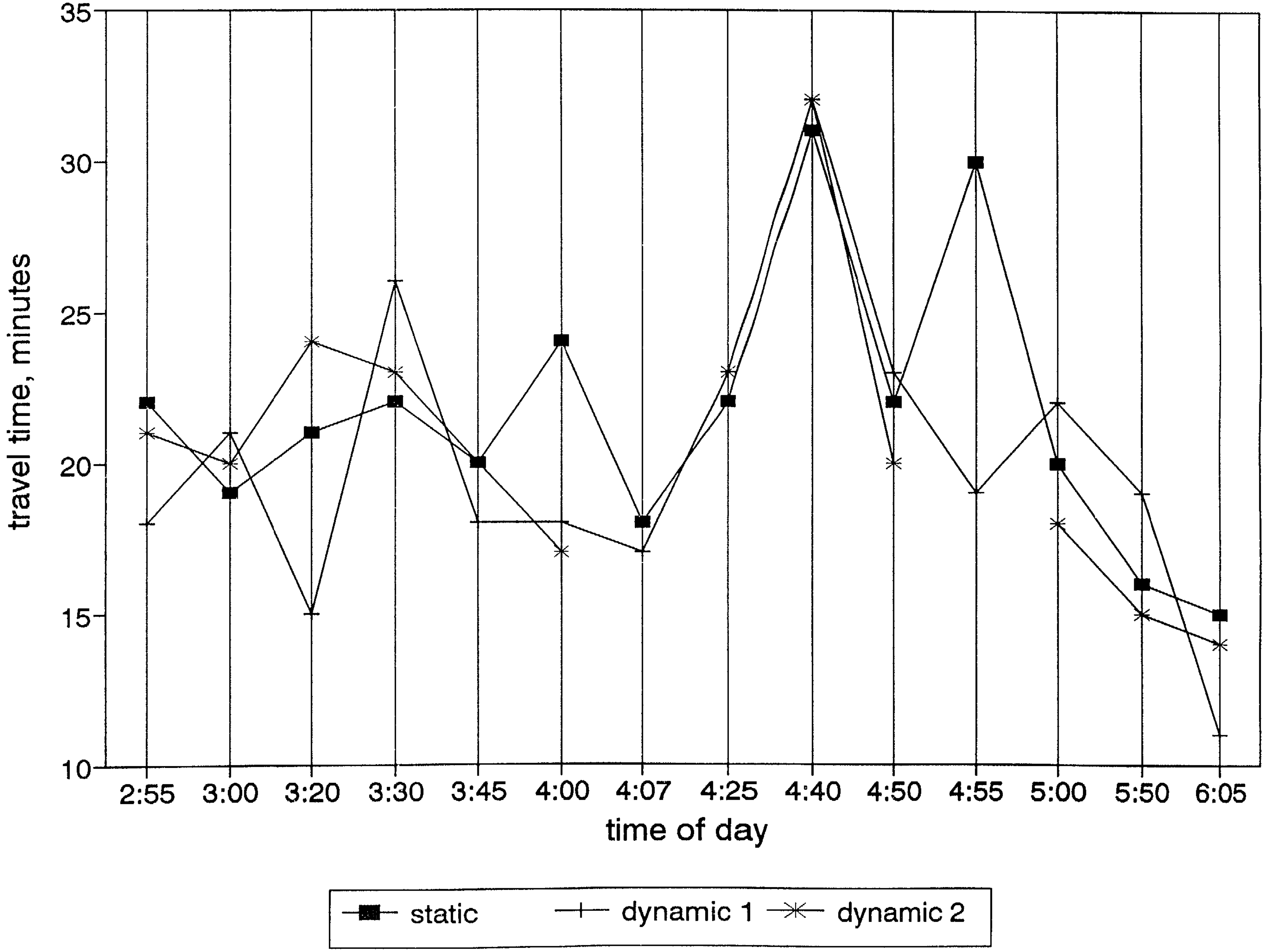


Figure 5: Static and Dynamic Travel Times for O-D Pair 5

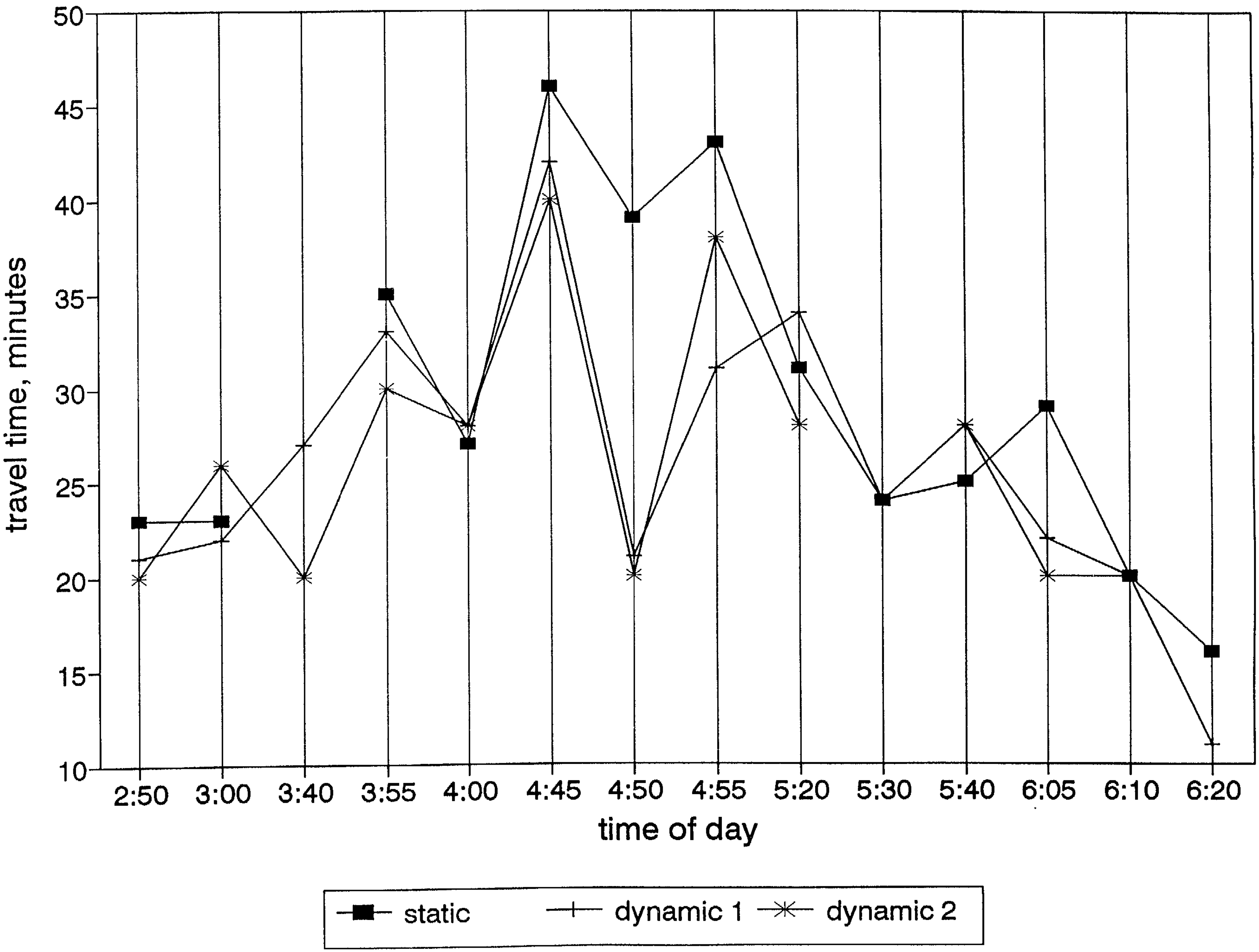


Table 3: O-D Tests with Large Dynamic-Static Times Differences

O-D pair	Time of day (p.m.)	Routes different?	Time saved (minutes)	Savings as % of static time	% of tests for this O-D pair
Dynamic car faster					
1	3:05	yes	6	32%	4%
2	4:30	yes	10	32%	4%
3	5:10	yes	7	47%	3%
4	4:00	yes	7	29%	8%
4	4:55	not recorded	11	36%	
5	4:50	yes	19	49%	12%
5	4:55	yes	12	28%	
5	6:05	yes	9	31%	
Static car faster					
1	2:50	yes	7	39%	15%
1	3:08	yes	15	167%	
1	4:05	yes	8	35%	
1	5:25	no	6	38%	
2	4:00	yes	7	30%	4%

- Short trips, network structure and travel time patterns may not provide many opportunities for substantial time savings.

- Because of limitations built into the route planning algorithm, it may not have found many opportunities for time savings.[6]

6 The route planner was designed to favor the use of arterial streets instead of local streets where possible.

- The potential for time savings may be greater in the case of non-recurring (e.g., incident-induced) congestion than for recurring congestion, because recurring congestion is eventually reflected in the static profiles (historical travel time database), and so the static car has access to this information.

Whatever the cause, occasional substantial savings were observed in these driver-reported data.

4.2 Analysis of Data from Computer Records

Origin-destination travel time data were also extracted from computer records of vehicle traversals to get a more accurate measure of comparative travel times. Data were record in Traffic Information Center (TIC) files based on radio frequency (RF) reports from the vehicles when they completed link traversals. These were not recorded for the static cars, which had their RF modems disconnected to prevent them from receiving real-time travel time updates. Link traversal records, including link identification and times, were also written to on-board memory cards for both static and dynamic cars. These data were downloaded and archived weekly and were the basis for this analysis.

We expected that the memory card data would be substantially better, i.e., more complete and accurate, than driver-reported data. While there is no evidence that these data are inaccurate, there were many missing data items which limited this analysis. Among the problems discovered were:

- Missing reports: many link traversal reports from yoked vehicles were missing; that is, vehicle tracks would end at one point on the network and begin at another several blocks downstream, with no data over the intervening distance.

- Mislabeled reports: for example, on one day reports from a probe vehicle, following a looping route to provide network coverage, were filed under the modem identification of a yoked car, and no reports were found from the yoked car itself. When this was discovered, a decision was made to trace all memory-card-recorded yoked vehicle paths by hand on a network map to verify that the path was logical for a yoked vehicle.

- Common points: to compare dynamic and static travel times, it was intended that timing begin and end at the pre-defined origins and destinations. In some cases, however, no reports were recorded of vehicles passing the actual origins and destinations. As a result, it was necessary to use the hand tracing of routes to identify common timing points for dynamic and static vehicles. Some of these common points were the defined origins and destinations; many were not.

  Because even for a single O-D pair the common timing points differed from day to day, the ratio of dynamic to static travel times was used as a measure of effectiveness, rather than the difference, so that all data for a given O-D pair could be pooled for analysis.

- Sufficiently long common paths: Visual analyses of the mapped paths of yoked vehicles revealed that in some cases the actual distances between common timing points for dynamic and static vehicles were very short. When distances were short, the prospects for detecting meaningful routing and travel time differences were dim. A subset of the data was extracted to include only the travel tunes between common points which represented at least 50% of the O-D static vehicle travel time. This reduced the available data set by as much as 50%. Analysis was done on both this subset and the full data set.

For all of these reasons, the number of meaningful data points derived from computer files was considerably less than the number gathered from driver records. Table 4 shows the data and resulting analyses. Results are reported separately for cases where static and dynamic routes were the same and different. Logically, if dynamic route guidance produces a time savings benefit, it would be expected to do this by directing the dynamic car to a different route than that used by the static vehicle. Thus, a solid "win" for dynamic route guidance occurs if (1) there was a statistically significant travel time savings; (2) the routes were different, and (3) there was at least 50% time overlap. This is a stringent requirement given all of the uncertainties in this test. Significant differences when the routes are identical are apparently favorable but difficult to rationalize. Significance was tested using a one-tailed t-test, where the hypothesis is that the ratio of dynamic to static travel times is less than 1.0. The null hypothesis is that the ratio is 1 .O or larger. A significance level of 0.1 is used, which means that there is only a 10% chance that a difference as large as that observed would occur when the static and dynamic times were in fact drawn from distributions with the <u>same</u> means. That is, there is only a 1 in 10 chance that a difference reported as significant is not. This is a liberal criterion, but it is reasonable given the uncertainties associated with these data.

Table 4: Dynamic-Static Travel Time Comparison (Computer Data)

	Sample	Ratio of mean travel times, dynamic/static	Standard deviation of travel time	t-statistic (critical t)
O-D Pair 1: all tests				
routes same	12	0.972	0.216	-0.449 (-1.363)
routes different	11	0.858	0.293	-1.607 (1372)
all routes	23	0.918	0.257	-1.530 (-1.321)
O-D-pair 1: 50% time overlap				
routes same	6	0.943	0.103	-1.356 (-1.476)
routes different	7	0.856	0.319	-1.194 (-1.444)
all routes	13	0.896	0.240	-1.562 (-1.365
O-D Pair 2: all tests				
routes same	13	0.996	0.144	-0.100 (-1.356)
routes different	2	0.996	0.055	-0.103 (-3.078)
all routes	15	0.996	0.134	-0.116 (-1.345)
O-D Pair 2: 50% time overlap				
routes same	10	0.941	0.098	-1.904 (-1.383
routes different	2	0.996	0.055	-0.103 (-3.078)
all routes	12	0.95	0.093	-1.862 (-1.363)

Table 4: Dynamic-Static Travel Time Comparison (Computer Data)

	Sample	Ratio of mean travel times, dynamic/static	Standard deviation of travel time	t-statistic (critical t)
O-D Pair 3: all tests				
routes same	17	1.039	0.190	0.846 (1.337)
routes different	3	0.899	0.299	-0.585 (-1.886)
all routes	20	1.018	0.206	0.390 (1.328)
O-D Pair 3: 50% time overlap				
routes same	14	1.052	0.208	0.935 (1.350)
routes different	3	0.899	0.299	-0.585 (-1.886)
all routes	17	1.025	0.223	0.462 (1.337)
O-D Pair 4: all tests				
routes same	15	0.969	0.191	-0.629 (-1.345)
routes different	2	1.174	0.068	3.619 (3.078)
all routes	17	0.994	0.192	-0.129 (-1.337)
O-D Pair 4: 50% time overlap				
routes same	14	0.974	0.197	-0.493 (-1.350)
routes different	2	1.174	0.068	3.619 (3.078)
all routes	16	0.999	0.197	-0.020 (-1.341)

Table 4: Dynamic-Static Travel Time Comparison (Computer Data)

	Sample	Ratio of mean travel times, dynamic/static	Standard deviation of travel time	t-statistic (critical t)
O-D Pair 5: all tests				
routes same	15	0.974	0.237	-0.425 (-1.345)
routes different	2	1.33	0.821	0.568 (3.078)
all routes	17	1.016	0.325	0.203 (1.337)
O-D Pair 5: 50% time overlap				
routes same	11	0.927	0.075	-3.228 (-1.363)
routes different	1	0.749	--	--
all routes	12	0.912	0.088	-3.464 (-1.363)
O-D Pair 1-5: all tests				
routes same	72	0.992	0.195	-0.348 (-1.294)
routes different	20	0.957	0.341	-0.564 (1.328)
all routes	92	0.984	0.234	-0.656 (-1.291)
O-D Pair 1-5: 50% time overlap				
routes same	55	0.975	0.160	-1.159 (-1.297)
routes different	15	0.918	0.267	-1.189 (-1.345)
all routes	70	0.963	0.187	-1.665 (-1.294)

Using data from all tests, a travel time ratio significantly less than 1.0 was found only for O-D pair 1 (shaded cells). O-D pairs 2 and 4 show time ratios less than 1.0 but the differences are not significant. Considering only cases where static and dynamic routes were different, O-D pair 1 again shows a ratio significantly less than one, but for O-D 4 it is significantly greater, though the latter is based on only two data points. When we examine only tests which cover common points representing at least 50% of the static travel time between origins and destinations, a more stringent test, O-D pairs 1,2 and 5 show mean travel time ratios significantly less than 1.0.

The final, most challenging test isolates only those cases where dynamic and static vehicles traveled different routes. With the exception of O-D pair 4, all other pairs show mean dynamic/static travel time ratios less than 1.0: 0.856; 0.996; 0.899; and 0.749. However, none of these is significantly less than 1.0. This is at least partly attributable to small sample sizes and associated larger standard deviations.

The aggregate data set, combining tests across all five O-D pairs, shows a mean travel time ratio of 0.918 for cases where static and dynamic routes were different. While this implies an 8% time savings for the dynamically guided vehicle, the ratio is not significantly less than 1.0 because of the small sample (only 15 of 92 total test runs) and relatively high standard deviation. Table 4 shows that the mean travel time ratio for all runs, with both the same and different routes, is significantly less than 1.0. This is because the ratios for cases where routes were both the same and different were less than 1.0 and the standard deviation was considerably less than for cases where the routes were the same.

It is not clear why in so many cases (O-D pairs 1,2 4 and 5, as well as all pairs) the dynamic cars averaged shorter travel times than the static cars and yet the routes followed were the same. This might occur if the driver of the dynamic car was always the same person, who drove faster than the driver of the static car.

During the field tests, a relatively small group of the more responsible drivers was typically assigned to drive the yoked cars, but efforts were made to rotate drivers between static and dynamic cars. Of two drivers who regularly drove the yoked cars, one drove the static car on four days and the dynamic car on 3 days. The other drove the static car seven days and the dynamic car six days. This is a rather even match. Another driver who was initially observed to be a bit slower than the others drove the static car eight days. Early in the test period this driver was reminded of the need to keep pace with traffic, and he did not appear to be relatively slower through the remainder of the test. Thus driver assignment was probably not an important threat to validity.

It is possible that the dynamic cars “beat” the static cars on some occasions because test administrators telegraphed their expectations that dynamic data should lead to shorter travel times. However, the instructions to drive with the flow of traffic, not to race, and not to follow other test cars were repeated to test drivers on a regular basis. While we believe that the yoked drivers followed this admonition, we cannot eliminate the possibility that they acted to bias the outcomes.

The statistical results of these tests are weak primarily because of the conditions of the test. They suggest a modest tendency for the dynamic car to have shorter travel times than the static cars; yet there are numerous cases where the static cars did better. In a number of the cases in which the dynamic car was faster, the vehicles took the same route anyway. For all cases, and for cases where routes differ, 3 of 5 O-D pairs showed time ratios less than 1.0 (one is significantly less). Where routes had at least 50% time commonality, 4 of 5 O-D pairs showed favorable travel time ratios and three of these are significant. All data pooled showed a time ratio of 0.963, which is significantly less than 1.0.

4.3 Analysis of Travel Time Updates

To explore the effect of real-time traffic information in more detail, we examined the travel time update messages sent from the TIC during the DRG test. Software in the TIC computer processes travel time reports received from probe vehicles, as well as traffic flow measures from a small number of pavement detectors for closed loop signal systems in the test area, to produce an estimate of current travel times on each link for which such data are available. If these travel times differ sufficiently from the times recorded in the historic data base (static travel times), an update message with new travel times is broadcast from the TIC. These updated link travel times are used by *ADVANCE*-equipped vehicles for route planning and replanning.

We would expect reroutes, which in turn might save travel time, if real- time data reported by the fleet of 18 probe vehicles in the DRG test showed sufficiently large increases in O-D travel time on the route planned with the *ADVANCE* system using only static travel times.

Travel time update reports sent to *ADVANCE* vehicles during each of the O-D test runs were extracted from computer files. Reports were considered only if they were transmitted within a fixed time window for each O-D pair. For example, only reports transmitted at least 20 minutes after the start of a test were considered, since the yoked cars did not begin their runs until 5-10 minutes beyond the twenty minute starting delay. Early update reports would be irrelevant, because update information is timed out using a decay function so that within 15 minutes an update has no effect and (in the absence of additional updates) assumed link times revert to the historic times.

Updates which occurred beyond some longer fixed interval after the tests began were also ignored. This interval was determined based on typical arrival times at the destination. Combining the starting delay, "a" minutes from the start of the test, and ending cutoff, "b" minutes from the start of the test, the following time windows were used to measure link travel time updates, where t = start time of a particular test:

O-D Pair	Start time	Ending time
1	t + 20 minutes	t + 60 minutes
2	t + 20 minutes	t + 60 minutes
3	t + 20 minutes	t + 45 minutes
4	t + 20 minutes	t + 60 minutes
5	t + 20 minutes	t + 70 minutes
generally	t + a minutes	t + b minutes

Update reports contain four travel time estimates for each link; these are an estimate of current time and forecasts of travel times for three additional five minute intervals. The latter information was available for the route planner to use in "looking ahead" to links which would not be traversed for several time intervals. The updates form either an ascending or descending trend, e.g., an update for link segment 88e399-92683a was 38 (seconds increase) at 17:25:01; 23 at 17:30:01; 13 at 17:35:01; and 8 at 17:40:01. The route planner as implemented used only the initial link time estimate, ignoring the forecasts.

We developed the following unified measure of updates:

$$update\ measure = \sum_{i=1,n} \frac{\sum_{j=t+a,t+b}(1^{st}\ update\ component\ [link\ i,\ time\ j])}{(b-a) * 0.2}$$

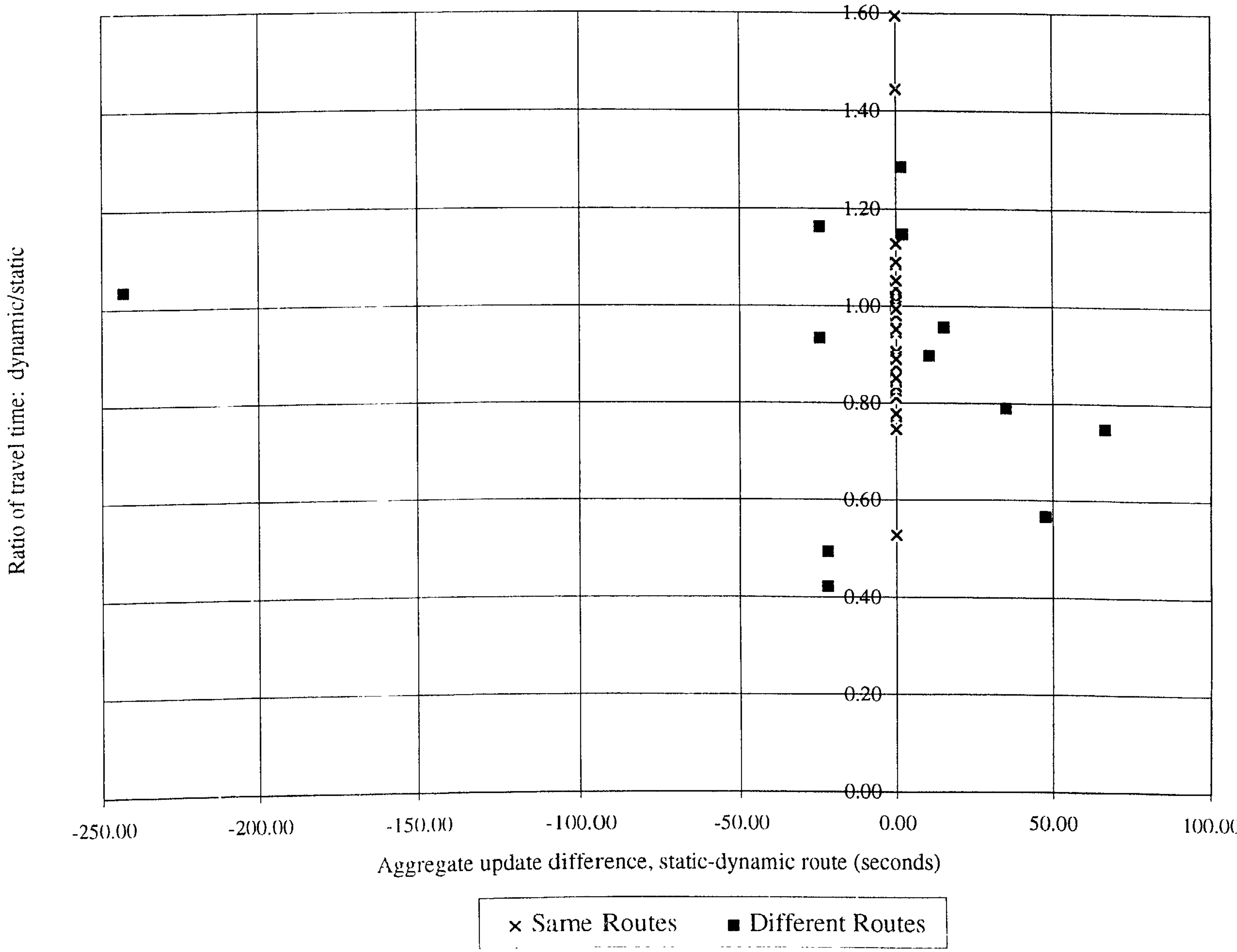
This is the sum over all links in the O-D path of the average first component update for each link over the time window as defined above, where the start time is t + a, the ending time is t + b, and n is the number of links in the path between common points. the denominator, (b-a)/5, is the number of update intervals. The path was known because it was recorded for both static and dynamic vehicles. We extracted the update messages in the time window for each link in the path. The first component of this four part message was averaged over the sequence of five minute intervals in the time window. These average updates were then summed across all links in the path.

There is the possibility of updates for both the static and dynamic paths. The measure used to represent the potential advantage of one path over another (*e.g.*, dynamic over static) is the difference in the update measures for these paths: static update - dynamic update. If the dynamic vehicle is to divert from its "normal" path based on historic travel times, it should be expected to find a time advantage. This could result if update on the static path increased (longer travel time), the update on the dynamic path decreased (shorter travel time), or both.

If the paths were the same, of course, this measure would be zero. There were several cases where no update record was found, either because no update was transmitted or because the data were lost.

Figure 6 shows the relationship between the update measure defined above, the net update, on the horizontal axis, and the travel time ratio (dynamic/static) on the vertical axis. These data points represent only cases where dynamic travel times were 50% or more of static times between common points on the O-D trip. There are too few data points to support statistical analyses. The cluster of points on the vertical axis (static-dynamic update values = 0) are mainly the cases where the routes were identical. The distribution of travel time ratios seems randomly arranged around 1.0. The pattern of data points in cases where the static and dynamic routes are different is ambiguous. We would expect a pattern which slopes downward to the right: as the difference between static and dynamic updates becomes increasingly large, the possibility of the dynamic car saving time increases and therefore the travel time ratios should decrease. Figure 6 does not deny that expectation, but it offers at best weak support for it.

Figure 6
Travel Time Ratios and Net Updates: O-D 1-5



The differences in the updates are very small, mostly under a minute. This is a small time differential which is not likely to offer much, if any, real time savings when one considers that missing or making a single traffic signal could make a difference of 2-3 minutes per trip. A separate analysis of updates on dynamic routes alone, using the same measure, produced a distribution of values from about -50 seconds to 1300 seconds (22 minutes), with the vast majority between zero and 180 seconds. If the path chosen for use showed such large increases in time, presumably the static path showed as large or larger time increases, or it was already an inferior path, though it was based on historic travel times. This may suggest that the static travel times were poor estimates of real travel time. It also implies that there may not have been substantially better paths for these O-D pairs, in terms of the potential to save much travel time, than the path based on static times.

4.4 Interpretation

Results from all of these tests suggest that real-time information can sometimes provide a travel time advantage. Data recorded by test drivers show this best, because they are most comprehensive. Significant time advantages are shown for 2 of 5 O-D pairs. Anecdotal evidence shows that substantial time savings were achieved on some occasions, but substantial losses were also experienced by dynamically-guided vehicles.

The statistical evidence from the computer (memory card) data is thin, because a variety of losses left only a small data set. Using only cases where common end points were relatively widely separated and static and dynamic cars used different paths, data from 4 of 5 O-D pairs showed time advantages for the dynamical vehicle; these differences suggest a potentially important trend but the results were not statistically significant. Pooling the data across all five O-D pairs produces similar results: the ratio of dynamic to static travel times is less than 1.0 (0.918), but the difference is not significant.

The relationship between travel time updates and dynamic/static time ratios is weakly visible in graphic form, but it does not support statistical evaluation.

A variety of confounding factors may have contributed to these results. They include:

- The initial data set was very small. The data set collected in the field was scaled based primarily on the availability of *ADVANCE*-equipped test cars.

- Data losses were substantial. Some were caused by malfunctions of the in-vehicle systems due to excessive heat and other factors. These resulted in failure of the whole system and /or failure to write to the memory cards. Some data were lost in the conversion process between memory cards and the *ADVANCE* database. In some cases problems were associated with the database itself, where some vehicle identifications were mislabeled, and thus vehicle tracks were misfiled.

- Routes provided by the *ADVANCE* route planner may have been inferior in some ways. For example, there might have been some bias in route quality which reduced the possible advantage for dynamically guided vehicles. Because the route planner itself was not separately evaluated, this possibility cannot be confirmed.

- The Traffic Related Functions (TRF) travel time data fusion and forecasting algorithms may have been deficient. Current travel time estimates and short-term predictions may have been of limited quality, reducing the advantage to the dynamically-guided vehicles. These are evaluated in separate reports [3] [4].

- The quality and quantity of real-time information was low because of limited probe coverage and density. More probe vehicles, and perhaps more precise scheduling of probe traversals, might have provided a more accurate database for route planning.

- Better (faster) routes may not have been (typically) available. The O-D pairs selected, and the associated intervening networks, may not have provided any, or many, routing options which would produce time savings. The sparse arterial network structure and general level of congestion on all links would be contributing factors to this threat.

5.0 Analysis of Incident Simulation Tests
5.1 Analysis of Data from Driver Reports

The only data used to evaluate the incident simulation tests were the routes planned by the *ADVANCE* unit based on real-time traffic information. Travel times experienced by the yoked vehicles were not relevant, because the probe vehicles generated reports of simulated incidents. The yoked vehicles following these probes would experience normal travel times. Thus, the relevant outcome measure is whether the dynamically-guided vehicles were diverted from the simulated incident path by the false, slow probe reports. Table 5 summarized the results of these tests.

The first row shows the number of route planning attempts, *i.e.*, the number of separate times the route was planned during tests of each O-D pair. As described in section 3.6, all three of the yoked cars had access to real-time traffic information. Drivers of two of these cars planned their routes after the predefined delay period to allow probes to cover the network, and then they began their trips to the destination. The third yoked driver stayed at the origin and periodically replanned the route to take advantage of the developing travel time data base. This generated many route planning attempts.

The second row of the table records the number of cases in which the yoked vehicle was diverted from the simulated incident link. Desirably this share of diversions should be high. The actual values ranged from a low of just over 8% to nearly 76% of the route planning attempts. Only in the case of O-D pair 4 were more than half of the attempts diverted from the incident links.

This can be compared with the third row of Table 5, which shows the percent of normal route planning attempts, from the first part of the DRG field test, which did not route the yoked vehicles through the incident links. The expectation is that when an incident was simulated, the dynamically-guided cars would tend to avoid the incident links more frequently than when incidents were not being simulated. This clearly occurs for O-D pair 4: in three-quarters of the incident simulation tests the yoked cars diverted from the incident link; this occurred in less than 20% of the tests conducted under normal conditions. There are slightly more diversions under simulated incidents than was the normal case for O-D pair 2. Pairs 3 and 5 showed the opposite results. The aggregate results shown in the last column of Table 5 are at best neutral.

Table 5: Summary of Results of Incident Simulation O-D Runs
(from driver reports)

	O-D Pair 1	O-D Pair 2	O-D Pair 3	O-D Pair 4	O-D Pair 5	Overall
Route planning attempts	95	55	66	62	78	356
Incident link diversions (number, %)	8 8.42%	11 20.00%	31 47.00%	47 75.81%	11 14.10%	108 30.34%
% normal attempts NOT through incident link	4/42 = 9.52%	6/42 = 14.29%	40/47 = 85.11%	7/38 = 18.42%	16/41 = 39.02%	73/210 = 34.76%
Number of route variations	9	13	6	3	5	36

Table 5 also shows the nurnber of route variations observed during normal (non-incident) tests. This may measure the potential for diversion. If a larger variety of routes is used under normal, day-to-day variation in congestion, which implies several competitive O-D routes, then an incident might be more likely to cause a diversion. This does not seem to be the case in these tests.

The results for O-D pair 3 may be more positive than Table 5 indicates. Diversion from the simulated incident link was induced in nearly half the cases; but under normal conditions 85% of the tests did not use the simulated incident link. This is the result of poor test implementation. After the tests were completed it was discovered that, during normal runs, a number of the yoked vehicle traversals used Palatine Road, which was actually 0.5 mile north of the test network, and thus avoided the simulated incident link. Palatine was part of an O-D path which was longer in distance, but apparently in many cases faster. Yoked cars also tended to use Palatine because their specific starting locations in the staging area, a large shopping center, put them closer to it. The result was that the yoked cars sometimes "escaped" from the planned test network. The incident simulation link, which was not on the chosen path in 85% of the normal runs (Thomas between Arlington Heights and Rand Road), was selected for safety reasons; simulating incidents on higher speed Palatine Road would have been quite risky. Thus the 47% diversion rate, second highest among the 5 O-D pairs, may be interpreted as a rather positive outcome, even though only 15% of the normal runs actually used this link.

5.2 Computer-Recorded Data

The analysis plan for this evaluation called for examining computer records of routes of yoked cars, to verify driver records, and a comparison of link updates, using the update measure defined in Section 4.3, with actual diversion experience. The latter would have provided a more substantive basis for analyzing why yoked cars did and did not divert from the simulated incident link.

We were not able to carry out most of this analysis because of loss of data from the field tests. Specifically, the records of virtually all of the yoked vehicle link traversals during the incident simulation week were missing from the database, both the TIC records of probe vehicle reports and the memory card records. We found no explanation for this, but it is possible that these records may not have been downloaded and archived. In addition, only a fraction of the link update records needed could be found in the database. For O-D pair 1, no update records could be found for any incident simulation tests. For O-D pair 2, the simulated incident section comprised two coded links, but updates could be retrieved for only one of these.

Table 6 shows the limited update data which could be extracted. There were 19 incident simulation tests (Table l), but limited update data could be extracted on only eight tests. Available data show that updates were generated, presumably by the incident simulation process, that ranged from 7% to 80% increases over historic travel times. However, the absolute increases were only on the order of one minute, and the maximum updates did not exceed 2.25 minutes. While some of the updates were a relatively large proportion of the base time on the incident links, they represent a small change in overall O-D travel time, which were on the order of 30-40 minutes. These results suggest that the delays due to simulated incidents were generally too small to cause diversions on this test network.

The fraction of tests diverting off the incident link ranged from none to 100%. Table 6 reveals a modest positive association between the magnitude of the travel time update and the percentage diversion. We might expect this to be a step function, requiring travel time to exceed some threshold value before all or most trips switched off the (simulated) incident link.

5.3 Interpretation

The overall results of the incident simulation tests suggest that real-time information simulating incidents can, under certain circumstances, cause route diversions. This did not happen often in the field tests, suggesting that the results may be dependent on a variety of factors, including:

- The network structure and availability of alternative routes which are closely competitive with the original, preferred route in terms of travel time.

Table 6: Link Update Data for Incident Simulation Tests

O-D Pair	Date	Time	Mean Update-seconds	Maximum Update-seconds	Historic Travel Time-seconds	Mean/ historic travel time	% Diversion
3	9/26	18:20	63.40	120.00	103.65	0.61	80%
	9/28	15:50	15.80	81.00	349.08	0.05	0%
4	9/25	18:05	26.00	46.00	98.00	0.27	0%
	9/27	15:05	53.50	114.00	96.66	0.55	100%
	9/28	16:40	59.63	136.00	98.00	0.61	100%
5	9/26	15:05	55.54	133.00	134.87	0.41	7%
	9/27	16:l0	48.57	103.00	113.28	0.43	11%
	9/29	14:50	73.75	135.00	89.00	0.83	25%

- The increase in travel time caused by the incident. In the field tests described here, physical and safety factors limited the increase in travel time to around 1 minute. Much larger delays may be necessary to warrant a diversion.

- *The ADVANCE* route planner may have been insensitive to these time increases because of its structure or decision rules. For example, a 2-minute time advantage was required before a reroute was offered.

- At least some of the data losses described here may have actually occurred in real time, resulting in failure to deliver update information to dynamically-guided vehicles, at all, or in a timely manner.

These limited memory card data seem to suggest a logical, positive relationship between the size of the travel time update and the likelihood of diversion from the incident link.

6.0 Conclusions

The overall results of this series of field tests suggest that route diversions and travel time savings are sometimes associated with the use of real-time data for route planning. Time savings, and especially large time savings, are not the typical outcome, but they do occur occasionally.

In some cases substantial time savings resulted from route diversions. Anecdotally, these cases seemed to have occurred on exceptionally congested routes in places where considerably longer, and less congested, links were nearby. Qualitative assessment of some of these diversion routes, using maps and field investigations, suggests that sometimes they were counter-intuitive, in that they used links orthogonal to the direction of travel toward the destination for up to one mile, but they were quite productive as time savers. A route planner using real-time data did find them and may be the only way to identify them routinely.

Results from incident simulations seem to follow a similar pattern. Diversions under dynamic route guidance occurred, but not often. In both normal and incident situations, this might be explained by the network structure (availability of alternative routes) and travel times: there may not be many opportunities for saving substantial travel time on urban and suburban arterial street networks. The preferred route, or the set of preferred routes, may be quite superior to any other alternatives, unless there is some large disturbance which changes the time topology of the network in a major way. Increasing travei times on blocks (links) by one minute or so may not be enough.

Yet a large incident, a major road construction project or special event which greatly increases traffic volumes may produce temporary changes in congestion which could lead to diversions producing substantial time savings. The incident simulations did not get to this point because safety considerations and the design of the *ADVANCE* system limited the size of the travel time increase which could be generated.[7] Congestion producing large delays was experienced on several occasions under the normal runs, which could explain the cases in which a substantial travel time saving was produced through a diversion.

---

7 We considered having probe vehicles pull off the road and park to generate longer delays safely; but if the on-board system detected an off-route condition, a probe report would not be generated for the incident simulation link..

In some cases the dynamically-guided vehicle took longer from origin to destination than the cars without real-time information. This underscores the variability in the overall DRG system. The factors contributing to this variability include:

- Variability in performance among and within drivers.

- Limited number of, and network coverage of, probe vehicles.

- Delays in collecting, processing, broadcasting, and utilizing real-time data. For *ADVANCE* this cycle could take as long as 10 minutes.

- Normal variability of traffic conditions, i.e., the travel time difference between making or missing a signal at a major arterial intersection could be as much as 3 minutes.

- Stochastic nature of operating conditions, which could make a "good" route "bad' in a matter of seconds. For example, an accident could occur, or a major employer could end a work shift, seconds after a probe vehicle passes, significantly changing travel times on links.

These factors suggest that, in the absence of a very dense coverage with high speed sensors, and a rapid capability to move data back to on-board guidance systems, DRG, much like the unassisted driver, can be expected to produce a mixture of successes and failures. Drivers are not likely to notice the minor travel time changes, whether increases or decreases. The success of future DRG systems, especially in arterial street settings such that tested here, may more likely come from the ability to detect, and respond to, major, unexpected delays on the road network.

The volume of data available from these tests was severely limited, which restricts the confidence with which any conclusions can be formed. The small data set is partly attributable to the experimental design, which was constrained by the test schedule and availability of vehicles. It was further restricted by data losses, which may have occurred in the measurement, recording, transfer, or storage processes. Data from driver reports, although less precise, were much more complete and were essential in providing a basis for the limited inferences which have been drawn here.

This experience provides a number of lessons for future field tests of this type:

- Data should be checked in near-real time to verify receipt, storage, and usefulness. The timing of these tests, the delays in data availability, and the complexity of accessing and interpreting data, made it impractical to check data quickly and comprehensively.

- Field experiments should be scaled to allow for reasonable loss of data for various reasons without compromising the test results.

- Driver records turned out to be critically important data source, but they were originally viewed only as a way of monitoring driver performance in the tests. Greater reliance on carefully-maintained driver records would have been feasible and beneficial. This would have required clearer and more formal reporting procedures, more driver training, better reporting forms, closer monitoring of driver reports, and more field personnel. Additional personnel would have allowed us to add observers, responsible only for data collection, to all yoked runs. As it turned out, excess staff hired to assure that all probe runs could be fulfilled were typically used as ride-along observers in yoked cars, which improved data quality.

7.0 References

1. Schofer, Joseph L., Frank S. Koppelman and William A. Charlton, "Familiar Driver Perspectives on *ADVANCE* and Future Dynamic Route Guidance Systems," *ADVANCE* Document # 8462.01, July 24, 1996.

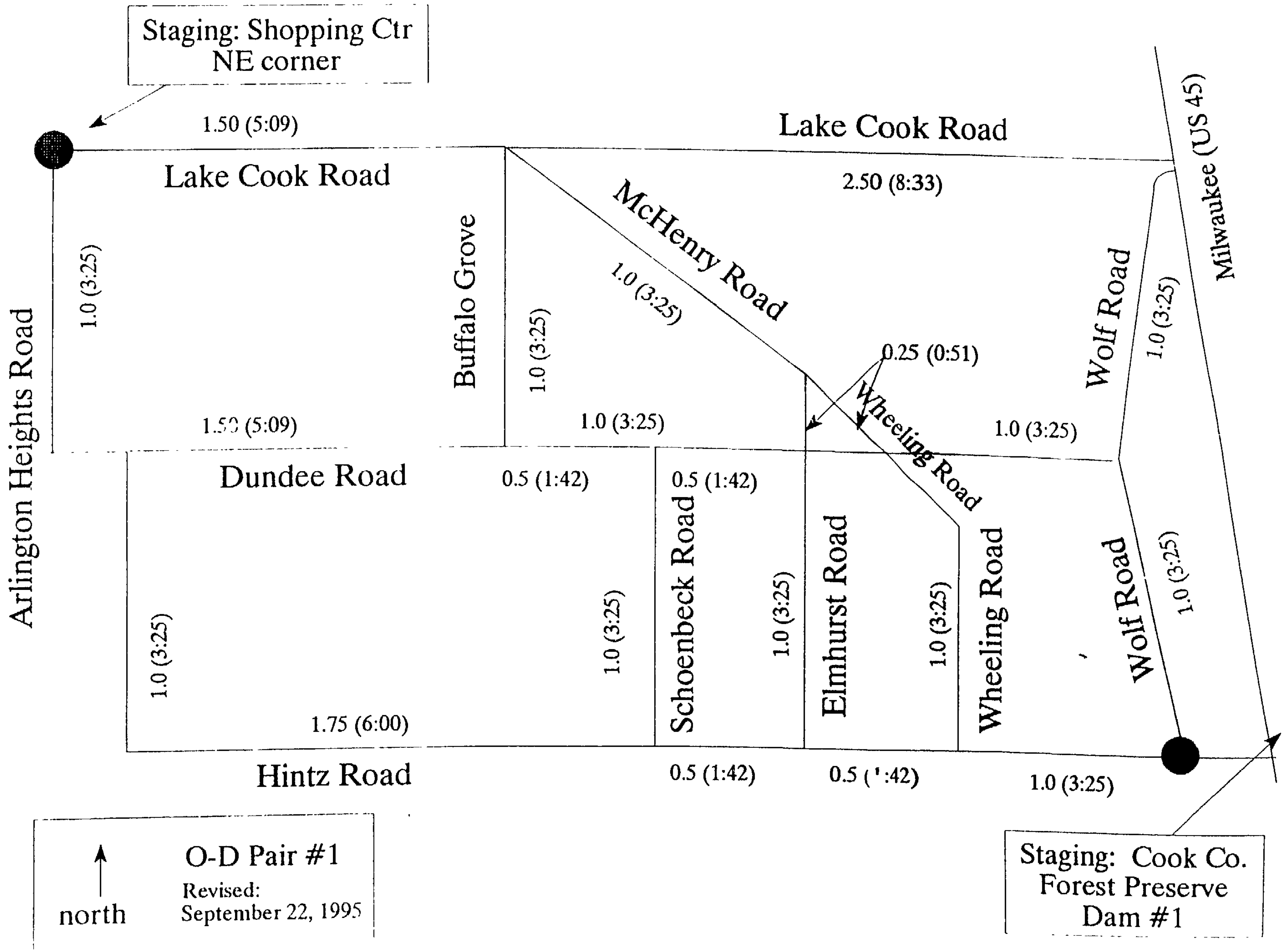
2. The original test plan is presented in "Dynamic Route Guidance - Yoked Driver Study Evaluation Test Plan," *ADVANCE* Document # 8463.ADV.00, prepared by Northwestern University and Booz-Allen & Hamilton, June 19, 1995.

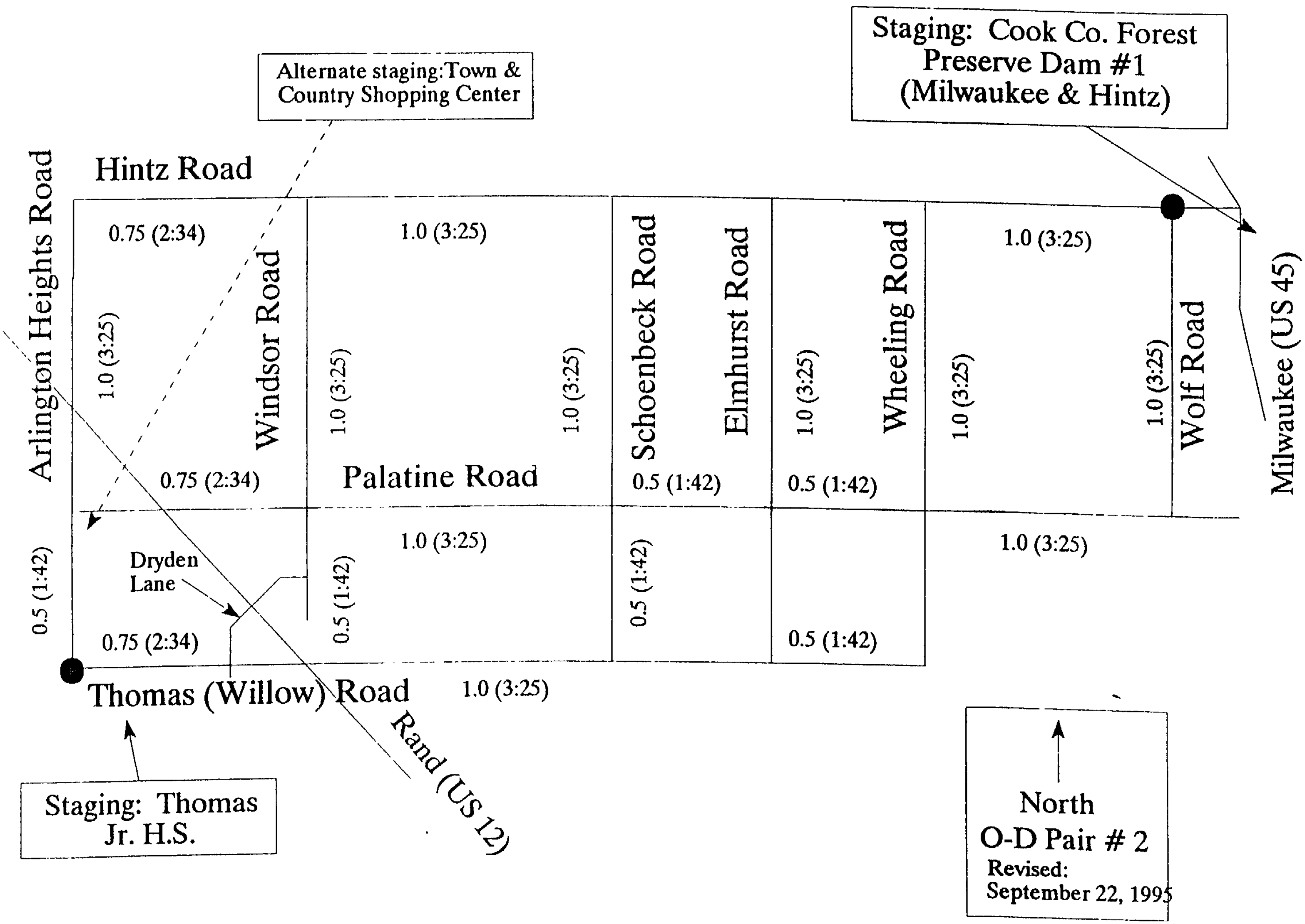
3. Berka, Stanislaw, Helen Condie and Aaron Sheffey, "Detector Travel Time Conversion and Fusion of Probe and Detector Data: Evaluation Report," *ADVANCE* Document # 8460-05.01, University of Illinois at Chicago, Urban Transportation Center, June 1996.

4. Sen, Ashish, X. Tian and H.Condie, "Travel Time Prediction and Performance of Probe and Detector Data: Evaluation Report," *ADVANCE* Document # 8460-04.01 , University of Illinois at Chicago, Urban Transportation Center, September 1996.

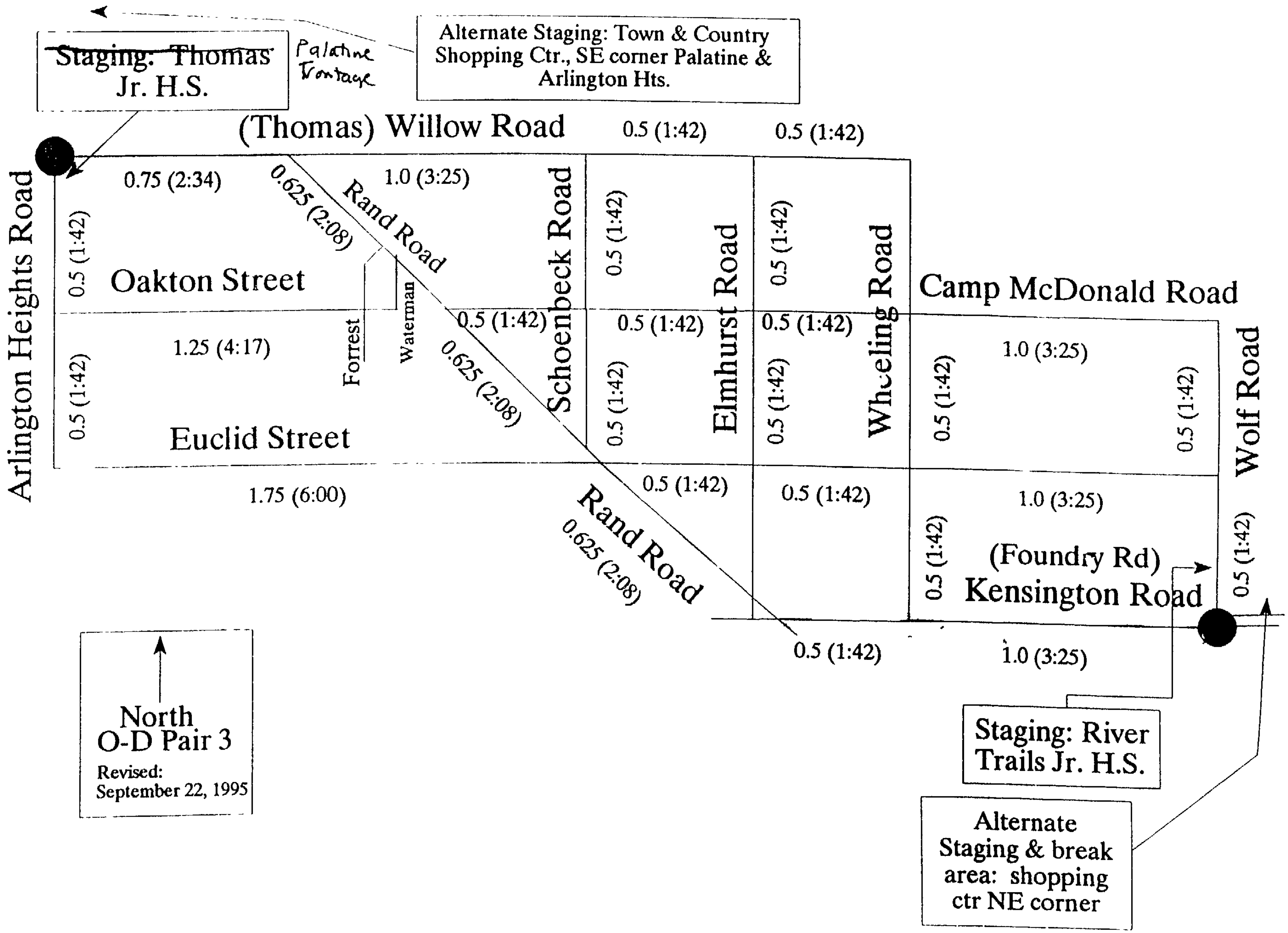
Appendix A: Sketch Maps of 5 Origin-Destination Pairs and Associated Networks

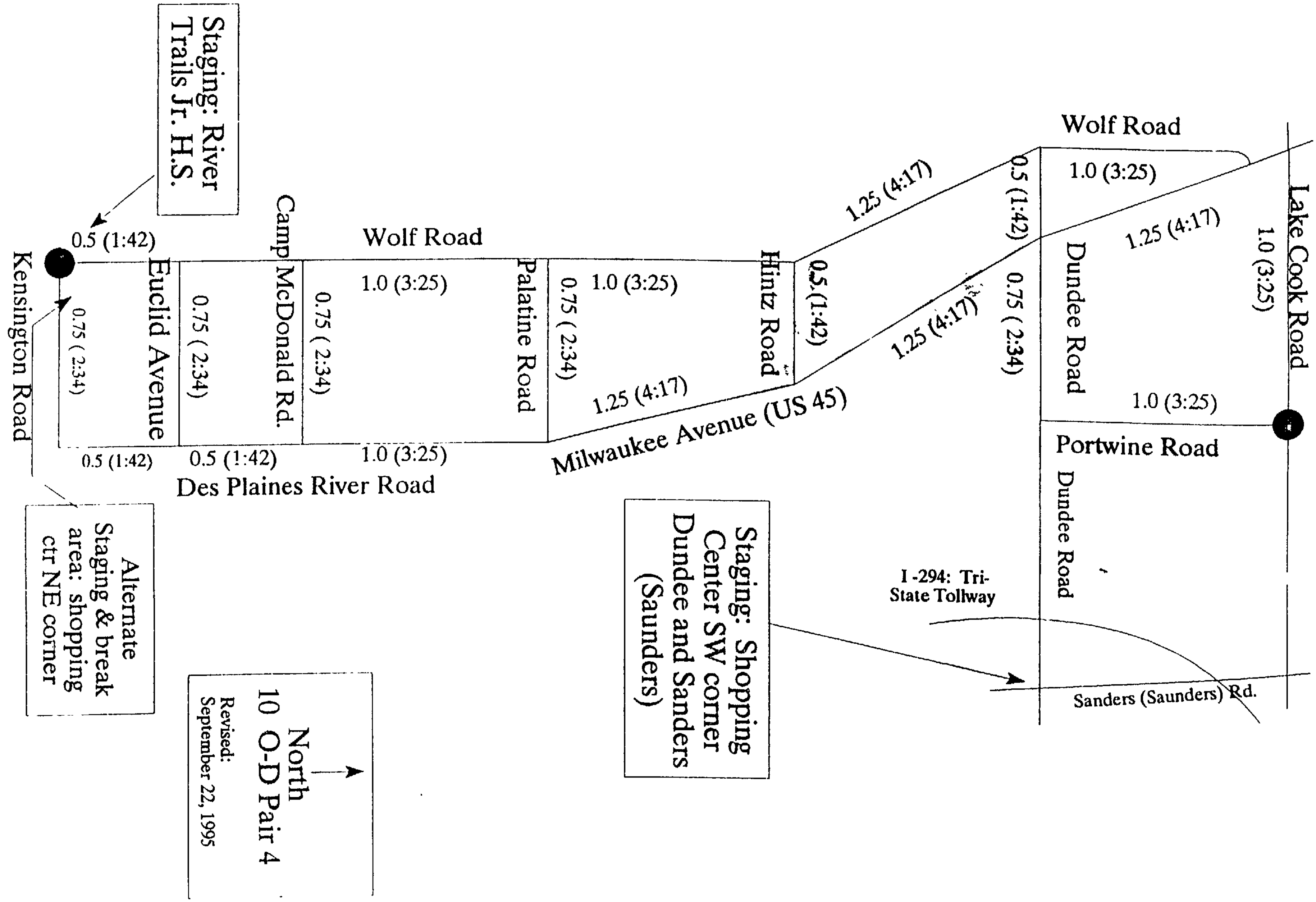
Note: these are schematic maps and show only the arterial streets; a substantial number of local streets were present but omitted. Numbers on the links are estimated miles (and travel times in minutes), which were used to plan the probe vehicle routes. Staging areas are described in boxed text and origins and destinations are filled circles. The maps are only roughly to scale.

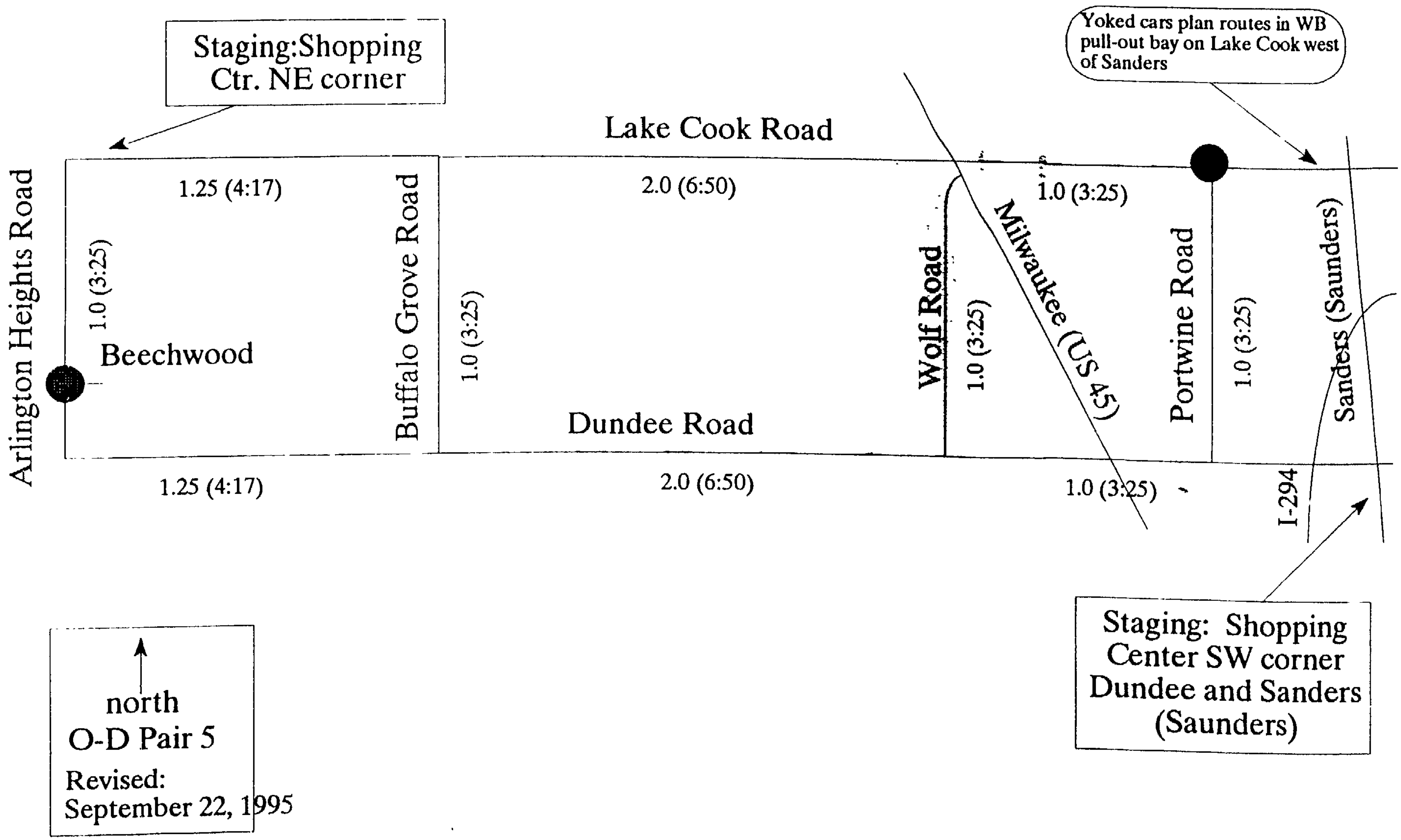

Staging: Shopping Ctr
NE corner
1.50 (5:09)
Lake Cook Road
Lake Cook Road
2.50 (8:33)
Milwaukee (US 45)
McHenry Road
1.0 (3:25)
Arlington Heights Road
1.0 (3:25)
Buffalo Grove
1.0 (3:25)
Wolf Road
1.0 (3:25)
0.25 (0:51)
Wheeling Road
(5:09)
1.0 (3:25)
1.0 (3:25)
Dundee Road
0.5 (1:42)
0.5 (1:42)
Schoenbeck Road
Elmhurst Road
Wheeling Road
Wolf Road
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.75 (6:00)
Hintz Road
0.5 (1:42)
0.5 (:42)
1.0 (3:25)
north
O-D Pair #1
Revised:
September 22, 1995
Staging: Cook Co.
Forest Preserve
Dam #1



Alternate staging:Town & Country Shopping Center
Staging: Cook Co. Forest Preserve Dam #1 (Milwaukee & Hintz)
Hintz Road
Arlington Heights Road
Windsor Road
Schoenbeck Road
Elmhurst Road
Wheeling Road
Wolf Road
Milwaukee (US 45)
Palatine Road
Dryden Lane
Thomas (Willow) Road
Rand (US 12)
0.75 (2:34)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
0.75 (2:34)
0.5 (1:42)
0.5 (1:42)
1.0 (3:25)
1.0 (3:25)
0.5 (1:42)
0.5 (1:42)
0.5 (1:42)
0.75 (2:34)
0.5 (1:42)
1.0 (3:25)
Staging: Thomas Jr. H.S.
North
O-D Pair # 2
Revised: September 22, 1995

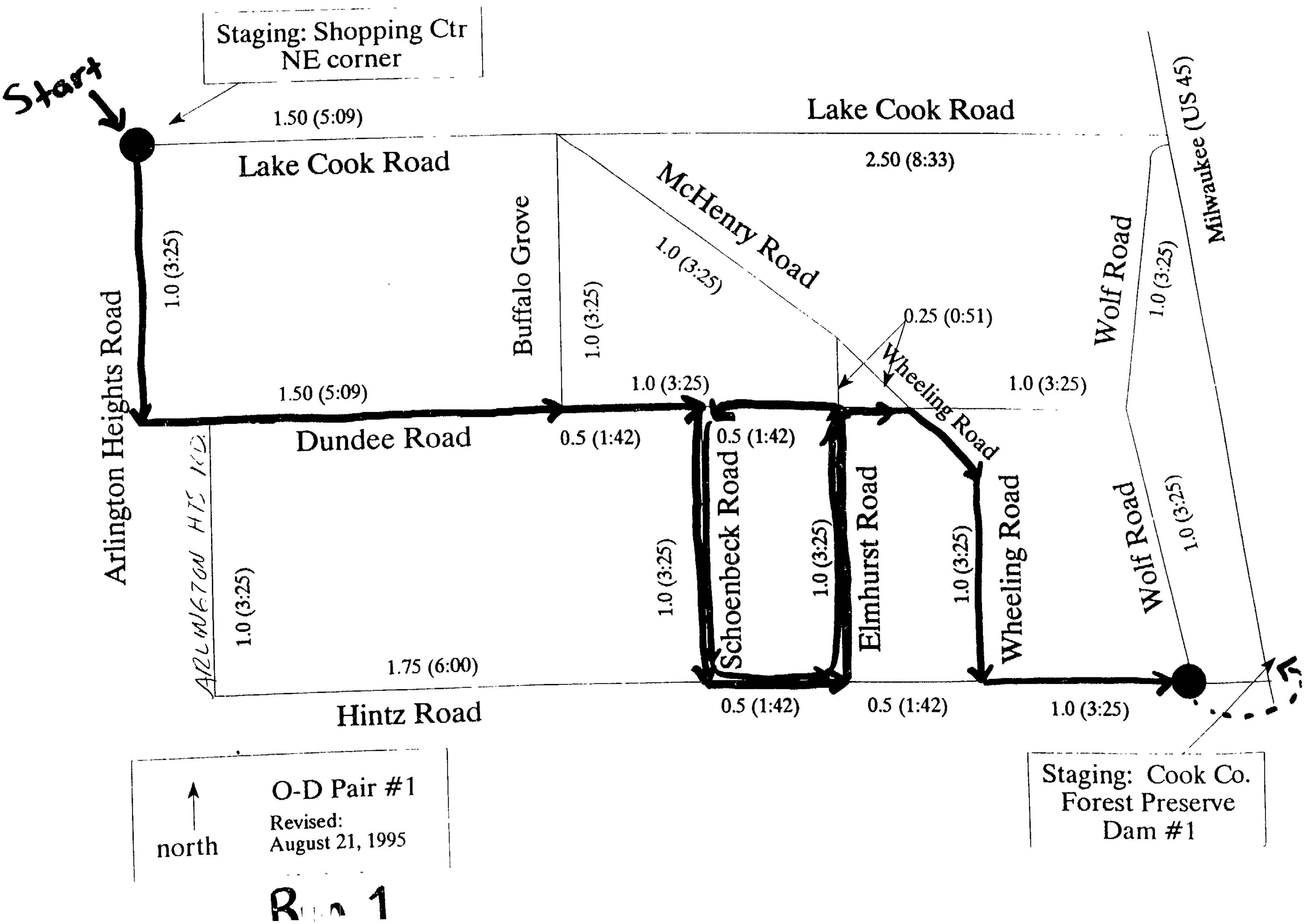

Staging: Thomas Jr. H.S.
Palatine Frontage
Alternate Staging: Town & Country Shopping Ctr., SE corner Palatine & Arlington Hts.
(Thomas) Willow Road
0.5 (1:42)
0.5 (1:42)
0.75 (2:34)
0.625 (2:08)
Rand Road
1.0 (3:25)
Arlington Heights Road
0.5 (1:42)
Oakton Street
Schoenbeck Road
0.5 (1:42)
Elmhurst Road
0.5 (1:42)
Wheeling Road
Camp McDonald Road
Forrest
Waterman
0.5 (1:42)
0.5 (1:42)
0.5 (1:42)
1.25 (4:17)
0.625 (2:08)
1.0 (3:25)
0.5 (1:42)
0.5 (1:42)
0.5 (1:42)
0.5 (1:42)
0.5 (1:42)
0.5 (1:42)
Wolf Road
Euclid Street
1.75 (6:00)
0.5 (1:42)
0.5 (1:42)
1.0 (3:25)
Rand Road
0.625 (2:08)
0.5 (1:42)
(Foundry Rd)
Kensington Road
0.5 (1:42)
0.5 (1:42)
1.0 (3:25)
North
O-D Pair 3
Revised: September 22, 1995
Staging: River Trails Jr. H.S.
Alternate Staging & break area: shopping ctr NE corner

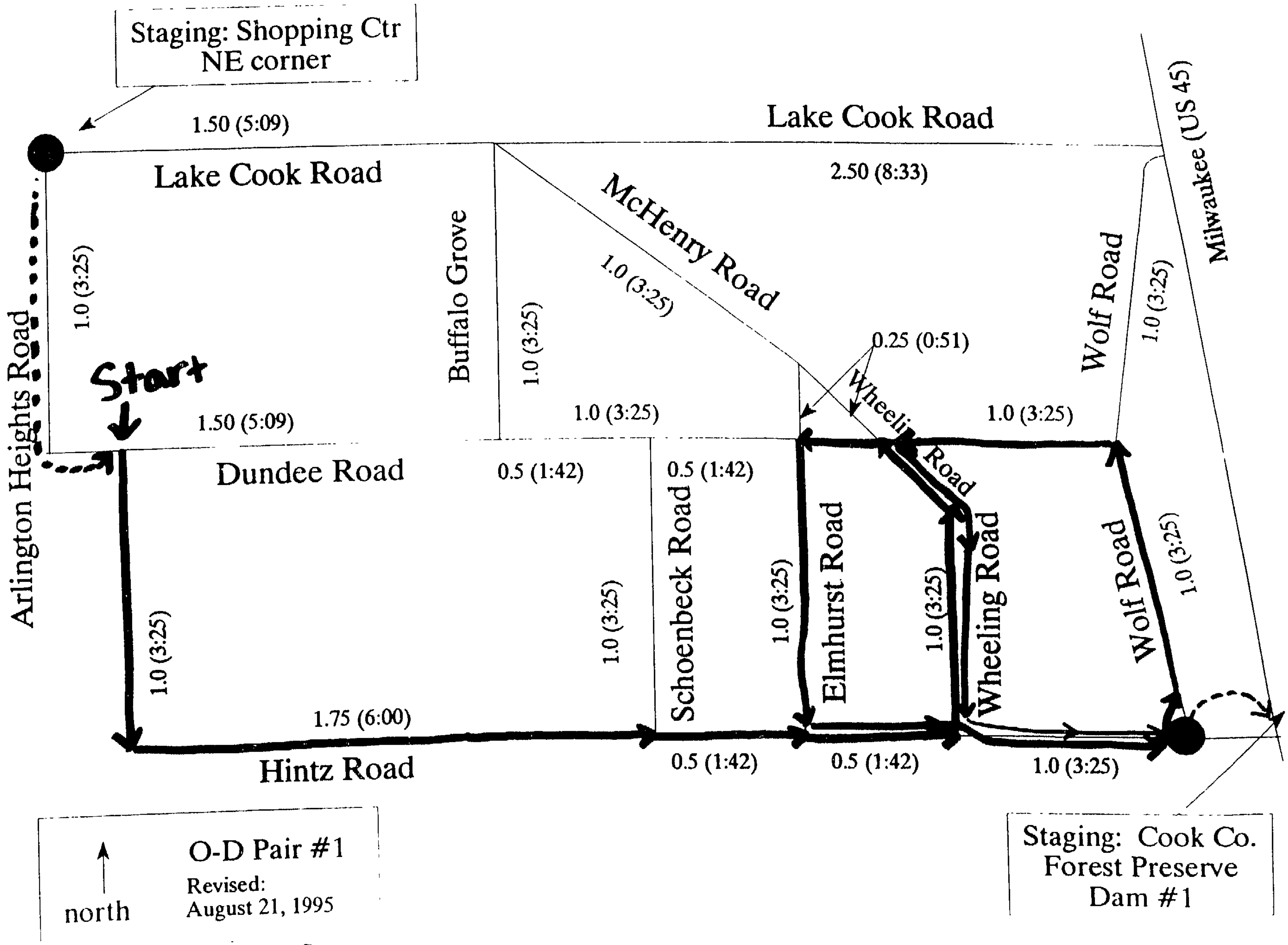

Staging: River Trails Jr. H.S.
0.5 (1:42)
Wolf Road
Camp McDonald Rd.
Kensington Road
Euclid Avenue
0.75 (2:34)
0.75 (2:34)
0.75 (2:34)
1.0 (3:25)
Palatine Road
0.75 (2:34)
1.0 (3:25)
Hintz Road
0.5 (1:42)
1.25 (4:17)
1.25 (4:17)
0.5 (1:42)
Wolf Road
1.0 (3:25)
1.25 (4:17)
Dundee Road
0.75 (2:34)
1.0 (3:25)
Lake Cook Road
1.0 (3:25)
1.25 (4:17)
Milwaukee Avenue (US 45)
0.5 (1:42)
0.5 (1:42)
1.0 (3:25)
Des Plaines River Road
Portwine Road
Dundee Road
Alternate Staging & break area: shopping ctr NE corner
Staging: Shopping Center SW corner Dundee and Sanders (Saunders)
I -294: Tri-State Tollway
Sanders (Saunders) Rd.
North
10 O-D Pair 4
Revised: September 22, 1995


Staging:Shopping Ctr. NE corner
Yoked cars plan routes in WB pull-out bay on Lake Cook west of Sanders
Lake Cook Road
1.25 (4:17)
2.0 (6:50)
1.0 (3:25)
Arlington Heights Road
1.0 (3:25)
Beechwood
Buffalo Grove Road
1.0 (3:25)
Wolf Road
1.0 (3:25)
Milwaukee (US 45)
Portwine Road
1.0 (3:25)
Sanders (Saunders)
Sanders
Dundee Road
1.25 (4:17)
2.0 (6:50)
1.0 (3:25)
I-294
north
O-D Pair 5
Revised: September 22, 1995
Staging: Shopping Center SW corner Dundee and Sanders (Saunders)

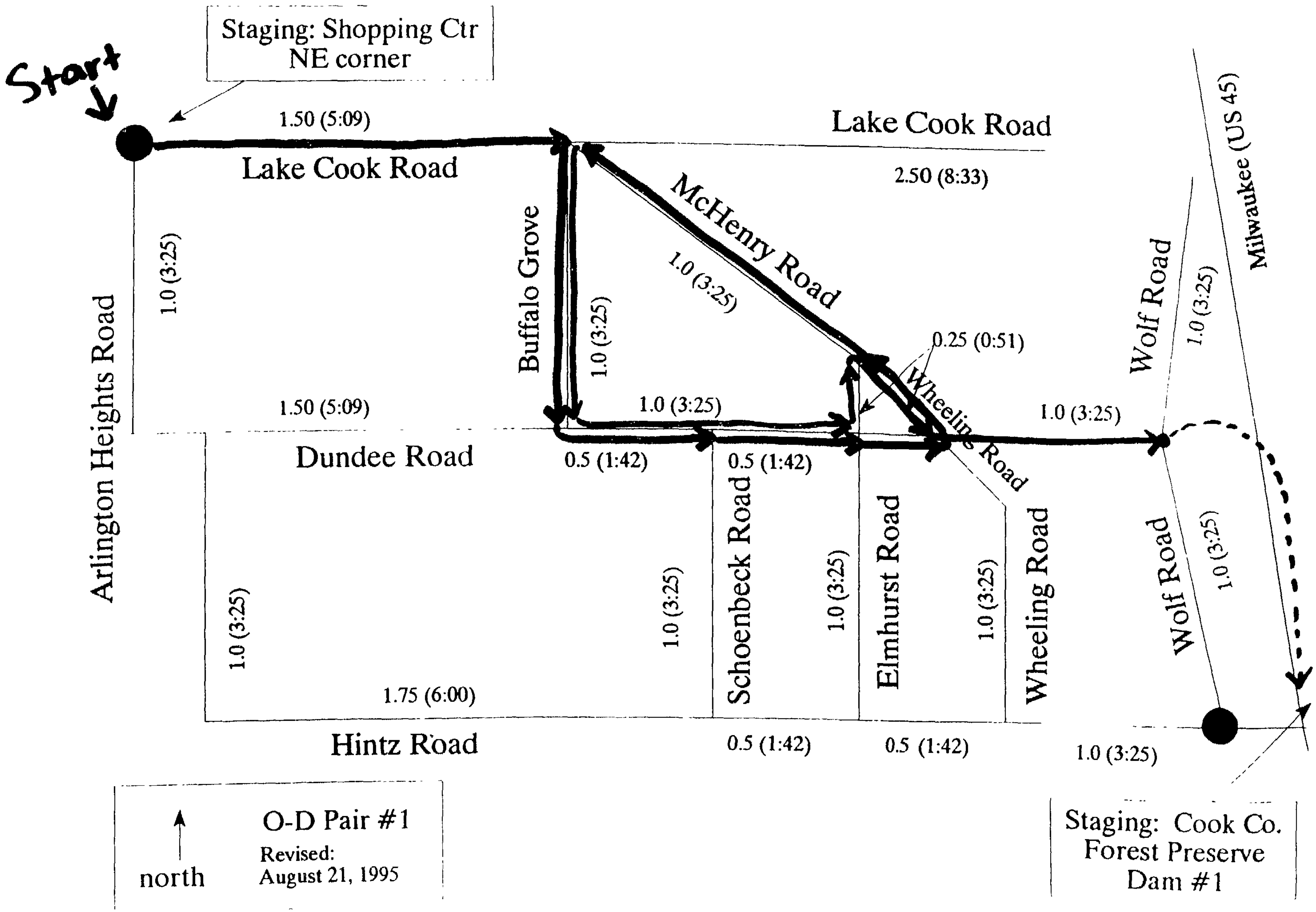
Appendix B: Examples of Probe Vehicle Routes (O-D-Pair 1)

Probe routes are shown as marked by hand with marking pens. The versions presented to drivers were in colors. Each work day each driver was issued a bound booklet containing probe route or "run" maps for a given run number, e.g. , routes for probe run number 1 for all of the five O-D pairs. During a single shift, a driver would operate his/her vehicle as a particular run number (1 through 6) and vehicle sequence number (1 through 3, as there were three vehicles on each probe route). For example, the second probe vehicle on probe route 4 would be known as run 4-2.

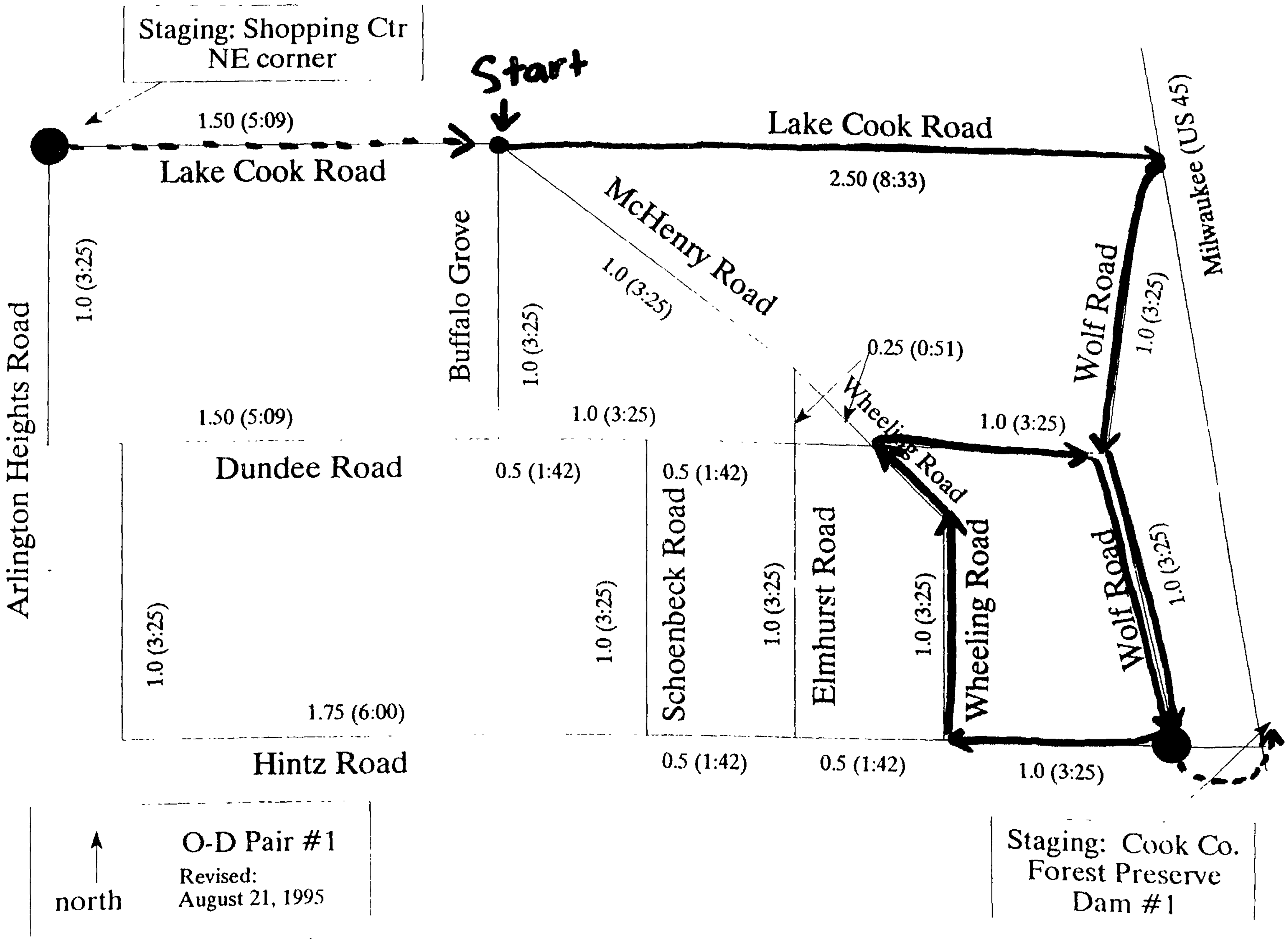

Start
Staging: Shopping Ctr
NE corner
1.50 (5:09)
Lake Cook Road
Lake Cook Road
2.50 (8:33)
Milwaukee (US 45)
1.0 (3:25)
Arlington Heights Road
Buffalo Grove
1.0 (3:25)
McHenry Road
1.0 (3:25)
0.25 (0:51)
Wheeling Road
Wolf Road
1.0 (3:25)
1.50 (5:09)
1.0 (3:25)
1.0 (3:25)
Dundee Road
0.5 (1:42)
0.5 (1:42)
ARLINGTON HTS RD
1.0 (3:25)
1.0 (3:25)
Schoenbeck Road
1.0 (3:25)
Elmhurst Road
1.0 (3:25)
Wheeling Road
Wolf Road
1.0 (3:25)
1.75 (6:00)
Hintz Road
0.5 (1:42)
0.5 (1:42)
1.0 (3:25)
north
O-D Pair #1
Revised:
August 21, 1995
Staging: Cook Co.
Forest Preserve
Dam #1


Staging: Shopping Ctr
NE corner
1.50 (5:09)
Lake Cook Road
Lake Cook Road
2.50 (8:33)
Milwaukee (US 45)
McHenry Road
1.0 (3:25)
Buffalo Grove
1.0 (3:25)
Wolf Road
1.0 (3:25)
0.25 (0:51)
Wheeling Road
Arlington Heights Road
1.0 (3:25)
Start
1.50 (5:09)
1.0 (3:25)
1.0 (3:25)
Dundee Road
0.5 (1:42)
0.5 (1:42)
Schoenbeck Road
Elmhurst Road
Wheeling Road
Wolf Road
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.75 (6:00)
Hintz Road
0.5 (1:42)
0.5 (1:42)
1.0 (3:25)
Staging: Cook Co.
Forest Preserve
Dam #1
north
O-D Pair #1
Revised:
August 21, 1995

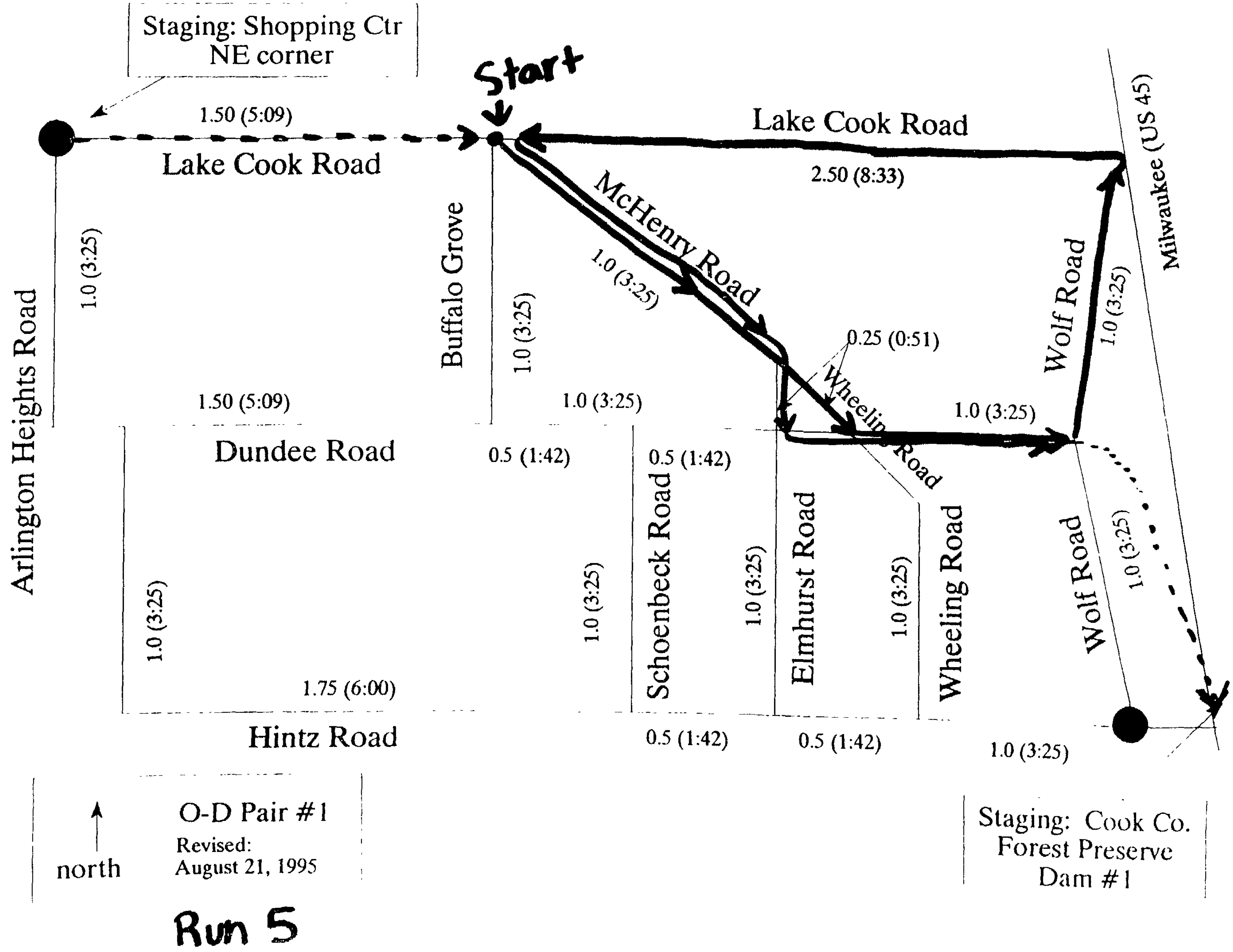
Run 2


Start
Staging: Shopping Ctr
NE corner
1.50 (5:09)
Lake Cook Road
Lake Cook Road
2.50 (8:33)
Arlington Heights Road
1.0 (3:25)
Buffalo Grove
1.0 (3:25)
McHenry Road
1.0 (3:25)
0.25 (0:51)
Wheeling Road
Wolf Road
1.0 (3:25)
Milwaukee (US 45)
1.50 (5:09)
1.0 (3:25)
1.0 (3:25)
Dundee Road
0.5 (1:42)
0.5 (1:42)
Schoenbeck Road
Elmhurst Road
Wheeling Road
Wolf Road
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.75 (6:00)
Hintz Road
0.5 (1:42)
0.5 (1:42)
1.0 (3:25)
north
O-D Pair #1
Revised:
August 21, 1995
Staging: Cook Co.
Forest Preserve
Dam #1

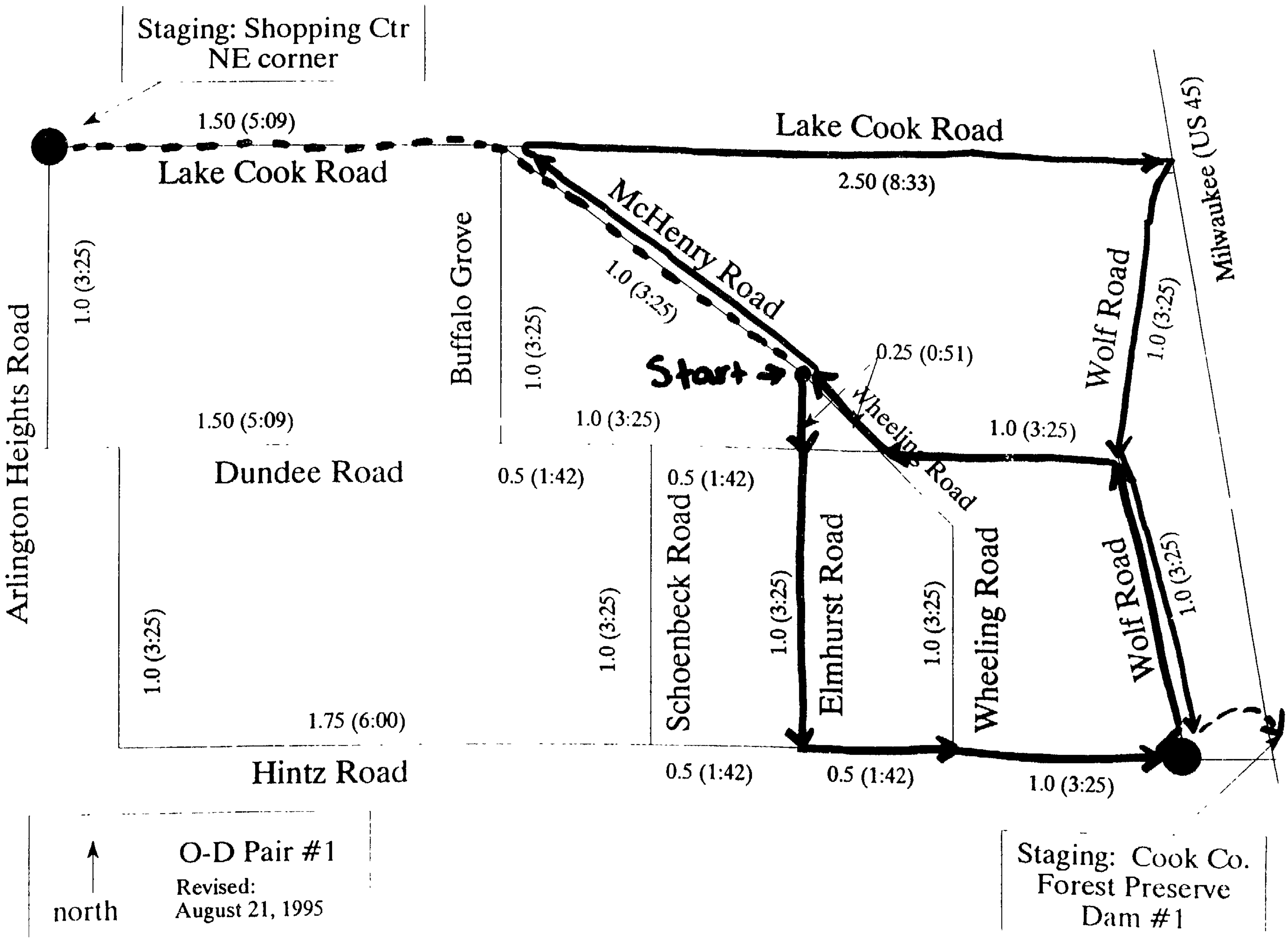
Rm 3


Staging: Shopping Ctr NE corner
Start
1.50 (5:09)
Lake Cook Road
Lake Cook Road
2.50 (8:33)
Milwaukee (US 45)
McHenry Road
1.0 (3:25)
Arlington Heights Road
1.0 (3:25)
Buffalo Grove
1.0 (3:25)
Wolf Road
1.0 (3:25)
0.25 (0:51)
Wheeling Road
1.50 (5:09)
1.0 (3:25)
1.0 (3:25)
Dundee Road
0.5 (1:42)
0.5 (1:42)
Schoenbeck Road
Elmhurst Road
Wheeling Road
Wolf Road
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.75 (6:00)
Hintz Road
0.5 (1:42)
0.5 (1:42)
1.0 (3:25)
north
O-D Pair #1
Revised: August 21, 1995
Staging: Cook Co. Forest Preserve Dam #1

Run 4



Staging: Shopping Ctr
NE corner
Start
1.50 (5:09)
Lake Cook Road
Lake Cook Road
2.50 (8:33)
Milwaukee (US 45)
McHenry Road
1.0 (3:25)
Buffalo Grove
1.0 (3:25)
Arlington Heights Road
1.0 (3:25)
Wolf Road
1.0 (3:25)
0.25 (0:51)
Wheeling Road
1.50 (5:09)
1.0 (3:25)
1.0 (3:25)
Dundee Road
0.5 (1:42)
0.5 (1:42)
Schoenbeck Road
Elmhurst Road
Wheeling Road
Wolf Road
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.75 (6:00)
Hintz Road
0.5 (1:42)
0.5 (1:42)
1.0 (3:25)
north
O-D Pair #1
Revised:
August 21, 1995
Staging: Cook Co.
Forest Preserve
Dam #1
Run 5


Staging: Shopping Ctr
NE corner
1.50 (5:09)
Lake Cook Road
Lake Cook Road
2.50 (8:33)
Milwaukee (US 45)
Arlington Heights Road
1.0 (3:25)
Buffalo Grove
1.0 (3:25)
McHenry Road
1.0 (3:25)
Start
0.25 (0:51)
Wheeling Road
Wolf Road
1.0 (3:25)
1.50 (5:09)
1.0 (3:25)
1.0 (3:25)
Dundee Road
0.5 (1:42)
0.5 (1:42)
Schoenbeck Road
Elmhurst Road
Wheeling Road
Wolf Road
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.0 (3:25)
1.75 (6:00)
Hintz Road
0.5 (1:42)
0.5 (1:42)
1.0 (3:25)
north
O-D Pair #1
Revised:
August 21, 1995
Staging: Cook Co.
Forest Preserve
Dam #1

Run 6

Appendix C: Example of Vehicle Dispatch Times (O-D Pair 1)

O-D Pair 1

Date: ________ Actual start time________

Run Number	Vehicle Number	Start time (Relative)
1	1	9 minutes
	2	10 minutes
	3	11 minutes
2	1	0 minutes
	2	1 minutes
	3	2 minutes
3	1	4 minutes
	2	5 minutes
	3	6 minutes
4	1	6 minutes
	2	7 minutes
	3	8 minutes
5	1	4 minutes
	2	5 minutes
	3	6 minutes
6	1	0 minutes
	2	1 minutes
	3	2 minutes
Yoked	Dynamic 1	30 minutes
	Dynamic	31 minutes
	Static	30 minutes

APPENDIX K

ADVANCE

Advanced Driver and Vehicle
Advisory Navigation Concept

TIC Architecture and User Interface Evaluation Report

Prepared by
De Leuw, Cather & Company
Castle Rock Consultants

DISCLAIMER

ADVANCE

ADVANCED DRIVER AND VEHICLE ADVISORY NAVIGATION CONCEPT

Illinois Department of Transportation
Federal Highway Administration
Motorola
Illinois Universities Transportation Research Consortium
American Automobile Association

TIC Architecture & User Interface Report
Document # 8464. TIC.03

Prepared by: De Leuw, Cather & Company
Castle Rock Consultants

Issue Date: July 15, 1996

TIC ARCHITECTURE AND USER INTERFACE EVALUATION REPORT

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

SECTION 1 EXECUTIVE SUMMARY

ADVANCE, the Advanced Driver and Vehicle Advisory Navigation ConcEpt, is an advanced traveler information system (ATIS) demonstration project. *ADVANCE* aimed to provide dynamic traffic information for the roadway network in eastern Illinois. Over a seven month period, 75 vehicles were utilized in a 300 square mile area. The vehicles utilized differential GPS navigation as well as dead-reckoning and map matching to navigate their way through the study area. The vehicles themselves acted as probes, sending real-time travel information to a Traffic Information Center (TIC) that in turn transmitted the information to other vehicles as an aid to dynamic route planning.

The route guidance system also used information from a variety of other existing sources, such as: a closed loop traffic signal system; *999, a cellular-based motorist call-in system; the Illinois Department of Transportation (IDOT) Traffic Systems Center (TSC), which monitors operations on expressways in the Chicago area; IDOT's Communications Center, which communicates with the Minutemen, a motorist aid system; weather data provided by Surface Systems, Inc.; data from the Illinois State Toll Highway Authority (ISTHA); and Northwest Central Dispatch, an area-wide emergency dispatch system. However, the primary source of information was the vehicles themselves acting as traffic probes. Drivers were recruited to utilize project vehicles to perform tests over a seven month period commencing in June 1995.

The Steering Committee for *ADVANCE* includes the Federal Highway Administration (FHWA), the University of Illinois at Chicago and Northwestern University - acting together through the Illinois Universities Transportation Research Consortium (IUTRC), Motorola Inc., the Illinois Department of Transportation (IDOT), and the American Automobile Association (AAA). This unique public-private cooperative effort blended public and private funds and expertise. In addition to the five participants listed above, more than 20 other industry leaders participated in *ADVANCE.* De Leuw, Cather & Company was retained as a consultant to the project and is responsible for overseeing the system design, system integration, assisting IDOT in project management and this evaluation of the TIC.

The *ADVANCE TIC* subsystem provided the central computing resources, console functions, communications interfaces, active data storage, and data archiving and services within *the ADVANCE* project. The evaluation of the TIC Architecture and User Interface commenced in September 1995.

This TIC Evaluation Report contains details of the activities undertaken as part of the evaluation of the *ADVANCE* TIC Architecture and User Interface. *The ADVANCE* TIC evaluation had the overall goal of assessing the degree to which the implemented TIC Architecture and operational practices met the needs of all the agencies involved in or affected by the subsystem operation. The evaluation aimed to produce a detailed description of the advantages and shortcomings of the TIC Architecture and User Interface as presently configured. To achieve this, several aspects of the performance of the various TIC subsystems, both individually and as a complete system, were assessed. In addition, human factors issues relating to TIC operation were also assessed as part of the evaluation.

The results contained within this report are divided into two main sections, reflecting the parallel TIC Architecture and TIC User Interface evaluation activities. The approach, procedures and results of the TIC Architecture evaluation are presented, followed by the equivalent information relating to the User Interface evaluation. The report also contains an assessment of the project in terms of the meeting of the evaluation hypotheses. Seven hypotheses were devised for the evaluation of the *ADVANCE* TIC Architecture and User Interface evaluation. The first five hypotheses concerned the TIC Architecture, while the last two hypotheses related to the TIC User Interface. The hypotheses and an overview of the findings relating to each hypothesis are contained in the following paragraphs.

Hypothesis 1: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test provides an acceptable level of performance, both in terms of the hardware and software as individual components, and as a complete system.

Various aspects of the TIC Architecture, including functionality, reliability and maintenance requirements, efficiency and potential system design alternatives, were evaluated in order to ascertain whether Hypothesis 1 was verified. It was found by the evaluation team that the TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test provided an acceptable level of performance, both in terms of the hardware and software as individual components and as a complete system.

Hypothesis 2: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test is expandable to cover additional services within the current test area.

The functionality of the implemented TIC was reviewed by a peer review team, in order to ascertain whether Hypothesis 2 was verified. The feedback received from the peer reviewers indicated four key areas where they considered that potential existed for expanding the functionality of the TIC. These areas are described in the Evaluation Report. It is concluded that these areas should be investigated further to ascertain the potential advantages and disadvantages of their implementation. However, based on the input received from the peer reviewers, it is concluded that the expandability of the *ADVANCE* TIC to incorporate additional services is largely constrained due to inherent system limitations resulting from Targeted Deployment.

Hypothesis 3: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test is transferable to other geographic areas.

The functionality of the implemented TIC was reviewed by a peer review team, in order to ascertain whether Hypothesis 3 was verified. The feedback received from the peer reviewers indicated two key areas where they considered that potential could exist for such system transferability. These areas are described in the Evaluation Report. It is concluded that the knowledge and expertise gained by project participants during the *ADVANCE* operational test in terms of the lessons learned from the implementation appear to be the major transferable elements of the *ADVANCE* TIC Architecture created for the Targeted Deployment. As was noted by the peer reviewers, it must be concluded that the *ADVANCE* project produced a unique technical solution that, as an entire system, will have limited application in meeting local requirements in other areas. To maximize future transferability potential, it is proposed that further investigations be carried out into a change in focus for the *ADVANCE* TIC, from ATIS to a combined approach incorporating both ATIS and ATMS.

Hypothesis 4: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test provides acceptable cost efficiency.

The development, implementation and operation costs of the implemented TIC were reviewed by a peer review team, in order to ascertain whether Hypothesis 4 was verified. These costs are contained in the Evaluation Report. The peer reviewers considered all TIC equipment costs to be reasonable. It was also remarked that although the system development costs were significant, given the complexity of the data sources, including the probe vehicles, these labor costs were in line with the overall TIC complexity. Reviewers also assessed the monthly TIC operating costs as reasonable, given that the system was providing an essentially full-time information service. A potential area where ongoing cost savings could be made was identified as a fully automated TIC system, which would not require staffing by operators. However, it is concluded the TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test provided acceptable cost efficiency.

Hypothesis 5: The operational practices in place at the *ADVANCE* TIC enable acceptable system operation and ensure reasonable operator workload.

Various aspects of the policies, procedures, and staffing levels at the TIC were assessed in order to ascertain whether Hypothesis 5 was verified. In terms of the assessment of the TIC policies and procedures, three key areas were identified where revisions to TIC policies or procedures could be made. These areas are described in the Evaluation Report. In terms of the TIC staffing requirements, it was found that the staffing levels in place for the *ADVANCE* Targeted Deployment were reasonable and did not result in undue pressure being placed upon operators. To conclude, it was found by the evaluation team that the operational practices in place at the *ADVANCE* TIC enabled acceptable system operation and ensured reasonable operator workload.

Hypothesis 6: The TIC User Interface as implemented for the *ADVANCE* Targeted Deployment operational test provides an acceptable level of usability.

Various aspects of the usability of the TIC User Interface were assessed in order to ascertain whether Hypothesis 6 was verified. Operators assessed the ease of use of all the interface features as being either very easy, moderately easy, or neither particularly easy nor difficult. No features were rated as being either moderately or very difficult. It is therefore concluded that the user perceptions of the ease of use of TIC systems are substantially positive. However, given the large volume of operator comments and suggestions for enhancing the TIC systems usability, it is clear that there exists room for improvement in many of the features of the TIC User Interface. It is concluded that the TIC User Interface as implemented for the *ADVANCE* Targeted Deployment operational test provided an acceptable **level** of usability.

Hypothesis 7: The TIC User Interface as implemented for the *ADVANCE* Targeted Deployment operational test provides an acceptable level of functionality.

Numerous aspects of the functionality of the TIC User Interface were assessed in order to ascertain whether Hypothesis 7 was verified. It was found that the TIC User Interface functionality met the requirements of the TIC operators to a large degree. From the various suggestions made by operators for possible additional interface functionality, four key areas were identified for further study. It is recommended that further investigations be undertaken into the feasibility and implications of implementing these as it is considered that the inclusion of these features would significantly enhance the present interface. Various other functions had been never or rarely used by all three operators.It is recommended these items undergo further investigation to ascertain their utility to operators in everyday use of the TIC subsystems. In addition, there are certain features which are currently displayed on the TIC User Interface but which are not available to system users. It is recommended that these non-functioning items be removed from the TIC User Interface. It is concluded that the TIC User Interface as implemented for the *ADVANCE* Targeted Deployment operational test provided an acceptable level of functionality.

Consequently, all the above hypotheses were verified. However, the various comments and recommendations contained in the Evaluation Report relating to all the areas described above should be taken into account should further development on the existing TIC take place, or for any future systems which are based either partly or wholly on the *ADVANCE* TIC concept.

SECTION 2 PROJECT OVERVIEW

ADVANCE, the Advanced Driver and Vehicle Advisory Navigation ConcEpt, is an advanced traveler information system project. *ADVANCE* aimed to provide dynamic traffic information for the roadway network in Eastern Illinois. In this section, the roles of the *ADVANCE* project participants are described, after which the goals of the project are outlined. *ADVANCE* within the framework of the ITS technology evolution is then considered.

Appendix A provides a glossary of terms and definitions of acronyms used throughout this report. Appendix B consists of the Evaluation Test Plan (ETP) for the evaluation of the TIC Architecture and User Interface. Appendix C contains the data collection tools utilized during the evaluation activities.

2.1 *ADVANCE* Project Participants

The Steering Committee for *ADVANCE* includes the Federal Highway Administration (FHWA), the University of Illinois at Chicago and Northwestern University - acting together through the Illinois Universities Transportation Research Consortium (IUTRC), Motorola Inc., the Illinois Department of Transportation (IDOT), and the American Automobile Association (AAA). This unique public-private cooperative effort blended public and private funds and expertise. In addition to the five participants listed above, more than 20 other industry leaders participated in *ADVANCE.*

The roles and responsibilities of the project participants expanded as the project progressed. All participants jointly participated in technical development and reviews. The following are the specific responsibilities of the members of the Steering Committee:

Federal Highway Administration
- provide national coordination
- provide technical interface with other ITS projects
- oversee development of a comprehensive evaluation strategy
- oversee implementation of the project evaluation

Illinois Department of Transportation
- provide project management and liaison with other local agencies
- provide expertise in traffic operations
- obtain the radio frequencies
- assist in development of the operational system
- operate the Traffic Information Center

Motorola, Inc.
- develop, provide and maintain the in-vehicle navigation and route guidance system
- develop, provide and maintain the communications subsystem

- provide and maintain the in-vehicle database

Illinois Universities Transportation Research Consortium
- design and implement the hardware and software in the Traffic Information Center
- develop enhancements for the operation of the system
- identify guidelines and procedures for driver training and recruitment

American Automobile Association
- provide leadership in the recruitment and training efforts

In addition, De Leuw, Cather & Company was retained as a consultant to the project and is responsible for overseeing the system design, system integration, assisting IDOT in project management and the evaluation of the TIC.

2.2 *ADVANCE* Project Goals

The policy goals which inspired the *ADVANCE* project are as follows:

- to increase traveler mobility
- to reduce travel times and costs
- to reduce transportation infrastructure costs
- to increase highway and traffic safety
- to reduce energy consumption
- to reduce transportation impacts on air quality and noise levels.

More specifically, *ADVANCE* had the following program goals:

- to improve individual travel times by providing real-time information that will allow travelers to adjust mode choice, route choice, departure times and other traveler related behavior
- to provide navigational assistance to travelers
- to enhance existing efforts to provide traffic information to travelers by integrating the demonstration with IDOT District 1 operations
- to investigate to what extent congestion can be reduced through more effective utilization of the existing transportation network
- to evaluate the effectiveness of using vehicles as probes in addition to other various Intelligent Transportation Systems (ITS) technologies
- to evaluate the behavior and perception of travelers, including those not involved in the demonstration
- to identify and evaluate transition paths and costs to develop and implement an operational ITS
- to help to determine the future deployment of ITS

The last goal listed above was intended to provide a basis for an enhanced transportation system of the future. This enhancement could incorporate both the application of the existing ***ADVANCE*** TIC concept to other locations and the broadening of the concept within the Chicago area to include additional transportation information and management services. This goal is now of particular relevance with the development of the Gary-Chicago-Milwaukee Corridor concept.

2.3 *ADVANCE* Within the Framework of ITS Technology Evolution

Traffic congestion has been identified as one of the most serious problems facing urban road networks today and its effects have the potential to put a stranglehold on urban life in the near future. Current traffic volumes are increasing at a rate of four percent per year with the largest urban areas reporting as high as two billion vehicle hours of delay on expressways alone. The Federal Highway Administration (FHWA) projections for the next 15 years suggest that there will be a 200 percent to 450 percent increase in delay time - a projected growth rate so large that conventional highway construction and traffic management will not be viable solutions by themselves.

Although the interstate highway construction program has been largely successful over the past 35 years, Intelligent Transportation Systems (ITS) are expected to be a significant part of the post-interstate highway program. This program is essential to the future viability of the transportation system and will develop, test and deploy advanced technology to meet the increasingly critical needs of the transportation system over the next several years.

The *ADVANCE* operational test was targeted to measure road network performance, monitor vehicle locations, detect incidents, and produce driver guidance information in the context of a suburban arterial network. *ADVANCE's* primary role in advancing the national ITS technology was the use of probe vehicles with emphasis on an arterial road network. In addition, *ADVANCE* developed and implemented techniques to fuse the data from such diverse sources as probe vehicles, fixed detectors and anecdotal reports to provide dynamic route guidance information to drivers.

The United States Department of Transportation (USDOT) has determined that operational tests must be an integral and major part of the national ITS program and are to serve as the transition between research and development and the full scale deployment of ITS technologies. An operational test should evaluate how well newly developed ITS hardware and software products work under real world operating conditions. The *ADVANCE* operational test fitted this description, and furthermore, has demonstrated the feasibility of its technologies in a suburban deployment.

SECTION 3 SYSTEM OVERVIEW

The in-vehicle testing part of the *ADVANCE* project aimed to provide dynamic traffic information for the roadway network in eastern Illinois. Over a seven month period, 75 vehicles were utilized in a 300 square mile area. The vehicles utilized differential GPS navigation as well as dead-reckoning and map matching to navigate their way through the study area. The vehicles themselves acted as probes, sending real-time travel information to a Traffic Control Center (TIC) that in turn transmitted the information to other vehicles as an aid to dynamic route planning. Throughout this report the term "real-time" is utilized to denote information received at the TIC from an information source in contrast to the information contained in the *ADVANCE* historical database of travel times.

The Targeted Deployment phase of the *ADVANCE* project was designed to maximize the benefits of the operational test. As *ADVANCE* moved forward through successive design releases, some concern arose within the project as to the necessity of achieving the originally planned 3,000 vehicle deployment. In light of the major changes in technology that had occurred since the project began in 1991, and the expansion of other ATIS capabilities, it was considered whether a more targeted deployment could achieve many of the original objectives of the project at a significantly reduced cost. Further the Steering Committee re-evaluated the time frame for public acceptance in view of the trend of small consumer purchases of the current commercially available, less complex, in-vehicle navigation systems. They decided that testing with a reduced number of vehicles along selected corridors would accomplish much of what had been planned, enable the budget to be significantly reduced and still meet many project goals. As a consequence, a more useful and efficient way to proceed with *ADVANCE* was created - Targeted Deployment. Under the Targeted Deployment plan, the *ADVANCE* project had the following features:

- testing was conducted using existing project test vehicles;
- vehicle guidance systems were installed in 75 vehicles;
- the on-road test using volunteer drivers was conducted for two to four weeks per driver;
- many aspects of the *ADVANCE* system were tested in a controlled environment; and
- the time frame for testing and evaluation was reduced.

During the Targeted Deployment phase of the project, drivers were provided with route guidance in real-time. The route guidance system used information from a variety of existing sources, such as: a closed loop traffic signal system; *999, a cellular-based motorist call-in system; the Illinois Department of Transportation (IDOT) Traffic Systems Center (TSC), which monitors operations on expressways in the Chicago area; IDOT's Communications Center, which communicates with the Minutemen, a motorist aid system; weather data provided by Surface Systems, Inc.; data from the Illinois State Toll Highway Authority (ISTHA); and Northwest Central Dispatch, an area-wide emergency dispatch system. However, the primary source of information was the vehicles themselves acting as traffic probes. Drivers were recruited to utilize project vehicles to perform tests over a seven month period commencing in June 1995.

The in-vehicle equipment was capable of determining the vehicle location, selecting a near optimum route to the driver's destination, and providing the driver with route guidance instruction via analog voice and a visual display. Actual travel times on roadway links were determined by these probe vehicles as they traversed the test area, and this information was transmitted over a radio system to the TIC. Data fusion algorithms within the TIC provided a synthesis of the probe reports, loop detector information, anecdotal reports and historical data to provide near optimum estimates of link travel times for transmission to the probes. Any revised estimates of travel times were transmitted by the TIC to the probe vehicles. On receipt of revised travel times, the on-board equipment determined if the traffic information received would appreciably affect the route that had been selected by the driver. If there would be an impact, the driver was then presented with an alternative route which could then be selected by the driver in order to avoid the traffic incident or congestion. As the *ADVANCE* probe vehicles collected additional information, the updated travel times were also used to improve the historical knowledge base on travel conditions in the test area.

3.1 *ADVANCE* Subsystems

The *ADVANCE* system consisted of four subsystems, namely the Traffic Information Center (TIC) which contained the Traffic Related Functions (TRF) subsystem and connections to the outside world, as well as the operator interface; the TRF subsystem which included the traffic algorithms; the Cornrnunications Subsystem (COM) which provided message carrying capability between the TIC and the vehicles in the field; and the Mobile Navigation Assistant (MNA), the in-vehicle unit which provided route planning and display capabilities. The development and implementation of the TIC and the TRF were the direct responsibility of the Universities, while the MNA and COM were the responsibility of Motorola. Both the TIC software and the TRF online software resided on the TIC central computer. Among the components which interfaced the TIC were the Global Positioning System, (GPS) and the Differential GPS (DGPS) system.

As this evaluation report concerns the TIC, throughout the remainder of the report the TIC subsystem of the *ADVANCE* project is referred to as the TIC system for ease of discussion,

3.2 *ADVANCE* Test Area

ADVANCE was implemented in an area covering more than 300 square miles in the northwest suburbs of Chicago, Illinois. The operational test area included portions of the City of Chicago and more than 40 northwest suburban communities. This is a high growth region with heavily congested areas and including O'Hare International Airport, the Schaumburg / Hoffman Estates office and retail complexes, and the Lake-Cook Road development corridor. It also includes major sports and entertainment complexes such as the Arlington Heights International Racecourse and the Rosemont Horizon theater.

Approximately 750,000 people live in the area. The region is representative of modem suburban developments and has significant traffic congestion problems. Typical journey times are of sufficient duration to make route changes an option to drivers and the road network in the area offers numerous alternatives for most trips. As outlined above, the project involves 75 vehicles equipped with the navigation and route guidance system. The estimated total number of vehicles in the area is 500,000. The project test area is illustrated in Figure 3.1. The bold line indicates the extent of the test area.

3.3 Implementation Process

The project was divided into two phases: the Development Phase and the Targeted Deployment Phase. Each phase contained several releases. The different releases allowed the software and hardware components to be phased in over time so that products could be developed and tested incrementally as additional functionality was provided. The Development Phase was completed in May 1995. The Targeted Deployment Phase began in June 1995 and was completed by the end of December 1995.

As with all systems development, the project team was able to modify theory with practice. Specifically, as testing progressed, it was found necessary to re-calibrate the various algorithms, for example, the data fusion, travel time prediction, incident detection, and static profile algorithms with real data. This calibration involved both the adjustment of parameters as well as modification of the algorithms themselves in order that they could accept limited, incomplete, or unconfirmed data.

Throughout the spring of 1995, extensive effort took place on the development of an evaluation plan for *ADVANCE* based on the Targeted Deployment concept. A plan devised by Booz-Allen & Hamilton, Inc., was implemented under the overall direction of Argonne National Laboratory (ANL) commencing in June 1995. The plan called for data collection to assess the usefulness of the algorithms that were implemented in the TIC, a comparison of route planning options in a yoked driver test, an evaluation by drivers familiar with the test area using *ADVANCE* equipped vehicles over two week periods, an evaluation of the performance of the TIC and its user interface, a safety evaluation and the documentation of lessons learned in relation to various aspects of the project. This Evaluation Program Plan, Document #8400.ADV.03, dated July 17, 1995, formed the basis of the TIC Architecture and User Interface Evaluation Test Plan. The Evaluation Test Plan (ETP) for the evaluation of the TIC Architecture and User Interface is contained in Appendix B .

3.4 Future Directions

The *ADVANCE* TIC is now in the process of being transformed into the Corridor Transportation Information Center (C-TIC). The C-TIC results from the recommendations contained in a report on the Gary-Chicago-Milwaukee (GCM) Corridor, one of the four priority corridors in the United States. The corridor is broadly identified as the 16 urbanized counties in the states of Wisconsin, Illinois and Indiana. It includes all major freeways, airports, transit and rail systems, ports and inter-modal transfer stations in the region. The GCM corridor extends 130 miles and covers more than 2,500 square miles. It is home to more than 10 million and employs more than four million persons.

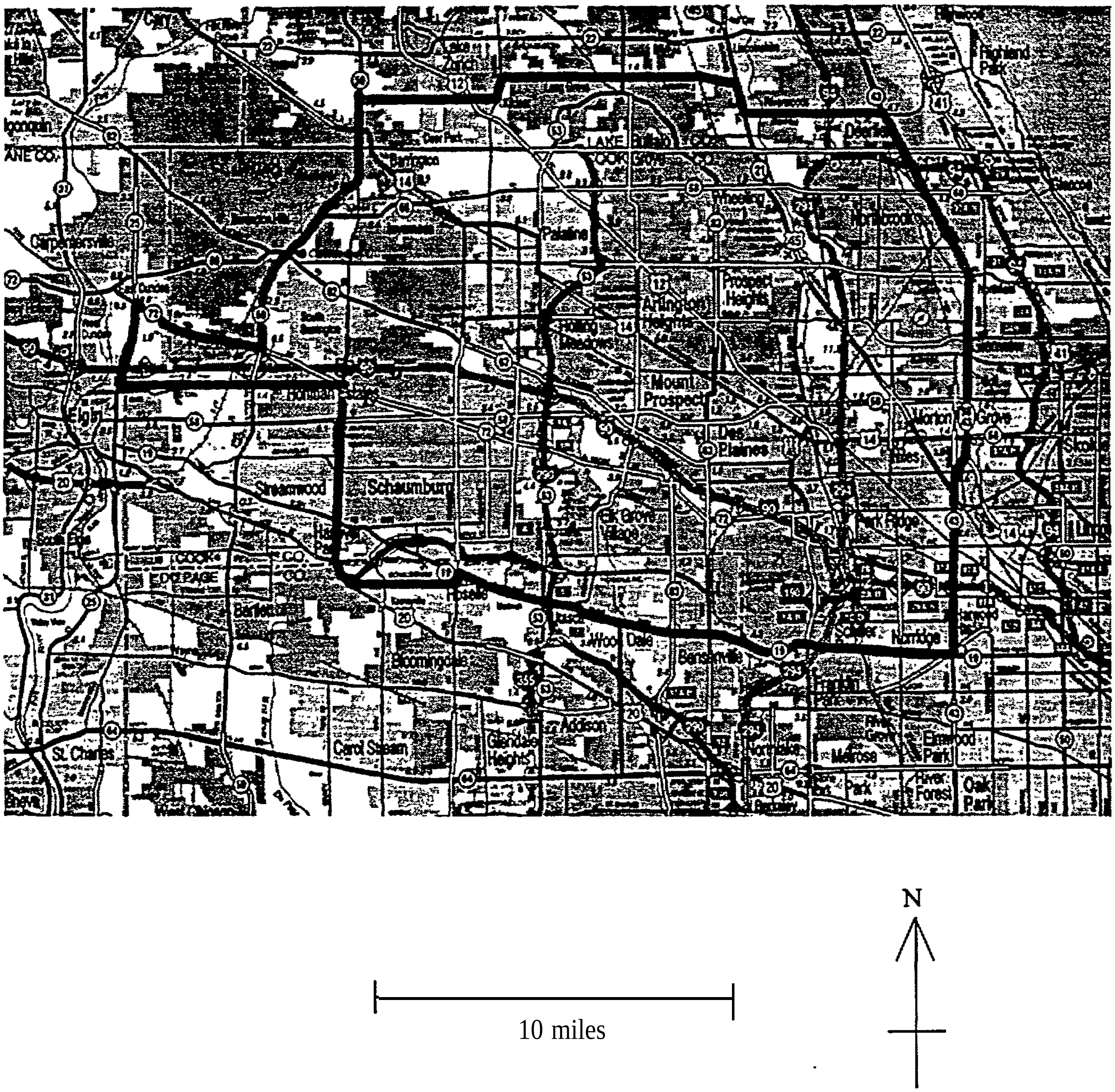


Figure 3.1 ***ADVANCE*** **Test Area Map**

The GCM corridor offers the opportunity to support USDOT ITS operational tests and to provide a testbed for long-term research and evaluation of ITS. As part of the effort a Corridor Program Plan has been developed. This plan outlines a vision for ITS applications and the creation of a state-of-the-art testbed. One of the recommendations in the plan was the implementation of a Corridor Transportation Information Center (C-TIC). The C-TIC is to be designed to act as a pass-through between various information sources in Illinois, Indiana and Wisconsin. It is not designed to control and monitor traffic control devices but rather to facilitate the sharing of information between various agencies, control centers and private firms. As such, minimal processing of the data will occur in the C-TIC. The information to pass through the C-TIC will include travel times on selected routes, weather information, incident locations, construction information, transit delays, and incidents. Thus, the results of the TIC evaluation will be utilized to guide the evolution of the TIC to form the C-TIC.

SECTION 4 EVALUATION OVERVIEW

The *ADVANCE TIC* evaluation had the overall goal of assessing the degree to which the implemented TIC Architecture and operational practices met the needs of all the agencies involved in or affected by the system operation. The current evaluation aimed to produce a detailed description of the advantages and shortcomings of the TIC Architecture and User Interface as presently configured. To achieve this, several aspects of the performance of the various TIC subsystems, both individually and as a complete system, were assessed. In addition, human factors issues relating to TIC operation were also assessed as part of the evaluation.

This section of the TIC Evaluation Report contains an overview of the TIC evaluation hypotheses, goals, objectives, and Measures of Effectiveness (MOEs) The terms "Measures of Effectiveness" and "Measures of Performance" (MOP) are commonly utilized in ITS evaluation documentation. In this document no distinction in meaning is made and MOE is used throughout.

The roles of the agencies involved in the evaluation are also outlined in this section. The evaluation schedule illustrating the timings of the various stages for both the TIC Architecture and the User Interface evaluations is then provided. Further details on all these elements of the evaluation are available in the TIC Architecture and the TIC User Interface Evaluation Test Plan, Document #8464.ADV.00, provided as Appendix B.

4.1 Evaluation Hypotheses, Goals, Objectives and Measures of Effectiveness (MOEs)

A series of hypotheses was constructed for the evaluation of the TIC Architecture and User Interface. The first five hypotheses relate to the evaluation of the TIC Architecture, while the last two hypotheses relate to the evaluation of the User Interface. The evaluation hypotheses are as follows.

Hypothesis 1: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test provides an acceptable level of performance, both in terms of the hardware and software as individual components, and as a complete system. This hypothesis is addressed by Goal A.

Hypothesis 2: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test is expandable to cover additional services within the current test area. This hypothesis is addressed by Goal B.

Hypothesis 3: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test is transferable to other geographic areas. This hypothesis is addressed by Goal B.

Hypothesis 4: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test provides acceptable cost efficiency. This hypothesis is addressed by Goal C.

Hypothesis 5: The operational practices in place at the *ADVANCE* TIC enable acceptable system operation and ensure reasonable operator workload. This hypothesis is addressed by Goal D.

Hypothesis 6: The TIC User Interface as implemented for the *ADVANCE* Targeted Deployment operational test provides an acceptable level of usability. This hypothesis is addressed by Goal E.

Hypothesis 7: The TIC User Interface as implemented for the *ADVANCE* Targeted Deployment operational test provides an acceptable level of functionality. This hypothesis is addressed by Goal E.

Goals and objectives relating to each of the hypotheses were also constructed. Within each of the objectives, various MOEs define in greater detail the aspects of the system which were assessed. These goals, objectives and MOEs are listed below.

Goal A: Evaluate the performance of the TIC Architecture

Objective A.1 Evaluate the performance of the TIC hardware

MOEs
- A. 1.1 TIC hardware functionality
- A. 1.2 TIC hardware reliability
- A. 1.3 TIC hardware maintenance requirements
- A.l.4 TIC hardware efficiency

Objective A.2 Evaluate the performance of the TIC software

MOEs
- A.2.1 TIC software functionality
- A.2.2 TIC software reliability
- A.2.3 TIC software maintenance requirements
- A.2.4 TIC software efficiency

Objective A.3 Evaluate potential system design alternatives

MOE
- A.3.1 Number and type of elements of the architecture which could be simplified to reduce system complexity without compromising system performance

Goal B: Evaluate the expandability and transferability of the *ADVANCE* TIC

Objective B.l Evaluate TIC Architecture expandability

MOE
- B.1.l Number and type of additional transportation information and management functions which could be consolidated within the *ADVANCE* TIC

Objective B.2 Evaluate TIC Architecture transferability

MOE
- B.2.1 Number and type of elements and capabilities of the *ADVANCE* TIC which are non-specific to the Chicago area implementation and which could be utilized to provide TIC services in other geographic locations

Goal C: Evaluate the cost efficiency of the TIC

Objective C.l Evaluate TIC system costs

MOEs
C. 1.1 Fixed and variable TIC capital costs
C. 1.2 Fixed and variable TIC operating costs

Objective C.2 Evaluate alternative TIC cost options

MOEs
C.2.1 Number and type of elements of the TIC implementation which could be simplified to reduce cost without compromising system performance
C.2.2 Alternative cost options

Goal D: Evaluate operational practices at the TIC

Objective D.l Evaluate TIC policies and procedures

MOEs
D.1.l Number and type of areas where policy and procedure impact efficient TIC operation or operator workload
D.l.2 Number and type of revisions to TIC policies and procedures recommended to streamline TIC operations or operator workload

Objective D.2 Evaluate TIC staffing requirements.

MOEs
D.2.1 Number and type of difficulties resulting from existing staffxng levels experienced during TIC operation which effect TIC efficiency or operator workload
D.2.2 Number and type of revisions to TIC staffing levels recommended to streamline TIC operations or operator workload

Goal E: Evaluate the human factors aspects of the TIC User Interface

Objective E.l Evaluate TIC User Interface usability

MOEs
E. 1.1 User perceptions of level of ease with which system can be operated in everyday use
E. 1.2 Number and type of difficulties reported by operators in everyday use

Objective E.2 Evaluate TIC User Interface functionality

MOEs
E.2.1 Difference between desired and actual functionality of the TIC User Interface
E.2.2 Number and type of interface functions not utilized during TIC operation

4.2 *ADVANCE* Parties Evaluation Responsibilities

De Leuw, Cather & Company was responsible for the overall TIC evaluation; Castle Rock Consultants (CRC) provided assistance in this activity within a subconsultant agreement. This included the evaluation planning effort represented by the Evaluation Test Plan (ETP) for the TIC Architecture and the TIC User Interface, Document #8464.ADV.00, the performing of all data collection and analysis activities, the monitoring of evaluation progress to ensure that task scheduling remained on target and that Quality

Assurance procedures were adhered to, and the preparation of the interim and final reports. Human factors expertise was also provided by CRC as part of the De Leuw, Cather team, to facilitate evaluation data collection and analysis of the objectives relating to TIC User Interface human factors issues.

ADVANCE Project Office staff, primarily the TIC operators, were involved in some of the data collection tasks at the TIC, and forwarding this data to the De Leuw, Cather evaluation team as specified in the ETP. Data collection activities included the completion of the TIC Real-Time Log, the TIC Operator Observation Log, and the retrieval of automated logs provided by the TIC systems as required. TIC operators were also interviewed as part of the human factors evaluation tasks.

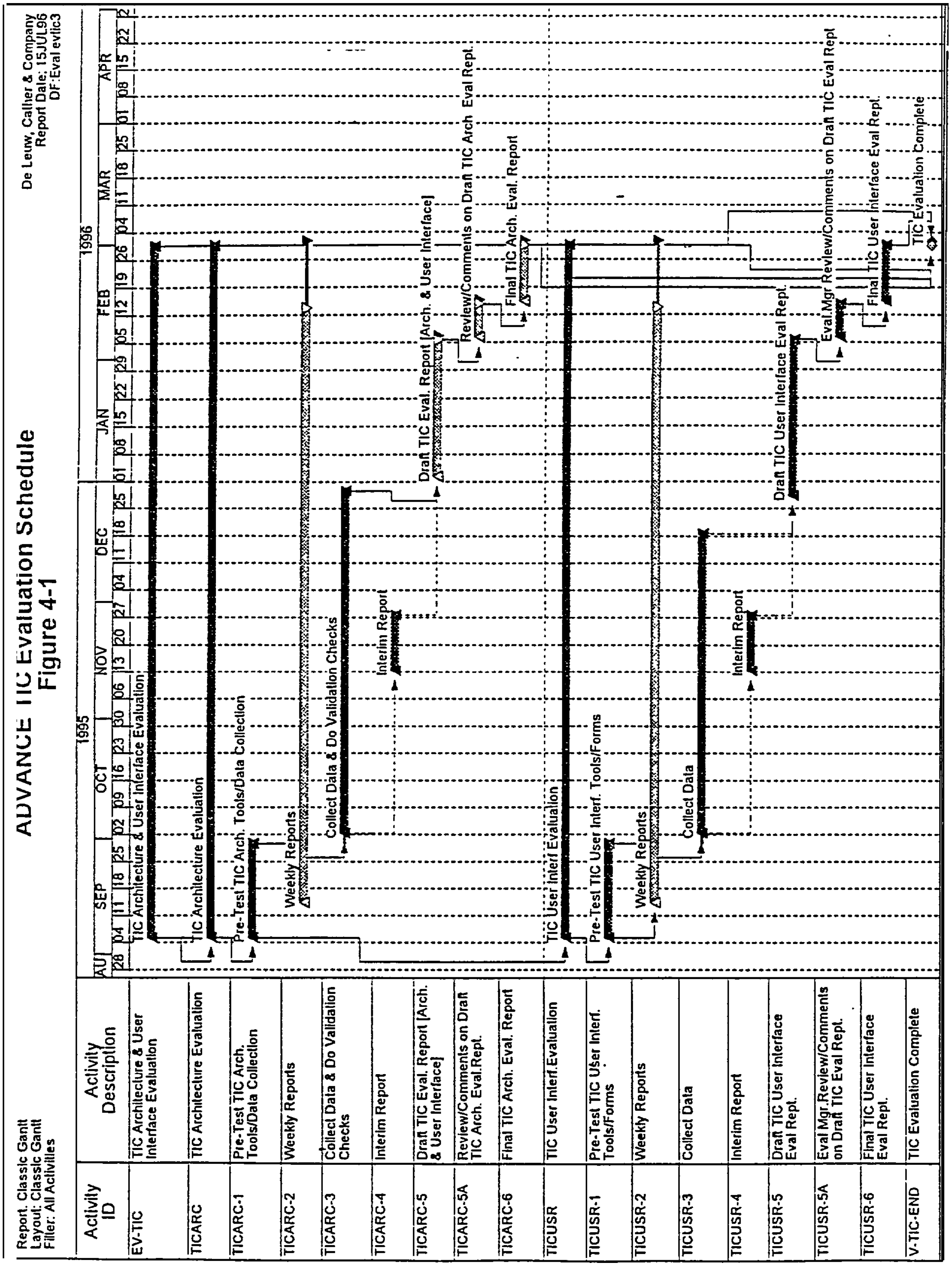
The University of Illinois at Chicago - Electrical Engineering and Computer Science department (UIC-EECS) though not directly involved in the data collection and analysis activities of the TIC evaluation, provided the necessary technical advice regarding ongoing operation of the TIC systems during the evaluation activities. UIC-EECS also provided valuable assistance in retrieving electronic logs from the TIC, and formatting the data to enable analysis.

Utilizing the evaluation plan devised by Booz-Allen Hamilton, Inc., Argonne National Laboratory (ANL) was the evaluation manager for the *ADVANCE* project as a whole, and as such was responsible for approving all status reports, interim reports and the final report of the TIC Architecture and User Interface subtest. This function is referred to throughout this report as the *ADVANCE* Evaluation Manager. Though ANL was not actively involved in the actual data collection and analysis activities of the TIC evaluation, it was responsible for storing all electronic log archived data resulting from the evaluation.

The Illinois Department of Transportation (IDOT) was the contracting agency with De Leuw, Cather. Prior to submitting the Interim and Final Reports to ANL, IDOT approval has been sought. Weekly status reports were also submitted simultaneously to IDOT and ANL.

4.3 TIC Evaluation Schedule

Figure 4.1 provides an overview of the timing of the various evaluation stages for both the TIC Architecture and the User Interface.



ADVANCE TIC Evaluation Schedule
Figure 4-1
Report: Classic Gantt
Layout: Classic Gantt
Filter: All Activities
De Leuw, Cather & Company
Report Date: 15JUL96
DF:Eval evtic3
Activity ID
Activity Description
1995
1996
AU
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
EV-TIC
TIC Architecture & User Interface Evaluation
TICARC
TIC Architecture Evaluation
TICARC-1
Pre-Test TIC Arch. Tools/Data Collection
TICARC-2
Weekly Reports
TICARC-3
Collect Data & Do Validation Checks
TICARC-4
Interim Report
TICARC-5
Draft TIC Eval. Report [Arch. & User Interface]
TICARC-5A
Review/Comments on Draft TIC Arch. Eval.Rept.
TICARC-6
Final TIC Arch. Eval. Report
TICUSR
TIC User Interf.Evaluation
TICUSR-1
Pre-Test TIC User Interf. Tools/Forms
TICUSR-2
Weekly Reports
TICUSR-3
Collect Data
TICUSR-4
Interim Report
TICUSR-5
Draft TIC User Interface Eval Rept.
TICUSR-5A
Eval Mgr.Review/Comments on Draft TIC Eval Rept.
TICUSR-6
Final TIC User Interface Eval Rept.
V-TIC-END
TIC Evaluation Complete

SECTION 5 TIC ARCHITECTURE EVALUATION RESULTS

This section of the Evaluation Report contains the approach, procedures and findings relating to the TIC Architecture evaluation activities. The aim of this component of the evaluation was to evaluate the performance of the various elements of the TIC architecture, including the TIC hardware and software, and to document how these elements perform as a whole system. Several characteristics were selected for the hardware and software evaluation.The functionality of the hardware and software, that is, what functions the system elements performed, was documented. Their reliability and maintenance requirements were also evaluated, including how frequently systems were unavailable, the cause of any system failures, and what interventions were necessary to return systems to full operation. In addition, a measure of the efficiency of the hardware and software systems was documented by recording various system throughput times. Using the results of the review of the system functionality as input, potential system design alternatives were also investigated, in terms of the number and type of elements of the TIC Architecture which could be simplified to reduce system complexity without compromising system performance.

By means of a peer review process, the TIC Architecture expandability was also reviewed by identifying any other functions the *ADVANCE* TIC could incorporate to streamline additional traffic information or management functions in the Chicago area. In addition, the transferability of the TIC concept to other geographic locations was assessed by identifying elements of the TIC which were not specific to the current implementation and matching these against the requirements of other areas for this type of service. The TIC capital and operating costs were documented and possible alternative cost options which could reduce any of these system costs were also investigated.

Other aspects of the TIC Architecture which were evaluated concerned the TIC operating policies, procedures and staffing requirements. Issues which had an impact on the effectiveness of TIC operation or staffworkload were identified. Recommendations for revising any procedures or staffing levels deemed necessary were also documented.

The key assumptions and constraints of the TIC Architecture evaluation are presented in the next section. The subsequent sections are structured according to the list of objectives and associated MOEs created for the TIC Architecture evaluation, provided in Section 4.1 above. Following the presentation of the TIC Architecture findings in this section and the findings of the TIC User Interface evaluation in Section 6, these data are then summarized in Section 7, in relation to their respective hypotheses.

5.1 Key Assumptions and Constraints

As for any evaluation, the results of the *ADVANCE* TIC Architecture evaluation must be considered in the light of the assumptions which were made by the evaluation team and the constraints which may have influenced the findings. In this subsection, the assumptions and constraints relating to the TIC Architecture evaluation are described.

5.1.l Assumptions

The key assumptions that were made' for the evaluation phase are as follows. For MOEs A.1 .l, TIC ***hardware functionality;*** and A.2.1, ***TIC software functionality;*** it was assumed that sufficient documentation existed to enable a comprehensive review and that access to this documentation was not problematic. In addition, it was also assumed that system designers and operators would be available for interviews if required.

For MOEs A.l.2, ***TIC hardware reliability;*** A.l.3, ***TIC hardware maintenance requirements;*** A.2.2, ***TIC software reliability;*** and A.2.3, ***TIC software maintenance requirements;*** it was assumed that the information required in the TIC Real-Time Log was available to the operators and that TIC operators correctly filled in the log sheet as requested.

For MOEs A. 1.4, ***TIC hardware efficiency;*** and A.2.4, ***TIC software efficiency;*** it was assumed that the various measures of time to process data were being accurately recorded by the system processes. In addition, it was assumed that the transcription of data from the various system logs to a single file and the transfer of this file to the data analysis package was accurately performed. It was also assumed that the TIC was sustaining full Targeted Deployment operation prior to the data collection activities.

For MOE A.3.1, ***the number and type of elements of the architecture which could be simplified to reduce system complexity without compromising system performance;*** it was assumed that the input data from previous functionality analyses would be accurate. It was assumed that the peer review team had sufficient knowledge of both the implemented TIC system and possible alternatives to be able to undertake the review process, and that the team members would not be positively or negatively biased towards the existing TIC Architecture.

For MOEs B. 1.1 and B.2.1, concerning ***TIC Architecture expandability and transferability,*** again it was assumed that the input data from previous functionality analyses would be accurate. It was assumed that the peer review team would have sufficient knowledge of the transportation situation in the Chicago area and of national ITS requirements, and that the team members would not be positively or negatively biased towards the existing implementation. It was assumed the peer review participants would consist of members of the existing De Leuw, Cather team.

For MOEs C. 1.1 to C.2.2, relating to ***TIC Architecture capital and operating costs,*** it was assumed that data relating to these items would be available, that the costs would be itemized in sufficient detail and that data were accurate. It was also assumed that cost data would be correctly entered into the analysis package.

For MOEs D. 1 .l to D.2.2, relating to ***the impact ofpolicies, procedures and staffing levels on efficient TIC operation,*** it was assumed that the TIC operators and the supervisor would be available to take part in the questionnaires and informal discussion process, and that they would not be positively or negatively biased towards the existing TIC operational practices. In addition, it was assumed that the TIC Operator Observation Log would be completed by operators whenever appropriate.

On completion of the TIC Architecture evaluation activities, the evaluation team has established that all of the above assumptions were found to be appropriate.

5.1.2 Constraints

The key constraints, or limitations, of the evaluation process were as follows. For all MOEs relating to the TIC Architecture evaluation, the key limitation was the availability and completeness of data from all sources, whether these were manual or automated logs, subjective data obtained from questionnaires or during discussions, or the knowledge of the various peers involved in the consultation process. For the TIC hardware and software performance evaluation, a specific constraint was that timestamp resolution provided by the TIC systems was no finer than one second.

It must also be recognized that the *ADVANCE* project is a Targeted Deployment with a limited number of vehicles in the field. As such, the amount of probe data processed by the system represented a small proportion of that which would be processed in a large-scale test or during full operation. However, data input from all other sources was considered comparable to a larger implementation.

In addition, a constraint of the TIC Architecture evaluation was the depth of analysis which was possible given the level of funding allocated to this portion of the overall *ADVANCE* project evaluation effort.

5.2 Objectives A.1 and A.2 - Evaluate the Performance of the TIC

Within this section, the TIC Architecture MOEs for both hardware and software are considered in conjunction according to the list of MOEs relating to their performance. In Section 5.2.1, the functionality of the TIC Architecture hardware and software is considered. In Section 5.2.2, hardware and software reliability and maintenance requirements are described. In Section 5.2.3, various aspects of the hardware and software efficiency are documented and assessed.

5.2.1 Functionality - MOEs A. 1 .l and A.2.1

In this section, the functionality of the TIC Architecture hardware and software is considered.

5.2.1.1 Functionality - Data Collection Procedures

For MOEs A. 1.1, ***TIC hardware functionality;*** and A.2.1, ***TIC software functionality;*** the input data was derived partly from the Requirements Specification - Final Implementation, Document #8l00.ADV.05-2.0, which relates to the Targeted Deployment of the *ADVANCE* project. A summary of the TIC Architecture functionality was prepared using this Requirements Specification. This information was then compared with the features of the actually implemented system, obtained during a review process involving various partners of the *ADVANCE* project who had participated in the design, development and implementation of the TIC.

These reviewers, comprising Project Office systems developers and designers, were requested to identify areas where the implemented TIC offered additional functionality to that outlined in the requirements documentation, and also any areas where the implemented TIC did not meet the stated requirements.

The feedback from the Project Office reviewers was then incorporated into the original functionality summary to create a document which described the actual functionality of the implemented TIC Architecture. This data is reproduced in the following section. An overview of the function of the TIC within the *ADVANCE* project is provided. Summaries of the functionality of the following items are then provided: the TIC hardware, TIC software, TIC reliability, the communications interface, the archival system and data service, and the operator interface.

5.2.1.2 Functionality - Findings

The following subsections contain the findings of the TIC Architecture functionality review. The implemented TIC Architecture met the Requirements Specification with the few exceptions noted in the following text.

5.2.1.2.1 Overall Function of the *ADVANCE TIC*

The primary responsibility of the TIC consisted of the collection, analysis, and reporting of data on network link travel times and incident locations within the *ADVANCE* test area. The TIC received input data from vehicle probes, the Illinois Department of Transportation (IDOT) Traffic System Center (TSC), operator-interpreted information from various anecdotal sources and a closed loop signal system. It also contained predictive models to forecast information on link travel times. This data is screened, interpreted and saved, allowing the TIC to output appropriate information to the vehicle probes in the test area. These data were also distributed to an independent evaluation database. The major subcomponents that comprised the TIC were the communications interface, the archiving and data services, and the operator interface.

The TIC system provided the central computing resources, console functions, communications interfaces, active data storage, and data archiving and services within the *ADVANCE* project. It also allowed an operator to process memory card data, and prepare historical data for the CD-ROMs of the *ADVANCE* system. The TIC system comprised the necessary hardware and software to provide reliable operations for all TIC functionalities of the *ADVANCE* project. The following subsections provide further detail on the functionality of the various components and subsystems of the TIC.

5.2.1.2.2 Hardware Functionality

The TIC computer distributed its processing power among its software processes such that each process received sufficient capacity to perform its function. The TIC system computer was sufficiently powerful, scalable and capable of handling a heavy processing load, with its associated inputs and outputs. In addition, the TIC system server was capable of supporting multiple users simultaneously as well as processing multiple tasks simultaneously. The TIC system hardware components are outlined as follows:

- 128 MB RAM server, with transparent error detection and correction for single bit errors;
- 13.6 GB hard disk storage;
- 5.0 GB off-line storage on eight millimeter tape;
- 16 serial ports capable of supporting 14.4 Kbps modems and 24 serial ports capable of supporting 9.6 Kbps modems;
- one laser printer;
- one Ethernet Local Area Network (LAN), to connect the workstations running X-windows graphic applications, and to support a high speed connection to the UIC-EECS facility;
- two GPS antennae on the roof of the TIC building which feed into two independent GPS receivers within the TIC;
- one direct connected administrator terminal for operations, administration, and maintenance (OAM) functions;
- two X-terminals which form the TIC operator consoles; and
- one PC with a memory card reader installed.

5.2.1.2.3 Software Functionality

The TIC system's software and database management system (DBMS) were both compatible with and capable of supporting the chosen hardware platform. The TIC system was capable of housing, supporting and managing the Traffic Related Function's (TRF) on-line functions, and it provided simultaneous access to its operations and databases for the various "in-house" processes, components, and system users.

The system indicated via a visual display when any of the ***ADVANCE*** applications were not executing. However, the system did not provide direct feedback to the operator if a remote data source ceased to provide data, or if a remote data source provided erroneous data to the TIC system. The system communicated every process outage or failure to the administrator terminal and to the operator consoles also.

The TIC system had the ability, through manual intervention, to selectively discontinue non-critical activities in order to maintain real-time performance of critical activities. It was stated in the Requirements Specification that the system was also to have allowed "higher priority" activities access to its operations before "lower priority" activities in the event of an access conflict. An example of a higher priority activity is travel time prediction. Lower priority activities include Web browsing via the user interface. The Sun

Operating System utilized featured a processing management scheme which allocated a larger proportion of processing power to higher priority activities.

The TIC system processed the Motorola Interchange File (MIF) database files into its own internal format to support the road network map data and its associated attributes. The TIC system provided a flexible software environment. The server ran the UNIX operating system, and the DBMS was configurable to support different system resource utilizations.

5.2.1.2.4 Reliability

The TIC system was able to operate in an automatic mode to provide full ***ADVANCE*** system capabilities twenty-two and a half hours per day, seven days a week, in the absence of hardware or software failures. During the Targeted Deployment, the TIC system closed down automatically for approximately one and one-half hours early each morning to perform system back-ups. The system was available for use by ***ADVANCE*** probe vehicles and other users for at least 95 percent of the time during the six months of evaluation, disregarding the nightly period when the TIC was shut down for backups to be performed.

In the event of a transient hardware failure, power failure, or a software failure requiring a complete reboot, the TIC system immediately, or upon restoration of power, automatically rebooted and restored all ***ADVANCE*** related operations within 60 minutes. The software design minimized loss of information during a hardware or power failure. In the event of a transient application software fault, the system automatically re-established full operations within 20 minutes if a complete reboot was not necessary.

5.2.1.2.5 Communications Interface

The TIC system served as the communications interface for the various real-time input data streams and supported the physical interface and protocol requirements for each of these. The system was able to read and support each in-bound data stream as often as the individual components could transmit the information to the TIC system. The system created active data files or databases of every in-bound data stream to support all of the TIC system's operations, including TRF functions.

The TIC was responsible for detecting errors of syntax or transmission. It also detected errors of individual message content in the case of loop detector reports whose data inputs caused predicted travel times to be unrealistic. Any data source whose content was known to be erroneous was logged by the system. The system did not accept or distribute any information which contained known errors of syntax, transmission or content. Although the system did electronically log every error detected, the Requirements Specification stated that the system would also maintain statistical information pertaining to each error encountered. This latter function was not implemented.

In-bound Mobile Navigation Assistant (MNA) Communication

The TIC system was capable of receiving in-bound probe vehicle MNA reports and data messages from the communications subsystem (COM). The TIC system provided access to these MNA reports through its database. The TIC system managed the probe vehicle activation process which assisted the COM's message receipt process. This assistance provided confirmation to the COM that all accepted in-bound MNA reports originated from valid probe vehicles, whose modems each possessed a uniquely identifiable code.

An enhancement to the TIC Requirements Specification was the addition of a process, the short link resolver, which reconciled missing link identifications within probe vehicle reports. This addition was necessary due to an inherent characteristic of the MNAs which occasionally caused invalid link identifications (IDs) to be transmitted by the MNAs when traversing very short links. An invalid link ID comprised a link ID which was not consecutive to the immediately preceding transmitted link ID along the route that a probe vehicle was traveling, that is, two consecutive transmitted link IDs were non-connecting. The correct intervening links were found by locating the path between the two reported (non-connected) segments via database queries. An alias table was also created that contained the invalid link IDs along with the corresponding valid link IDs in order to process the short links.

Out-bound MNA Communication

The TIC system had an outbound message scheduler which organized and managed the outbound MNA data messages that were broadcast over the Radio Frequency (RF) communications system. The message scheduler delivered to the COM each unique, outbound MNA message within sixty seconds of the message's creation. The Requirements Specification stated that the message scheduler should be capable of sending travel time updates at a rate of at least one update per second. The implemented message scheduler is in fact capable of sending updates more frequently than once per second, though it should be noted that the limitations of the communications equipment dictated the actual number / rate that could be transmitted.

The message scheduler transmitted link update and Global Positioning System (GPS) correction messages to the MNA units via the COM. As configured for the Targeted Deployment, the message scheduler allowed for a four second gap between outbound messages in order to ensure that the COM did not become overloaded. Updates to link travel times were transmitted as frequently as the volume of updates permitted within a five minute interval.

Other Communications

The TIC system was capable of receiving in-bound data from the IDOT TSC at one minute intervals, and from the Dundee Road closed loop signal system at five minute intervals. An enhancement was added to the TIC which also allowed this loop detector information to be viewed by the operator in a log file window.

The TIC system was capable of receiving information in the form of a log file from Northwest Central Dispatch (NWCD), which contained short- and long-term traffic related incident reports. In addition, IDOT and Illinois State Toll Highway Authority (ISTHA) roadway and lane closures were received daily at the TIC by facsimile. Data from these sources were entered into the TIC database manually by the TIC operator once received by log file or fax. The system then provided access to these data through its database. In addition, the TIC received limited weather data in a log file. However, the entry of these data into the system database was not required, and therefore not performed, during the Targeted Deployment.

The TIC system was capable of retrieving information from all off-line archived files as needed for off-line analysis including old static profiles, probe reports, travel time prediction data, TSC data, loop detector data and certain anecdotal data. The TIC system maintained a network representation database and stored static profile information for each link. It provided access to these data to TRF programs executing in the TIC.

The TIC system received the differential GPS signal, formulated a message and transmitted the differential GPS broadcasts at configurable intervals to the probe vehicle's MNA units. The Requirements Specification stated that these messages were to be broadcast no more than six times per minute. In the implemented system, messages were broadcast at a rate of four times per minute.

The TIC accessed information on the host interface, RF interface, General Communications Controller (GCC) / Base Station Controller (BSC), MNA terminal and Network Control Processor (NCP) from the NCP.

5.2.1.2.6 Archival System and Data Service Functionality

Archived information is being kept on record at least for the entire duration of the *ADVANCE* project. The TIC system enabled an operator to create archive data storage tapes. The practice during Targeted Deployment was to prepare two archive tapes, one for storage at the TIC and one off-site. The TIC system was capable of archiving all data and information necessary to support all TIC and TRF analyses, processes, and evaluation needs. The data items required for these analyses, processes and evaluation needs included input data streams such as MNA reports, the operator system administration message log, in-bound RF communications from probe vehicles, out-bound RF communications to probe vehicles, link travel-time predictions, detected incidents and anecdotal data.

The TIC system archived records into a single file. The TIC system provided for the migration of data from the active, immediately accessible database to the archival system and was capable of providing various functions to assist the archival system's operations.

Data services were provided to the *ADVANCE* parties and other external data users. For remote user access, appropriate security features and protection were provided to ensure that users only accessed data that were appropriate and that the data were not corrupted. These systems contained the appropriate level of security, user access and virus protection necessary to ensure that the archived data and system operation were not compromised. Modification of archived data was impossible except by those with the highest security access. The TIC system's archival functions allowed the archived data to be read and written to, and the functions also supported multiple and simultaneous access and outputs.

ADVANCE Parties Access

The TIC system allowed the *ADVANCE* Parties to retrieve information from the TIC. Non-obvious passwords were required when the system was accessed from a remote location. The system restricted remote access as necessary in order to maintain system integrity as well as to prevent interference with the TIC system's real-time processing requirements. The Requirements Specification also stipulated that the TIC system was to restrict access on a time of day, and day of week basis. This latter function was not implemented.

Overall Access

The Requirements Specification for the *ADVANCE* TIC stated that the operator consoles and access points should provide a means to error-check semantically all operator inputs to the TIC system; however, this was not implemented. The system's password mechanism was able to differentiate and prioritize levels of functionality and system access for each user account. The TIC system provided a menu-driven and/or iconic user interface for all tasks.

Memory Card Data Retrieval

The TIC enabled an operator to read the memory cards from MNAs. The TIC categorized and performed initial analyses of data, and archived the information. The memory card reader was connected through a hardware interface to an IBM compatible PC. The memory card reader used a vendor supplied software driver that made the memory card appear as a standard peripheral input/output (I/O) device. Random access of memory card data was not stated as a requirement. The Requirements Specification stipulated that the data retrieval rate should be such that an entire memory card could be read in less than four minutes. During the Targeted Deployment, MNA cards processed by the PC within the TIC had on average 10 percent of their memory utilized. These memory cards were read by the PC in approximately one minute, thus meeting the requirements. However, if the cards would have had significantly more than 10 percent of their memory written to, there is a possibility that this requirement would not have been met.

The Requirements Specification also stipulated that the TIC should ensure that maliciously changed memory cards were detected without harm to the TIC. Although the TIC did not explicitly check for modified cards, various algorithms within the TRF checked this data for reasonableness, and this procedure was deemed sufficient for the purposes of the Targeted Deployment.

5.2.1.2.7 Operator Interface Requirements

The TIC system provided an operator interface which allowed operators to monitor general system conditions and take actions where necessary. The system also provided an administrator interface to allow a system administrator to perform privileged operations, such as creating new user accounts, and changing passwords. All significant administrator and operator inputs, such as changing of access privileges, creation of user accounts, stopping or starting of TIC processes, or anecdotal data entry, were logged to a file which includes the date, time, and input or modification made.

The TIC system provided both graphical and textual displays on its operator consoles. Display features that the TIC operations consoles included were test area maps, probe vehicle locations, map manipulation features and text features, such as menus and data entry windows.

The TIC system provided a graphical user interface (GUI) for the TIC operator. The GUI allowed the TIC operator to monitor the *ADVANCE* system's entire operations from a single console and provided access to the TIC system, The GUI provided the necessary security measures when the TIC operator accessed the TIC system and allowed the TIC operator to perform the following functions:

- perform administrative functions, including initiating backup and archival processes;
- manually enter data into the database system, based on data received from the various anecdotal sources;
- override the MNA reporting criteria and other parameters as required for evaluation. The Requirements Specification also stated that the operator should be able to override the automatically generated travel time estimates; however, as these are generated so rapidly, the operator is unable to do this other than by inputting overriding anecdotal data.
- the Requirements Specification stipulated that the TIC should be able to produce static profile, probe data and disk space available reports. Though the data existed within the system, they could not be easily interpreted other than by technical system administrators / developers;
- display the contents of the latest MIF file;
- display the contents of a selected static profile, link attributes, or segment attributes file;
- display probe reports which are currently in the active database. The Requirements Specification also stipulated that the operator should be able to specify a start and end time period for reports displayed. If no end time was specified, then all available probe reports to the current time were to have been displayed. This facility was not implemented. The display window updated automatically whenever a new probe report message arrives;
- display the link update messages which are currently in the active database. Again, the Requirements Specification stipulated that the operator should be able to specify a start and end time period for reports displayed. If no end time was specified, then all available link updates to the current time period were to have been displayed. This facility was not implemented. The display window updated automatically whenever a new link update message is generated;
- view the loop detector data at the TIC. The operator was able to select either Dundee Road detector data or TSC detector data. This was limited to the data currently available in the active database.

Again, the Requirements Specification stipulated that the operator should be able to specify a start and end period for reports displayed. If no end time was specified, then all available detector data to the current time period were to have been displayed. This facility was not implemented. The window updated as new detector data arrive;

- monitor all anecdotal and NWCD inputs;
- monitor all incidents reported by the Incident Detection (ID) algorithm;
- view the entire test area, scroll the map in the horizontal and vertical fields, and zoom in and out when viewing the test area map;
- select the roadway classification levels to be displayed on the test area map;
- display roadway names on the test area map. Only the roadway names for the various expressways in the test area were implemented;
- select and monitor data for segments, links, and intersections;
- list the cross streets for a selected roadway;
- the Requirements Specification stipulated that the operator should be able to open up to twelve windows at any one time. In the implemented system, there was no fixed limit to the number of windows that may be displayed. However, system usage issues such as the current processor load and the amount of memory in use did affect the number of windows that could be displayed at any one time. It was found practicable to have no more than six to eight windows open at one time;
- locate any segment, link, roadway, or loop detector, and locate a point on the map by specifying the point's latitude and longitude;
- input incident, and road and lane closure information; and
- allow a privileged user to modify the TRF parameters.

The Requirements Specification stated that the TIC should provide a mechanism for the console operator to accept, reject, or modify a TRF-initiated incident detection prior to its use by other system components. This mechanism was to have been a window with an audible notification tone, with the duration of presentation of this window being adjustable by the operator from 30 seconds to three minutes. The required default response would have been a rejection of the incident if the operator failed to respond in the pre-specified window display duration. In the Targeted Deployment system, an alternative solution was implemented. The implemented feature displayed a flag icon on the test area map at the location of a predicted incident, without an audible notification being provided to the operator. The operator was then able to initiate a window which contained the particulars for the predicted incident, and could modify that data if required.

The TIC also allowed the operator to enter an incident which had been determined from outside sources, the so-called anecdotal input. The TIC system provided access to static data describing the entire *ADVANCE* system's operations. These items of information included lane and road closures, incidents, and travel times. The TIC allowed archiving of this and the system data by an operator. During Targeted Deployment, data were archived on a daily basis.

The TIC system provided an interface to allow authorized operations, administration, and maintenance (OAM) operators to create and modify new user accounts, and view and change privileged parameters concerning the TIC system, including those which pertained to system configuration and generation. The TIC system required a password different from that used by the *ADVANCE* operator to be used when the *ADVANCE* system administrator accessed the TIC system.

ADVANCE system OAM access allowed the system operator to monitor the performance of the system and to make changes as required. The TIC Requirements Specification stipulated that various diagnostic tests were to have been provided to aid the operator in diagnosing failures and performance problems. However no such diagnostic capabilities were provided to the operators. Some diagnostic tests were available only for the use of the technical system administrators. The system maintained a log of all repeated logon failures, communications failures, system restarts, power failures, and all other significant system events.

5.2.1.2.8 Functionality - Summary of Findings

This section provides a summary of the fmdings of the hardware and software functionality review. Any areas where the Requirements Specification was not met and those areas where it was exceeded are listed below.

Non-conformance with the Requirements Specification has been noted in the following areas:

- The system indicated via a visual display when any of the *ADVANCE* applications were not executing. However the system did not provide direct feedback to the operator if a remote data source ceased to provide data, or if it provided erroneous data to the TIC system.
- Although the system did electronically log every error detected, the Requirements Specification stated that the system would also maintain statistical information pertaining to each error encountered. This latter function was not implemented.
- The TIC system allowed each of the several *ADVANCE* Parties to access the system from remote locations. The Requirements Specification also stipulated that the TIC system was to restrict access on a time of day, and day of week basis. This latter function was not implemented.
- The Requirements Specification for the *ADVANCE* TIC stated that the operator consoles and access points should provide a means to error-check semantically all operator inputs to the TIC system; however this was not implemented.
- The Requirements Specification stated that the operator should be able to override the automatically generated travel time estimates. However, as these are generated so rapidly, the operator was unable to do this other than by inputting overriding anecdotal data.
- The Requirements Specification stipulated that the TIC should be able to produce static profile, probe data and disk space available reports. Though the data existed within the system, they could not be easily interpreted other than by technical system administrators / developers.
- The Requirements Specification stipulated that the operator should be able to specify a start and end time period for the display of probe reports, link update messages, and loop detector data which are currently in the active database. If no end time was specified, then all available reports to the current time were to have been displayed. Only the present conditions were accessible.

- The Requirements Specification stipulated that the operator should be able to open up to twelve windows at any one time. In the implemented system, there was no fixed limit to the number of windows that could be displayed. However, system usage issues such as the current processor load and the amount of memory in use did affect the number of windows that could be displayed at any one time. It was found practicable to have no more than six to eight windows open at one time.
- The TIC Requirements Specification stipulated that diagnostic tests were to have been provided to aid the operator in diagnosing failures and performance problems. However, only limited diagnostic capabilities were provided and these were available only for the use of the technical system administrators / developers.

In most of these areas no significant difficulties were experienced as result of the Requirements Specification not being adhered to. Key areas in which the non-adherence to the Requirements Specification could be more significant are discussed further in Section 5.2.1.2.9.

The *ADVANCE* TIC has exceeded the Requirements Specification in the following areas:

- An enhancement to the TIC Requirements Specification was the addition of a process, the short link resolver, which reconciles missing link identifications within probe vehicle reports. This addition was necessary due to an inherent characteristic of the MNAs which occasionally caused invalid link identifications to be transmitted by the MNAs when traversing very short links. An invalid link ID comprised a link ID which was not consecutive to the immediately preceding transmitted link ID along the route that a probe vehicle was traveling, that is, two consecutive transmitted link IDs were non-connecting. The correct intervening links were found by finding the path between the two reported (non-connected) segments via database queries. An alias table was also created that contains the invalid link identifications (IDs) along with the corresponding valid link IDs in order to process the short links.
- The TIC system was capable of receiving in-bound data from the IDOT TSC at one minute intervals and from the Dundee Road closed loop signal system at five minute intervals. An enhancement was added to the TIC which also allowed this loop detector information to be viewed by the operator in a log file window.

5.2.1.2.9 Functionality - Conclusions

It is concluded that the *ADVANCE* TIC as implemented for the Targeted Deployment of the *ADVANCE* project substantially met the final implementation Requirements Specification. It is also recognized that the specified functionality of the TIC systems was exceeded in some cases, where additional features were added to the systems.

There exist three key areas where it is considered further effort is warranted in order to enhance the TIC as implemented for the Targeted Deployment. The key areas to be modified have been identified with the benefit of the operational experience gained during the Targeted Deployment of the *ADVANCE* project. These areas are as follows:

- The TIC systems should be enhanced to provide direct, preferably audible, feedback to the operator if a remote data source ceases to provide data, or if it provides erroneous data to the TIC system.
- A review should be completed to determine if there is a need for the TIC to have the ability to automatically discontinue non-critical activities selectively in order to maintain real-time performance of critical activities.
- The TIC user interface should be enhanced to provide diagnostic tests which an operator can easily use in diagnosing failures and performance problems.

5.2.2 Reliability and Maintenance Requirements - MOEs A.1.2. A.l.3. A.2.2 and A.2.3

MOEs A.l.2, ***TIC hardware reliability;*** A.1.3, ***TIC hardware maintenance requirements;*** A.2.2, ***TIC software reliability;*** and A.2.3, ***TIC software maintenance requirements;*** were assessed using electronic and manual logs of the various TIC processes and components. The TIC Architecture as a whole was evaluated, as were all the constituent processes which form the architecture.

Definitions of terms pertaining to the reliability evaluation which are used in the following subsections are as follows. A ***failure*** is defined as the unscheduled termination of the ability of an item to perform a required function. ***The Mean Time Between Failures*** (MTBF) is defined as, for a stated period in the life of an item, the mean value of the length of time between consecutive failures. The ***Mean Time to Repair*** (MTTR) is defined as the total corrective maintenance time divided by the total number of corrective maintenance actions during a given period of time. ***Corrective maintenance*** is defined as the actions performed, as a result of failure, to restore an item to a specified condition. ***Preventive maintenance*** is defined as the action performed in an attempt to retain an item in a specified condition by providing systematic inspection, detection and prevention of incipient failure. ***Availability*** is defined as the ability of an item to perform its required function at a stated instant of time or over a stated period of time. Availability was calculated as follows:

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

Uptime is defined as the length of time between consecutive failures for a given item, and ***total uptime*** is defined as the total of these lengths of time for a stated period in the life of the item. ***Percentage uptime*** is defined as the total uptime for a given item taken as a percentage of the total length of time of a stated period in the life of the item. ***Downtime*** is defined as the length of time from the occurrence of a failure for a given item until the time when that item becomes functional again, and ***total downtime*** is defined as the total of these lengths of time for a stated period in the life of the item. The reliability calculations utilized the full daily 24-hour period, and did not deduct from this time the early morning periods during which the TIC was non-operational when the daily system back-ups were being performed.

For the TIC reliability and maintenance requirements evaluation activities, the period of data collection was from 00:00 am on November 18, 1995, to 23:59 pm on December 28, 1995 This resulted in the stated period of time for the reliability calculations, referenced in the above definitions, of 984 hours. All values obtained from the reliability calculations have been expressed to four significant figures.

It should be noted that the measures obtained and described in this report should not be considered to be indicative of system reliability throughout the Targeted Deployment. Due to the relatively brief data collection period of 984 hours, inferences as to the reliability of TIC components outside the finite data collection period should not be made. It should also be noted that for several components or processes described in the following subsections, only one failure was experienced during the data collection period. These limitations of the reliability assessment must be borne in mind when considering the data presented.

Initially, it was proposed to record data relating to the reliability and maintenance requirements of the TIC hardware and software throughout the duration of the TIC evaluation period from October to December 1995. However, through analyzing various logs during the data collection activities it was established that the policy on the status of the "Watchdog" process had changed since the beginning of the evaluation period. This process is responsible for monitoring all other processes and restarting any process which shuts down. At the outset of the evaluation phase the Watchdog process was left switched off in order that the operators could troubleshoot any processes which shut-down. Subsequently, this policy evolved and Watchdog was sometimes left on, and sometimes switched off. This had several consequences for the reliability and maintenance requirements evaluation, as follows.

When the Watchdog process was left switched off, the MTTR was largely dependent on the operator noticing a process failure and re-starting the relevant process if this was possible. When the Watchdog process was left switched on, the process automatically detected that a process had shutdown and re-started the process if possible. In the latter scenario, the MTTR was shortened as the restart was usually achieved automatically. There were also consequences for the MTBF. Consequently, the evaluation team, the TIC System Manager, and the *ADVANCE* Evaluation Manager agreed that for the remainder of the evaluation period, from November 18, 1995 to December 28, 1995, the TIC Watchdog process would be left on as this would be the default setting in a permanent implementation. The data presented in this section therefore reflects only the activated Watchdog process condition.

It should be noted that no quantitative reliability goals for the TIC Architecture for the Targeted Deployment, nor for any other data collection period, were established prior to the design and implementation of the TIC. Therefore, the results contained in the following subsections could not be considered in the light of any such goals. An overview is provided of the data collection, reduction, and analysis methodology for the reliability and maintenance requirements MOEs. The results of the analyses are then provided.

5.2.2.1 Hardware Reliability and Maintenance Requirements - Data Collection Procedures

In terms of the TIC Architecture hardware reliability and maintenance requirements, data was collected by means of the TIC Real-Time Log. The TIC Real-Time Log is a manual log, completed by TIC operators and their manager. On this log is recorded the time and date a malfunction occurs, if known, and when it was identified if this differs from the actual time of failure, the system, process, or domponent experiencing failure, known or suspected cause of failure, maintenance action necessary, the time the system, process, or component became operational again, and the identity of the operator completing the log should any further clarification of the log be required after the event. An entry in the TIC Real-Time Log was typically completed on each occasion that a system malfunction was perceived by TIC operators throughout the evaluation period. The TIC Real-Time Log contains details of both hardware and software malfunctions perceived by the TIC Operators or their manager. The log was completed only at times when these staff were on duty at the TIC, that is from 6:00 am to 7:00 pm each week day.

For the purposes of analysis, the log entries were sorted by hardware and software malfunctions. From these log entries the Mean Time Between Failures (MTBF) and Mean Time TO Repair (MTTR) were calculated for the system hardware.

5.2.2.2 Hardware Reliability and Maintenance Requirements - Findings

During the period of data collection for the reliability assessment, that is from, 00:00 am on November 18 to 23:59 pm on December 28, 1995, just one hardware failure was experienced, as described below.

Modem 5

Figure 5.1 contains data relating to the reliability of Modem 5. Modem 5 was responsible for receiving weather data. During the 984 hour data collection period, a single failure was recorded for this component, so that the MTTR of 109.7 hours also represents the total component downtime. The MTBF of 874.3 hours translates to total Modem 5 up-time as a percentage of the 984 hour data collection period of 88.85 percent. The availability of Modem 5 was also calculated, and a value of 0.8885 was obtained. As was noted in Section 5.2.2 above, inferences as to the reliability of this component outside the finite data collection period should not be made based on these findings. The reliability data for Modem 5 were wholly influenced by the timing of the failure of this component. The SSI process logfile for incoming weather data indicated that Modem 5 failed on Sunday, December 24, 1995. No operators were on duty at this time and technicians were not available for support due to the holiday period., The first attempt at repair was performed when the TIC Manager restarted the SSI process on December 26, 1995. This restart did not correct the problem and the failure continued through the end of the data collection period on December 28, 1995. Technicians repaired the hardware failure following the holiday period on January 2, 1996. Repairs consisted of a modem cold start which required approximately 30 minutes to perform.

It should be noted that the Time To Repair (TTR) for Modem 5 was measured as being from 10: 15 am on December 24, 1995, to the end of data collection at 23:59 pm on December 28, 1995, even though the modem had not been repaired by the end of the data collection period. It should also be noted that the repair of Modem 5 was not critical to any formal operational testing. All the in-vehicle tests had been completed prior to December 24, 1995.

Mean Time To Repair Data

Date	stop	Date	Start	Down Time	
				dd:hh:mm:ss	Hours
Dec 24	10:15:13	Dec 28	23:59:59	04: 13:44:46	109.7
Total Stops=1			Total	*04: 13:44:46*	109.7
			Mean	*04: 13:44:46*	109.7

Mean Time Between Failures Data

Date	Start	Date	stop	Up Time	
				dd:hh:mm:ss	Hours
Nov 18	00:00:00	Dec 24	10:15:13	36:10:15:13	874.3
			Total	36:10:15:13	874.3
			Mean	36:10:15:13	874.3

Figure 5.1 Modem 5 Reliability Data

All other hardware components within the TIC Architecture were functional during 100 percent of system operation time, and therefore the value for their availability is 1 .0000.

5.2.2.3 Software Reliability and Maintenance Requirements - Data Collection Procedures

In terms of the TIC Architecture software reliability and maintenance requirements, the TIC Real-Time Log software malfunction data was augmented by the automated process logs created by the TIC. The individual constituent processes which form the system software are listed below, along with a brief description of their respective functions. The order of the list of processes is that in which the processes are activated when the TIC is started up, the top item being initiated first.

Process	Description
Watchdog	This process is responsible for monitoring all other processes and restarting any process which shuts down.
Data Server	This process is responsible for transferring data between the Traffic Systems Center (TSC), Dundee Road #l, Dundee Road #92, Short Link Resolver, Msg Scheduler, MNA Reports, Travel Time Prediction, Incident Tracker, 5 Minute TSC Logger and Dundee Logger processes.
TSCDRV	This process monitors data entering from the TSC and formats this for use in other processes.

Archiver	This process receives and saves data from all other TIC processes.
TSC Status	This process takes formatted data, provided in one minute intervals, from the TSCDRV process, aggregates it into five minute intervals, and then transfers the aggregated data to the TIC database.
MNA Tracker	This process receives probe reports from the MNA Reports process and determines the number of vehicles currently active in the test area.
Dundee Road #l & #92	These two Dundee Road processes receive data from the Dundee Road loop detector master controllers, #l and #92, format the data, and save the data to the TIC database.
NWCD Incidents	This process receives data from the Northwest Central Dispatch Center, and displays this in a log file.
SSI Weather	This process receives weather related data.
Short Link Resolver	This process is responsible for correcting any probe reports containing non-existent link identifiers.
RF Router/Translator, MDC4800 Gateway, and NCP Server	These three processes provide communications to and from the probe vehicles.
Msg Scheduler	This process receives data ready for transmission to the probes, formats it, and sends the data to probe vehicles.
GPS Messages	This process receives differential GPS messages, formats the data, and sends the data to the Msg Scheduler for transmission to the probe vehicles.
MNA Reports	This process receives data from probe vehicles, formats it, and then saves the data to the TIC database.
Travel Time Prediction	This process actually performs all three traffic related functions (TRF), that is, the Incident Detection, Data Fusion and Travel Time Prediction algorithms, on data received from the Data Server and transfers the processed data forward to the Message Scheduler.
Incident Tracker	This process is responsible for moving incidents and closures through their various states (inactive, active, cleared and deleted), and for communicating these state changes to other TIC processes as needed.

1 Minute TSC Logger	This process saves the Traffic Systems Center (TSC) data in the format sent by the TSC every one minute.
5 Minute TSC Logger	This process aggregates and saves data from the 1 Minute TSC Logger every five minutes.
Dundee Logger	This process formats and saves data from the Dundee Road loop detector processes.
TSC to Web Converter	This process creates the Internet Web pages for the Gary-Chicago-Milwaukee (GCM) project.
Database	The Versant database process that handles data from the TSC, Dundee Road #l , Dundee Road #92, Short Link Resolver, MNA Reports, Travel Time Prediction, Incident Tracker, 5 Minute TSC Logger and Dundee Logger processes.
RLDR	The Remove Loop Detector Report (RLDR) process deletes any database material older than a specified number of days. At present all data older than three days are deleted.

The interdependencies of the various TIC processes have consequences for the evaluation of their reliability. A process hierarchy exists whereby should a higher ranking process experience a failure or shutdown, then the processes which depend on it also shutdown or fail. For example, should the Archiver process fail, then the Dundee #l, Dundee #92, MNA Reports, Travel Time Prediction, and TSC Status processes would also fail. The Watchdog process does not fall within this process hierarchy, due to its peripheral monitoring function within the TIC. The list of process failure dependencies is illustrated in Figure 5.2

For the TIC Architecture software reliability evaluation, if a failure of a higher level process was recorded on the system logs, its failure only and not the failures of its dependent processes were translated into the failure rates provided in this document.

Data contained in the TIC main computer SAVELOG directory was used to calculate the mean time between failures (MTBF) and mean time to repair (MTTR) for the TIC and for each TIC process. One logfile contains details of startups and shutdowns for all processes, whether these be planned or in response to an emergency. This log was transferred from the TIC to a PC prior to analysis. Planned process and TIC startups and shutdowns include those for routine operations and maintenance activities such as the backing-up or archiving of data. However, the current evaluation only concerned any non-scheduled or emergency shutdowns of processes or the TIC software as a whole. Therefore, evaluators removed any timestamps relating to planned startups and shutdowns prior to data analysis. This was performed manually by comparing the timestamp data on the electronic log to the manually completed TIC Real-Time Log.

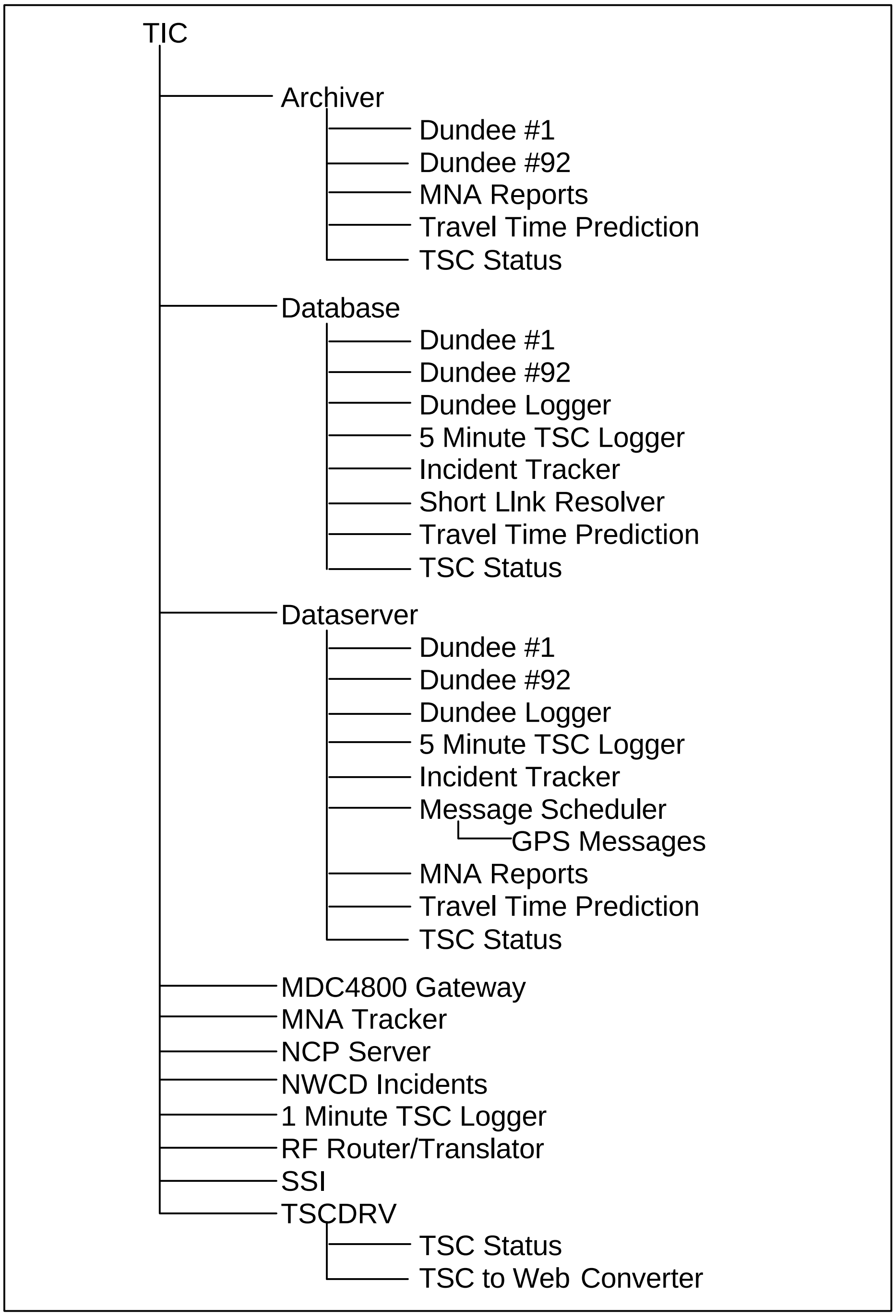


Figure 5.2 TIC Process Failure Hierarchy

As was outlined above, the TIC Real-Time Log records the time and date when both planned and emergency shutdowns occur. It also records the time and date a malfunction occurs, if known, and when it was identified if this differs from the actual time of failure, the system experiencing failure, known or suspected cause of failure, maintenance action necessary, the time system became operational again, and the identity of the operator completing the log should any further clarification of the log be required after the event. An entry in the TIC Real-Time Log was completed on each occasion that a system malfunction was perceived by TIC operators throughout the evaluation period, and whenever a planned process or TIC shutdown occurred.

By comparing the two sources of information it was possible to extract the planned shutdowns from the electronic log data prior to data analysis. The reduced data was then imported into a Lotus spreadsheet analysis program. A macro within this program was designed which calculates the MTBF and MTTR for the TIC as a whole and for each of the above listed TIC processes.

Following these automated calculations, the TIC Real-Time Log was then utilized to identify the causes of the emergency shutdowns, the actions taken to return the system to full operation, and any consequences due to the failure. It should be noted that although the electronic logs comprehensively record all system shutdowns and startups, the TIC Real-Time Log is completed by operators, and therefore, is not exhaustive as operators may not be present when a process shuts down. Some such instances of electronic logs recording failures for which no corresponding TIC Real-Time Log entries were made are noted in the following section where applicable.

5.2.2.4 Software Reliability and Maintenance Requirements - Findings

For the period of data collection for the reliability assessment, that is from, 00:00 am on November 18 to 23:59 pm on December 28, 1995, the data relating to software reliability are contained in Figures 5.3 to 5.8. It was found that during this data collection period, the TIC as a whole failed on three occasions, and only six of the 25 processes experienced failures. All other process or TIC shutdowns during the same period were part of standard maintenance, data back-up, and archival procedures. The following results should be considered bearing in mind the function of the Watchdog process which monitors all other processes and restarts any process which shuts down, as described in Section 5.2.2.

TIC

Figure 5.3 contains data relating to the reliability of the TIC as a whole. The MTTR for the TIC as a whole was 2.907 hours. The minimum Time To Repair (TTR) was 0.1653 hours, and the maximum TTR was 8.383 hours. The three failures experienced during the data collection period of 984 hours resulted in total TIC downtime of 8.721 hours. The MTBF of 243.8 hours translates to total TIC up-time as a percentage of the 984 hour data collection period of 99.11 percent. The availability of the TIC was also calculated and a value of 0.9882 was obtained. As was noted in Section 5.2.2 above, inferences as to the reliability of the system outside the finite data collection period should not be made based on these findings.

As outlined previously, these results do not take into account any planned TIC startups and shutdowns which were performed for routine operations and maintenance activities such as the backing-up or archiving of data.

Mean Time To Repair Data

Date	stop	Start	Down Time	
			dd:hh:mm:ss	Hours
Nov 21	09:17:43	09:27:38	00:00:09:55	0.1653
Nov21	16:20:00	16:30:23	00:00:10:23	0.1731
Nov26	08:48:00	17:10:57	00:08:22:57	8.383
	Total Stops=3	Total	00:08:43:15	8.721
		Mean	00:02:54:25	2.907

Mean Time Between Failures Data

Date	Start	Date	Stop	Up Time	
				dd:hh:mm:ss	Hours
Nov 18	00:00:00	Nov 21	09:17:43	03:09:17:43	81.30
Nov 21	09:27:38	Nov 21	16:20:00	00:06:52:22	6.873
Nov 21	16:30:23	Nov 26	08:48:00	04:16:17:37	112.3
Nov 26	17:10:57	Dec 28	23:59:59	32:06:49:02	774.8
			Total	40:15:16:44	975.3
			Mean	10:03:49:11	243.8

Figure 5.3 TIC Reliability Data

The first TIC failure comprised a system shutdown and start-up by the TIC Manager as the probe vehicles were not receiving differential GPS. Investigation of the failure log indicated that the source of the problem had occurred within a sub-process of the NCP Server process. This failure is reported separately below as an NCP Server process failure. The TIC operator on duty was unaware of the differential GPS loss as the TIC continued to operate without the differential GPS signal. It should be noted that the overall TIC failure in this case was recorded with the manually initiated TIC shutdown at 9:17 am although probe vehicles had not been receiving differential GPS since 5:41 am.

The second system failure occurred later that day when the TIC spontaneously failed due to a Versant database software crash and was restarted by the TIC Operator on duty. The third system failure was caused by a RF communications interface problem. Technicians corrected the problem by re-coordinating the related communications processes through a system restart. The greater time to recovery is mostly due to the fact that this failure occurred on a Sunday. In terms of the maintenance requirements for these TIC failures, it is not registered on the TIC Real-Time Log if subsequent system adjustments were made in response to these failures. In all three cases, no other actions were immediately necessary other than the re-starting of TIC operation.

Dundee 92 Process

Figure 5.4 contains data relating to the Dundee 92 process reliability. This is one of the two processes which receive data from the Dundee Road loop detector master controllers, format the data, and save the data to the TIC database. During the 984 hour data collection period, a single failure was recorded for this process, so that the MTTR of 2.849 hours also represents the total process downtime. The MTBF of 490.6 hours translates to total Dundee 92 Process up-time as a percentage of the 984 hour data collection period of 99.71 percent. The availability of the Dundee 92 process was calculated and a value of 0.9942 was obtained. As was noted in Section 5.2.2 above, inferences as to the reliability of this component outside the finite data collection period should not be made based on these findings.

Mean Time To Repair Data

Date	stop	Start	Down Time	
			dd:hh:mm:ss	Hours
Dec 6	04:37:00	07:27:57	00:02:50:57	2.849
	Total Stops=1	Total	00:02:50:57	2.849
		Mean	00:02:50:57	2.849

Mean Time Between Failures Data

Date	Start	Date	stop	Up Time	
				dd:hh:mm:ss	Hours
Nov 18	oo:oo:oo	Dec 6	04:37:00	18:04:37:00	436.6
Dec 6	07:27:57	Dec 28	23:59:59	22: 16:32:02	544.5
			Total	40:21:09:02	981.2
			Mean	20:10:34:31	490.6

Figure 5.4 Dundee 92 Process Reliability Data

The process failure was recorded in the TIC Real-Time Log by the operator. When the operator came on duty and checked the reporting status of the various remote data sources, it was noticed that the last time the Dundee 92 process had reported to the TIC was approximately three hours earlier at 4:37 am. The process failed because the early morning back-up routine did not make the normal socket connection to the Dundee 92 modem when processes were restarted following back-up. The maintenance action required was the shutting down and restarting of the Dundee 92 process which then reported as normal. It is noted that the Dundee 92 process status indicator itself did not display a process failure. At present the TIC is unable to diagnose when a remote data source stops reporting to the appropriate TIC process, only if that process itself fails. Nonetheless, the non-provision of Dundee 92 data has been considered as a process failure.

Watchdog Process

Figure 5.5 contains data relating to the reliability of the Watchdog process.

Mean Time To Repair Data

Date	Stop	Start	Down Time	
			dd:hh:mm:ss	Hours
Dec 2	00:35:16	05:27:44	00:04:52:28	4.874
Dec 3	00:36:26	05:33:54	00:04:57:28	4.958
Dec 4	00:36:19	05:18:40	00:04:42:21	4.706
Dec 5	00:35:57	05:32:38	00:04:56:41	4.945
Dec 6	00:36:20	04:27:18	00:03:50:58	3.849
Dec 13	00:36:17	05:10:03	00:04:33:46	4.563
Dec 14	00:35:51	05:32:24	00:04:56:33	4.943
Dec 15	00:36:26	05:11:00	00:04:34:34	4.576
Dec 16	00:36:16	05:27:04	00:04:50:48	4.847
	Total Stops=9	Total	01:18:15:37	42.26
		Mean	00:04:41:44	4.696

Mean Time Between Failures Data

Date	Start	Date	stop	Up Time	
				dd:hh:mm:ss	Hours
Nov 18	00:00:00	Dec2	00:35:16	14:00:35:16	336.6
Dec2	05:27:44	Dec3	00:36:26	00:19:08:42	19.15
Dec 3	05:33:54	Dec 4	00:36:19	00:19:02:25	19.04
Dec4	05:18:40	Dec 5	00:35:57	00:19:17:17	19.29
Dec5	05:32:38	Dec 6	00:36:20	00:19:03:42	19.06
Dec6	04:27:18	Decl3	00:36:17	06:20:08:59	164.1
Dec13	05:10:03	Dec 14	00:35:51	00:19:25:48	19.43
Dec14	05:32:24	Dec 15	00:36:26	00:19:04:02	19.07
Dec15	05:11:00	Dec 16	00:36:16	00:19:25:16	19.42
Dec 16	05:27:04	Dec28	23:59:59	12:18:32:55	306.5
			Total	39:05:44:22	941.7
			Mean	03:22:10:26	94.17

Figure 5.5 Watchdog Process Reliability Data

This process is responsible for monitoring all other processes and restarting any process which shuts down. A total of nine failures were recorded for this process and the MTTR was 4.696 hours. The minimum TTR was 3.849 hours, and the maximum TTR was 4.958 hours. The nine failures experienced during the data collection period of 984 hours resulted in total downtime of 42.26 hours. The MTBF of 94.17 hours translates to total Watchdog Process up-time as a percentage of the 984 hour data collection period of 95.71 percent. However, for reasons which are explained in the following paragraph, this percentage does not reflect the amount of time that the Watchdog process was non-functional, but reflects the percentage of operating time within the data collection period during which Watchdog caused difficulties for other processes by switching them on when they should have been switched off. The availability of the Watchdog process was calculated and a value of 0.9525 was obtained. As was noted in Section 5.2.2 above, inferences as to the reliability of this component outside the finite data collection period should not be made based on these findings.

When analyzing the context of these Watchdog process failures, it was found that the failures occurred when the TIC systems shut down automatically early each morning in order that system back-ups could be performed. As part of the daily back-up procedures, the RLDR process is activated. This in turn shuts down the Travel Time Prediction (TIP) process in order that the TTP data may be backed-up. As outlined above, the function of the Watchdog process is to restart any process which fails. However, on the occasions recorded, the Watchdog process was not aware that the TTP process had been shut down by RLDR intentionally as part of the back-up procedures and it restarted the TTP process. This caused difficulties for other processes when they should have been restarted following the back-up procedures.

This scenario was not encountered on each occasion when back-ups were performed, that is, daily, but seemed to result from a random effect of timing whereby Watchdog only detected that TTP had been shutdown on a subset of days. No immediate maintenance action was performed as the process failures occurred when the TIC was unstaffed, and the processes did ultimately correct themselves. In terms of preventive maintenance, it is presumed that this failure of Watchdog could be eliminated by enabling it to be aware of the contexts in which processes can be shutdown intentionally by other processes, or to shutdown the Watchdog with TTP and restart it after RLDR completes its routine.

TSCDRV Process

Figure 5.6 contains data relating to the reliability of the TSCDRV process. This process monitors data entering from the IDOT TSC and formats this for use in other processes. During the 984 hour data collection period, a single failure was recorded for this process, so that the MTTR of 1.008 hours also represents the total process downtime. The MTBF of 49 1.5 hours translates to total TSCDRV Process up-time as a percentage of the 984 hour data collection period of 99.90 percent. The availability of the TSCDRV process was calculated and a value of 0.9980 was obtained. As was noted in Section 5.2.2 above, inferences as to the reliability of this component outside the finite data collection period should not be made based on these findings. The lone failure was caused by an intercommunications problem between driver and client. A technician performed repairs by restarting both the driver and the client.

Mean Time To Repair Data

Date	Stop	Start	Down Time dd:hh:mm:ss	Down Time Hours
Dec 12	10:14:04	11:14:32	00:01:00:28	1.008
	Total Stops=1	Total	00:01:00:28	1.008
		Mean	00:01:00:28	1.008

Mean Time Between Failures Data

Date	Start	Date	Stop	Down Time dd:hh:mm:ss	Down Time Hours
Nov 18	00:00:00	Dec 12	10:14:04	24:10:14:04	586.2
Dee 12	11:14:32	Dec 28	23:59:59	16:12:45:27	396.8
			Total	40:22:59:31	983.0
			Mean	20:11:29:45	491.5

Figure 5.6 TSCDRV Process Reliability Data

Database Process

Figure 5.7 contains data relating to the reliability of the Database process.

Mean Time To Repair Data

Date	Stop	Start	Down Time dd:hh:mm:ss	Down Time Hours
Nov 21	09:21:29	09:25:58	00:00:04:29	0.07472
Dec 15	09:18:58	09:33:55	00:00:14:57	0.2492
	Total Stops=1	Total	00:00:19:26	0.3239
		Mean	00:00:09:43	0.1619

Mean Time Between Failures Data

Date	Start	Date	Stop	Down Time dd:hh:mm:ss	Down Time Hours
Nov 18	00:00:00	Nov 21	09:21:29	03:09:21:29	81.36
Nov 21	09:25:58	Dec 15	09:18:58	23:23:53:00	575.9
Dec 15	09:33:55	Dec 28	23:59:59	13:14:26:04	326.4
			Total	40:23:40:33	983.7
			Mean	13:15:53:31	327.9

Figure 5.7 Database Process Reliability Data

Database is the Versant database process which handles data from the TSC, Dundee Road #l, Dundee Road #92, Short Link Resolver, MNA Reports, Travel Time Prediction, Incident Tracker, 5 Minute TSC Logger and Dundee Logger processes. A total of two failures were recorded for this process and the MTTR was 0.1619 hours. The minimum TTR was 0.07472 hours and the maximum TTR was 0.2492 hours. The two failures experienced during the data collection period of 984 hours resulted in total downtime of 0.3239 hours. The MTBF of 327.9 hours translates to total Database process up-time as a percentage of the 984 hour collection period of 99.97 percent. The availability of the Database process was calculated and a value of 0.9995 was obtained. As was noted in Section 5.2.2 above, inferences as to the reliability of this component outside the finite data collection period should not be made based on these findings.

Both failures are identical in that the Database process failed to shutdown initially for logfile back-up in each case. The first failure occurred when the TIC operator had to request that the Database process be shutdown three times in order to perform a weekly database back-up. The second failure occurred when the TIC operator had to request Database process shutdown four times in order to perform a database back-up. No further data were available on the cause of these failures and any subsequent preventive maintenance action taken.

MNA Reports Process

Figure 5.8 contains data relating to the reliability of the MNA Reports process. This process receives data from probe vehicles, formats it and saves the data to the TIC database. A total of three failures were recorded for this process and the MTTR was 0.001204 hours, The minimum TTR was 0.001111 hours and the maximum TTR was 0.00 1389 hours. The three failures experienced during the data collection period of 984 hours resulted in total downtime of 0.003611 hours. The MTBF of 246.0 hours translates to total MNA Reports process up-time as a percentage of the 984 hour collection period of 99.99 percent. The availability of the MNA Reports process was calculated and a value of 0.9999 was obtained. As was noted in Section 5.2.2 above, inferences as to the reliability of this component outside the finite data collection period should not be made based on these findings. The cause of each of these failures is unknown. The failure was corrected in each case when Watchdog restarted the process.

Mean Time To Repair Data

Date	Stop	Start	Down Time	
			dd:hh:mm:ss	Hours
Nov 25	14:45:33	14:45:37	00:00:00:04	0.001111
Dec 6	18:05:29	18:05:33	00:00:00:04	0.001111
Dec 13	22:31:32	22:31:37	00:00:00:05	0.001389
	Total Stops=3	Total	00:00:00:13	0.003611
		Mean	00:00:00:04	0.001204

Mean Time Between Failures Data

Date	Start	Date	Stop	Up Time	
				dd:hh:mm:ss	Hours
Nov 18	00:00:00	Nov 25	14:45:33	07:14:45:33	182.8
Nov 25	14:45:37	Dec 6	18:05:29	11:03:19:52	267.3
Dec 6	18:05:33	Dec 13	22:31:32	07:04:25:59	172.4
Dec 13	22:31:37	Dec 28	23:59:59	15:01:28:22	361.5
			Total	40:23:59:46	984.0
			Mean	10:05:59:57	246.0

Figure 5.8 MNA Reports Process Reliability Data

NCP Server **Process**

Figure 5.9 contains data relating to the NCP Server process reliability. This is one of three processes which are responsible for maintaining the interface with the COM sub-system of *ADVANCE.* During the 984 hour data collection period, a single failure was recorded for this process, so that the MTTR of 3.755 hours also represents the total process downtime. The MTBF of 490.1 hours translates to total NCP Server process up-time as a percentage of the 984 hour data collection period of 99.62 percent. The availability of the NCP Server process was calculated and a value of 0.9924 was obtained. As was noted in Section 5.2.2 above, inferences as to the reliability of this component outside the finite data collection period should not be made based on these findings.

Mean Time To Repair Data

Date	Stop	Start	Down Time	
			dd:hh:mm:ss	Hours
Nov 21	05:42:20	09:27:38	00:03:45:18	3.755
	Total Stops=1	Total	00:03:45: 18	3.755
		Mean	00:03:45: 18	3.755

Mean Time Between Failures Data

Date	Start	Date	stop	Up Time	
				dd:hh:mm:ss	Hours
Nov 18	00:00:00	Nov 21	05:42:20	03:05:42:20	77.71
Nov 21	09:27:38	Dec 28	23:59:59	37:14:32:21	902.5
			Total	40:20: 14:41	980.2
			Mean	20:10:07:20	490.1

Figure 5.9 NCP Server Process Reliability Data

The process failure was noted when a probe vehicle driver reported that probe vehicles were not receiving differential GPS. The TIC Process Controller did not reflect the differential GPS loss. The cause of the differential GPS loss was identified in the logfile for the MNA Reports process. The logfile noted an error that a Remote Procedure **Call (RPC)** program had not been recognized by the MNA Reports process when the system stied following the early morning back-up procedure. The RPC program recognition error was traced to one of the sub-prodesses of the NCP Server process. The maintenance action required was the shutting down and restarting of the TIC which was referred to previously. The TIC restart restored differential GPS and all systems then reported as usual.

Other TIC Processes

All other software processes within the TIC Architecture were functional during 100 percent of system operation time, and therefore the value for their availability is 1.0000. This was the case except as was noted previously, when processes lower in the process hierarchy, that is, processes dependent on higher processes, failed as a direct consequence of higher level process failures.

5.2.2.5 Reliability and Maintenance Requirements - Summary of Findings and Conclusions

As was noted in Section 5.2.2 above, inferences as to the reliability of the various components outside the finite data collection period should not be made based on these findings.

In terms of MOE A. ***1.2 TIC hardware reliability,*** during the period of data collection for the reliability assessment, that is from, 00:00 am on November 18 to 23:59 pm on December 28, 1995, just one hardware failure was experienced, as is summarized in Table 5.1.

Component	MTTR (hours)	MTBF (hours)	% Up-time	Availability
Modem 5	109.7	874.3	88.85	0.8885

Table 5.1 Summary of Hardware Reliability Data

The hardware component which experienced a failure was TIC Modem 5, which is responsible for receiving weather data. The timing of the modem failure, which occurred during the Christmas holiday period, significantly impacted the MTTR. However, this failure did not impact the ADVANCE operational testing as all in-vehicle tests had been completed by the time of this failure.

All other hardware components within the TIC Architecture were functional during 100 percent of system operation time, and therefore the value for their availability is 1.0000.

In terms of MOE A. 1.3 ***TIC hardware maintenance requirements,*** the maintenance action required for the Modem 5 hardware failure consisted of a modem cold start which required approximately 30 minutes to perform. This action required the assistance of the system designers.

It is concluded that the TIC hardware provided an acceptable level of reliability for the *ADVANCE* Targeted Deployment. It is also concluded that the maintenance requirements of the TIC hardware proved to be reasonable, although it should be noted that the maintenance required the assistance of technical staff, and so continued access to these, or similar, staff should be ensured.

In terms of the assessment of MOE A.2.2 ***TIC software reliability,*** for the same data collection period it was found that the TIC as a whole failed on three occasions and only six of the 25 processes experienced failures. All other process or TIC shutdowns during the same period were part of standard maintenance, data back-up, and archival procedures. Reliability data for these failures are summarized in Table 5.2.

All other software processes within the TIC Architecture were functional during 100 percent of system operation time, and therefore the value for their availability is 1.0000.

In terms of the assessment of MOE A.2.3 ***TIC software maintenance requirements, the*** maintenance action required for the TIC, the Dundee 92 process, the TSCDRV process, and the NCP Server failures was the shutting down and then restarting of the respective systems or processes which then functioned as normal. It was not documented on the TIC Real-Time Log if subsequent system adjustments were made in response to these failures. It should be noted that when the TIC as a whole or individual processes required shutting down, this action had to be performed by either the TIC Manager or system administration technical staff.

System / Process	MTTR (hours)	MTBF (hours)	% Up-time	Availability
TIC	2.907	243.8	99.11	0.9982
Dundee 92	2.849	490.6	99.71	0.9942
Watchdog	4.696	94.17	95.71	0.9525
TSCDRV	1.008	491.5	99.90	0.9980
Database	0.1619	327.9	99.97	0.9995
MNA Reports	0.001204	246.0	99.99	0.9999
NCP Server	3.755	490.1	99.62	0.9924

TabIe 5.2 Summary of Software Reliability Data

No immediate maintenance action was performed for the Watchdog process failures as these occurred when the TIC was unstaffed, and the processes ultimately corrected themselves. No further data were available on the cause of the Database process failures nor any subsequent preventative maintenance action taken.. The immediate action taken in response to the failure of the Database process to shutdown for logfile backups was to repeat the process shutdown commands until these were registered and executed by the process. The MNA Reports process failures were corrected in each instance when Watchdog restarted the process. No further maintenance action was required.

It is concluded that the TIC software provided an acceptable level of reliability for the *ADVANCE* Targeted Deployment. Should the current system be utilized or adapted for use in a longer term or more extensive implementation, it is proposed that further effort would be required to ensure that, during unstaffed operations, the overall TIC MTTR is reduced from the current value of 2.907 hours. However, due to the frequency with which the TIC as a whole failed, that is 3 times within 984 hours, this MTTR did not severely impact the system availability of 0.9982.

The reliability data for the Watchdog process should be considered bearing in mind that the MTTR of 4.696 hours does not represent the amount of time that the Watchdog process was non-functional, but reflects the time during which Watchdog caused difficulties for other processes by switching them on when they should have been switched off.

It is also concluded that the maintenance requirements of the TIC software proved to be reasonable. However, as was the case with the TIC hardware, it should be noted that the maintenance action in response to software failures largely required the assistance of technical staff, and so continued access to these, or similar, staff should be ensured.

5.2.3 TIC Efficiency - MOEs A.l.4 and A.2.4

MOEs ***A.*** 1.4, *TIC hardware efficiency;* and A.2.4, *TIC software efficiency;* were assessed in conjunction using various measures. This section presents a description of the data collection procedures and the results of analyses for these efficiency MOEs. The efficiency evaluation comprised the following areas:

- the measurement of the time taken to process data originating from automated sources, and the volume of data inputs that could be entered into the TIC before the five minute TRF cycle was reached;
- the measurement of the time taken to process data involving manual input;
- the measurement of the frequency of the TIC data back-up cycle required; and
- the measurement of the efficiency of the TIC in providing an information service without manual data entry.

This section is structured according to these four areas. It should be noted that the findings presented in the following subsections are of course dependent on maintaining the same system parameters utilized for the Targeted Deployment and the same typical range of data reports which habitually entered the TIC during Targeted Deployment. Therefore, the conclusions drawn from the findings should not be taken out of the context of the *ADVANCE* Targeted Deployment.

Prior to the presentation of the procedures and findings of the efficiency evaluation, a description of the data flow through the TIC is provided. This description highlights the various timestamps that were available to the evaluation team for use in the evaluation process.

5.2.3.1 Data Flow through the TIC

Preliminary analyses of the electronic logs provided by the TIC were performed to identify the timestamps that were available for the purposes of the TIC evaluation. The four main components of the TIC and the seven main timestamps which were available to the evaluation team are illustrated in Figure 5.10. The following paragraphs provide a brief and simplified description of the data flow through the architecture in terms of the timestamps that are logged by the system.

Data that enter the TIC originate from three sources: probe vehicles, loop detectors, and anecdotal reports. A single report contains data for one test area link. Probe report data include travel times and congestion distances for each link traversed. Loop detector data provided to the TIC include raw and smooth volumes and occupancies for links in the test area from the Traffic Systems Center (TSC) and Dundee Road loop detector systems. The entry of the data reports from the probe vehicles and loop detectors into the TIC are automated processes, requiring no manual intervention. Timestamp Tl for these inputs represents the time that the reports are initiated by these remote systems.

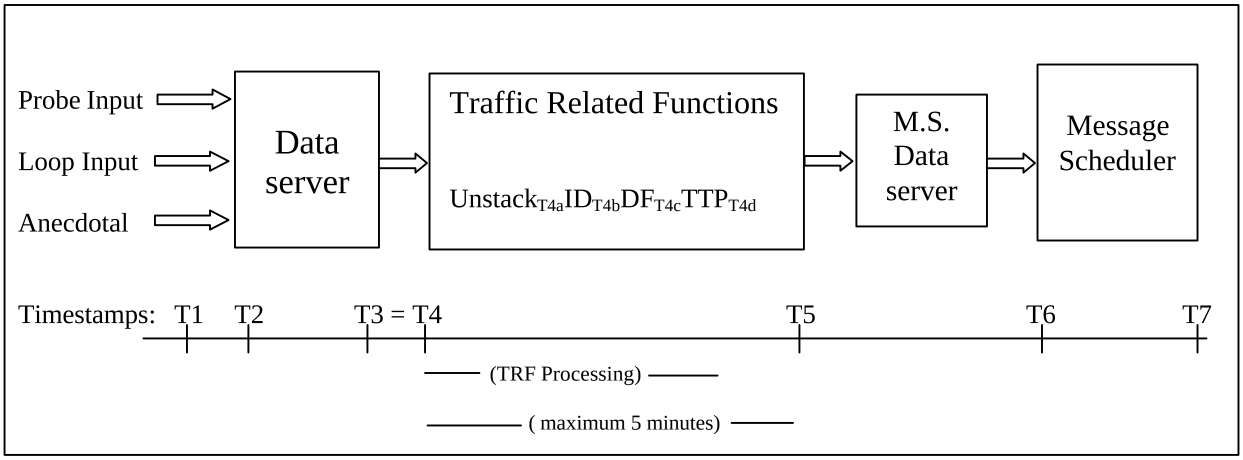


Figure 5.10 Timestamps Logged by the TIC

Anecdotal input into the TIC consists of Northwest Central Dispatch (NWCD) reports as well as lane and road closure information which is provided by Illinois Department of Transportation (IDOT) and the Illinois State Toll Highway Authority (ISTHA). The TIC server has a direct connection with the NWCD printer feed which provides reports in near real-time. The operator is required to scan the incoming reports to ascertain if the reports are both relevant to the geographic scope of the test area and appropriate for the ADVANCE operational test, that is, will they affect traffic within the test area. If the NWCD information is relevant, then the operator is required to manually create a report based on this information for entry into the TIC database. Anecdotal NWCD data input includes incident type, impact, intensity, and duration. Timestamp Tl for the NWCD anecdotal inputs represents the time at which the reports are entered remotely into the NWCD database by the NWCD operator.

Lane and road closure information arrives on a daily basis by facsimile at the TIC. This anecdotal data is also manually entered by the operator into the TIC. However, as this non-real-time information is typically received the day before the start of any lane or road closure, a Tl timestamp for this information type was not applicable in the context of the efficiency evaluation.

T2 for all three types of inputs represents the time at which the data reports entering the TIC data server are subsequently written to the TIC database. Reports are accumulated within the data server until the Traffic Related Functions (TRF) process is initiated. Data reports exit the data server at time T3. The TRF acquires the accumulated data reports from the data server every five minutes. T4 represents the time at which the TRF process commences. Due to the coarseness of the timestamps recorded by the TIC, that is, only to within one second, T3 is identical to T4.

At the beginning of each TRF cycle, TRF prepares all reports received from the data server for processing through the various algorithms [Incident Detection (ID), Data Fusion (DF) and Travel Time Prediction (TIP)]. Following preparation, TRF passes each report individually through the various TRF algorithms in order to identify those reports that warrant a dynamic update to the static travel time database. For each data report in the stack, four "sub-timestamps" are created by the TIC. These relate to the times that each report is "unstacked" (T4a), runs through ID (T4b), runs through DF (T4c), and runs through TTP (T4d). For a single data report, these times are virtually indistinguishable due to the coarseness of the timestamping within the TIC, that is, to within one second.

A data report is identified as a dynamic update to the static travel time database if the absolute value of the difference between the data report link travel time and the static link travel time is greater than or equal to a threshold of 20 seconds. Data reports identified as dynamic updates receive a set of four new travel time adjustments from the static travel time for that particular link. These four values comprise travel time adjustments for each of the next four 5-minute intervals. If any of the four adjustment values is zero, that is, when the dynamic value equals the static travel time, the report remains in the message scheduler cycle where it will "timeout" when static conditions return. If all four adjustment values are non-zero, the report will be processed in a single message scheduler cycle using the adjustment value for the first five minutes after which it returns to TRF for processing using the adjustment value for the second five minutes as input. This routine is repeated until any of the four adjustment values is zero at which time the report remains in the message scheduler where it will "timeout" when static conditions return.

To provide an indication of the approximate number of reports which result in an update of a link travel time, all data reports within a typical operating scenario from 4:00 pm to 6:00 pm on 4 December, 1995 were examined. The percentage of data reports processed by TRF which resulted in a travel time update being produced and transmitted by the TIC was 4.4 percent of the total inputs entered into the TIC. This number of total inputs included travel time update data reports, data reports which did not result in a travel time update and data reports for travel time updates from previous TRF cycles which remain in the system until the appropriate time-out point. This figure of 4.4 percent of entered reports resulting in travel time updates would change if certain TRF parameters were altered. At present, a modifiable threshold, set at 20 seconds for the Targeted Deployment, governs if an incoming probe report is considered to contain a travel time update based on the magnitude of the difference between the dynamic reported link travel time and the travel time contained in the static database. The effects of modifying TRF parameters and the update thresholds were not part of the current evaluation.

T5 represents the time at which the last unstacked data report passes through the various TRF algorithms. The time that TRF takes to process data is dependent upon the size of the stack of data reports obtained from the data server. Any data obtained from the data server at the start of a five minute cycle which has not been processed by TRF within the next five minutes, that is, before the start of the subsequent cycle, is discarded by TRF. All data reports collected during regular TIC operations and which were analyzed as part of the evaluation activities were processed by TRF in approximately two minutes. This interval represents the difference between T4 and T5.

Data reports qualifying as an update to the static travel time database are passed to the message scheduler data server where they await the start of the next message scheduler cycle. All other reports which would not result in an update to a travel time contained within the static travel time database are discarded by TRF.

The message scheduler cycle also initiates every five minutes, although the TRF cycle and the message scheduler cycle are not synchronized. The interval between the start of the TRF cycle and the start of the message scheduler cycle varies and is established when each process goes on-line as part of a TIC systems startup. The TIC systems are shutdown and started up daily following the early morning backup routine. During Targeted Deployment operations, the interval between the start of the TRF cycle and the start of the message scheduler cycle tended to be between three and four minutes. This non-synchronization of the two cycles and the interval between the starts of the two cycles was the main governing factor in the time to process data reports.

T6 represents the time at which the updated reports which have accumulated in the message scheduler data server are accessed by the message scheduler at the start of its five minute cycle. Aged data reports that have not yet timed out are also reprocessed at this time. The message scheduler "bundles" groups of processed data reports into a format suitable for transmission from the TIC. T7 represents the time at which the first bundle of data reports is forwarded to the communications subsystem of *ADVANCE* (COM).

Within the TIC, various time periods and day types are differentiated for the static link travel times. However, the efficiency evaluation was based on the assumption that there was no difference in data processing time between the various day types and time periods for an equal number of data reports. The validity of this assumption was confirmed by the TIC system integrators.

In preliminary analyses of the electronic log data provided by the TIC it was established that the timestamps available were precise only to within one second. At this level of definition, it was not possible to distinguish any variations in the time taken to process the different types of data once these entered the TIC, for example, the time to process probe reports compared to loop detector reports compared to anecdotal inputs. This meant that the efficiency evaluation was restricted to measures of the times taken to process the entire volume of data within the TIC rather than the times taken to process individual types of data by source.

The timestamps outlined above which were utilized for the evaluation were as follows. Timestamp Tl for the automated reports originating from the probe vehicles and the loop detectors was not included. The timing and frequency of these data reports were governed by the reporting schedule of their remote sources, and as such were outside of the control of the TIC. Timestamp Tl for the anecdotal, manually entered, reports was recorded. This is discussed further in Section 5.2.3.3.

As was noted previously, the TRF acquires the accumulated data reports from the data server every five minutes. Therefore, the mean time the data reports remain in the data server is two minutes, 30 seconds. For data reports originating from automated sources this value of two minutes, 30 seconds was utilized as a default value for the time difference between T2 - the time at which reports enter the data server, and T3

- the time at which reports exit the data server, for the purposes of the effkiency evaluation. For the lesser quantity of manually-entered anecdotal data reports, the actual values for timestamps T2 and T3 were extracted from the appropriate log file. The remaining timestamps, that is, T4 to T7, were then recorded for all data reports and included in the time to process data calculations,

5.2.3.2 Time to Process Data and TRF Cycle Capacity

5.2.3.2.1 Time to Process Data and TRF Cycle Capacity - Data Collection Procedures

Live Data Collection

This part of the efficiency evaluation involved entering a varying number of inputs into the TIC in order to investigate the dependency of TIC processing time on the volume of inputs and the capacity of the TRF cycle for processing reports. "Live data" are defined as those data which were received from actual operational information sources during the data collection period.

A straightforward method of varying the number of inputs, or reports, entering the TIC was to isolate certain combinations of input sources. In effect this involved "switching off" combinations of data sources such as the probe reports and the two sources of loop reports: Dundee Road and the Traffic Systems Center (TSC) Though the manual anecdotal reports still entered the TIC during the data collection activities, the number of manual anecdotal inputs being entered into the TIC were not a significant factor. During the evaluator observation sessions it was noted that the operator was capable of entering only three incidents during an average five minute interval. As such, the number of anecdotal reports entered into the system was negligible compared to the number of reports entered from the automated sources, therefore when designing which combinations of inputs to manipulate, the manual anecdotal inputs were not considered.

This method of analysis was limited in that there were only three main types of automated inputs to the TIC: Dundee Road loop detectors, probe reports, and TSC loop detectors. To offset this limitation, the evaluation team also used a utility which simulated a large number of probe reports for the purposes of system evaluation. This utility allowed a significantly higher number of inputs to be entered into the system and analyzed. It is described in further detail later in this section,

As the input of probe vehicle data reports into the TIC could not be switched off during the Targeted Deployment without impacting the operational test and other evaluation activities, the "live" automated data source combinations available for analysis were as follows:

- probe reports only;
- probe reports and Dundee loop detectors;
- probe reports and TSC loop detectors; and
- probe reports, TSC loop detectors, and Dundee loop detectors.

As it was assumed that, for an equal number of data reports, there was no variance in TIC processing time according to the day type or time of day, the time selected for data collection and recording was arbitrary as long as it provided inputs from the required data sources at an acceptable level for the evaluation. For example, data sampling had to take place at a time when probe vehicles were using the test area roadways.

For each of the combinations of live data sources listed above, data were isolated and analyzed for several five minute intervals within a typical weekday 24 hour period. These five minute intervals were designed to coincide with the five minute TRF cycle. It was only possible to collect live data using this procedure during a relatively short time period due to the need to avoid affecting regular TIC operations and other *ADVANCE* evaluations in progress. The data collection period for the live data took place on December 4, 1995.

The sampling outline is illustrated in Table 5.3. The live data obtained for both Measure 1and Measure 2 were entered into a spreadsheet program for processing. A macro was designed which extracted the required timestamps for both measures and calculated the time difference as required. Both measures were then plotted against the corresponding volume of live data reports. These plots are contained in Section 5.2.3.2.2.

SOURCE	MEASURE 1	MEASURE 2
Probe reports only	T4 to T5	T2 to T7
Probe reports and Dundee loops	T4 to T5	T2 to T7
Probe reports and TSC loops	T4 to T5	T2 to T7
Probe reports, TSC loops, and Dundee loops	T4 to T5	T2 to T7

Table 5.3 Data Sampling Outline

Simulated Data Collection

As was noted above, the evaluation team also utilized a program, titled ***mnarep-sim,*** which simulated a large number of probe reports for the purposes of system evaluation. The results for the time to process data originating from both the actual loop detector systems, which feed into the TIC, and the simulated data source were used to extrapolate the approximate number of reports which would overload the TIC.

Programmers designed ***mnarep-sim*** to simulate the actual MNA Reports process as closely as possible. The major difference is that ***mnarep-sim*** does not simulate actual probe vehicles, only probe reports. Reports from a probe vehicle are generated for a continuous series of links which are determined by the route of the vehicle as it executes a trip. Travel times and congestion distances are dependent on the actual road conditions. ***The mnarep-sim*** program generates reports by choosing a test area link at random, and then setting a travel time for that link of a random value between 50 percent and 150 percent of the travel time contained in the static travel time database. The TIC processes actual and simulated probe reports in an identical manner as both the live and the simulated reports contain the same volume of data in identical formats.

The simulated probe report test was performed on December 2 1, 1995, data being collected from l0:24 am to 7:00 pm. This date was chosen as the MNA-equipped vehicles were no longer in circulation in the test area, and therefore the creation of simulated probe reports would not affect drivers. The output of the ***mnarep-sim*** program was increased in 50 report increments.

The test began by limiting the reports entering the TIC to Dundee Road loop detector reports only. This set the number of new reports entering the TIC at 26 reports every five minutes. Reports generated by the ***mnarep-sim*** program were then entered into the TIC in 50 report increments. For each new level of simulated report inputs, ***the mnarep-sim*** program was allowed to generate reports at that level for at least 20 minutes. This procedure was followed until 176 reports every five minutes were generated from the combination of Dundee Road loop detectors and ***the mnarep-sim*** program.

The simulated probe report inputs were then switched off, returning the number of incoming data reports to the 26 resulting from the Dundee Road loop detectors only. Next, TSC loop detector reports were allowed to enter the TIC, resulting in a total of 212 new reports being processed in every subsequent five minute cycle. Reports generated by ***the mnarep-sim*** process were again entered into the TIC in 50 report increments until 465 reports were generated from the combination of loop detectors and the ***mnarep-sim*** program every five minutes. The test procedure resulted in data report input volumes ranging from 26 reports to 465 reports every five minutes being entered into the TIC. At this level of data report inputs it was observed that the capacity of the TRF cycle to process all of these reports was exceeded during some of the five minute data collection periods, and thus one or more of the incoming data reports was then rejected by TRF. In order to minimize any possible effects that such incrementing of simulated data reports may have had upon processing time, each level of report increments was allowed to run for several five-minute cycles before the data utilized for these analyses were captured. It should be noted that the number of data reports which entered the TIC during the simulation tests also included a very small number of anecdotal inputs made by the TIC operators,

As was the case with the live data, simulated data obtained for both Measure 1 and Measure 2 above were entered into a spreadsheet program for processing. A macro was designed which extracted the required timestamps for both measures, and calculated the time difference as required. Both measures were then plotted against the corresponding volume of data reports. These plots are contained in Section 5.2.3.2.2.

5.2.3.2.2 Time to Process Data and TRF Cycle Capacity - Findings

Live Data Test

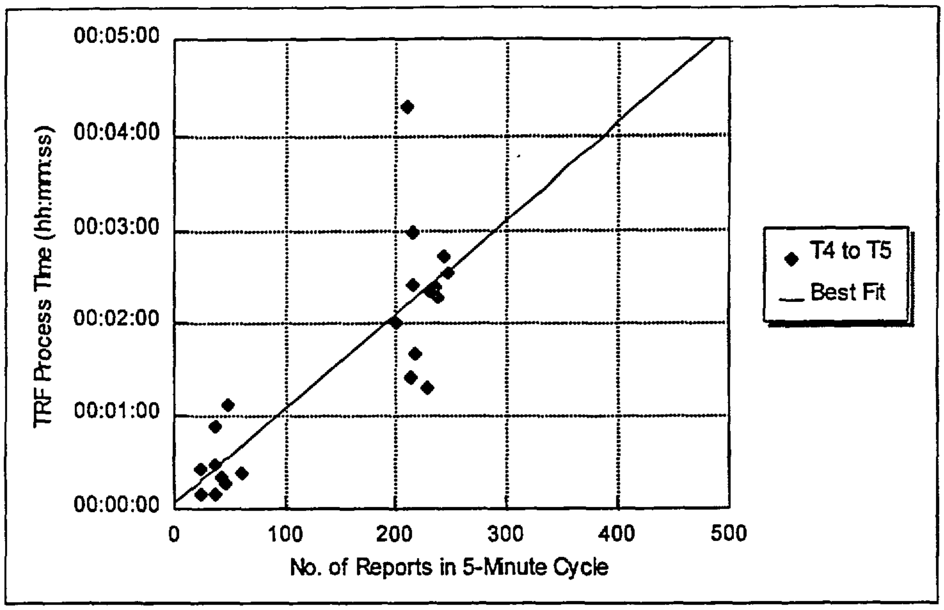
Table 5.4 contains details of the live data sets that were recorded during the data collection activities.

Data Sources	Number of Data Reports	Time to Process T4 to T5 (hh:mm:ss)	Time To Process T2 to T7 (hh:mm:ss)
Probe Reports only	24	00:00:09	00:05:30
	25	00:00:09	00:05:31
	25	00:00:26	00:05:30
Probe Reports and Dundee Loop Detectors	37	00:00:29	00:05:30
	38	00:00:53	00:05:31
	38	00:00:09	00:05:30
	44	00:00:21	00:05:31
	47	00:00:16	00:05:31
	48	00:01:07	00:05:30
	61	00:00:23	00:05:31
Probe Reports and TSC Loop Detectors	201	00:02:00	00:05:30
	211	00:04:16	00:10:31
	214	00:01:24	00:05:29
	217	00:02:24	00:05:31
	217	00:02:59	00:05:31
	219	00:01:39	00:05:30
Probe Reports, Dundee and TSC Loop Detectors	229	00:01:17	00:05:31
	232	00:02:20	00:05:29
	237	00:02:23	00:05:27
	239	00:02:17	00:05:26
	245	00:02:44	00:05:29
	247	00:02:33	00:05:30

Table 5.4 Time Taken to Process Varying Numbers of Data Reports Using Live Data

Each line of Table 5.4 represents a five minute data collection period. The combinations of live data sources utilized are provided in the first column of Table 5.4. The second column contains the number of data reports that entered the system during a five minute data collection period. These data collection periods were designed to coincide with the five minute TRF cycle. The numbers of reports within each data source combination varies between these periods due to the movement of the probe vehicles across links of various lengths and at various speeds in the test area. The third column contains the tunes to process the respective numbers of live data reports within the TRF process alone, that is, from timestamps T4 to T5. The fourth column contains the total time to process live data between timestamps T2 and T7, that is, from when data reports enter the data server to when they exit the message scheduler.

The TRF processing time, that is, processing which took place from timestamps T4 to T5, for the live data sets presented in Table 5.4 were plotted against the volume of data reports processed. This is illustrated in Figure 5.11. Each data point represents a five minute data collection period. Due to the combinations of live data reports whose sources could be manipulated for the evaluation tests, the data are clustered around the 25 to 60 and the 200 to 250 report points. That is, when probe reports alone were allowed to enter the TIC, approximately 25 reports were processed, see Table 5.4. When Dundee Road loop detector reports were also allowed to enter the TIC, the number of incoming reports increased from between approximately 40 and 60 reports. When TSC loop detectors were allowed to enter the TIC in combination with the probe reports, the number of data reports being processed rose to between approximately 200 to 220 reports, and so on. There is no other significance to the interval between 60 and 200 data incoming reports.



Regression Output:

Constant [y-intercept]	0.0000415
Std Err of Y Est	0.00044091
R Squared	0.71162084
No. of Observations	22
Degrees of Freedom	20
X Coefficient(s) [slope]	7.027E-06
Std Err of Coef.	1.000E-06

Figure 5.11 TRF Processing Time and Number of Reports Processed Using Live Data

A direct relationship can be seen between the time to process data and the volume of data reports contained within each data set. A linear regression analysis was performed using a spreadsheet program to produce the best fit line shown in Figure 5.11. Based on the TRF processing time for live data plotted in Figure 5.11, the approximate number of incoming data reports which would cause TRF processing to run to its five minute cycle capacity was extrapolated. Any additional data reports which had not been processed by the end of the five minute TRF cycle would be discarded by the TRF process.

Table 5.5 contains the times to process reports within the TRF cycle (T4 to T5) in 100 report increments, derived from the best fit line of Figure 5.11. It is acknowledged that this line does not precisely intersect the origin of the plot. Using the best fit line it has been calculated that approximately 488 data reports could be entered into the system before any additional reports would be automatically rejected by the TRF process due to capacity limitations. However, the finding that the capacity of TRF was occasionally exceeded at the level of 465 incoming data reports during the simulation tests should be borne in mind when considering this approximation.

Number of Data Reports	Time to Process (hh:mm:ss)
0	00:00:04
100	00:01:04
200	00:02:05
300	00:03:06
400	00:04:06
500	00:05:07
600	. .

Table 5.5 Time to Process Live Data Reports within TRF Cycle Derived from Best Fit Line

However, the five minute TRF cycle is not the only stage at which the TIC could potentially reach processing capacity. Bearing in mind that at present just 4.4 percent of the incoming data reports comprise updates to travel times, the capacity of the message scheduler to format these updates for subsequent transmission is not reached. For example, at this level of updates to data reports being created, only approximately 11 link travel time updates would be created for 250 incoming data reports. As configured for the Targeted Deployment, the message scheduler, which processes not only updates to travel times but also differential GPS messages prior to transmission by the COM subsystem, is designed to be capable of processing 728 travel time updates during each five minute message scheduler cycle. Were the number of incoming data reports which result in updates to travel times to increase substantially, the ability of the message scheduler to process and transmit these updates within its five minute cycle could also be affected.

Figure 5.12 illustrates the total TIC processing time, from timestarnps T2 to T7, plotted against the volume of live reports entering the TIC. Each data point in Figure 5.12 represents a five minute data collection period. Due to the similarity in the time to process the Iive data sets, many of the points on the plot overlap or are superimposed.

The “plateau” of data processing time illustrated in Figure 5.12 is due to the combined effect that the TRF cycle and the message scheduler cycle have on data processing time. It can be seen from this figure that the volume of data reports entering the TIC had very little impact on total time to process these reports within the TIC. Apart from one outlying point which represents 211 reports, of which one or more data reports were processed by the TIC in 10 minutes, 31 seconds, the remainder of the data sets were processed by the TIC in between five minutes, 26 seconds and five minutes, 31 seconds.

From examination of the log files it appears that the data set represented by the outlying point in Figure 5.12 missed the commencement of a message scheduler cycle (T6), remained in the message scheduler data server (T5 to T6), and did not leave the TIC until after the next message scheduler cycle commenced, five minutes later. As was noted in Section 5.2.3.1, both the TRF cycle and the message scheduler cycle initiate every five minutes, although these are not synchronized. From examination of the log files it was

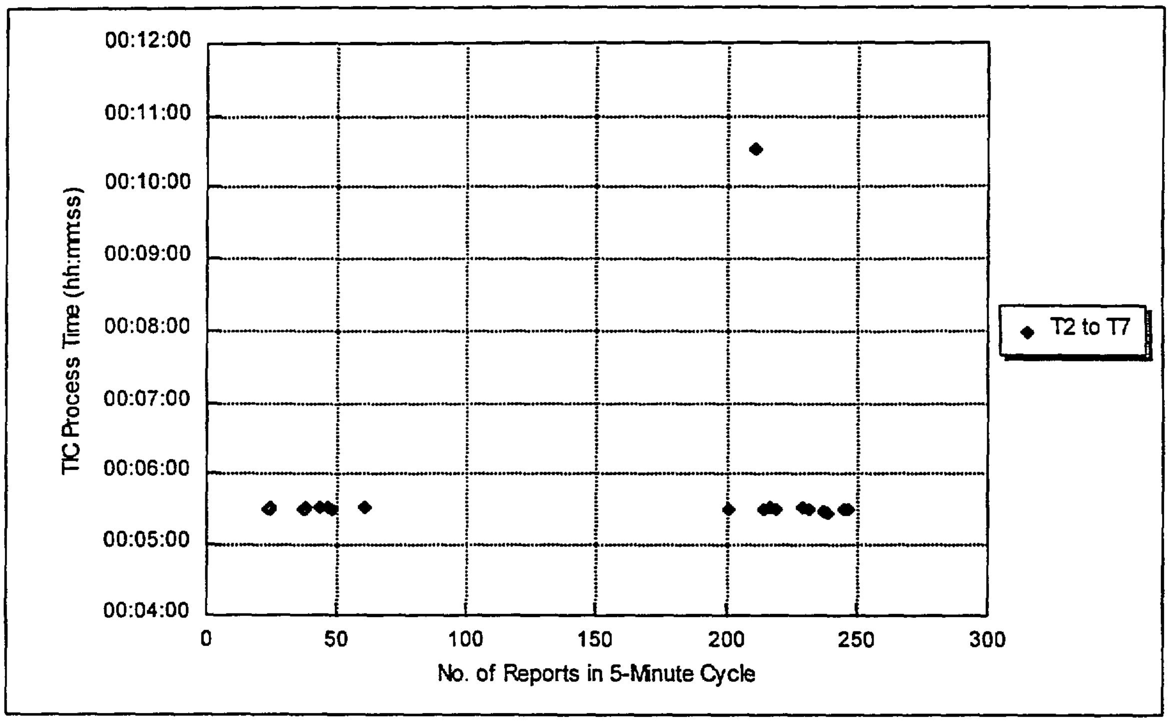


Figure 5.12 TIC Processing Time and Number of Reports Processed Using Live Data

established that during the data collection period for the live data, the interval between the start of the TRF cycle and the start of the message scheduler cycle was three minutes. Depending on the time taken to process data during the TRF cycle (T4 to T5) and the interval between the start of the TRF cycle (T4) and the start of the message scheduler cycle (T6), data sets could easily arrive in the message scheduler data server immediately after the start of a message scheduler cycle and remain in the message scheduler data server until the commencement of the subsequent message scheduler cycle. This was the case with the outlying point plotted in Figure 5.12.

It should be noted that not all the data reports within the five minute data collection period represented by this outlying data set were processed during the later message scheduler cycle. Bearing in mind that during the data collection period the interval between the start of the TRF cycle and the start of the message scheduler cycle was three minutes, any data reports within this data set which were processed during the first three minutes of the TRF cycle arrived in the message scheduler data server in sufficient time to be input to the first available message scheduler cycle. However, if one or more of the data reports within any data set were processed by a later message scheduler cycle, in Figure 5.12 the whole data set has been plotted against the time that the later data reports were processed by the message scheduler. This feature of the TIC indicates that consecutive data reports entering the architecture could exit the architecture five minutes apart, depending on where they were in the stack of data reports, and the interval between the start of the TRF cycle and the start of the message scheduler cycle.

Simulated Data Test

Figure 5.13 contains a plot of TRF processing time, that is, timestamps T4 to T5, against the number of reports processed during the simulation tests. This was produced in order to attempt to replicate the findings of the live data collection. Again, each data point represents a five minute data collection period. These periods coincided with the five minute TRF cycle.

Due to the large number of data sets, a total of 104 sets, entered into the TIC during the simulation tests and plotted in Figure 5.13, a separate table containing the number of data reports within each data set and the time taken to process each data set has not been provided. As in the plot of live data, many of the 104 points on this plot overlap or are superimposed due to the similarity of the process times.

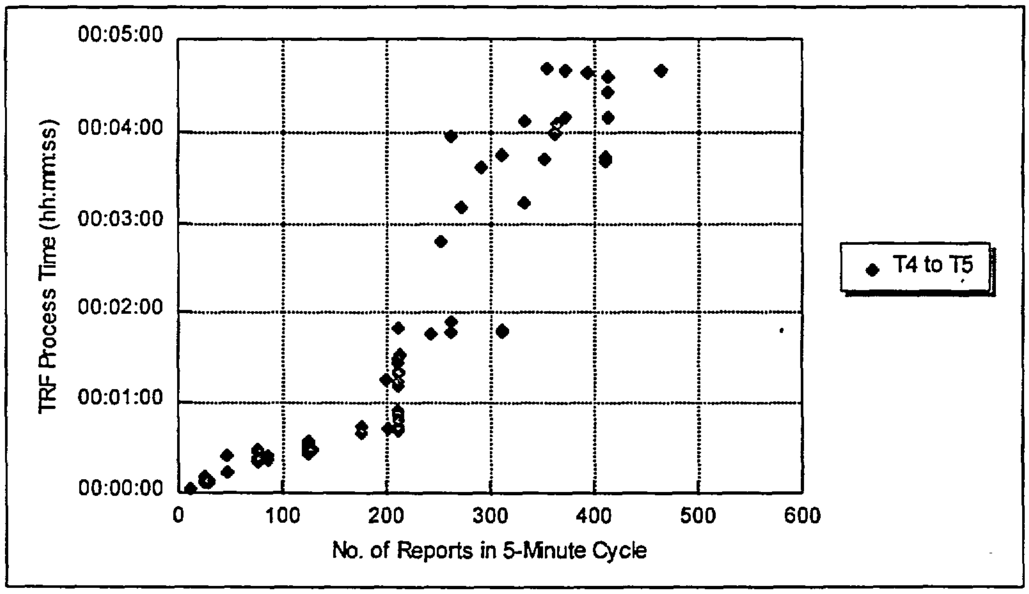


Figure 5.13 TRF Processing Time and Simulated Probe / Loop Detector Reports

Further examination of the data presented in Figure 5.13 revealed that during several five minute cycles TRF was not able to process all the incoming data reports within a data set. This resulted in one or more of these data reports being discarded by TRF. The lowest number of data reports within a data set for which TRF was unable to complete report processing during its five-minute cycle was 372 data reports. However, it was also observed that one of the data sets whose data reports were all processed by TRF within the five minute cycle contained as many as 454 data reports. Thus it would appear that a precise number of data reports which TRF can process within its five minute cycle cannot be calculated. The TIC system is evidently sensitive in terms of other system activities influencing the time taken to process data reports. Further investigation of the factors which influenced processing time was not possible within the resources available for the TIC Architecture evaluation.

Figure 5.14 illustrates the total TIC processing time, that is timestamps T2 to T7, plotted against the number of simulated probe reports plus loop detector reports which entered the TIC during the simulation tests. Due to the similarity in the time to process the simulated data sets, many of the points on the plot overlap or are superimposed.

It can be seen from Figure 5.14 that the spread of data points plotted was much more even than was possible with the live data. The "plateau" effect of data processing time was again experienced. It can be seen that when the volume of data reports within a data set exceeded between 250 and 300 reports, the time to process one or more of these reports increased from approximately six minutes to approximately 11 minutes. It is believed that this is a feature of the lack of synchronization of the TRF and the message scheduler cycles, as one or more data reports within these data sets tended to miss a message scheduler cycle and wait in the message scheduler data server for a further five minutes before being processed by the message scheduler and then being conveyed from the TIC.

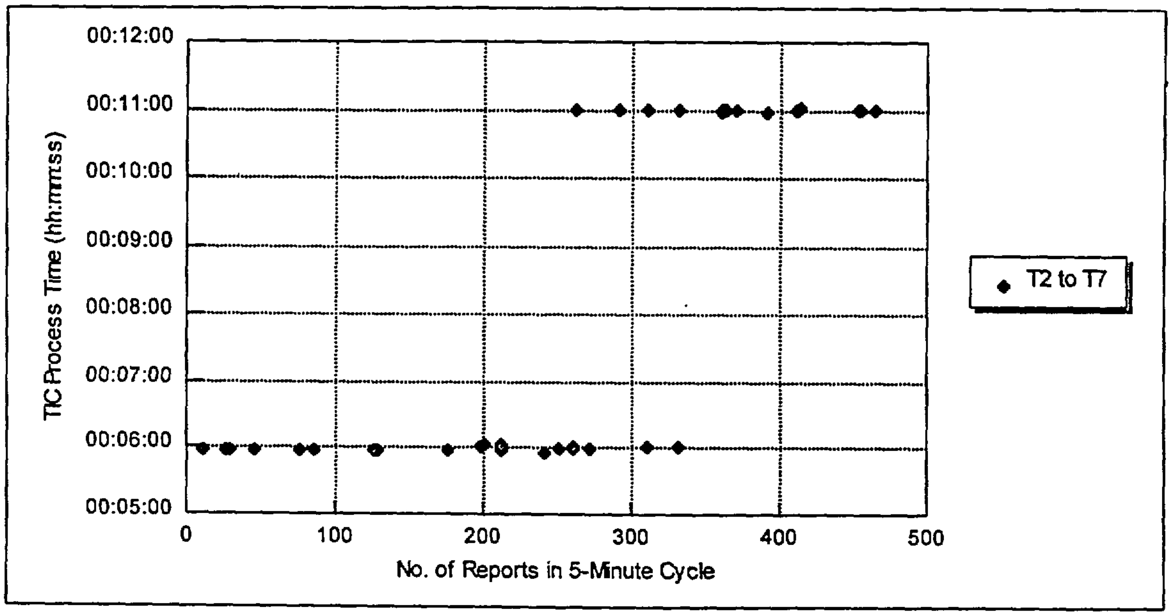


Figure 5.14 TIC Processing Time and Simulated Probe / Loop Detector Reports

It was established from examination of the log files that during the simulation tests, the interval between the start of the TRF cycle and the start of the message scheduler cycle was three minutes, 30 seconds. Therefore, any data reports which took longer than three minutes, 30 seconds to be processed by TRF missed the first available message scheduler cycle, and remained in the message scheduler data server until the start of the next message scheduler cycle. To reiterate, the maximum number of live data reports observed within a five minute live data set was 247 reports. The results of the simulation tests illustrate that if the volume of live data reports which entered the TIC during the Targeted Deployment regularly exceeded 250 to 300 data reports, then the total time, T2 to T7, to process any data reports not processed within the first three minutes, 30 seconds of the TRF cycle could be expected approximately to double, as shown in Figure 5.14.

It should be noted that not all the data reports within the five minute data collection periods plotted as the higher "plateau" were processed during the later message scheduler cycle. Bearing in mind that during the data collection period the interval between the start of the TRF cycle and the start of the message scheduler cycle was three minutes, 30 seconds, any data within this data set which were processed during the first three minutes, 30 seconds of the TRF cycle arrived in the message scheduler data server in sufficient time to be input to the first available message scheduler cycle. However, if one or more of the data reports within any data set were processed by a later message scheduler cycle, in Figure 5.14 the whole data set has been plotted against the time that the later data reports were processed by the message scheduler.

It should also be noted that the random generation of ***travel*** times by ***mnarep-sim*** produced a significantly higher percentage of updates during the simulated data test. Of the 17,794 simulated reports that entered the system during the test, 4,294 reports warranted a dynamic update to the static travel time database which corresponds to 24.13 percent of total reports processed. This percentage is significantly higher than the 4.4 percent of total processed reports resulting in updates which was observed using the live data. However, it is believed that the effect that this higher percentage of updates had on the simulated data plotted in Figure 5.14 was largely limited to a higher processing overhead being encountered at the message scheduler stage, that is, more time was spent forming the bundles of messages and less time was spent forwarding the bundles to the COM.

5.2.3.3 Time to Process Data Involving Manual Input

The purpose of this portion of the efficiency assessment was to measure the effect that the manual input of anecdotal data into the TIC had on the total time to process these data reports. This involved the consideration of timestamp Tl in addition to timestamps T2 to T7 for the NWCD anecdotal data reports only. Timestamp Tl for the anecdotal data reports was utilized as the TIC operator was required to respond to entries contained in the NWCD event log and create TIC-format data reports from them. As was noted in Section 5.2.3.1, lane and road closure information is also manually entered into the TIC database. However, as this non-real-time information is typically received a day in advance of the start of any lane or road closure, a Tl timestamp for this information type was not applicable in the context of the efficiency evaluation.

As the time at which the anecdotal reports were entered into the remote NWCD database was not logged by the TIC itself, these timestamps required manual extraction from the separate NWCD log and matching against the remaining timestamps, T2 to T7, within the TIC logs for each individual data report. Data pertaining to all anecdotal reports created within a full day of TIC operation were extracted and analyzed in this manner. The data collection period was the same day, December 4, 1995, as was used for the automated data analysis described in Section 5.2.3.2.1.

Table 5.6 contains details of the times taken to process the anecdotal data reports entered into the TIC on December 4, 1995. These 15 data inputs were all the anecdotal entries made during that day. From examination of log files it was found that this number of anecdotal inputs was representative of the numbers regularly entered each day during Targeted Deployment.

	Timestamps T1 to T2 (hh:mm:ss)	Timestamps T2 to T7 (hh:mm:ss)	Timestamps T1 to T7 (hh:mm:ss)
	00:08:02	No Update	No Update
	00:04:09	00:04:50	00:08:59
	00:04:35	00:06:01	00:11:19
	00:05:28	00:05:46	00:11:14
	00:02:16	O&05:23	00:07:39
	00:05:37	00:05:21	00:10:58
	00:04:00	**00:07:04**	**00:11:04**
	00:02:59	00:07:22	00:10:21
	00:02:56	00:06:32	00:09:28
	00:03:16	00:04:39	00:07:55
	00:01:18	00:04:19	00:05:37
	00:01:39	00:06:41	00:08:20
	00:01:12	00:04:29	00:05:41
	00:01:11	00:05:03	00:06:14
	00:08:47	00:07:51	00:16:38
Total Time.	00:49:23	01:22:04	02:11:27
Mean Time	00:03:32	00:05:52	00:09:23

Table 5.6 Time to Process Anecdotal Data

Timestamps Tl to T2 are provided in the first column, From this column it can be seen that the interval of time between when anecdotal data were remotely entered into the NWCD log by NWCD staff, until the time when TIC operators entered the data into the TIC was between one minute, 11 seconds, to eight minutes, 47 seconds, with a mean time of three minutes, 32 seconds. During these intervals, the data are transmitted from NWCD and are received at the *ADVANCE* TIC in a log file which is displayed at the user interface. When new log entries have been perceived by operators, operators must then determine whether the log file entries relate to incidents occurring within the test area and whether the incidents will affect traffic. If the operator considers the incident to be relevant, then the incident data are manually entered into the TIC database.

The second column contains the times taken to process these same anecdotal data reports within the TIC from timestamps T2 to T7. Within the degree of accuracy to which the TIC logs the data reports as they pass through the various stages of processing, that is, to within one second, these times to process anecdotal data were found to be comparable to the times to process the data from automated sources contained in Table 5.4. The mean time to process the automated source data between timestamps T2 to T7 previously derived from the data in Table 5.4 is five minutes, 44 seconds. It can be seen from Table 5.6 that the mean time to process the anecdotal data from timestamps T2 to T7 is five minutes, 52 seconds. However, as was noted in Section 5.2.3.1, when comparing the times taken to process the automated and the anecdotal data it should be borne in mind that the difference between timestamps T2 and T3 for the automated sources was estimated as an average of two minutes, 30 seconds. For the anecdotal data reports timestamps T2 and T3 represented the actual time to process these data reports taken from system logs. The average value for the difference between timestamps T2 and T3 measured for the anecdotal inputs was two minutes, 31 seconds.

The third column of Table 5.6 contains the total times to process anecdotal data from timestamps Tl to T7. Here, the effect that the need for operator intervention has on the total time to process anecdotal data reports can be seen. The minimum time to process anecdotal data from Tl to T7 during the data collection period was five minutes, 37 seconds, while the maximum time to process data was 16 minutes, 3 8 seconds, with a mean time of nine minutes, 23 seconds.

5.2.3.4 Required Frequency of TIC Back-up Cycle

A further measure assessed was the frequency of the back-ups of the TIC process log files which was necessary during the Targeted Deployment in order that the efficiency of TIC functions was not compromised. A back-up is a procedure which will help replace or restore an item in the event of a failure. The back-up cycle of a system is the duration between the execution of successive data back-ups. Impacts on efficiency could include longer time to process data or the loss of data. For example, during the Targeted Deployment of the *ADVANCE* project it was necessary to back-up the TIC system on a regular basis since the TIC would fail if its data directories reached capacity.

Log files displayed through the TIC Process Controller are initially written to the "advance1 " data directory. TIC process log file back-ups are executed in two cycles. The first cycle is automatically executed when the "advance1 " log files are transferred to the "advance8" data directory by the Remove Loop Detector Reports (RLDR) process. The second cycle is executed when the "advance8" log files are transferred to magnetic data tape. The two cycles are utilized to reduce the number of times operators perform the time-consuming tape back-up task.

The necessary frequency of each TIC back-up cycle was calculated by dividing the capacity of the directory in which all TIC data were stored by the volume of data created daily by the regular operation of the TIC systems, taken as an average over 14 days of operation.

The advance1 data directory is capable of storing a total of 1,255.494 megabytes (MB) of data. The volume of data stored daily in this directory, taken as an average over 14 days of TIC operation, was 139.13 MB, Thus, 9.02 days worth of TIC data may be stored in this directory at one time. However, it was found that when an operator chose to display a large log file on the TIC terminal screen when advance1 had not been backed-up daily, the response time of the TIC user interface deteriorated as the volume of data contained with each log file increased. For this reason, it is concluded that the first back-up cycle should be executed daily in order to maximize the efficiency of the user interface.

The advance8 data directory is capable of storing a total of 914.54 megabytes (MB) of data. The volume of data stored daily in this directory, taken as an average over 14 days of TIC operation, was 139.13 MB. Thus, 6.57 days worth of TIC data may be stored in this directory at one time. However, in order to ensure that the capacity of this data directory was not reached, it is recommended that the second cycle be performed more frequently than this, say, every five days.

Therefore, it was found that in order to prevent the efficiency of the TIC functions being compromised, the first back-up cycle should be performed daily and the second cycle should be executed at least every five days. In actuality, during the Targeted Deployment a three day cycle was utilized.

5.2.3.5 Efficiency of the TIC in Providing an Information Service Without Manual Data Entry

Data were collected relating to the efficiency of the TIC in continuing to provide an information service without manual data entry taking place. This was achieved by calculating the amount of data entered manually, the so-called anecdotal input, as a proportion of the total data reports entering the TIC, most of which entered the system and were processed automatically. These automatically processed data sources included the probe vehicles and the loop detector systems which feed into the TIC.

Data for this measure were collected from over the five working days from 00:00 am on December 2, 1995, to 23:59 pm on December 8, 1995. During the five day data collection period, it was found that a total of 290,867 data reports entered the TIC from all sources. Of this total, 1 ,185 data reports resulted from the manual input of anecdotal data, which comprised incident information received from NWCD and road and lane closure data received from IDOT District 1 and ISTHA. It should be noted that this number of data reports does not represent the number of anecdotal inputs entered by operators. Any anecdotal input made by an operator results in a number of data reports being created, as a data report is created for each link travel time update. It should also be noted that a greater number of possible anecdotal inputs arrived at the TIC from NWCD than were entered by operators. The TIC operator was required to scan all the reports of incidents which were provided from NWCD and ascertain if their location and content were relevant to *ADVANCE*, that is, would they affect traffic in the test area. Therefore, only a subset of the received NWCD incident reports was entered by operators into the TIC.

It was calculated that 0.4 percent of the data reports entered into the TIC during the data collection period originated from operators manually entering anecdotal input. However, it is known that all of these 0.4 percent of anecdotal inputs represented updates to link travel times held within the TIC database, whereas a high proportion of the data reports received from probe vehicles and loop detectors contained no updates to link travel times. Therefore, although in absolute terms in appears as though the manually entered anecdotal inputs represented very few data reports, in reality all of the data reports resulting from these anecdotal inputs were eventually used by the TIC to update link travel times. It is believed that as such, the NWCD anecdotal input represents a highly valuable data source to feed into the *ADVANCE* TIC.

5.2.3.6 Efficiency - Summary of Findings and Conclusions

MOEs. A. 1.4, TIC *hardware efficiency;* and A.2.4, *TIC software efficiency;* were assessed in conjunction using various measures. A summary of the findings from the efficiency data collection activities and the conclusions drawn from them are presented in the following paragraphs. The summary of findings and the conclusions are presented in accordance with the order of Sections 5.2.3.2 to 5.2.3.5. It should be noted that the findings presented in the following subsections are of course dependent on maintaining the same system parameters utilized for the Targeted Deployment and the same typical range of data reports which habitually entered the TIC during Targeted Deployment. Therefore, the conclusions drawn from the findings should not be taken out of the context of the *ADVANCE* Targeted Deployment.

5.2.3.6.1 Time to Process Data and TRF Cycle Capacity

Live Data

By allowing a varying number of live data reports to enter the TIC from automated sources it was demonstrated that for the TRF processing time, that is, processing which takes place from timestamps T4 to T5, a direct relationship was identified between the time to process live data and the volume of live data reports contained within each five minute data set. Based on the TRF processing time for live data, it was calculated that approximately 488 data reports could be entered into the system before any additional reports would be automatically rejected by the TRF process due to capacity limitations.

However, the five minute TRF cycle was not the only stage at which the TIC could potentially reach processing capacity. Bearing in mind that during Targeted Deployment just 4.4 percent of the incoming live data reports comprised updates to travel times, the capacity of the message scheduler to format these updates for subsequent transmission was not reached. Were the number of incoming data reports which result in updates to travel times to increase significantly, the ability of the message scheduler to process and transmit these updates within its five minute cycle could also be affected.

It was also demonstrated that a "plateau" effect existed for the total time to process the live data from timestamps T2 to T7, that is, from the time data reports enter the data server until they exit the message scheduler. It is believed that this effect was experienced due to the combined effect that the TRF cycle and the message scheduler cycle have on total data processing time. It is concluded that the volume of live data reports entering the TIC had very little impact on total time to process these reports within the TIC, at least for the numbers of live data reports that were habitually entering the TIC during Targeted Deployment.

Simulated Data

A simulation test was also performed to attempt to replicate the findings of the live data test and to establish how many incoming data reports would cause the five minute TRF cycle to run to capacity.

Again, TRF processing times, from timestamps T4 to T5; were examined. Using the simulated data, it was found that the lowest number of data reports within a data set that caused the five minute TRF cycle capacity to be exceeded, resulting in some of these reports being automatically rejected, was 372 data reports.

It was found that the "plateau" effect of data processing time from T2 to T7 was again experienced. It was also found that when the volume of simulated probe and loop detector data reports within a five-minute data set exceeded between 250 and 300 reports, the time to process one or more of these reports increased from approximately six minutes to approximately 11 minutes. It is believed that this was a feature of the lack of synchronization between the TRF and the message scheduler cycles, as one or more of these data reports within the data sets tended to miss a message scheduler cycle and wait in the message scheduler data server for a further five minutes before being processed by the message scheduler and being conveyed from the TIC.

Comparison of Live and Simulated Data Findings

The difference in total processing times, that is, from timestamp T2 to T7, which can be observed between the live test data and the simulated test data is explained due to the difference in the interval between the start of the TRF cycle and the start of the message scheduler cycle between the two data collection periods. During the live data collection period, the interval between the start of the TRF cycle and the start of the message scheduler cycle was three minutes. During this test the time taken to process data reports between timestamps T2 and T7 was either approximately five minutes, 30 seconds, or approximately 10 minutes, 30 seconds. During the simulated data collection period, the interval between the start of the TRF cycle and the start of the message scheduler cycle was three minutes, 30 seconds. During this test the time taken to process data reports between timestamps T2 and T7 was either approximately 6 minutes, or approximately 11 minutes.

Both the data captured during the live data test and that captured during simulated data tests indicate that the major governing factor in the time taken to process data between timestamps T2 and T7 is the interval between the start of the TRF cycle and the start of the message scheduler cycle. It is therefore recommended that the TRF cycle and the message scheduler cycle be synchronized in order to optimize the time taken to process data reports. If these cycles were synchronized this would eliminate the possibility of data reports, once processed by TRF, missing a message scheduler cycle and remaining in the message scheduler data server for a further five minutes until the start of the subsequent message scheduler cycle.

It is also recommended that the length of both cycles be reduced, again to minimize the time taken to process data reports. Further investigations need to be carried out in order to determine the ideal length of the two cycles which would optimize data report processing time while not creating an excessive processing overhead.

It is concluded that the processing capacity of the five minute TRF cycle as configured for the Targeted Deployment was between 372 data reports - the lowest number of data reports within a data set which caused TRF to run to capacity during the simulation tests, and 488 data reports, the value extrapolated from the live data test best fit line. A precise number of data reports which TRF can process within its five minute cycle cannot be calculated. The TIC system is evidently sensitive in terms of other system activities influencing the time taken to process data reports. Further investigation of the factors which influenced processing time was not possible within the resources available for the TIC Architecture evaluation.

Based on the number of incoming data reports observed during the live data tests, it is believed that this level of reports was not reached during Targeted Deployment. Therefore the capacity of the TRF cycle did not result in any incoming data reports being rejected for lack of processing time, and it is concluded that the capacity of the TRF cycle was adequate for the Targeted Deployment. It is noted that the potential is limited for increasing the numbers of probe vehicles or loop detectors, thereby increasing the numbers of incoming data reports, utilizing the existing system configuration.

5.2.3.6.2 Time to Process Data Involving: Manual Input

The time to process data reports which required manual input was also investigated. It was found that the mean interval of time between timestamps Tl and T2, that is, when anecdotal data were remotely entered into the NWCD log by NWCD staff until the time TIC operators entered the data into the TIC, was three minutes, 32 seconds. It was found that the times taken by the TIC to process data reports both from the automated sources and from the manually input anecdotal sources from timestamps T2 to T7 were highly comparable. The mean time to process the automated source data between timestamps T2 to T7 derived from the data in Table 5.4 was five minutes, 44 seconds. It can be seen from Table 5.6 that the mean time to process the anecdotal data from timestamps T2 to T7 was five minutes, 52 seconds. It was found that the mean total time to process the anecdotal data reports from timestamps Tl to T7, that is, from remote entry into the NWCD database until output from the TIC, was nine minutes, 23 seconds. However, the maximum time to process these reports was as high as 16 minutes, 38 seconds, demonstrating the effect that operator intervention can have on the total time to process anecdotal data reports. In extreme cases, this may have resulted in anecdotal data relating to incidents which were already cleared being entered into the TIC. It is concluded that, based on a worst case scenario for the total time taken to process anecdotal inputs, the automation of the entry of these inputs into the TIC database may be warranted.

5.2.3.6.3 Required Frequency of TIC Back-up Cycle

Two back-up cycles exist to transfer active TIC process logfiles from the "advance 1" directory to magnetic tape. The first cycle transfers data from the "advancel" data directory to the "advances" data directory automatically via the RLDR process. The second cycle transfers data from the "advances" data directory to tape. The two cycles are utilized to reduce the number of times operators must perform the time consuming tape backup.

It is concluded that in order to prevent the efficiency of TIC functions being compromised by system failures when full log files continued to be written to and in order to maximize the efficiency of the user interface, the "advance1 " data directory back-up cycle should be executed daily. In addition, the "advances" data directory back-up cycle should be performed at least every five days.

5.2.3.6.4 Efficiency of the TIC in Providing an Information Service Without Manual Data Entry

Data were also collected relating to the efficiency of the TIC in providing an information service without manual data entry. This was achieved by calculating the amount of data entered manually, the so-called anecdotal input, as a proportion of the total data reports entering the TIC, most of which entered the system and was processed automatically. It was calculated that 0.4 percent of the data reports entered into the TIC during the data collection period originated from operators manually entering anecdotal input. However, it is known that all of these 0.4 percent of anecdotal inputs represented updates to link travel times held within the TIC database, whereas a high proportion of the data reports received from probe vehicles and loop detectors contained no updates to link travel times. It is concluded that as such, the NWCD anecdotal input represents a highly valuable data source for the *ADVANCE* TIC, and that the efficiency of the TIC in providing a full coverage information service without the entry of this anecdotal incident data would be negatively impacted.

5.3 Objective A.3 - Evaluate Potential System Design Alternatives

5.3.1 Potential System Design Alternatives - Data Collection Procedures

For MOE A.3.1, *the number and type of elements of the architecture which could be simplified to reduce system complexity without compromising system performance;* the input data fed from the data collection activities undertaken for MOEs A. 1.1 to A.2.4 relating to TIC *hardware and software performance.* To reiterate, these MOEs were as follows:

- A. 1.1 and A.2.1, concerning TIC hardware and TIC software functionality;
- A. l.2 and A.2.2, concerning TIC hardware and TIC software reliability;
- A. 1.3 and A.2.3, concerning TIC hardware and TIC software maintenance requirements; and

- A. 1.4 and A.2.4, concerning TIC hardware and TIC software efficiency.

The data collected relating to these MOEs were circulated to a peer review team consisting of ITS professionals from De Leuw, Cather. These peers were selected as they had a working knowledge of the *ADVANCE* project goals, scope, and content, although they were not directly involved in the *ADVANCE* project activities, nor in the evaluation of the TIC Architecture and User Interface. These peers also possessed in-depth knowledge of many ITS technologies and implementations on a national and au international level. One of the peer reviewers had professional experience spanning more than 21 years, covering a broad range of transportation consulting services, including roadway, transit, and aviation projects involving planning, design, construction engineering and management. This reviewer also had special expertise in the development and application of ITS and other advanced traffic engineering principles to surface transportation networks. The other peer reviewer had more than 25 years experience in planning, designing, managing, implementing, and operating complex transportation systems, and also possessed hands-on experience with most technologies used in ITS and advanced public transportation systems.

The peers who took part in this review process were the same personnel who performed the expandability, transferability and costs reviews discussed in Sections 5.4, 5.5, and 5.6. It should be noted that the feedback received from the peer reviewers and reproduced in this report represents the views of the peers and does not necessarily constitute recommendations by the *ADVANCE* participants.

In accordance with the TIC Architecture and User Interface Evaluation Test Plan, the peer review process was scheduled to take place at a time which would permit their input to be considered and reported upon in this TIC Evaluation Report. Therefore, a subset of the data which was finally available and which is provided in this report was supplied to the peer reviewers. As such, the data input to the peer review process represented the preliminary findings of the evaluation, collected from the commencement of the evaluation data collection phase on October 2, 1995, until December 6, 1995. The findings contained within this Final Report are based upon data collected both during this period and from that time until the conclusion of data collection activities on December 28, 1995. The areas in which significant additional data were collected during this latter part of the data collection phase, from December 6, 1995 to December 28, 1995, and which the peer reviewers did not have access to are as follows.

The hardware and software reliability and maintenance requirements data presented in this report were collected from November 18, 1995 to December 28, 1995 inclusive. The exclusion of prior data for the reliability assessments is explained in Section 5.2.2. When considering the input from the peer reviewers, it should be noted that reviewers had access to reliability data from November 18, 1995 to December 6, 1995 only.

In addition, in terms of the hardware and software efficiency data provided to the peer reviewers, the following data were not available at the time of the peer review process:

- the results of the simulated data tests which were performed to ascertain the volume of data inputs that could be entered into the TIC Architecture before the five minute TRF cycle capacity was reached, described in Section 5.2.3.2.2;
- the findings from the measurement of the time to process data involving manual input, described in Section 5.2.3.3; and
- the findings relating to the required frequency of the TIC data back-up cycle, described in Section 5.2.3.4.

The hardware and software functionality data provided to the peer reviewers were identical to that presented in Section 5.2.1.2 of this Final Report.

The peer review process took place from December 14, 1995 to January 2, 1996. On receipt of the evaluation data at the commencement of the peer review process, reviewers were requested to consider these data and to identify and describe any elements of the TIC Architecture which they believed could be simplified to reduce system complexity without compromising system performance. The findings reported in the following subsection comprise the feedback received from the peer reviewers. These findings should be considered in conjunction with the data contained in Section 5.2, which represent the input to the review process except where data were not available as described above.

5.3.2 Potential System Design Alternatives - Findings and Conclusions

In terms of the assessment of MOE A.3.1, *the number and type of elements of the architecture which could be simplified to reduce system complexity without compromising system performance;* the feedback received from the peer reviewers indicated three key areas which they considered could be streamlined, as follows.

First, it was noted that it appeared that the TIC could be limited in terms of serving both the primary TIC functions and the needs of the operator in performing tasks within the graphical user interface (GUI). It was suggested that an architecture which incorporated full-function operator workstations with the GUI functions based on these workstations instead of on the main server could perhaps improve system performance. It was also suggested that this would reduce the complexity of the software, while incurring minimal extra cost for the more expensive operator workstations.

Second, it was suggested by reviewers that it should be considered whether provision for central system hardware redundancy should be provided, for example, in the case of the TIC server and disk storage within a full deployed operational system. It was thought that inclusion of this redundancy would indirectly streamline the architecture through increased functional and operational efficiency. It was noted that should the current *ADVANCE* TIC Architecture be utilized as the basis of an enhanced TIC which handled information relating to intermodal ITS applications in the Chicago. area, this would place significant demands on the TIC which would warrant hardware redundancy.

Third, it was thought that the TIC system's omission of an automated procedure for discontinuing non-critical activities in order to maintain real-time performance of critical activities could have a potentially negative impact on the efficiency of the TIC in a fully deployed operational system. It was suggested that access conflict prioritization routines should be incorporated to ensure that any negative impacts are not experienced.

In addition, in terms of the hardware and software reliability data provided to the peer reviewers, it was noted that the data indicated that the TIC systems provided a very good level of reliability. However, it was added that given the number of inputs which regularly entered the TIC Architecture during the Targeted Deployment, TIC systems had not been stressed to capacity. Peer reviewers suggested that had the level of data inputs during the Targeted Deployment been significantly higher over a prolonged period of time, then additional operational difficulties could have been experienced which may then have warranted further streamlining of TIC systems to cater for such volumes of data.

It is concluded that the three key areas listed above should be investigated further to ascertain if their implementation would indeed result in a reduction in system complexity without compromising system performance. These areas should also be taken into consideration by any agencies considering the establishment of similar TICs, supporting probes and dynamic route guidance, based either partly or wholly on the *ADVANCE* TIC concept.

5.4 Objective B.l - Evaluate TIC Architecture Expandability

5.4.1 Expandability - Data Collection Procedures

For MOE ***B.l.l, the number and type of additional transportation information and management functions which could be consolidated within the ADVANCE TIC***; the input data comprised the findings presented in Section 5.2.1.2 from the earlier data collection activities undertaken for MOEs A.l.1, ***TIC hardware functionality;*** and A.2.1, ***TIC software functionality.***

The data collected relating to the functionality MOEs were circulated to the peer review team described in Section 5.3.1. Although the peer review process took place prior to the completion of all data collection activities, the hardware and software functionality review had been completed at the time of the review process. The peer review took place from December 14, 1995 to January 2, 1996. The hardware and software functionality data provided to the peer reviewers were identical to that presented in this Final Report in Section 5.2.1.2.

On receipt of the evaluation data at the commencement of the peer review process, reviewers were requested to consider these data and to identify and describe any additional services or functions which could be incorporated into the TIC Architecture in its present context of the Chicagoland urban area. This required consideration of any current or potential transportation functions in this area which could be handled by an expanded TIC Architecture. Reviewers were requested to consider the technical;

organizational, and financial impacts of expanding the TIC Architecture to incorporate any such additional functions.

The findings reported in the following subsection comprise the feedback received from the peer reviewers. These findings should be considered in conjunction with the data contained in Section 5.2.1.2, which represent the input to the review process.

5.4.2 Expandability - Findings and Conclusions

In terms of the assessment of MOE B.l. 1, *the number and type of additional transportation information and management function which could be consolidated within the ADVANCE TIC;* the feedback received from the peer reviewers indicated four key areas where they considered that potential existed for expanding the functionality of the TIC.

First, peer reviewers suggested that the TIC/TRF software algorithms designed to utilize the in-bound MNA communications may be adaptable for other types of probe vehicles which could provide data for the TIC. It was thought that these other types of probes could include Automatic Vehicle Identification (AVI) equipped vehicles passing fixed point transponders, for example.

Second, it was also suggested that specific areas in which future systems could expand upon the TIC functionality could include the incorporation of real-time adaptive control of signal systems based on data received from the loop detectors and the probe vehicles.

Third, the provision of personal emergency services and notification services were also suggested as possible areas for expansion of the current functionality of the TIC.

Fourth, in terms of additional information types which could be of use to the end users of the TIC, it was thought that the inclusion of weather related and surface condition data would be of significant benefit to the drivers of the MNA equipped vehicles. The TIC as implemented for the Targeted Deployment did have a weather data feed from an information supplier. This data could be displayed by the TIC operators as a log file. However, as part of the system rationalization which resulted in the Targeted Deployment, it was decided that these data were not to be entered automatically into the database by the TIC system. Given that the weather-related data supply is already provided to the TIC, its entry into the database would expand the information types provided to end users without significant extra resources being expended.

In addition, it was noted by the peer reviewers that should the TIC as developed for the Targeted Deployment of the ***ADVANCE*** project expand beyond the scope of the test implementation, hardware redundancy and a much faster recovery time from system failures would be highly desirable.

Peer reviewers stated that, as at the time of the peer review process the actual capacity, as opposed to the design capacity, of the TIC for in-bound MNA reports had not yet been determined, the potential to expand the number of vehicle units feeding into the TIC as currently implemented could not be addressed.

Reviewers also stated that the expandability of the *ADVANCE TIC* to incorporate additional transportation management functions is largely constrained due to inherent system limitations resulting from Targeted Deployment. This finding is particularly relevant given the trend towards the consideration of intermodal transportation systems which has occurred largely since the inception of the *ADVANCE* project.

It is concluded that the four key areas listed above should be investigated further to ascertain the potential advantages and disadvantages of their implementation. In the case of the fourth suggestion above, the provision of weather-related data had initially been intended for inclusion in the *ADVANCE TIC*, and indeed during Targeted Deployment operations data fed from a weather information supplier and was provided at the interface in a logfile. It is considered that minimal additional effort would be required to have this data entered automatically into the TIC database.

5.5 Objective B.2 - Evaluate TIC Architecture Transferability

5.5.1 Transferability - Data Collection Procedures

For MOE B.2.1, ***the number and type** of **elements and capabilities** of **the ADVANCE TIC which are non-specific to the Chicago area implementation and which could be utilized to provide TIC services in other geographic locations,*** the input data comprised the findings presented in Section 5.2.1.2 from the earlier ***data*** collection activities undertaken for MOEs A. 1.1, ***TIC hardwarefinctionality;*** and A.2.1, ***TIC software functionality.***

The data collected relating to the functionality MOEs were circulated to the peer review team described in Section 5.3.1. Although the peer review process took place prior to the completion of all data collection activities, the hardware and software functionality review had been completed at the time of the review process. The peer review took place from December 14, 1995 to January 2, 1996. The hardware and software functionality data provided to the peer reviewers were identical to that presented in this Final Report in Section 5.2.1.2.

On receipt of the evaluation data at the commencement of the peer review process, reviewers were requested to consider these data and to identify and describe the number and type of elements and capabilities of the *ADVANCE TIC* which were non-specific to the Chicago area implementation and which could be utilized to provide TIC services in other geographic locations.

The findings reported in the following subsection comprise the feedback received from the peer reviewers. These findings should be considered in conjunction with the data contained in Section 5.2.1.2, which represent the input to the review process.

5.5.2 Transferability - Findings and Conclusions

Regarding the assessment of MOE B.2.1, *the number and type of elements and capabilities of the ADVANCE TIC which are non-specific to the Chicago area implementation and which could be utilized* *to provide TIC services in other geographic locations;* the feedback received from the peer reviewers indicated two key areas where they considered that potential could exist for such system transferability.

First, it was thought that the techniques developed, tested and proven *within the ADVANCE* project for the distribution of real-time traffic and traveler information to vehicles could be of use to other corridors and metropolitan areas. These techniques include, for example, travel time prediction techniques, map database integration methods and data fusion processes for various real-time data sources including anecdotal sources.

Second, it was noted that the implementation of the TIC User Interface for the Targeted Deployment phase of *ADVANCE* offers the opportunity to expand current knowledge of the interaction between the system and the operator in combining automatically generated information, anecdotal information and subjective judgement to establish predicted roadway conditions and travel times. It was noted that this should be of value to all future Traffic Management Center (TMC) and TIC implementations.

However, concerning the specific features of the *ADVANCE TIC*, it was thought that due to the rapid pace of the continuing evolution of ITS technologies and deployment in the United States that the *ADVANCE* project implementation produced a product that will have limited application in meeting local requirements in other areas. It was remarked that *since the ADVANCE* project's conception, the functional concept for transportation management coordination in other major metropolitan areas of the United States has evolved towards integrated intermodal systems. Reviewers added that this issue is further compounded by privatization initiatives that have evolved to focus on information services, including the dynamic route guidance services offered by the ***ADVANCE*** system.

To maximize transferability potential, reviewers suggested that a change in focus of the *ADVANCE* TIC should be considered, from Advanced Traveler Information Systems (ATIS) to a combined approach incorporating ATIS and Advanced Traffic Management Systems (ATMS). It was proposed by the peers that this could be accomplished through a change in the functional concept at the data management and operations levels with minimal change in the TIC Architecture.

It is concluded that the knowledge and expertise gained by project participants during the *ADVANCE* operational test in terms of the lessons learned from the implementation appear to be the major transferable elements of the *ADVANCE TIC* Architecture created for the Targeted Deployment. Further information will be available by late 1996 within the "Lessons Learned from the *ADVANCE* Project", Document #8465.ADV.01. As was noted by the peer reviewers, it must be concluded that the *ADVANCE* project produced a unique technical solution that, as an entire system, will have limited application in meeting local requirements in other areas.

5.6 Objectives C.l and C.2 - Evaluate TIC System Costs and Alternative TIC Cost Options

5.6.1 Objective C.l - Evaluate System Costs

5.6.1.1 System Costs - Data Collection Procedures

MOEs C. 1.1 and C.1.2 relating *to TIC Architecture capital and operating costs* were assessed using the available expenditure information provided by *ADVANCE* project partners. Data were compiled from project partners and *ADVANCE* Project Office financial records to provide as full a picture as possible of the financial investment in the TIC Architecture subsystem of the overall *ADVANCE* project. As data were collected, they were entered into a spreadsheet software package to aid analysis. The information collected was then reviewed for accuracy and completeness by the affected *ADVANCE* parties and participants.

The costs break down into two main areas:

- development and implementation costs, comprising the TIC equipment costs in addition to all expenditure associated with the design, implementation and testing of the TIC; and
- operating costs, which include TIC operator and supervisor staff costs, maintenance staff costs, and any other ongoing expenditure associated with the continued operation of the TIC.

The subsequent sections are structured in accordance with the above main areas.

5.6.1.2 System Costs - Findings

5.6.1.2-l Develonment and Implementation Costs

This section provides details of the costs associated with the development and implementation of the TIC. Tables 5.7, 5.8, and 5.9 contain details of these costs. Table 5.7 itemizes the TIC equipment costs, including system hardware and TIC furniture. It should be noted that as much of this equipment was obtained through the University of Illinois at Chicago, the costs contained in Table 5.7 reflect significant contributions from various suppliers and should not be considered as available to the public.

Table 5.8 itemizes the labor costs expended on system development and implementation, and various additional costs incurred during the development and implementation stages. These labor rates include salaries, overheads, profit, and benefits as appropriate. The itemization of the staff costs for requirements and specifications analysis, hardware and software design, coding, integration, and adaptive and perfective software maintenance is an estimate due to the structure of the billing procedures of *the ADVANCE* project and the institution responsible for this effort, whereby billing by specific development activities was not performed. The breakdown by development activities has been derived using a typical costs breakdown for systems development provided by the systems developer. These costs do not include the research-oriented activities which were directed at developing algorithms, that is, the Traffic Related Functions, that were ultimately utilized within the TIC, but which were evaluated separately.

SUPPLIER	ITEM	DESCRIPTION	QTY	$/UNIT	COST
ADC	DSERV DSU S/A 110V V.35	T1 modem interface	2	$1,187	$2,374
Central Data	ST-1800+	SCSI terminal server	1	$995	$995
Cisco Systems	19" Rack Mount Kit 3000	High speed network bridge/router	1	$77	$77
	1e2t Router/Bridge 2MF,4MD		2	$4,057	$8,113
	Feature: ISDN (3000)		2	$315	$630
	10' V.35 DTE Cable V2		2	$70	$140
Compudyne	486 Personal Computer		1	$3,912	$3,912
HON	Cabinet Table	Furniture	1	$661	$661
	Lateral File Cabinet		1	$560	$560
	Special Computer Table Assembly		1	$3,300	$3,300
	Chairs		2	$237	$474
MicroAccess	Databook thincard drive TMB-240	Memory card reader	1	$135	$135
SEPS, Inc.	SEPS ESD Installation	Uninterruptable power supply system	1	$3,067	$3,067
	Ext. Switch w/AC Disc.		1	$405	$405
	5.3KVA Ferrups		1	$4,769	$4,769
Solar Sys	Upgrade to Ross HyperSparc	50 to 72 MHZ upgrade	1	$5,580	$5,580
SUN	SbusCard SCSI 2 Buffered Card	Additional SCSI port	1	$657	$657
	8.4GB Multi-Disk Pack	*ADVANCE* disk drives	1	$5,460	$5,460
	4.26GB Desk Top Server Storage		2	$3,480	$6,960
	1.3GB SCSI-2DT Storage Module		1	$2,340	$2,340
	20" Color X-Terminal	Operator X-Terminals	2	$3,272	$6,544
	UNIX Country Kit		2	N/C	N/C
	AUI Only Adapter Cable		2	$45	$90
	Newsprinter 20 Package	Laser printer	1	$2,997	$2,997
	Family for Sparcsystem 670MP:	Main *ADVANCE* server	—	—	—
	12-Slot Office Server		1	$34,500	$34,500
	ALM2	**16 port RS232 serial**	2	$2,577	$5,154
	North American/Asia Power Cord Kit		1	N/C	N/C
	Module Upgrade Ross to Viking	Upgrades to *ADVANCE*	1	$3,600	$3,600
	Module Upgrade to Model 512	**45 to 50 Mhz Upgrade**	2	$6,000	$12,000
	UG,S600MP M512-M514		1	$6,000	$6,000
ZyXEL	Rack Sys Chassis-16 Slots/20x4 LCD	16 slot rack modem	1	$1,040	$1,040
	Int. Rack Data/Fax/Voice	Modems	6	$585	$3,510
	GPS Equipment at TIC	GPS antenna and receiver	2	$1,000	$2,000
		Power Supply	2	$100	$200
	Panasonic UF-322	Fax machine	1	$350	$350
	Additional TIC Cabling Materials			$150	$150

Sub-Total	$128,744
Freight	$818
Total	**$129,562**

Table 5.7 TIC Equipment Costs

ITEM	DESCRIPTION	COST
Labor Costs (UIC-EECS)	Requirements and specifications analysis	$374,937
	Hardware and software design	$468,671
	Coding	$393,684
	Integration	$356,190
	Adaptive software maintenance	$187,468
	Perfective software maintenance	$93,734
Labor Costs (De Leuw, Cather)	Design / Design Review	$104,324
	Testing	$150,000
	Documentation	$160,000
Other	Assembly and installation for GPS systems	$2,300
	One high-speed data line installation	$900
	Nine regular telephone lines installation	$705
	Installation of Uninterruptible Power Supply and rewiring of TIC electrical system	$375
	TIC cabling installation costs	$244
	Total	$2,293,532

Table 5.8 Labor and Miscellaneous Costs for TIC Development and Implementation

Table 5.9 contains the totals of the equipment costs and the development and implementation labor costs.

Total equipment costs	$129,562
Labor and miscellaneous costs	$2,293,532
Total	$2.423.094

Table 5.9 Total TIC Development and Implementation Costs

5.6.1.2.2 Operating Costs

This section provides 'details of the costs associated with the ongoing operation of the TIC. Table 5.10 contains the monthly operating costs of the TIC.

The TIC labor costs have been derived as follows. The TIC is staffed from 6:00 am to 7:00 pm, on Monday to Friday. One TIC operator is on duty at any time, the working day being subdivided into two shifts. Therefore, 65 hours per week, or 286 hours per month, are worked by TIC operators, based on a 22 day working month. The TIC Manager, though on-site throughout the working day at the *ADVANCE* Project Office, spends approximately five hours per week, or 22 hours per month, on TIC related management tasks, again based on a 22 day month. The rates provided for these staff in Table 5.10 take into account the hourly rate paid to the staff member types, plus overheads, profit, and benefits as appropriate.

The costs for TIC technical systems maintenance staff are based on 20 hours per month for a system developer to make routine adjustments and refinements to TIC systems, and 20 hours per month for a UNIX administrator to perform various system administration tasks. Calculations have been made on the basis of a 22 day working month. Again the hourly labor rates for these staff quoted in Table 5.10 include the appropriate benefits and overheads rates.

ITEM	DESCRIPTION	COST/ MONTH
Labor*		
TIC Manager	22 hours per month at $39 per hour	$858
TIC Operators	286 hours per month at $11.41 per hour	$3,263
System Developer	20 hours per month at $60.94 per hour	$1,219
UNIX Administrator	20 hours per month at $60.94 per hour	$1,219
Other Costs		
TIC Office Rental	Comprising 363 sq.ft.	$523
	Servicing costs exceeding those included in rental	$9
Telecommunications	Line rental and charges for 9 lines	$660
	Line rental and charges for 1 high speed line	$556
Miscellaneous supplies	Including electronic media and printer supplies	$45
Total Cost	Month	$8,352

* Labor rates include benefits, overhead, and contractor profit

Table 5.10 TIC Monthly Operating Costs

Additional costs involved in the ongoing operation of the TIC include the rental of the facility space occupied by the TIC equipment and staff, and the telecommunications costs associated with the TIC. As the TIC occupies one room which forms part of a suite rented by the ADVANCE Project Office, it was not possible to itemize precisely these costs for the TIC alone. The method utilized to arrive at the figure provided in Table 5.10 was to calculate the square footage of the TIC facility as a proportion of the total square footage of the Project Office suite. The total amount paid by the Project Office for office space rental was then scaled down to determine a value for the approximate sum expended resulting from TIC operation. This figure includes all utilities, maintenance, and servicing of the office space. However, should the utilities, maintenance, and servicing costs exceed the amount allowed for within the rental costs, the balance is payable by the Project Office at the end of each year. Again, a scaled down value which represents the TIC-attributable share of the total cost for this item is contained in Table 5.10.

The TIC utilizes various lines for communications. Two voice lines are installed in the TIC, and one regular line is utilized for fax communications. In addition, six regular telephone lines connect the TIC systems to:

- the IDOT Traffic System Center (TSC);
- Northwest Central Dispatch (NWCD);
- the weather information data source;

- Dundee 1 loop detector master controller;
- Dundee 92 loop detector master controller; and
- the antenna site which provides RF communications with the MNA-equipped vehicles.

In Table 5.10 the costs relating to these regular lines have been aggregated. In addition, one high-speed data line connects the TIC to the University of Illinois at Chicago - Electrical Engineering and Computer Science department (UK-EECS) which is responsible for ongoing systems maintenance. This high-speed line is used to perform system maintenance and administration tasks remotely.

5.6.1.3 System Costs - Conclusions

The data which represent MOEs ***C.*** 1 .l and ***C.*** 1.2, concerning the *TIC Architecture capital and operating costs,* are as follows. The TIC equipment costs have been calculated at $129,562, and the labor and miscellaneous costs for TIC development and implementation have been calculated at $2,293,532, resulting in total costs for TIC development and implementation of $2,423,094. The costs accrued on a monthly basis for the continuing operation of the TIC have been calculated at $8,352.

5.6.2 Objective C.2 - Alternative TIC Cost Options

5.6.2.1 Alternative Cost Options - Data Collection Procedures

Foe MOEs C.2.1, *the number and type of elements of the TIC implementation which could be simplified to reduce costs without compromising system performance;* and C.2.2, *any alternative cost options; the* input data comprised the findings from the earlier costs data collection activities undertaken for MOEs C.l.l and C.1.2.

The data collected in respect of the functionality MOEs were circulated to the peer review team described in Section 5.3.1. Although the peer review process took place prior to the completion of all data collection activities, the costs data collection had been completed at the time of the review process. The peer review took place from December 14, 1995 to January 2, 1996. The costs data provided to the peer reviewers were identical to that presented in this Final Report in Sections 5.6.1.2. to 5.6.1.3

On receipt of the evaluation data at the commencement of the peer review process, reviewers were requested to consider these data and to identify and describe the number and type of elements of the TIC implementation which could be simplified to reduce costs without compromising system performance, and any alternative cost options. The findings reported in the following subsection comprise the feedback received from the peer reviewers. These findings should be considered in conjunction with the data contained in Sections 5.6.1.2. to 5.6.1.3, which represent the input to the review process.

5.6.2.2 Alternative Cost Options - Findings and Conclusions

The peer reviewers noted that capital cost avoidance was not possible as the system had already been implemented. However, reviewers considered all equipment costs to be reasonable. As was noted above, as much of this equipment was obtained by the University of Illinois at Chicago, the equipment costs reflect significant contributions by suppliers and no sales tax. It was also remarked that although the system development costs were significant, given the complexity of the data sources, including the probe vehicles, these labor costs were in line with the overall TIC complexity.

Reviewers ‘also assessed the monthly TIC operating costs as reasonable, given that the system was providing an essentially full-time information service. However, a potential area where ongoing cost savings could be made was identified as a fully automated TIC system, which would not require staffing by operators. As has been described above, the peer reviewers not only received information relating to the system costs but also information on various aspects of the system performance. Reviewers noted that as only approximately 0.4 percent of data in the Targeted Deployment was entered by operators, see Section 5.2.3.5, the automation of the operators' data entry tasks could eliminate the need to staff the TIC on a daily basis. Although various other tasks, such as system maintenance, the backing-up and archiving of data, and limited system monitoring, would still require manual effort, it was proposed by reviewers that a large proportion of the $3,263 spent monthly during the Targeted Deployment on TIC operators' labor could be saved. It was also acknowledged that this saving of approximately 30 percent of the Targeted Deployment monthly operating costs would have to be offset against the increased development costs that would be incurred in providing for a fully automated system.

Therefore, in terms of the assessment of MOE C.2.1, *the number and type of elements of the TIC implementation which could be simplified to reduce system costs without compromising system performance;* only one such element was identified by the peer reviewers: This was the potential cost saving which would result from enhancing the TIC to provide fully automated information processing, thereby removing the need to staff the TIC on a daily basis. As a consequence, in terms of the assessment of MOE C.2.2, *alternative cost options;* the only alternative costs option proposed by the peer reviewers was the increased expenditure necessary to enhance the TIC as implemented for the Targeted Deployment to allow for fully automated operation, which would decrease the monthly operating costs by the amount currently expended on operators' labor costs.

It should be borne in mind that the TIC operators fulfilled many additional functions during the *ADVANCE* Targeted Deployment operational test such as assisting other Project Office staff with *ADVANCE* evaluation data collection and also performing various administrative tasks concerning the MNA equipped vehicles. However, it is believed that some of these tasks would not be required of operators in the context of a permanently operating system. Thus, it is recommended that this proposal, for enhancing TIC capabilities to include fully automated information processing, be investigated for any future TIC systems either partly or fully based on the *ADVANCE TIC* concept.

5.7 Objective D.l - Evaluate TIC Policies and Procedures

5.7.1 Policies and Procedures - Data Collection Procedures

Data for MOEs D.1.1, *the number and type of areas where policy and procedure impact efficient TIC operation or operator workload,* and D.1.2, *the number and type of revisions to TIC policies and procedures recommended to streamline TIC operations or operator workload,* were collected by means of a structured questionnaire. This questionnaire, the TIC Evaluation Questionnaire, is included in Appendix C of this Final Report. The questionnaire incorporated the data collection both for the TIC policies, procedures and staffing requirements and the TIC User Interface objectives which are discussed in Section 6. The questionnaire was administered towards the end of the TIC operation period, in the week commencing November 20, 1995, in order to enable maximum exposure of the operators to the procedures in place at the TIC.

It should be borne in mind when considering the information contained in the following sections that the responses to the TIC Evaluation Questionnaire represent operators' perceptions of the effects of TIC policies, procedures and staffing requirements which may account for some variance in responses. Throughout these sections where the TIC systems designers or developers are referred to, these roles were performed by UIC-EECS technical staff.

The questions concerning the policies and procedures of the TIC were designed utilizing a document which was available to the operators and which aimed to inform them of the policies and working practices in place at the TIC. This document was the TIC Policies and Procedures Manual, Document #8750.01. This document provides detailed descriptions of the tasks and responsibilities of the TIC operators. Operators also had access to the TIC Console Operator's User Manual, Document #8700-3 .0, which concentrates on the specifics of navigating around the TIC User Interface and performing tasks. Further discussion on the use of this Manual is contained in Section 6.

5.7.2 Policies and Procedures - Findings

The responses to a series of introductory questions provided some basic information regarding the characteristics of the TIC operators. The *ADVANCE* TIC was staffed by three operators during the project's Targeted Deployment phase. All three operators employed at the TIC were male. One operator was between 18 and 25 years of age, and the remaining two were aged between 26 and 35. With respect to the operator's level of education, all three were attending college while working at the TIC. Operators were also asked how long they had been working at the TIC, to the nearest month. The duration of employment at the TIC varied considerably. Operator A had been working at the TIC for six months, Operator B for three months, and Operator C for two months. This difference in duration of employment at the TIC should be borne in mind when considering operator's responses to subsequent questions, discussed below. Another characteristic of TIC operation which affected operators' responses to certain questions was the pattern of shifts worked. Table 5.11 illustrates the shifts worked by the three operators.

	Monday	Tuesday	Wednesday	Thursday	Friday
6:00 am to 12:00 pm	Operator A	Operator C	Operator A	Operator C	Operator C
12:00 pm to 7:00 pm	Operator B	Operator A	Operator B	Operator A	Operator B

Table 5.11 Shifts Worked by TIC Operators

It can be seen that not only had Operator A been employed at the TIC for the longest duration but also that he worked four shifts per week, alternating morning and afternoon shifts. Operators B and C worked three shifts per week each, with Operator B only working during the afternoon shifts, and Operator C only working during the morning shifts. Therefore, it should be recognized that the combination of the length of employment at the TIC and the number of shifts worked per week has an effect on the likelihood of an individual operator having been exposed to certain operational scenarios or difficulties covered by the TIC Evaluation Questionnaire. In addition, some activities of the TIC Operators are performed at specific times during the day. For example, the daily system backups are performed during the morning shift, and so Operator B only had the opportunity to experience this procedure in exceptional circumstances when he may have provided cover for one of the other operators if they were unable to work a particular morning Shift.

The subsequent questions within Part 1 of the TIC Evaluation Questionnaire aimed to ascertain how familiar operators were with the TIC Policies and Procedures Manual. As can be seen from Figure 5.15, two operators stated that they were familiar with this document, while the third operator stated he was unfamiliar with this document, though he added that he was familiar with an appendix to this document which contains the Daily TIC Operations Procedures. That appendix serves as a summary of the information contained within the main document, and outlines the routine tasks which operators are required to perform on a daily basis. It should be noted that throughout the Targeted Deployment operational test, systems developers and De Leuw, Cather staff were generally available to assist operators with any queries or difficulties they may have had concerning policies or procedures.

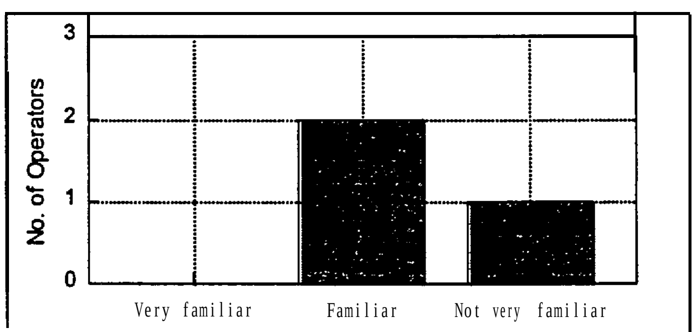


Figure 5.15 Familiarity with TIC Policies and Procedures Manual

Operators were then asked how frequently they consulted the TIC Policies and Procedures Manual. As can be seen from Figure 5.16, two operators consulted the Manual relatively infrequently, whereas one operator consulted the Manual more than once per day. This was the operator who was unfamiliar with the document as a whole but who referred to the daily tasks appendix frequently. This difference in frequency of use of the Manual may be explained by the fact that this operator had worked at the TIC for the least length of time.

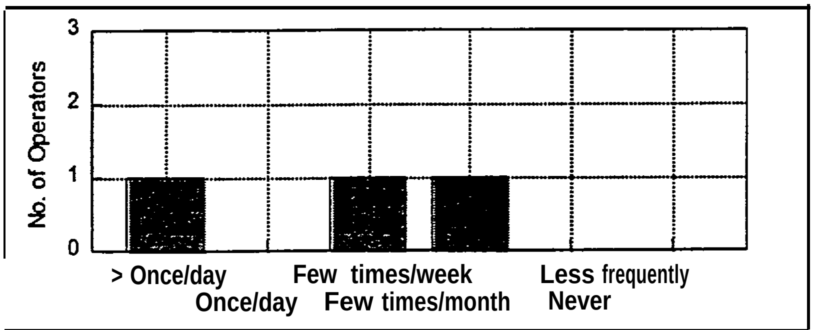


Figure 5.16 TIC Policies and Procedures Manual Frequency of Use

Figure 5.17 shows that all three operators found the TIC Policies and Procedures Manual to be either useful or very useful when seeking guidance on how to respond to situations which arose in the TIC.

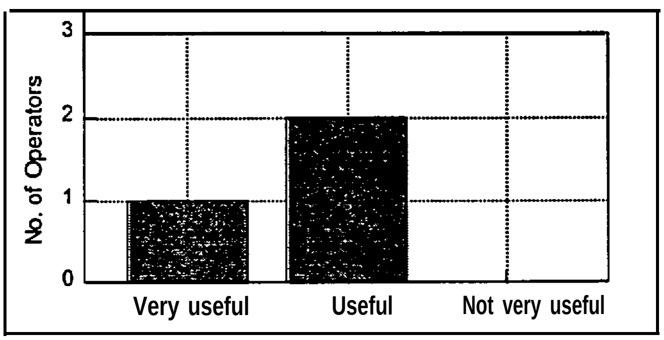


Figure 5.17 Usefulness of TIC Policies and Procedures Manual

The subsequent questions aimed to establish the frequency with which operators performed various tasks which were described within the TIC Policies and Procedures Manual and whether they had experienced any difficulties in performing any of these tasks. Operators were asked how frequently they had been required to validate manually the results of the TRF algorithm if an apparent malfunction occurred when monitoring the TRF subsystem. Two operators had never performed this task, one adding that he had not been aware that this was required, while the third operator had performed the task a few times per month, see Figure 5.18. This was Operator A who had the longest period of employment at the TIC and who worked the greater number of shifts. This operator reported that he had not experienced any difficulties in completing this task. The comment from the operator who had not been aware that this task was required of him may indicate the need for more comprehensive initial training procedures to be put into place at the

TIC, or for periodic "refresher" training sessions to be provided for all operators in order to ensure that they remain fully aware of their responsibilities.

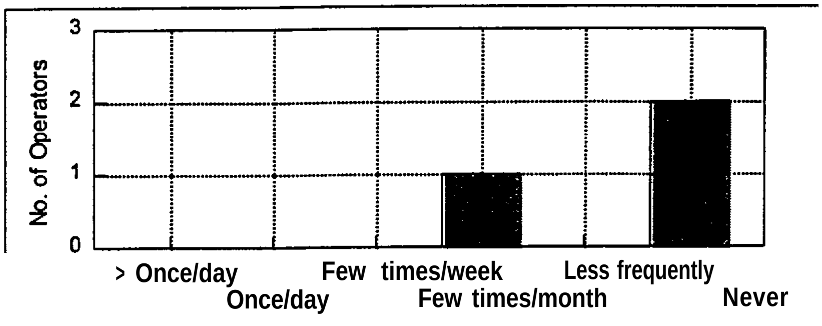


Figure 5.18 Manual TRF Validation Frequency

Operators were asked how frequently they had had to request a new travel time database of static profiles when monitoring the frequency that the TIC updated the travel times in the MNAs, see Figure 5.19. This task had never been performed by two of the operators while the third operator had performed the task less frequently than a few times per month. Again, only Operator A had performed the task, and again, no difficulties in completing the task had been experienced. During the analysis of questionnaire data it was established that this responsibility had been removed from the TIC operators some time into the Targeted Deployment.

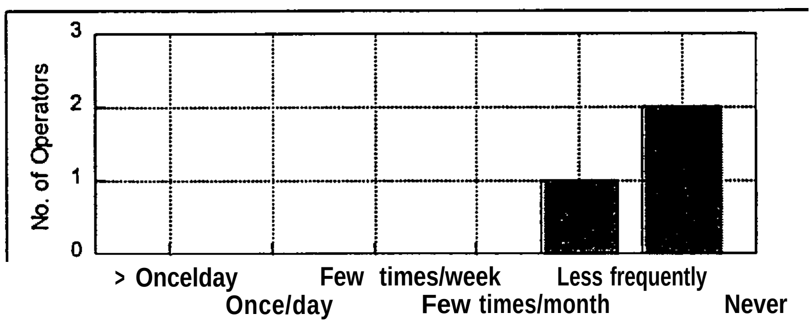


Figure 5.19 Request New Travel Time Database Frequency

The TIC Policies and Procedures Manual also provides guidance on how operators should respond to emergency telephone calls from project vehicle drivers should these be received outside regular office hours, when other *ADVANCE* Project Office staff were not available to provide assistance. Figure 5.20 illustrates that this scenario had been either infrequently or never experienced by the three operators. No problems had been experienced in completing this task.

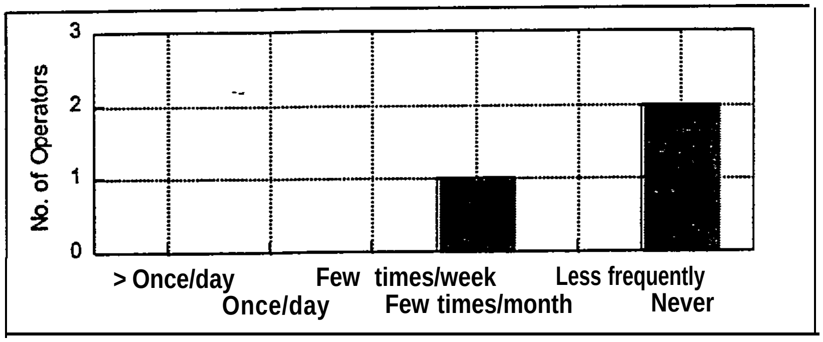


Figure 5.20' Frequency of Handling Emergency Calls from Drivers

Operators were then asked about various aspects of the TIC systems maintenance procedures which could affect the completion of their tasks or impact their workload. None of the three operators had experienced any adverse impacts on the operation of the TIC due to the scheduling of maintenance activities, indicating that no alterations to the scheduling of these activities is necessary. The TIC Policies and Procedures Manual also described the approach to be taken by operators if requested to assist in the verification of an update of the travel time database. None of the operators had been required to assist in this procedure as it had been performed by other Project Office staff.

Another task described by the TIC Policies and Procedures Manual was the processing of MNA memory cards. This task comprises downloading the travel time data contained on the cards, erasing the cards and returning them to the MNA units in the project vehicles. As illustrated in Figure 5.21, two of the operators had never performed this task, while one operator had performed the task a few times per month. This operator, Operator A, explained that at the outset of the TIC Targeted Deployment he had been required to perform this task, though since the other two operators had been working at the TIC, policy had changed and other *ADVANCE* Project Office staff now performed the task. Therefore, it should be considered whether the task description in the Manual should be amended to indicate that operators themselves are not required to perform the task.

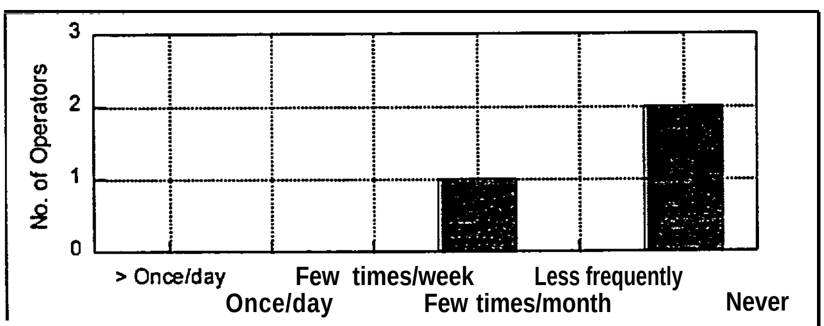


Figure 5.21 MNA Memory Card Processing Frequency

Operators were asked about their involvement in emergency shutdowns of the TIC, such as could be caused by software malfunctions or hardware failures. Two of the operators had never been involved in an emergency shutdown of the TIC, see Figure 5.22, while Operator A had experienced emergency shutdowns of the TIC a few times per month. Operator A was then asked several further questions regarding these shutdowns. Some problems had been experienced by this operator both in diagnosing the specific problem which necessitated an emergency shutdown, and in judging whether the problems experienced warranted such a shutdown. It was remarked by the operator that the system provided little feedback to assist in these situations and that technical support from the systems developers had been required on each occasion, not just in order to restore systems from any failures but also in diagnosing the problem. However, this operator also reported that no unforeseen consequences of performing emergency shutdowns had been encountered, and that all the technical support needed to restore TIC operations from an emergency shutdown had always been received.

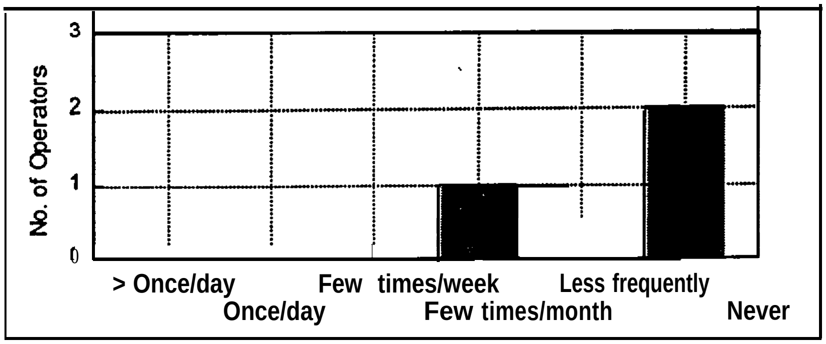


Figure 5.22 Frequency of Involvement in Emergency Shutdowns of TIC

Operators were also asked about their involvement in planned shutdowns of the TIC, such as might be necessary to perform routine, non-critical maintenance activities, or to update hardware or software components. Figure 5.23 shows that two of the three operators had been involved in such a shutdown and that this occurred a few times per month. These operators were then asked several further questions regarding these shutdowns. Neither operator had experienced any unforeseen consequences of planned shutdowns, and both had received all the technical support necessary to restart TIC systems.

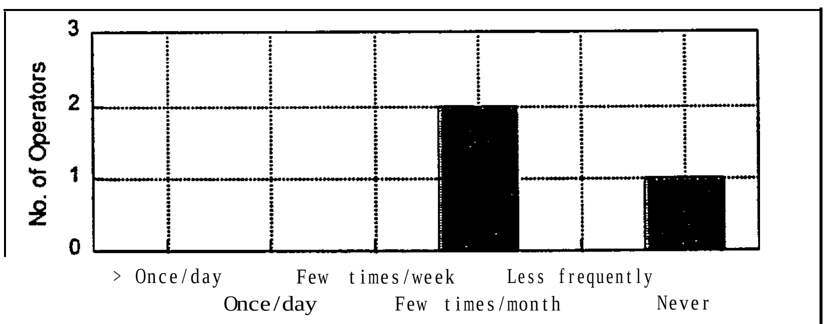


Figure 5.23 Frequency of Involvement in Planned Shutdowns of TIC

The subsequent questions concerned communications subsystem malfunctions, that is, any problems experienced with the RF modems in the equipped vehicles. Two of the three operators had experienced such problems, and one operator had also experienced difficulties in diagnosing communication subsystem malfunctions, highlighting the need to request assistance from the systems developers. However, both operators stated that they had received all the technical support required to restore the communications subsystem to full operation.

Operators were asked if they had ever been involved in the updating of the TIC software or hardware, or the testing of any updates that were made to the TIC systems. Two operators had not been involved in any such procedures. The one operator who had been involved in assisting with system updates or testing of updates had not experienced any difficulties in completing these tasks. The frequency with which operators had performed TIC database and applications software backups is illustrated in Figure 5.24. It can be seen from this figure that these tasks were only performed either a few times per month or less frequently by operators. No difficulties had been experienced by any of the operators in performing this task.

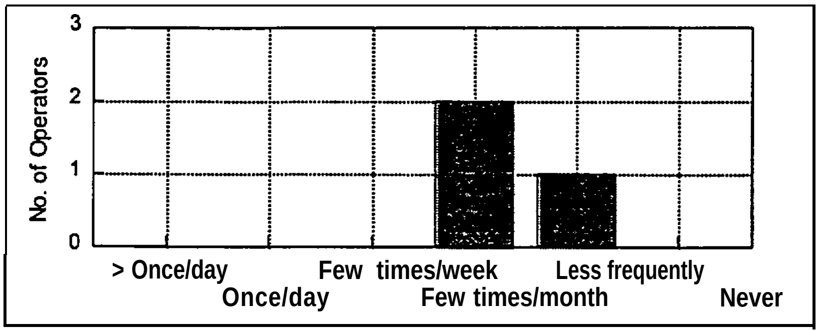


Figure 5.24 Frequency of TIC Databases and Applications Software Back-ups

The TIC Policies and Procedures Manual provides guidance on how operators should proceed if a critical malfunction requires them to authorize a change to any of the TIC subsystems in order to keep the TIC operational, that is, an "emergency fix". All operators reported that they had not been required to authorize such a change to TIC systems in response to a critical malfunction. However, given the responses to previous questions in which operators had highlighted the need to contact the systems developers for support in diagnosing system failures, it seems unlikely that the operators possessed the necessary system knowledge and experience in order to be able to authorize and/or make such changes without assistance in any case. In addition, the access permissions given to TIC operators do not allow them to perform fixes or even to start-up and shut-down processes in many cases. Therefore, unless operators with greater systems knowledge are to be employed at the TIC in the future, and unless greater access privileges are assigned to operators, it should be considered whether the procedures described in the Manual should be modified to indicate that operators are not required to perform this task.

The TIC Policies and Procedures Manual describes the approach to be taken by operators should requests for data from various types of agency be received, in order that data privacy and integrity may be ensured. Operators had dealt with requests for information from *ADVANCE* project participants either a few times per week or a few times per month, see Figure 5.25. These requests could be for data for evaluation purposes or for system maintenance. All operators reported no difficulties in obtaining approval for providing such information, although it is unclear whether operators were familiar with the official procedures for dealing with internal project requests for data as outlined in the Manual. The Manual states that all requests for data from within the project should be in writing and should be approved by the system manager. From observations made within the TIC and from discussions with the TIC operators, it is clear that these procedures were not adhered to in the majority of cases. However, as it is considered that complying with data requests from *ADVANCE* project participants is not likely to impact significantly the project's data integrity, it should be considered whether the procedures for the release of data described in the Manual could be relaxed in these cases.

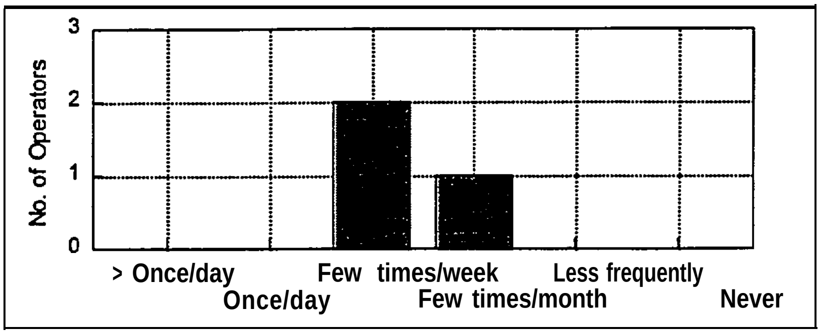


Figure 5.25 Frequency of Requests for Information from *ADVANCE* Participants

In terms of the frequency with which operators had handled requests for information from outside the *ADVANCE* project, two operators had never received such a request, while one operator, Operator A, reported that he had handled requests from non-*ADVANCE* participants a few times per month, see Figure 5.26. Again, no problems in obtaining approval for releasing requested information to non-project participants had been experienced by this operator, although the same observations as were made above in the case of internal requests for data may also apply here. Operators were also asked if they had ever been asked to provide any personal information held about drivers of the MNA equipped vehicles or their movements in the test area from outside of the *ADVANCE* project. None of the operators had been requested to provide such information.

The questionnaire also contained a series of questions relating to operator workload. Operators were asked if assisting the evaluation team in collecting data for the *ADVANCE* evaluation had caused any difficulties for the operation of the TIC or the operator's own workload. No operator had experienced any such difficulties.

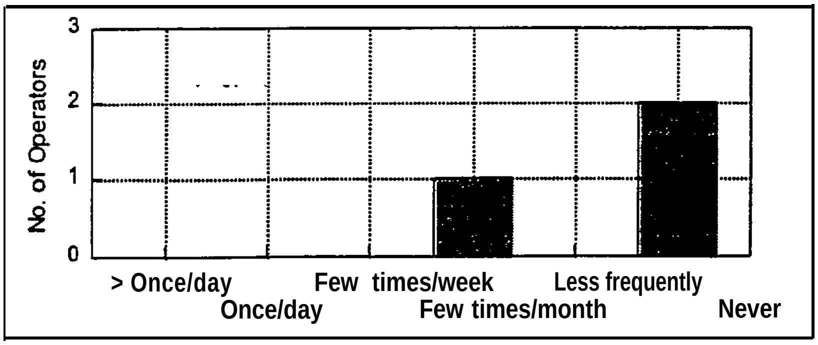


Figure 5.26 Frequency of External Requests for Information

Operators were asked if any *ADVANCE* project participants other than the systems developers had ever requested online access to the TIC or had attempted to login to the TIC system. None of the operators had experienced this scenario. The TIC Policies and Procedures Manual states that operators must monitor the systems developers' remote access to ensure that this does not impact regular TIC operations and that unauthorized changes are not made to TIC systems. Operators were asked if the systems developers' on-line access to the TIC had ever adversely affected the operation of the TIC. No problems associated with this remote on-line access were reported. Similarly, no operators were aware of any unauthorized changes having been made to the TIC system using these remote access links with the systems developers. However, one operator commented that he did not know how to distinguish when systems developer staff were remotely logged on to the TIC systems or whether this access could be the cause of any difficulties experienced. This comment highlights the need for either more comprehensive system feedback to inform operators of who is logged onto the system and any adverse consequences of this access, or more extensive training of operators to ensure that they possess sufficient system knowledge such that this task can be performed as described in the Manual. Alternatively, if this task is no longer deemed necessary then the Manual should be amended accordingly.

5.7.3 Policies and Procedures - Summary of Findings

The following points summarize the key findings for this objective, relating to the impact of policies and procedures on efficient TIC operation.

- All operators were familiar with either the TIC Policies and Procedures Manual, or the appendix to this document which serves as a summary of the information contained in the main document. In addition, all three operators found the TIC Policies and Procedures Manual to be either useful or very useful when seeking guidance on how to respond to situations which arose in the TIC.
- In the majority of cases, operators had not experienced difficulties in completing the tasks required of them. However, it was found that in several cases, tasks described within the TIC Policies and Procedures Manual had not been performed by all operators, and it is considered that this is partly due to the difference in lengths of employment at the TIC, two of the operators only having worked at the TIC for two and three months respectively, and the differences in the

number of shifts worked. It should be borne in mind that should all operators have had the opportunity to gain more experience in using the TIC systems over a longer period, then more of these tasks may have been encountered and, potentially more difficulties could then have been reported.

- Prom discussions with the TIC operators, it was found that varying perceptions existed of some of the tasks required of them. This was the case with the manual validation of the results of the TRF algorithm should an apparent malfunction occur when monitoring the TRF subsystem, and the monitoring of systems developers' remote access to ensure that this did not impact regular TIC operations and that unauthorized changes were not made to TIC systems.
- None of the three operators had experienced any adverse impacts on the operation of the TIC due to the scheduling of maintenance activities, indicating that no alterations to the scheduling of these activities are required.
- It was found that operators were no longer required to perform the processing of MNA memory cards, therefore it should be considered whether this task description in the TIC Policies and Procedures Manual should be amended to indicate that operators themselves are not required to perform the task.
- It was found that operators had experienced some difficulties both in diagnosing technical problems which arose with the TIC systems and in judging the appropriate action to take in response to any such difficulties. Operators also commented on the lack of feedback provided by the system when technical problems arise. This was encountered in the case of emergency shutdowns, and communication subsystem malfunctions.
- It was found that in all the scenarios listed above in which operators has not been able to diagnose or remedy problems experienced with TIC systems, that technical support from the systems developers had been required and sought. Operators did comment that this support had always been readily accessible.
- The TIC Policies and Procedures Manual provides guidance on how operators should proceed if a critical malfunction requires them to perform an "emergency fix". It is considered that the operators did not possess the required technical knowledge which would enable them to authorize or perform such fixes. Therefore, unless operators with greater systems knowledge are to be employed at the TIC in the future, it should be considered whether the procedures described in the Manual should be modified to indicate that operators should not attempt to make such emergency fixes.
- It was found that in the case of requests for data from *ADVANCE* participants, the procedures for releasing data described in the TIC Policies and Procedures Manual were not adhered to by the operators in the majority of cases.
- In terms of operator workload, no difficulties were experienced by operators as a result of assisting the evaluation team in data collection.

It should be noted during the Targeted Deployment operational test, systems developers and Project Office staff were often present in the TIC or generally available to assist operators with any queries or difficulties experienced that may have arisen.

5.7.4 Policies and Procedures - Conclusions

In terms of the assessment of MOE D. 1.1, *the number and type of areas where policy and procedure impact efficient TIC operation or operator workload*, four key areas for consideration have been identified.

First, efficient TIC operation and operator workload may have been impacted by the operators' varying perceptions of some of the tasks required of them. This was the case with the manual validation of the results of the TRF algorithm should an apparent malfunction occur when monitoring the TRF subsystem, and the monitoring of the systems developers' remote access to ensure that this did not impact regular TIC operations and that unauthorized changes were not made to TIC systems.

Second, during the Targeted Deployment phase of the *ADVANCE* project, operators experienced some difficulties both in diagnosing technical problems which arose with the TIC systems and in judging the appropriate action to take in response to any such difficulties. Operators also commented on the lack of feedback provided by the system when technical problems arise. This would increase workload as these operators with incomplete system knowledge attempted to resolve difficulties. It may also be that TIC efficiency was compromised by the need to contact an external agency, the systems developers, for technical support, rather than having this knowledge available "in-house" at the TIC.

Third, efficient TIC operation may also have been impacted by the operators not having been able to perform emergency maintenance on TIC system in the event of a critical malfunction. For example, should such malfunctions occur when systems developers staff were not available to provide assistance then it is considered unlikely that the TIC operators themselves possessed the required technical knowledge which would enable them to perform such fixes. Operators also lacked the necessary access privileges which would enable them to perform emergency maintenance activities.

Fourth, operator workload was lessened by the non-adherence to the procedures described in the TIC Policies and Procedures Manual for the release of data to *ADVANCE* project participants. The Manual states that all requests for data should be made in writing and that the TIC system manager's approval should be sought prior to any data being released. It is believed that this non-adherence to procedures occurred due to the constant involvement of Project Office staff, UIC-EECS developers and De Leuw, Cather in tasks within the TIC.

In terms of the assessment of MOE D.1.2, *the number and type of revisions to TIC policies and procedures recommended to streamline TIC operations or operator workload*, the issues outlined above translate into two key areas where revisions to TIC policies or procedures could be made.

The first key area relates to the levels of training and expertise of the TIC operators. Given that operators seemed to possess varying perceptions of some of the tasks required of them, it is suggested that more comprehensive system feedback be provided in order to provide prompts for operators. Alternatively, the variances in perceptions of tasks required could be eliminated by the implementation of comprehensive and standardized initial training procedures, supported by full documentation, or for periodic "refresher" training sessions to be provided for all operators in order to ensure that they remain fully aware of their responsibilities.

It is also possible that TIC operations could be streamlined by employing operators with higher levels of technical experience and knowledge which would enable them to diagnose technical problems arising with the TIC systems and to judge the appropriate action to take. However, it was found that in the scenarios in which operators had not been able to diagnose or resolve problems experienced with TIC systems, that technical support from the systems developers had always been readily accessible. Should operators with more technical backgrounds not be employed at the TIC in the future it must be ensured that continuing access to systems developers' technical staff is available. Similarly, as the operators employed during the Targeted Deployment were not equipped to perform emergency maintenance on TIC system in the event of a critical malfunction, it may also streamline TIC operation if operators with higher levels of technical experience and knowledge were employed in future. However, the increased staff costs which this would incur is typically not warranted and therefore continuing access to systems developers staff should be ensured.

The second key area relates to operator workload. Operator workload was lessened by the non-adherence to the procedures described in the TIC Policies and Procedures Manual for the release of data to ***ADVANCE*** project participants. However, the potential for breach of data privacy or integrity was minimal during the Targeted Deployment and therefore the procedures described in the Manual, solely in terms of internal project requests, could be eased. Although it was found that operators tended not to follow these procedures, thereby informally streamlining their workload, a formal change to the procedures would ensure that their workload would continue to be lessened in this manner. It is recommended that these procedures be revised to permit operators to release project information requested verbally by those project participants approved by the *ADVANCE* Steering Committee. Verbal requests for information received from all other participants should be referred to the TIC Manager, who would then seek approval for the release of the relevant information. It is believed that in a permanently operational system, the procedures contained within the Manual relating to release of information were appropriate. The above conclusion is drawn from experiences gained during the Targeted Deployment tests.

5.8 Objective D.2 - Evaluate TIC Staffing Requirements

5.8.1 Staffing Requirements - Data Collection Procedures

Data for MOEs D.2.1, *the number and type of difficulties resulting from existing staffing levels experienced during TIC operation which effect TlC efficiency or operator workload,* and D.2.2, *the number and type of revisions to TIC staffing levels recommended to streamline TIC operations or operator workload,* relating to the impact of staffing levels on efficient TIC operation and operator workload were collected by means of the TIC Evaluation Questionnaire, which is included in Appendix C of this Final Report. The questionnaire was administered towards the end of the TIC operation period, in the week commencing November 20, 1995, in order to enable maximum exposure of the operators to the procedures in place at the TIC.

5.8.2 Staffing Requirements - Findings

The basic background information regarding the operator characteristics was provided in Section 5.7.2 above. It should be noted that in addition to the routine operator tasks of entering anecdotal data, monitoring overall system status, and performing data back-ups, the TIC operators also assisted Project Office staff and other *ADVANCE* participants with various additional tasks during the Targeted Deployment phase. These tasks included the collection of data for the evaluation of various aspects of the *ADVANCE* project, and the collection of TRF data. For example, the latter task took place in several phases during the Targeted Deployment, typically from 2:00 pm to 7:00 pm. The performance of these tasks in conjunction with the operators' regular responsibilities resulted in operators' workload being increased beyond what would be required for a permanently operating system which would not normally be undergoing such testing or other data collection. This should be borne in mind when considering operators' assessments of their workload in the following paragraphs.

In order to provide some additional background information illustrating the magnitude of operator workload, a plot of the number of new traffic related incidents received hourly from NWCD averaged over seven representative weekdays is presented in Figure 5.27. The incidents included in this figure include all incidents reported by NWCD as "accident with injury", "accident with property damage", or "motorist assist", which are the types of incidents most commonly entered by operators. Figure 5.27 does not include any updates concerning previously received incident reports sent from NWCD.

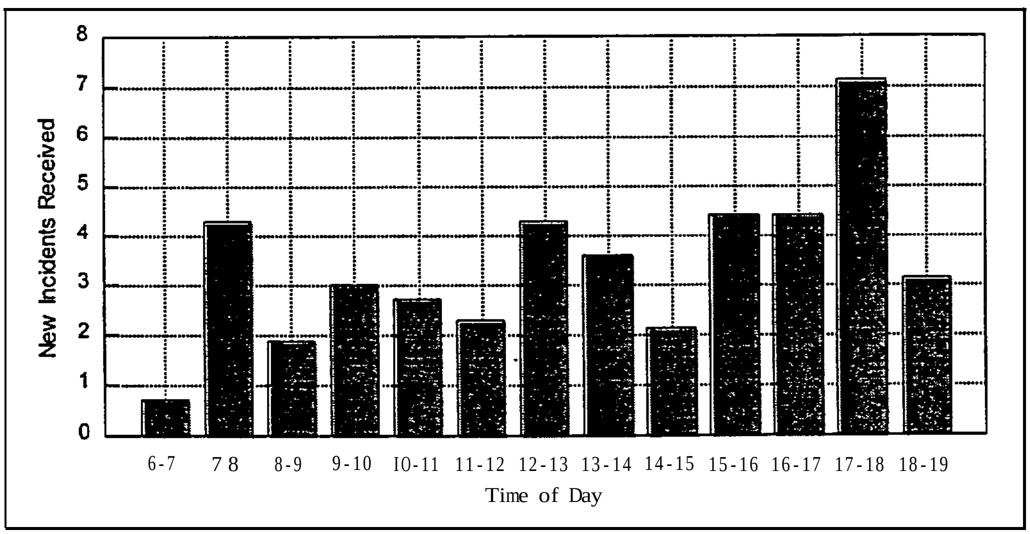


Figure 5.27 Volume of Traffic Related Incidents Received from NWCD

In addition to the entry of anecdotal data received from NWCD, operators also perform daily system data back-ups during the morning shift. This task typically takes place at some tune between 6:00 am and 7:30 am each weekday morning. Facsimiles containing details of any road and lane closures are received daily at the TIC from IDOT District 1 and ISTHA at around 4:00 pm to 5:00 pm. These are then entered into the TIC database if they fall within the test area. This information is provided to assist the reader when considering the perceived workload assessments provided by operators.

The questions relating to staffing levels aimed to establish operator's perceptions of their own workload at various times of the day when the TIC is staffed. Due to the shifts worked by the three operators illustrated in Table 5.12 above, not all three operators could provide a workload assessment for all of the time periods covered by these questions. The operators' responses are presented in Figures 5.28 to 5.3 1. The intervals chosen for these questions reflect the time periods utilized in the static profile travel time values used by the TIC systems which were designed to be representative of different travel conditions within the test area, for example, morning peak or daytime off-peak periods.

Operators assessed their own workload between the times of 6:00 am and 9:00 am as either heavy or moderate. This assessment reflects the larger number of anecdotal inputs the operator is required to enter into the TIC systems during the morning peak period, and also the various routine tasks which are also performed at this time, for example, the daily system data backups. Between the times of 9:00 am and 4:00 pm, operator workload was assessed as either moderate or light.

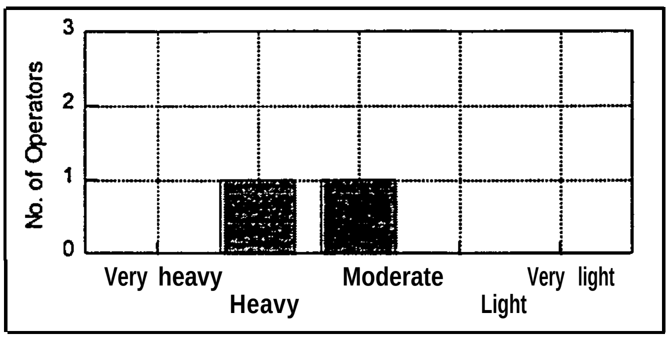


Figure 5.28 Perceived Operator Workload: 6:00 am to 9:00 am

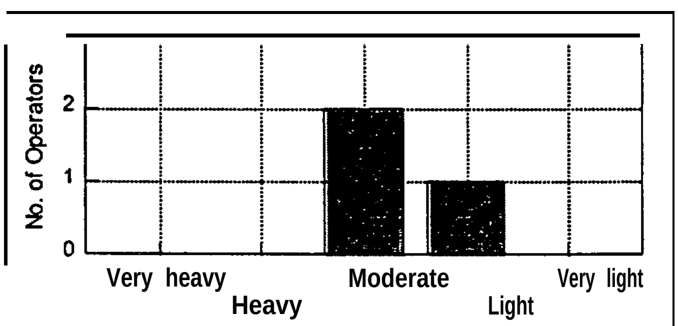


Figure 5.29 Perceived Operator Workload: 9:00 am to 4:00 pm

During the afternoon peak period, from 4:00 pm to 6:00 pm, again the operators' assessed their own workload as either heavy or moderate, though after this time, from 6:00 pm until when TIC staff came off duty at 7:00 pm workload was considered to be moderate or light. During none of these time periods was the workload perceived to be heavy by all operators, and at no times was workload considered to be very heavy. These assessments would indicate that the staffing levels in place for the *ADVANCE* Targeted Deployment were reasonable and did not result in undue pressure being placed upon operators.

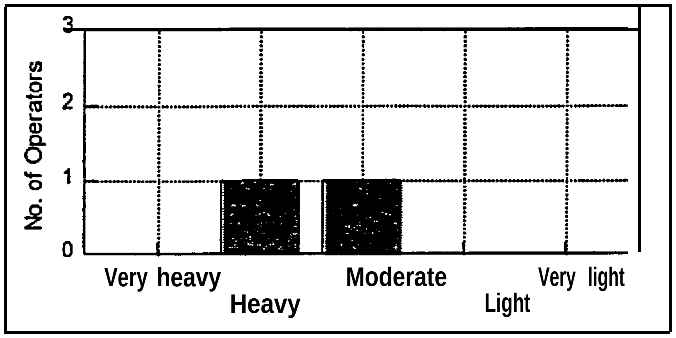


Figure 5.30 Perceived Operator Workload: 4:00 pm to 6:00 pm

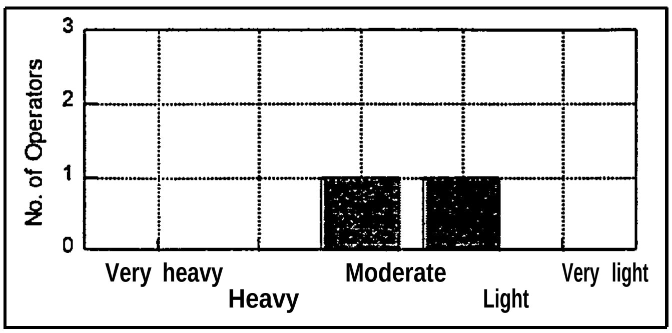


Figure 5.31 Perceived Operator Workload: 6:00 pm to 7:00 pm

The TIC system manager was on duty at the Project Office during regular office hours, that is, from 8:00 am to 5:00 pm, during the Targeted Deployment. In addition, it was ensured that operators could contact the TIC system manager, UK-EECS developers and De Leuw, Cather staff outside these hours by mobile phone or pager. Operators were asked if they had ever required any input or guidance from the system manager outside these hours in order to fulfil their duties. Two of the three operators had not required assistance from the system manager outside office hours. One operator had had cause to contact the system manager out of regular office hours on one occasion. He had done so by telephone and the difficulty had been resolved by this means. Thus, at least in terms of the Targeted Deployment, no adverse impacts were experienced by operators due to the system manager not being present throughout the daily period of staffed TIC operation. It should be noted that De Leuw, Cather staff were also generally available to provide assistance to operators if required.

5.8.3 Staffing Requirements - Summary and Conclusions

Therefore, to summarize the findings for this objective: first, it was found that the staffing levels in place for the *ADVANCE* Targeted Deployment were reasonable and did not result in undue pressure being placed upon operators; second, no adverse impacts were experienced by operators due to the system manager not being present throughout the entire period of daily staffed TIC operation.

In terms of the assessment of MOE D.2.1, *the number and type of difficulties resulting from existing staffing levels experienced during TIC operation which effect TIC efficiency or operator workload,* no such difficulties were experienced.

In terms of the assessment of MOE D.2.2, *the number and type of revisions to TIC staffing levels recommended to streamline TIC operations or operator workload,* it was found that the majority of the TIC operators' workload, including both administrative tasks and anecdotal data input, occurs from between 6:00 am and 9:00 am, and 4:00 pm and 7:00 pm. Therefore, it is recommended that further investigations be undertaken into the feasibility of staffing the TIC during these hours only. It should be recognized that unless some automation of NWCD anecdotal data is implemented, part-time staffing of the TIC would result in some loss of real-time data when the TIC is unstaffed However, it is believed that during normal system operations, when the operators would not be involved in other *ADVANCE* related tasks, such as TRF data collection and dealing with test drivers, no significant reduction in the level of service provided by the TIC would result from part-time staffing of the TIC.

SECTION 6 TIC USER INTERFACE EVALUATION RESULTS

The approach, procedures and results of the TIC User Interface evaluation are presented in this section. The purpose of this component of the TIC evaluation was to evaluate the usability and functionality of the TIC User Interface.

The usability of the interface relates to the ease with which the features of the interface can be utilized. The usability evaluation considered elements of the system such as workstation layout, screen format, task and menu structure, the demands made by the system on the operator for data input and process monitoring, and the degree of feedback provided by the system to the operator.

The functionality of the interface refers to the features which are available to the operator to fulfill the tasks required. The functionality evaluation involved assessing these features to identify any additional features that were required by the operator and any features which remained unused.

The key assumptions and constraints of the TIC User Interface evaluation are described below. The ensuing subsections, which contain the findings of the evaluation, reflect the series of objectives and associated Measures of Effectiveness (MOEs) created for the TIC User Interface evaluation which are listed in Section 4.1. In the subsequent section, Section 7, the findings of the evaluation, both for the TIC Architecture and the TIC User. Interface components, are considered in the light of their respective evaluation hypotheses.

6.1 Key Assumptions and Constraints

As for any evaluation, the results of the *ADVANCE* TIC User Interface evaluation must be considered in the light of the assumptions which were made by the evaluation team and the constraints which may have influenced the findings. In this subsection, the assumptions and constraints relating to the TIC User Interface evaluation are described.

6.1.1 Assumntions

For all the MOEs relating to the TIC User Interface evaluation, it was assumed that operators had sufficient experience in using the TIC User Interface in order to be able to provide comprehensive and reliable feedback. It was assumed that the same TIC staff would operate the TIC throughout the period of the evaluation in order to ensure continuity of data collection. It was assumed that operators would be neither positively nor negatively biased in their attitudes towards the interface. For all TIC User Interface MOEs it was assumed that the TIC operators and the supervisor would be available to take part in the survey process. It was also assumed that the TIC Operator Observation Log would be completed on a regular basis, whenever a relevant issue required reporting, and that log entries were accurate and complete.

Regarding the on-site observations made by the human factors specialist, it was assumed that the presence of an observer would not cause operators to alter their working practices or methods of completing tasks in any way.

6.1.2 Constraints

The key constraint, or limitation, of the TIC User Interface evaluation process which must be taken into consideration was the limited number of operators who were employed within the *ADVANCE* TIC. The data collection involved the full population of TIC operators, but due to the degree to which the *ADVANCE* TIC operations were automated, the population in fact represented very few subjects.

In addition, a constraint of the User Interface evaluation was the depth of analysis which was possible given the level of funding allocated to this portion of the overall *ADVANCE* project evaluation effort.

6.2 Objective E.l - Evaluate TIC User Interface Usability

For MOEs E. 1.1, *the user perceptions of the level of ease with which systems can be operated in everyday use,* and E.1.2 *the number and type of difficulties reported by operators in everyday use;* data were collected by means of the TIC Evaluator Observation Sheet, the TIC Evaluation Questionnaire, and the TIC Operator Observation Log which was completed by the operators and supervisor. The following paragraphs describe the format and implementation of these three data collection tools.

6.2.1 Data Collection Tools and Procedures

The TIC Evaluation Questionnaire is included in Appendix C. The questionnaire incorporated the data collection both for the TIC User Interface objectives and the TIC policies, procedures and staffing requirements objectives discussed in Section 5.7 and 5.8. The questionnaire was administered towards the end of the period of TIC operation, in the week commencing November 20, 1995, in order to enable maximum exposure of the staff to the TIC operations. The questionnaire was administered to the operators within the TIC to enable them to demonstrate any responses to questions as required. Operators were told that the questionnaire had been designed to help evaluate various aspects of the general operation and the user interface of the *ADVANCE* TIC, and that it was not being used to assess individual operator performance or knowledge.

The questions concerning the TIC User Interface usability and functionality had been partly designed utilizing a document provided to TIC operators to assist them with the navigation and use of the systems in the TIC. This document is the TIC Console Operator's User Manual, Document #8700-3.0. The document provides descriptions of the external appearance and behavior of the interface, how to navigate through the TIC User Interface, and how to access and manipulate the various functions within the interface. The document could be used as a source of reference if required when considering the findings of the TIC Evaluation Questionnaire and the other data collection tools, presented in the following sub-sections.

A non-real-time TIC Operator Observation Log was available in the TIC from the commencement of the evaluation period to enable operators or their supervisor to note any issues which were relevant to the TIC User Interface. TIC operators and the supervisor were briefed at the outset of the evaluation period on the purpose and scope of the User Interface evaluation and informed of the purpose of the TIC Operator Observation Log. The TIC Operator Observation Log sheet is also provided in Appendix C. An entry on the log sheet was completed on each occasion that an observation relating to the User Interface functionality or usability was perceived, or when any other issue relating to the operator's interaction with the system was raised. If clarification of log entries was required, this took place weekly as part of the regular log checking procedures.

Three evaluator observation sessions were also held. The TIC was staffed on weekdays from 6:00 am to 7:00 pm, and the observation sessions were scheduled to reflect these times. The sessions took place from 6:00 am to 12:00 pm on October 25, 1995, 12:00 pm to 7:00 pm on October 30, 1995, and 6:00 am to 9:00 am on November 2, 1995. The sessions were scheduled to ensure that each of the three TIC operators could be observed. The observer documented any actions or events of relevance to the assessment of the TIC User Interface. The observation was designed to be a non-intrusive activity in order that TIC operators would be subject to minimum disturbance of their duties, and no such problems were encountered during the sessions.

The data collection tools for the observation sessions were prepared at the outset of the evaluation period and are provided in Appendix C. Due to the nature of such observations, it was not possible to predict prior to the sessions the precise type and format of the data which could be collected. Therefore the Evaluator Observation Sheet was structured to permit free-form observations to be recorded by the evaluator. A list of criteria were also developed which were utilized to guide the observations made by the evaluator. Following the observation sessions, the observations recorded were classified into several types according to the criteria to facilitate analysis. The full list of criteria is reproduced in Appendix C. The criteria covered the following types:

- Type A: workload;
- Type B: working practices;
- Type C: operator characteristics;
- Type D: human factors; and
- Type E: TIC functionality.

The first four types correspond to the evaluation of the TIC User Interface usability, and the final type corresponds to the evaluation of the TIC User Interface functionality, which is discussed further in Section 6.3. Observations were classified as falling within the usability of the interface if they concerned existing features whose usability could be improved. Observations were classified as falling within the functionality of the interface if they concerned additional features not provided within the interface which were identified as being desirable.

Initially it was anticipated that three observation sessions of one day each would be required. This would in effect have covered six shifts of TIC operation. However, following the analysis of the observations recorded during the three initial half-day sessions it was found that for all but one of the observation criteria areas listed above, very similar observations were made for each of the operators. The criteria area concerning the individual operator characteristics was the only area where significantly different observations were recorded. In addition, it was found that the observations made by the evaluator were in a number of cases closely matched by the observations made by the operators themselves on the Operator Observation Log. Therefore, it was recommended by the evaluation team that the remaining observation sessions be omitted from the TIC User Interface Test Plan, as the data collected thus far would fulfill the requirements of the evaluation. Confirmation from the ADVANCE Evaluation Manager that this recommendation was acceptable was received and the testing schedule was amended accordingly.

For the purposes of data reduction and analysis, both the observations made by the TIC operators on the TIC Operator Observation Log and the evaluator observations were classified according to the list of criteria created for the observation sessions, listed above. Counts of the observations were then made according to type. If a particular observation was deemed to fall into more than one criteria heading, then a count was made under each of those headings.

An observation comprised a written remark concerning an action of an operator or the impacts of an operator action which related to the usability or functionality of the interface. In the three evaluator observation sessions, a total of 188 observations were recorded. 43.6% of these were recorded during the first session, 28.7% during the second session, and 27.7% during the third session. Of the total observations recorded during all three sessions, 22.4% were classified as relating to type A - workload, 8.5% were classified as type B - working practices, 20.7% were classified as type C - operator characteristics, 11.7% were classified as type D - human factors, and 3.2% were classified as type E - TIC functionality. The remaining 33.5% of observations related to the status of TIC systems at various times during the observation sessions. A "status" observation was made each time that the evaluator considered the context of observations to be particularly relevant to the observations being made. For example, the number of active probe vehicles, events happening within the TIC, or the condition of TIC processes were classified as status observations.

TIC staff began using TIC Operator Observation Log sheets on August 8, 1995. Log sheets from that time up to and including December 28, 1995 were utilized for this Evaluation Report. A total of 60 observations were made by the various TIC operators during that time. Of this total, 10 observations were disallowed from the analysis as they related to the status of processes or the system hardware which should have been entered onto the TIC Real-Time Log sheet. Of the remaining 50 observations, 12.0% were classified as type A - workload, 2.0% were classified as type B - working practices, 0.0% were classified as type C - operator characteristics, 54.0% were classified as type D - human factors, and 32.0% were classified as type E - TIC functionality.

The findings relating to the usability of the TIC User Interface which have been derived from all three data collection techniques - the TIC Evaluation Questionnaire, the TIC Operator Observation Log, and the TIC Evaluator Observation Sheet - have been combined and are considered below.

Following some sample screens taken from the TIC User Interface and some introductory information concerning the operators themselves, the subsequent sub-sections are structured in accordance with the criteria headings created for the observation sessions, listed above.

6.2.2 Sample User Interface Screens

Figure 6.1 illustrates a typical screen of the TIC User Interface. This screen displays the test area map to the left of the figure. The area within the thick lined shape represents the extent of the test area itself. The thinner lines represent the various roads within the test area for which traffic related information could be entered into the TIC database. The menu bar at the top of the test area map displays the various options which are available to the operator within the test area map window. On the sample screen pictured, the "Display" menu item has been selected in order to show the items within this menu. Within this menu it can be seen that the "Test Area Boundary" and the "Legend and Scale" options have been selected and hence these are displayed on the test area map.

To the right of the figure, the TIC Process Controller is displayed. This Controller display enables the TIC Operators to monitor the overall status of the processes within the TIC. In addition, this Controller display informs the operator of the number of active, that is, currently moving, probe vehicles within the test area. The TIC Process Controller also enables users with system administrator level access permissions to turn any of the TIC processes on or off, and to shut down or start up the TIC a whole.

Figure 6.2 illustrates an alternative sample screen configuration which operators may utilize. Again, to the left of this figure the test area map is displayed. Here, the "Select" menu item has been selected to display the menu items available to the operator.

To the right of this figure the TIC Subsystem Controller is displayed. The TIC Subsystem Controller offers an alternative means by which operators may monitor the status of TIC processes. Its structure is for the most part similar to that of the TIC Process Controller, though the TIC Subsystem Controller displays nested groups of related processes and the operator may chose to display the status of all the processes within a subsystem, or solely the status of the overall subsystem. Again, this Controller informs the operator of the number of active probe vehicles currently within the test area. As was the case with the TIC Process Controller, the Subsystem Controller enables users with system administrator level access permissions to turn any of the TIC processes on or off, and to shut down or start up the TIC a whole. Below the TIC Subsystem Controller the system clock is displayed.

Figure 6.1 Sample Screen 1

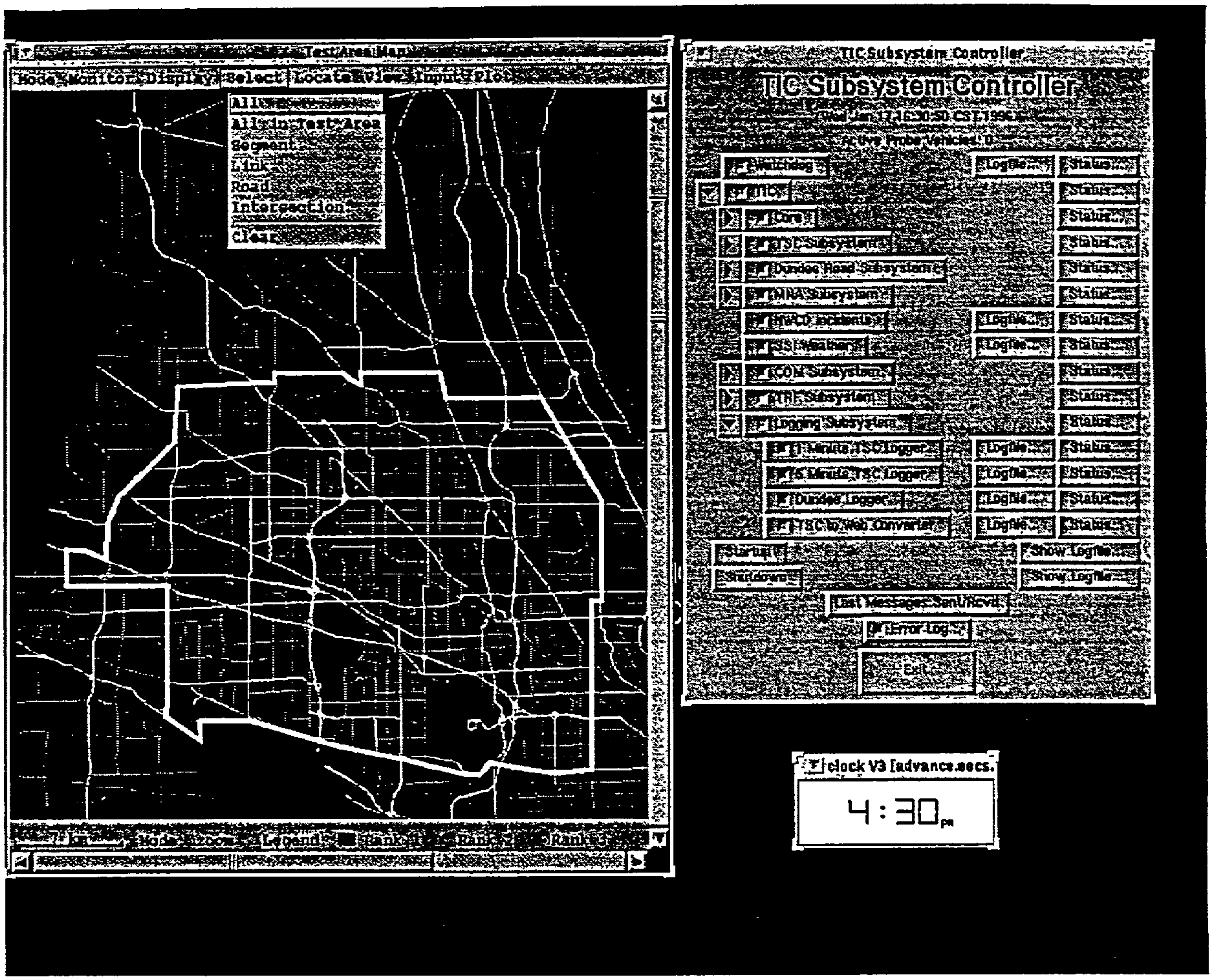


Figure 6.2 Sample Screen 2

6.2.3 General Information

The responses to a series of introductory questions within the TIC Evaluation Questionnaire provided some basic information regarding the background and prior experience of the TIC operators. The *ADVANCE* TIC was staffed by three operators during the project's Targeted Deployment phase. All three operators employed at the TIC were male. One operator was between 18 and 25 years of age, and the remaining two were aged between 26 and 35. With respect to the operators' level of education, all three were attending college while working at the TIC. Operators were also asked how long they had been working at the TIC, to the nearest month. The duration of employment at the TIC varied considerably. Operator A had been working at the TIC for six months, Operator B for three months, and Operator C for two months. This difference in duration of employment at the TIC should be borne in mind when considering operators' responses to subsequent questions, discussed below. Another characteristic of TIC operation which affected operators' responses to certain questions was the pattern of shifts worked. Table 6.1 illustrates the shifts worked by the three operators, the TIC being staffed only Monday through Friday.

	Monday	Tuesday	Wednesday	Thursday	Friday
6:00 am to 12:00 pm	Operator A	Operator C	Operator A	Operator C	Operator C
12:00 pm to 7:00 pm	Operator B	Operator A	Operator B	Operator A	Operator B

Table 6.1 Shifts Worked by TIC Operators

It can be seen that not only had Operator A been employed at the TIC for the longest duration but also that he worked four shifts per week, alternating morning and afternoon shifts. Operators B and C worked three shifts per week each, with Operator B only on duty in the afternoon shifts, and Operator C only on duty in the morning shifts. Therefore, it should be recognized that the combination of the length of employment at the TIC and the number of shifts worked per week has an effect on the likelihood of an individual operator having utilized features of the interface or having been exposed to certain operational scenarios covered by the TIC Evaluation Questionnaire. In addition, some activities of the TIC Operators were performed at specific times during the day. For example, the daily system backups were performed during the morning shift, and so Operator B only had the opportunity to experience this procedure in exceptional circumstances when he may have provided cover for one of the other operators if they were unable to work a particular morning shift.

The first few questions of Part 2 of the TIC Evaluation Questionnaire aimed to assess the operators' familiarity with the TIC Console Operator's User Manual and any prior experience with the types of systems used in the TIC. As can be seen from Figure 6.3, operators reported a varying degree of familiarity with the TIC Console Operator's User Manual. These responses correlated with the operators' length of employment at the TIC, the longest serving operator, Operator A, reporting most familiarity, and the operator with the least amount of TIC experience, Operator C, reporting least familiarity. These responses would seem to indicate that the difference in levels of familiarity with the Manual could be attributed to the length of experience as an operator.

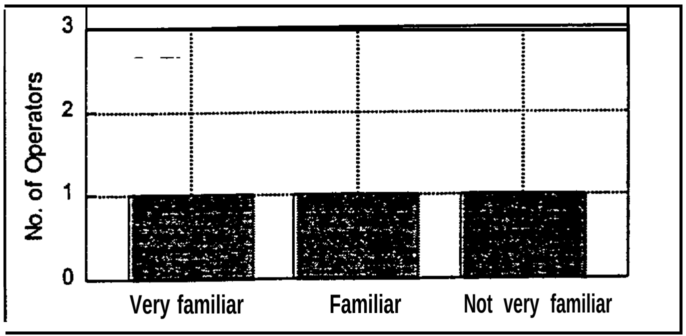


Figure 6.3 Familiarity with TIC Console Operator's User Manual

As can be seen from Figure 6.4, the operators stated that they consulted the Manual relatively infrequently. However, these responses also correlated with the operators' length of employment, Operator A stating that he consulted the Manual a few times per month, while Operator C stated that he never consulted the Manual. These responses were the reverse of the anticipated responses as it had been assumed that operators with less experience would need to consult the Manual more frequently. This would seem to suggest that the actual levels of familiarity with the Manual could not be attributed to length of service at the TIC. The reasons for the varying levels of familiarity with the Manual remain unknown, though this could be a result of the Manual not having been introduced to operators during their induction in a standardized manner, or the different operators tending to rely more or less on such documentation, or differences in operators' motivation.

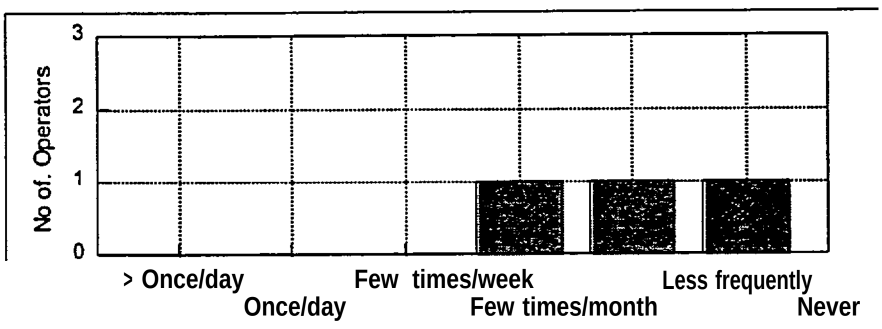


Figure 6.4 TIC Console Operator's User Manual Frequency of Use

Figure 6.5 illustrates that the two operators who did utilize the Manual found it either useful or very useful when seeking information on how to operate the TIC systems. The third operator did not use the Manual and therefore could not provide an assessment of its usefulness.

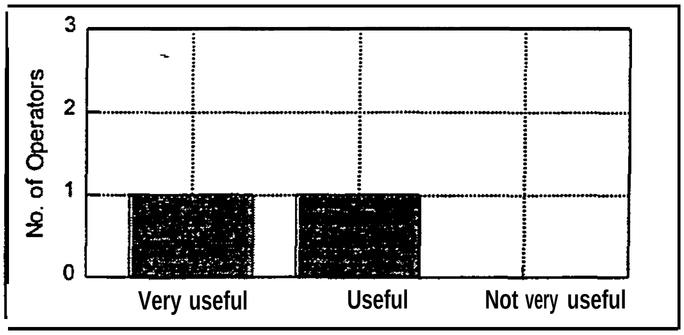


Figure 6.5 Usefulness of TIC Console Operator's User Manual

Operators were asked how familiar they had been with X-windows-based computer systems prior to starting work at the TIC. Figure 6.6 indicates that all operators had been familiar with such systems.

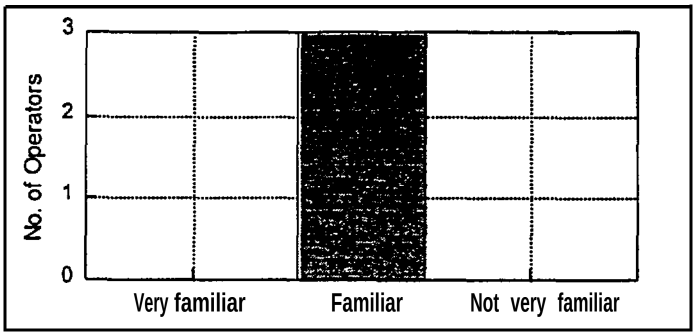


Figure 6.6 Prior Familiarity with X-windows-based Systems

Figure 6.7 illustrates that two operators stated they had been not very familiar with the UNIX operating system and commands before starting work at the TIC, while the third operator had been familiar with UNIX. Of the two operators who had been unfamiliar with UNIX systems, one reported that it taken more than a week before he had felt comfortable working with the UNIX system and commands, while the other stated that he had felt comfortable working with the system after one day.

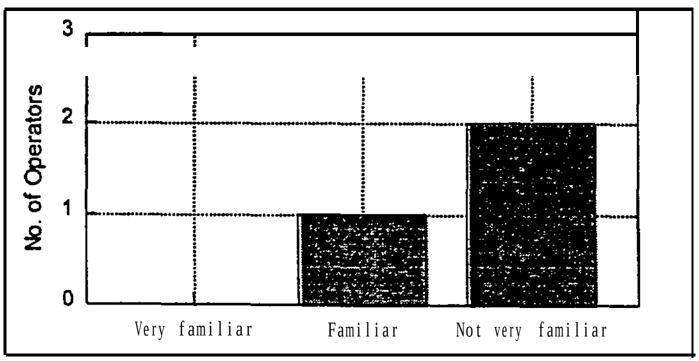


Figure 6.7 Prior Familiarity with UNIX Operating System and Commands

6.2.4 Workload

The first main area relating to the Usability of the User Interface to be discussed is that relating to the workload of the TIC staff Many of the observations made or responses to questions which were classified as being within this area overlapped with the human factors of the TIC system. For example, in some cases the manner in which a task had been structured and implemented by the system designers affected the workload of the TIC operators due to its human factors implications. Further information relating to the workload of the TIC operators, examined from the perspective of TIC staffing requirements is provided in Section 5.8.

Demands Upon the Operator and Operator Responsiveness to Data Requiring Manual Input

In terms of the demands made upon the operator and operator responsiveness relating to data requiring manual input, it was commented that the monitoring of the NWCD incident log to decipher which input required entry into the TIC system, was made more difficult by the need to scan a large number of log entries to ascertain if any updates to a previously received and entered incident had been subsequently received. It was suggested that to streamline this task, it would be helpful if the original "new incident" log records were marked with the number of updates that had been received relating to the same event, so that the operator would not have to scan up and down this large log file to see if any updates had occurred to an entered incident.

An operator commented that when entering anecdotal data, it would be useful if the system entered the appropriate values as defaults in the duration and impact data entry fields once the type of incident and its intensity had been entered by the operator. At present, the operator is required to enter data in all four fields. However, the sets of possible values to be entered for a particular type and intensity of incident are predefmed, and the automatic entry of the appropriate duration and impact values would save time in this data entry task.

Again, when entering anecdotal input, the operator is required to select an intersection before entering the incident information into the system. However, the selected intersection is not then automatically brought into view on the test area map if the map area previously in view did not contain this intersection. Therefore in order to view the intersection or any other item that has just been selected, the operator must then go through the "Locate" menu to view the selection. The number of steps needed to enter data in this manner could be streamlined by automatically displaying any selected location when the selection is made. A related observation was that when a new anecdotal entry requires inputting into the TIC system, the operator must clear the previously selected location before selecting a new one. It was suggested that if an incident had been entered for a previously selected location, the selection of that intersection or other item would automatically be cleared, again reducing the number of steps which the operator must perform to enter any subsequent incidents.

The remainder of the observations made relating to data requiring manual input involved discrepancies between the locations reported in the NWCD incident log and the locations available in the TIC database.

Operators had adopted various methods of dealing with such discrepancies, which resulted in varying levels of success in matching NWCD locations to TIC database locations. This is discussed further below in relation to operator characteristics; The issue is also covered here with respect to the workload demands made upon the TIC operators.

TIC operators are required to scan manually all log entries in the NWCD log file to ascertain if the location of incidents is within the geographic scope of the *ADVANCE* test area, and if the incident itself is of relevance to the operational test, that is, will it affect traffic. Various difficulties were experienced by operators during the course of performing this task, as noted in the following paragraphs.

From time to time, NWCD incidents displayed on the log file have no precise location identified such that the operator is unable to enter the incident into the TIC system. Some screening process which removes any entries having no suitable location identified would lessen the demands made upon the operator to scan the log. Similarly, NWCD incidents are often received which relate to residential streets. These are not within the scope of the current implementation, and therefore cannot be utilized. An enhanced screening process could also eliminate these incidents from the log file and reduce operator workload.

As was noted above, the various operators employed at the TIC have evolved different approaches to deal with NWCD log entries. As a consequence, individual operator workload varies according to the approach taken. This is perhaps an area where procedures could be put into place to assist the operators to deal with these circumstances. For example, Operator A, once having entered an NWCD incident would not remove that incident from the TIC database if an “incident cleared” message was later received on the NWCD log, but left that incident to “time out” according to the original duration assigned to it. Alternatively, Operator B would manually clear a previously-entered event which was reported as cleared by NWCD.

Operators also differed in their approach to incidents whose locations were relevant to the operational test but which were reported as not having been found by the TIC database. Operator A would disregard the incident if this was the case. However, Operators B and C would consult the Chicagoland Six Counties Atlas to locate the intersection or other item in question and then select it by entering one of the roads which formed the intersection and homing in on the crossroads which met it within the relevant city limits, and selecting the precise incident location from there. This method was successful approximately 50% of the time it was utilized. This consultation of the area atlas is a time-consuming task. It may be necessary to provide guidelines to the TIC operators as to how much time to spend in attempting to locate incidents by this means in order to reduce workload. Another consequence of using the atlas is that while locations are being identified manually, new incidents may be received from NWCD which are then subject to a delay in entry into the system.

Demands Upon the Operator and Operator Responsiveness to Processes Requiring Monitoring

In terms of the demands made upon the operator and operator responsiveness relating to processes requiring monitoring, the following observations were made. The TIC Process Controller process status buttons are displayed as one of the following colors: green - indicating that the process is running satisfactorily; yellow - which indicates that the process is experiencing some minor difficulties in running; red - which indicates the process has "crashed"; magenta - which indicates that a hardware component upon which a software process depends has failed; or gray - which indicates that the process is switched off. It was noted that often the Travel Time Prediction and Incident Tracker status buttons on the TIC Process Controller were displayed in yellow. However, operators reported that they had been briefed that this "caution" status was to be regarded as normal, and need not be reported to the system manager or maintenance staff However, it is proposed that the operator task of monitoring the status of these or any similar processes would be eased by altering the "status monitoring thresholds" for these two processes such that when currently the status is displayed in yellow, it would instead be displayed in green, given that the yellow status is apparently no cause for concern.

It was also found that no indication is provided to the operator if a remote data source has stopped responding. The process status buttons on the TIC Process Controller and the TIC Subsystem Controller display caution (yellow) and warning (red) conditions only when the processes are experiencing difficulties in executing. To ascertain that all the data sources are providing data to the TIC, the operator is required to enter the "Last messages sent / received" log periodically. To eliminate the need to perform this task, it would be preferable if more complete error checking allowed the process status buttons to inform the operator if a data source had ceased to provide data to the TIC. Alternatively, this task could be eliminated by the provision of an audible notification, accompanied by a dialog box on the interface explaining the meaning of the audible notification, whenever the current reporting status from a data source required some operator intervention. This feature of the system would also aid the operator in monitoring system status when otherwise engaged, at times when the operator may not be able to check the "Last messages sent / received" log as often as is appropriate.

Other recorded observations included a comment that whenever an operator enters the Internet to monitor the Expressway Map of the Chicago urban area, the TIC Subsystem Controller closes down. The operator then has to reopen the TIC Subsystem Controller each time in order to be able to monitor processes in the preferred manner. It was also noted that occasionally after having accessed the TIC Subsystem Controller window, after approximately two hours the buttons on this window do not respond when selected, so the Controller must be closed and re-opened before it can be used. In addition, occasionally when the operator restarts the TIC system, the TSC to Web Converter and the Database Process require restarting manually whereas this should be effected automatically.

The foregoing are all instances where the operator workload is increased unnecessarily. Operators also reported that occasionally the status buttons on the TIC Process Controller and the TIC Subsystem Controller displayed different colors for the same process, with no indication being provided by the system as to which controller was reporting the correct status.

Time Taken to Perform Tasks

In terms of the amount of time operators were involved performing various tasks, as part of the TIC Evaluation Questionnaire operators were asked if the time that the system took to process commands and data ever introduced any delays into the completion of their tasks. All operators reported instances of such system delays, although the descriptions of when delays occurred varied between the operators. Instances of system delays were reported during-peak periods - when overall system activity tended to be greater, and when entering lane closures. Delays also occurred when the daily log file back-ups were performed. Difficulties experienced at these times mainly comprised the input of anecdotal data into the TIC system taking many times longer than normal. However, one operator reported that increases in the time that the system took to process commands and data seemed to be largely random, and that he could not identify any particular contexts in which this tended to occur. Another operator commented that the system took a disproportionate amount of time when zooming into the test area map which delayed his later tasks.

An additional feature which introduced delays into the completion of operators' data input tasks was the need to wait while the anecdotal input facility started up each time a new incident required entering. This "start up" occurs even if ten incidents in a row require entry into the TIC system, not taking into account the real-time nature of incident input. It would be preferable if this anecdotal input facility could somehow be left running so that a series of anecdotal inputs could be entered more quickly.

6.2.5 Working Practices

The second area considered as part of the usability assessment relates to the working practices of the TIC staff. As far as the effectiveness of the TIC operator reporting structure is concerned, no problems were encountered. At present the TIC staff consists of three operators and one TIC system manager. This compact staff seems able to communicate and solve problems effectively.

However, the prioritization of tasks by operators is considered an area where more guidance could be provided. This comment stems largely from the observations made during anecdotal data entry tasks. It was noted that operators would interrupt this task when, for example, the daily road closures fax was received at the TIC, or when performing other administrative tasks. The non-real-time tasks were often performed prior and in preference to the real-time data entry task, introducing unnecessary delays into the delivery of anecdotal data to the end users. Further information on the TIC policies, procedures, and staffing levels, are provided in Sections 5.7 and 5.8.

6.2.6 Operator Characteristics

The third area considered as part of the usability assessment relates to the individual operator characteristics in as much as these affected the completion of tasks within the TIC. As was noted above, the various operators employed at the TIC had evolved different approaches to deal with tasks. The example discussed above concerned the treatment of NWCD incident log entries whose location had not been found by the TIC system location database, and the effect on an individual's workload.

Another area in which it was found that operators approached tasks in different ways was the decision-making process of considering which incidents on the NWCD log to enter into the TIC system. It was found that Operators A and C never entered incidents classified as ambulance calls by the NWCD, as they thought that these could not affect traffic. However, Operator B reported that he often entered ambulance call incidents after having scanned them to ascertain if they were on a major intersection or if they were of sufficient impact to affect traffic even though they were not on a major intersection.

Operators also differed in their terminal display preferences. Operator A displayed the whole test area and all the icons which represent incidents and road and lane closures so that an overview of the test area status could be maintained. Operators B and C viewed the highly "zoomed-in" portion of the test area which corresponded to the last incident they had entered, and also did not display the incident and road or lane closure icons, reporting that they did not feel it necessary to maintain an overview of the overall test area status. This may signal the need for guidelines to be issued to the operators on the appropriate monitoring approach to take.

6.2.7 Human Factors

The fourth area considered as part of the usability assessment relates to the human factors of the TIC User Interface. This was a major component of the overall User Interface evaluation as was reflected by the volume of observations made by operators which were classified as being human factors-related. The human factors-related responses to questions and observations have been further subdivided into the following types for ease of discussion:

- screen and data manipulation;
- display preferences;
- feedback;
- visibility;
- consistency; and
- physical layout.

6.2.7.1. Screen and Data Manipulation

The human factors issues relating to screen and data manipulation are considered in this sub-section. If required, additional information on the features of the interface is contained in the TIC Console Operator's User Manual, referenced above.

Test Area Map

When asked to assess the ease with which they could manipulate the test area map on the TIC monitor, for example, zooming in and out, resizing the window and scrolling across it, two operators considered these tasks to be very easy, while one operator considered the tasks to be neither particularly easy or difficult, see Figure 6.8.

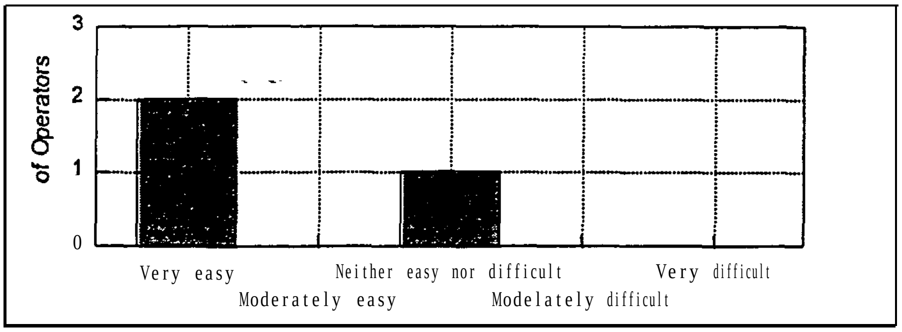


Figure 6.8 Ease of **Manipulation of Test Area Map**

A subsequent series of questions concerned the operators' usage of the various items within the test area map menus. None of the operators had experienced any difficulties in utilizing the following menus:

- the "Monitor" menu, which can be used by the operator to select various events to monitor;
- the "Display" menu, which controls which items are displayed on the test area map;
- the "Locate" menu, which is used to locate and display a portion of the road network;
- the "Input" menu, which is used to enter incidents and road closures on selected links, link updates on selected links, TRF parameters and map properties; and
- the "Data Pop-up" menu, which can be used to obtain various types of information on a selected map object by querying the system database. These map objects could include a segment, group of segments, or a link.

The "View" menu is used to create or remove map displays. All operators reported that they had never used any of the items on the "View" menu, and as a consequence had not had the opportunity to experience any difficulties in using any of these items

The "Select" menu is used to select roadway segments and links on the test area map without having to use the mouse to click on the map. Concerning the "Select" menu, one operator reported having experienced difficulties when using the "Clear" item. This item should deselect a selected item on the test area map; however, this operator stated that occasionally the item in question was not deselected as required after having used this feature.

Operators were then asked how they would assess the ease with which they could locate and select items on the test area map, such as segments, links, roads, intersections, etc., using the menus provided, see Figure 6.9. All operators reported that this task was either very or moderately easy, although one operator did also comment that the selection of items by the system was slow at busy times of the day.

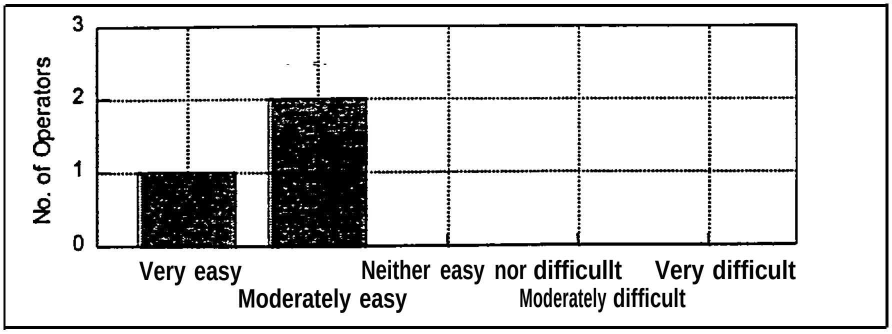


Figure 6.9 Ease of Location and Selection of Test Area Map Items Using Menus

The operators were then asked various questions concerning the data windows contained in the test area map window, which are accessed through the "Data Pop-up" menu. Operators were asked to assess the ease with which they could obtain the information they required to complete any tasks or monitor the system status using the various data windows. Interestingly, one operator reported that he never used any of the data windows. This was Operator C who had been employed at the TIC for the least length of time. The other two operators reported that they found this task to be either very or moderately easy, see Figure 6.10.

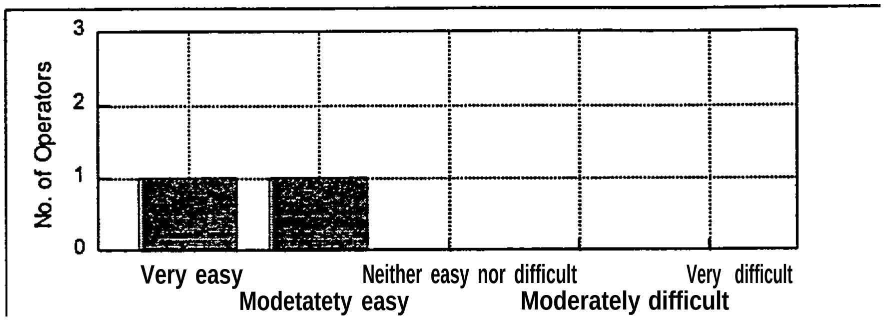


Figure 6.10 Ease of Obtaining Information Using Data Windows

Operators made many additional observations regarding the ways in which the test area map is manipulated, and suggestions for streamlining many tasks, as follows. It was suggested that "hot keys" be provided for some of the menu operations, in particular for switching between the zoom mode and the select mode. In addition, when in select mode it was commented that it would be very convenient to be able to zoom in and out of the test area map again using a "hot key" command. Following consultation with the TIC manager, it was learned that a zoom facility using the "+" and "-" keys had been requested during the system design activities, though this feature had not been implemented. An alternative suggestion was to provide a "zoom/select" box, drawn using the mouse, which would enable the operators to zoom in to or select every item within the box, such as is provided within many graphics software packages.

Again, in terms of manipulating items on the test area map, the following additional points were noted. It was commented that when in select mode there should be a way to deselect a link once it has been selected in case an error in selection was made. Indeed, many comments were made on the need for a universal "Undo" button or menu item in case of data entry or selection errors. Operators requested that they be able to "clear" an incident flag by placing the mouse device over the relevant flag and using a "hot key", instead of going through a series of menus.

It was also commented that it would be very helpful to have a numbering system for the incident flags such that a flag number could be entered, and that flag would then be selected so its data fields could be edited or the incident cleared. An alternative suggestion was to have access to a facility similar to that available in many word-processing packages whereby the filenames of the last four files accessed by a user may be displayed via a menu item in the interface. In the case of the TIC interface, this facility would include the names of the locations of a number of the most recently entered anecdotal inputs. By clicking on the required location name with the mouse, a data entry window relating to that event would be displayed and an operator could then edit the incident parameters or delete the incident.

One task which it was thought could be eliminated is the need to deselect the location of an incident on the test area map following the entry of anecdotal input. At present, when a operator needs to enter a new incident, the previously selected location must first be deselected before a new one may be selected.

Data Entry Windows

The TIC User Interface also provides various data entry windows. These are the Incident Reports and Road or Lane Closures data input window, the Link Updates data input window, and the Map Properties data input window. None of the operators reported having experienced any difficulties in using any of these data input windows. There also exists a TRF Pararneters data input window; however, only the system administrators have the required permissions to be able to alter TRF values using this data input window.

However, when entering any anecdotal input, it was observed that the mouse pointer needs to be on the data entry window during input. It was thought preferable to be able to click using the mouse within the data entry window to facilitate data entry, after which time the mouse pointer could leave the window without disabling the data entry process. .

Internet Sites

Operators were asked if they had experienced any difficulties in accessing the Expressway Map and the Gary-Chicago-Milwaukee (GCM) Project Home Page on the Internet via the TIC User Interface. The Expressway Map program provides a graphical view of the congestion levels on detectorized expressways in the Chicago urban area. One operator, Operator A, commented that after approximately 45 minutes the Internet screen sometimes went blank, and that he then needed to exit and re-enter in order to view the information.

Static Update Utility

Operators were also asked about any difficulties they may have experienced when using the Static Update utility. The one operator who had used the utility, Operator A, reported that he had experienced no problems in doing so.

TIC Process Controller Features

Operators were asked about the ease with which they could monitor the status of individual TIC processes using the TIC Process Controller. One operator considered this task to be moderately easy while the other two operators considered it to be very easy, see Figure 6.11.

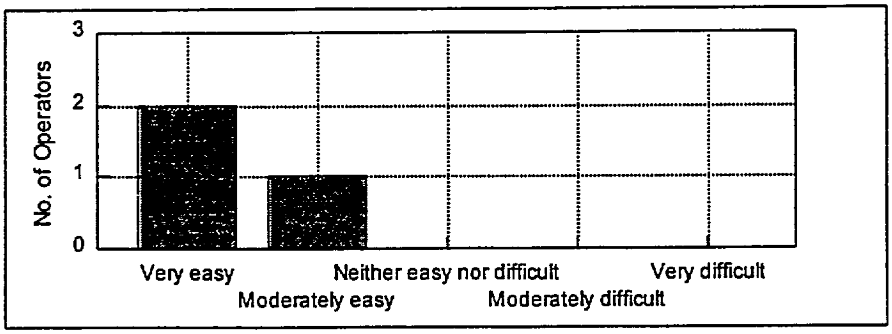


Figure 6.11 Ease of Process Monitoring Using TIC Process Controller

The format of the data contained in the various log files accessed through the TIC Process Controller, in terms of the ease with which operators could find the information they required was assessed as neither particularly easy nor difficult by all three operators, see Figure 6.12, although one operator, Operator C, commented that he had only used the Startup and Shutdown log files.

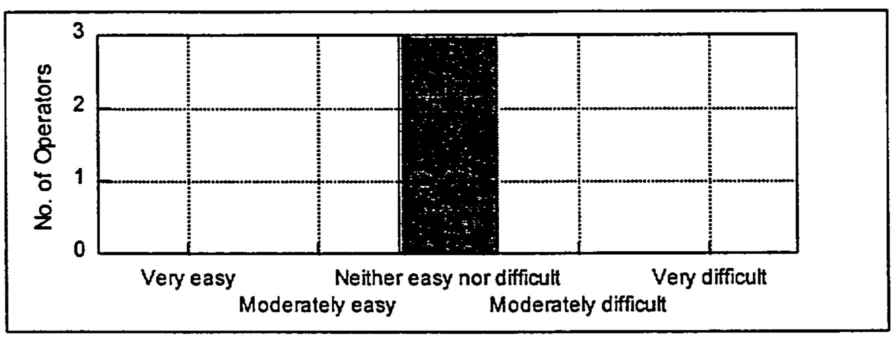


Figure 6.12 Ease of Use of TIC Process Controller Log Files

Operators were asked to assess the format of the error messages contained in the various status files accessed through the TIC Process Controller, in terms of the ease with which they could find the information they required. Operator A considered the ease of use of the Process Controller error messages to be neither particularly easy nor difficult, see Figure 6.13, whereas Operator C stated that he had never used these error messages. However, the Operator B reported that the language and content of the error messages were meaningless to him, and so he was unable to assess their format.

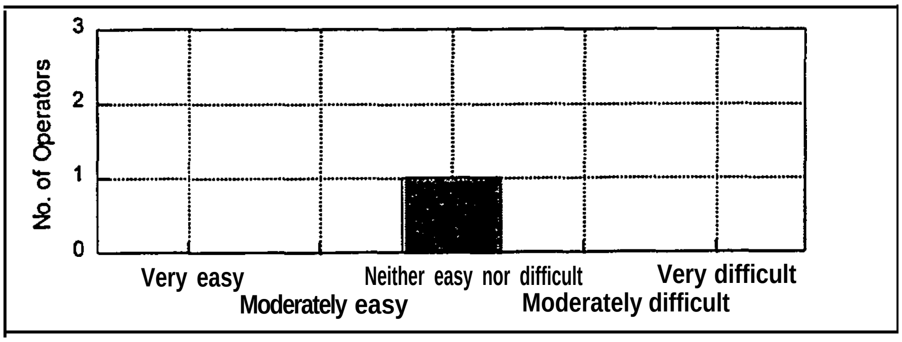


Figure 6.13 Ease of Use of TIC Process Controller Error Messages

TIC Subsystem Controller

The TIC Subsystem Controller offers an alternative means by which operators may monitor the status of TIC processes. This feature was added to the interface to make the task of performing back-ups more easy. It allows subsystems to be shut-down in a manner which facilitates the backing-up process. Its structure is for the most part similar to that of the TIC Process Controller, though the TIC Subsystem Controller displays nested groups of related processes and the operator may chose to display the status of all the processes within a subsystem, or solely the status of the overall subsystem. One operator, Operator A, added that he had occasionally experienced difficulties with the TIC Subsystem Controller in that it would not display when required.

6.2.7.2 Display Preferences

In terms of the display preferences of the TIC operators, the following observations and responses to questions within the TIC Evaluation Questionnaire were made.

The TIC operators have the option whether or not to display the icons which represent incidents and road or lane closures on the test area map when on duty at the TIC. It was found that two of the three operators chose not to display these icons. The operator who did display these icons, Operator A, assessed the ease with which he could distinguish between the different types of icons as moderately easy. In addition, at busy times when many icons were present on the test area map, this operator assessed the ease with which he could monitor the overall roadway status as moderately easy.

It was commented that if an operator had chosen to save the displayed windows prior to exiting the system, it would be preferable if the interface could save the system clock in the displayed format and also automatically reopen the TIC Process Controller or the TIC Subsystem Controller if either of these had been displayed when the operator exited the system.

When the operator first displays the NWCD Incident log, the items contained within this log scroll rapidly until the last received item is displayed at the foot of the log window. An operator suggested that it would be more helpful if the first page of entries only was displayed initially, allowing an operator to scroll manually through the entries to ascertain if these needed entering into the TIC system.

It was requested that the interface should allow block markers to be displayed within the Level 1 roads display option, and mile markers to be displayed on highways to aid the operators in identifying the location of an incident. It was also requested that the interface display road names for Level 1 roadways within the test area.

It was suggested that when a road or intersection is selected using the menu system, the test area map should automatically center the display to that intersection or road. It was also suggested that for easier road identification, the expressway and tollway roads should be displayed in different colors, as they are in the regular Illinois road map, such that the expressway is displayed in blue and the tollway is displayed in green.

It was thought that the TIC Subsystem Controller was a more useful default display to utilize as opposed to the TIC Process Controller. This was due to the TIC Subsystem Controller requiring less screen desk-top space to be displayed due to the tree-structure of the process logs. It was also observed that the default size of the NWCD incident log was an inefficient use of desktop space, as there were two blank inches on the right side of this data window. It was found that operators tended to re-size this window to maximize space on the monitor.

6.2.7.3 Feedback

In terms of the feedback which the TIC system provides to the operators to warn of system conditions or log files updates, it was suggested that when a system process goes off-line or turns red, an audible warning tone should be provided to alert the operator to this condition. It was also suggested that a pop-up data window, or dialog box, should provide an explanation of the warning tone and advise the operator of the appropriate action to take.

It was requested that when a new NWCD incident enters the log file an audible tone should call the operator's attention to the incident. An audible warning tone would also be useful to the TIC operators to replace the task of manually opening the "Last messages sent/received" log within the TIC Process Controller. At present the operator has to open this file periodically to monitor the reporting status of various systems. If an audible notification was provided when reporting status became abnormal, this would decrease the operator memory load of having to remember to check the last messages sent and received by the TIC.

A problem experienced with the feedback provided by the TIC User Interface was that occasionally, the TIC Subsystem Controller status buttons did not match the status of the same processes as displayed on the TIC Process Controller. At present, the operator is provided with no indication as to which data window is correct and should be utilized, as previously noted in Section 6.2.4, under the heading relating to demands upon the operator and operator responsiveness to processes requiring monitoring.

6.2.7.4 Visibility

In terms of the visibility of information provided by the TIC User Interface, the following comments and responses to questions were provided.

With respect to the colors that are used on the test area map, operators were asked how they would assess the ease with which they could distinguish the different types of road and any highlighted segments on the TIC monitor. As can be seen from Figure 6.14, while one operator assessed these actions as very easy, two operators considered the actions neither particularly easy nor difficult.

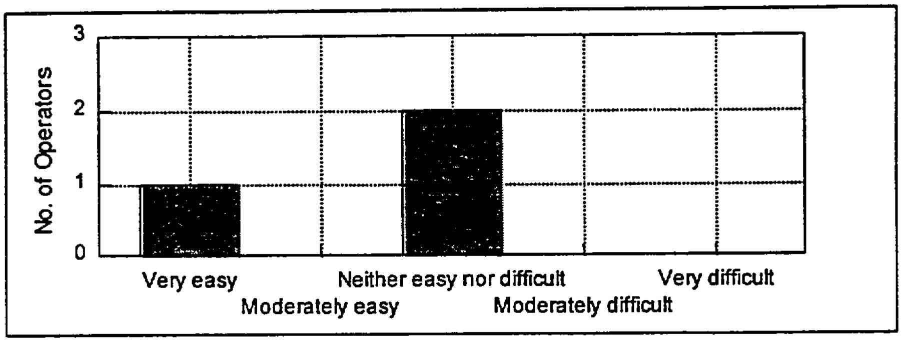


Figure 6.14 Ease of Distinction of Test Area Map Colors

Regarding the colors and the font sizes that are used on the test area map menus, operators were asked how they would assess the ease with which they could distinguish items in the menus. All operators assessed this task as being either very or moderately easy, see Figure 6.15.

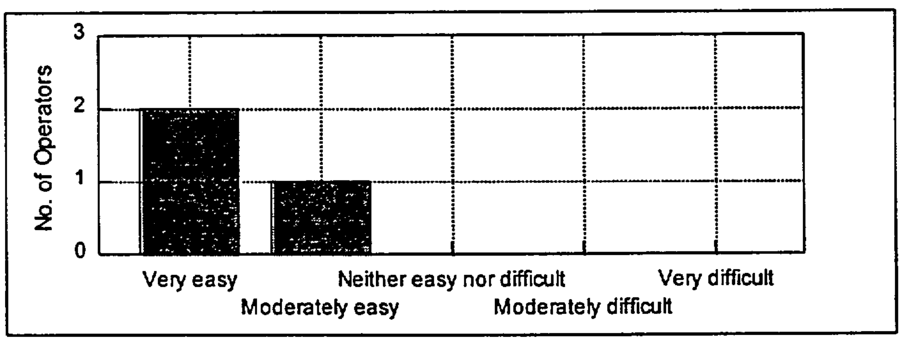


Figure 6.15 Ease of Distinction of Items in Test Area Map Menus

With respect to the colors and the font sizes that are used on the data input windows, operators were asked how they would assess the ease with which they could distinguish the various items in the windows, such as the buttons, data input fields, and the clarity of the text against the background. Two operators considered that the distinction of the various items was very easy, while the third operator considered it to be neither particularly easy nor difficult, see Figure 6.16.

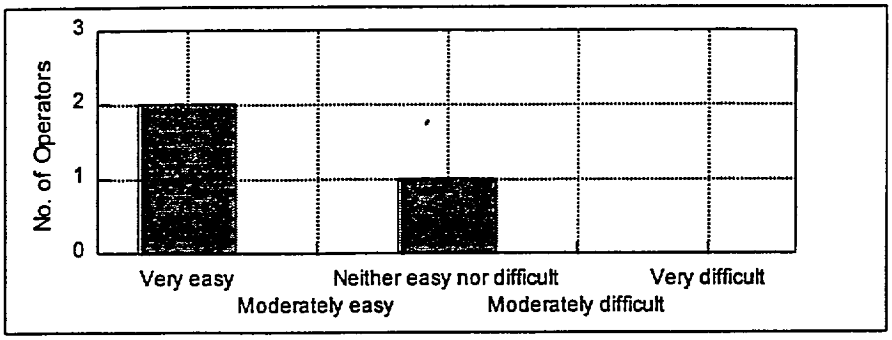


Figure 6.16 Ease of Distinction of Items in Data Input Windows

However, one operator did comment that the buttons which denoted that options in the data input windows were selected were too small to be easily distinguished. Another operator reported that occasionally the background in the data input windows changed from gray to white, which caused discomfort to the eyes. It was also noted that having larger status indicators on the TIC Process Controller and TIC Subsystem Controller would make the task of monitoring the status of processes more easy.

Operators noted that when the mouse pointer was used within any of the data windows in the database backup utility, the word beneath the mouse pointer vanished. Apparently this difficulty occurred some time into the TIC deployment, where previously no problem had been experienced.

In addition, when entering a link identification number while having the "Segment Network Attributes" data window present, it was found that the "Link" window overlapped the "Segment Network Attributes" data window. In these cases the entry of the link identification number was made difficult without rearranging the windows each time. This difficulty is illustrated in Figure 6.17.

It was also found that when entering anecdotal data, the data entry windows were occasionally obscured by the TIC Process Controller. In these instances the operator was required repeatedly to bring the data entry windows into the foreground before the data entry task could be completed. This difficulty is illustrated in Figure 6.18.

In general, it was noted that the TIC provides an extremely flexible User Interface as the operator is able to move and resize windows easily. However, it was observed that this flexibility can result in a highly confusing screen layout with very many windows remaining open at once. Operators were observed to have some minor difficulties perceiving and locating the required data window at times due to this.

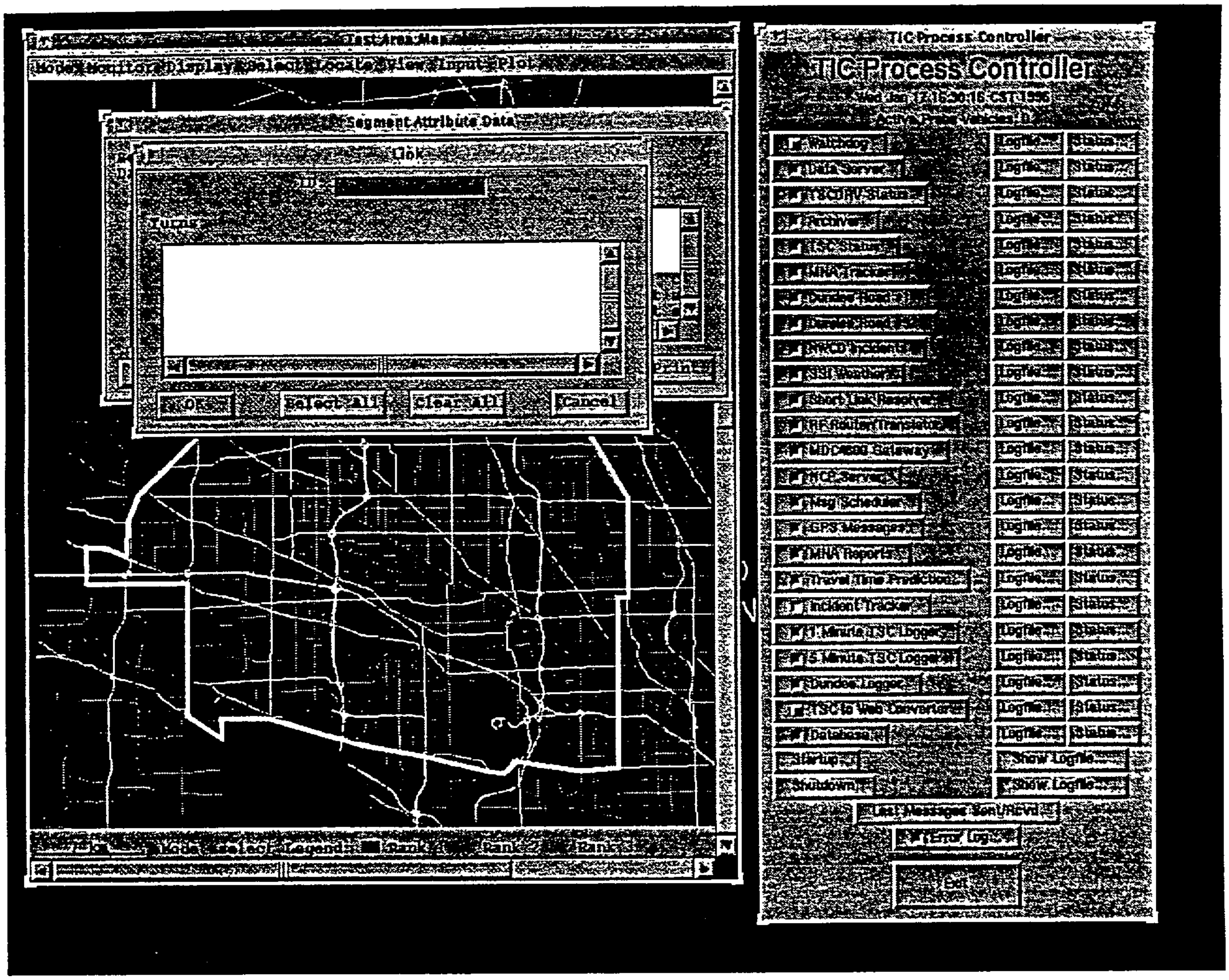


Figure 6.17 Entering a Link Identification Number

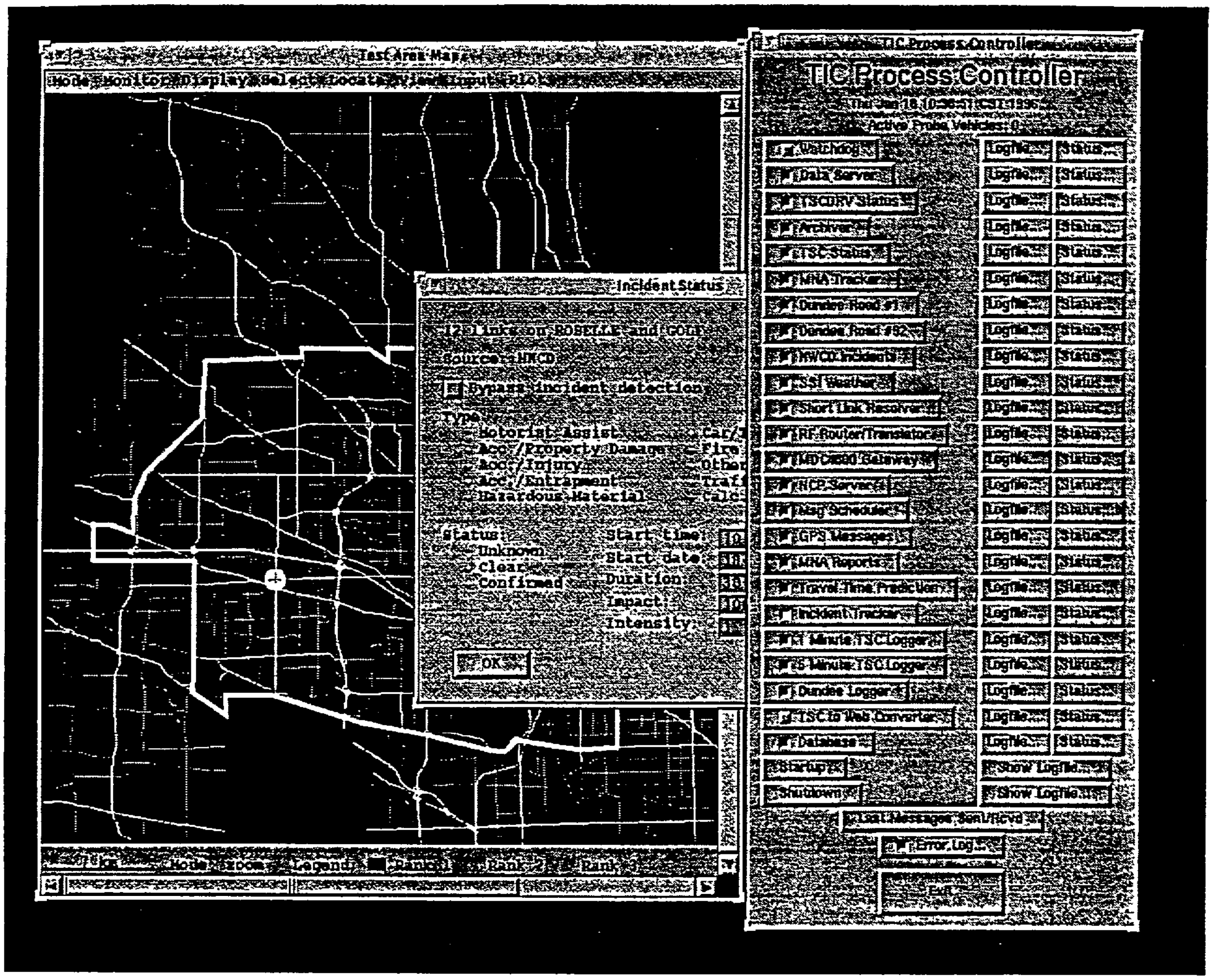


Figure 6.18 Entering Anecdotal Data

6.2.7.5 Consistency

It was found that fewer observations were made which related to the consistency of the TIC User Interface. However, it was noted that when entering anecdotal incidents, the list of the five input options within the Incident Reports and Road / Lane Closures data entry window displayed a different order of available items almost every time this window was accessed. This lack of consistency created delays in the selection of the appropriate option as the operator was required to search each time for the option. It was also commented that occasionally instead of a selected intersection being denoted by a yellow circle placed over the intersection, the intersection was highlighted in pink. Although this did not cause significant problems for the TIC operators, it is a feature of the system which could be misconstrued as being indicative of some TIC process failure.

6.2.7.6 Physical Layout

The physical characteristics and layout of the TIC were cause for few concerns. The operators were asked if the layout of the TIC room, such as positioning of the workstations, printer, computer cabinet, etc., had affected the ease with which they could perform their daily tasks. Only one operator reported any difficulties with the physical layout of the TIC, mentioning that the positioning of the desks on which the workstations were placed both restricted access to the computer cabinet, and prevented a secondary door occasionally used for access to the TIC from being opened fully.

Additional comments which were noted by the evaluator during the observation sessions included the need for the operator to leave the TIC terminal and walk across the TIC room in order to utilize the tape drive in the computer cabinet for system back-ups. At times of the day when few anecdotal incidents are arriving at the TIC, this would not necessarily cause any difficulties. However, it was practice within the TIC to perform the daily system back-ups when the operator came on duty during the morning peak period. At these times, many anecdotal incidents arrive from NWCD, and the need to leave the terminal delayed the entry of data into the TIC system from this source. The operator was also required to leave the TIC room in order to photocopy the print-out of the back-up tape contents which was then appended to the tape box. This again delayed the input of incidents during the morning peak period.

6.2.8 Summary of Usability Findings

The following points summarize the key findings for this objective, relating to the usability of the TIC User Interface. Due to the large amount of data which were gathered using the various data collection tools, it has been necessary to identify and focus upon what are considered the principal findings. The key findings are grouped according to the subsection headings previously utilized.

General Information

- Operators possessed a varying degree of familiarity with the TIC Console Operator's User Manual. Operators consulted this Manual relatively infrequently, and one operator never consulted it.

Operators who did utilize the Manual found it either useful or very useful when seeking information on how to operate the TIC systems.

- All operators had been familiar with X-windows-based computer systems prior to starting work at the TIC, while two operators stated they had not been very familiar with the UNIX operating system and commands before starting work at the TIC. It had taken these two operators between one day and over a week before they had felt comfortable working with the UNIX system and commands.

Workload

- Monitoring of the NWCD incident log would be made easier by marking “new incident” log records with the number of updates that had been received relating to the same event.
- Entry of anecdotal data would be made quicker if the system entered the appropriate values as defaults in the duration and impact data entry fields once the type of incident and its intensity had been entered by the operator.
- Entry of anecdotal data would also be made quicker if the system automatically brought into view a selected item on the test area map, and if the system deselected a map item once data relating to its location had been entered by the operator.
- It was found that operators had adopted various methods of dealing with discrepancies between locations reported in the NWCD incident log and locations available in the TIC database. These methods met with varying levels of success and impacted the workload of the operators.
- A screening process which removed NWCD log entries which had no precise geographic location or which related to residential streets not covered by the TIC database would reduce operator workload.
- It was found that operators had also developed different approaches to dealing with incidents reported as cleared by the NWCD log.
- It was found that the standard condition of the Travel Time Prediction and Incident Tracker status buttons on the TIC Process Controller was a yellow display, which operators had been briefed to regard as normal.
- It was found that the process status buttons on the TIC Process Controller and the TIC Subsystem Controller displayed caution and warning conditions only when the processes were experiencing difficulties in executing. No indication was provided to the operator if a remote data source had stopped providing data to the TIC.
- Operators reported that occasionally the status buttons on the TIC Process Controller and the TIC Subsystem Controller displayed different colors for the same process, with no indication being provided by the system as to which controller was reporting the correct status.
- It was found that operators had experienced various instances of TIC system delays when processing commands and data which slowed the completion of their tasks.
- The need to wait for the anecdotal input facility to open each time an operator needs to input anecdotal data introduced delays in the completion of this task.

Working Practices

- The TIC operators and their manager formed a compact team which seemed able to communicate and solve problems effectively.
- The prioritization of tasks by operators is considered an area where more guidance could be provided.

Operator Characteristics

- It was found that operators approached the decision-making process of considering which incidents on the NWCD log to enter into the TIC system in a variety of ways, which resulted in either more or less of the NWCD log entries being utilized.
- Operators differed in their test area map display preferences which affected their ability to monitor the overall roadway status within the test area.

Human Factors

Screen and Data Manipulation

- Operators rated the ease of use of most of the screen and data manipulation tools provided by the interface as being between neither particularly easy nor difficult and very easy. Exceptions to this finding are outlined in the following points:
    - The "Clear" item on the "Select" menu occasionally failed to deselect selected items.
    - One operator commented that after approximately 45 minutes the screen containing either the Expressway Map and the Gary-Chicago-Milwaukee (GCM) Project Home Page on the Internet occasionally went blank, and he needed to exit and re-enter in order to view the information.
    - It was found that one operator did not use the error messages contained in the status files accessed through the TIC Process Controller, and that these error messages were incomprehensible to another operator who therefore could not utilize them.
    - One operator reported that he had occasionally experienced difficulties with the TIC Subsystem Controller in that it would not display when required.
- Operators made various suggestions for streamlining screen and data manipulation tasks. These are outlined in the following points:
    - It was suggested that "hot keys" be provided for switching between the zoom and select modes, and for zooming in and out of the test area map.
    - An "Undo" button or menu item would be extremely useful in a wide variety of tasks.
    - It was suggested that a numbering or other reference system be provided for current operator-entered incidents, such that these could be easily accessed and edited.
    - Operators requested that the need to deselect the location of an incident following the entry of anecdotal input be eliminated.

Display Preferences

- The one operator who displayed the icons representing incidents and road or lane closures on the test area map assessed the ease with which he could distinguish between the different types of icons as moderately easy. At busy times when many icons were present on the test area map, this operator assessed the ease with which he could monitor the overall roadway status as moderately easy.
- Operators expressed a preference for more of the display options to be saved should the "Save Windows" option be selected.
- It was requested that the NWCD log entries not scroll to the last item in the log when this window is first accessed.
- Operators made various suggestions for the provision of more locational data within the test area map, for example, block markers and road names on Level 1 roads and mile markers on highways.
- It was suggested that when a road or intersection is selected using the menu system, the test area map should automatically center the display to that intersection or road.
- It was thought that the TIC Subsystem Controller was a more useful default display to utilize than the TIC Process Controller because the tree structure of the Subsystem Controller's process log buttons took up less window display space.

Feedback

- Operators requested an audible notification be provided in the event of a process failure, in addition to a pop-up data window advising the operator of the appropriate action to be taken.
- Audible notification of new NWCD log entries and any new entries occurring in the "Last messages sent/received" log within the TIC Process Controller were also requested.
- It was reported that on occasion the TIC Subsystem Controller status buttons did not match the status of the same processes as displayed on the TIC Process Controller.

Visibility

- Concerning the colors and font sizes utilized on the test area map, the test area map menus, and the data input windows, all operators described the ease with which they could distinguish various items within these displays as either very easy, moderately easy, or neither particularly easy nor difficult. However, one operator commented that the buttons which denoted that options in the data input windows were selected were too small to be easily distinguished.
- Some problems were experienced by the operators as certain screen windows, which needed to be utilized in conjunction, obscured each other.

Physical Layout

- It was found that the positioning of the desks on which the TIC workstations were placed both restricted access to the computer cabinet, and prevented a secondary door used for access to the TIC from being opened fully.
- The combination of the physical location of the tape drive used for system backups and the photocopier, and the practice of performing backups during the morning peak period resulted in delays in the entry of anecdotal data into the TIC system at this time.

6.2.8.1 Additional Usability Findings

Several additional issues arose during the usability data collection and analysis. These largely relate to operator training and guidelines, and are outlined in the following paragraphs.

Operators had adopted various methods of dealing with discrepancies between the locations reported in the NWCD incident log and the locations available in the TIC database, which resulted in varying levels of success in matching NWCD locations to TIC database locations. This also resulted in varying amounts of anecdotal data being entered into the system, depending on which operator was on duty. It may be necessary to provide guidelines to the TIC operators as to how much time to spend in attempting to locate incidents which are not immediately identified by the TIC database.

Another area in which it was found that operators approached tasks in different ways was the decision-making process of considering which types of incidents on the NWCD log, for example, ambulance calls, to enter into the TIC system. Other differences in approach were found in the case of removing entered NWCD incidents if these were subsequently reported as “cleared” by the NWCD log. Again, more guidance may be required to ensure that operators adopt the appropriate response to this circumstance. The prioritization of tasks by operators is considered an area where more guidance or training could be provided. This comment stems largely from the observations made during anecdotal data entry tasks which were often interrupted to perform other non-real time tasks.

Operators differed significantly in their terminal display preferences, either displaying the whole test area and all the icons which represent incidents and road or lane closures so that an overview of the test area status could be maintained, or merely viewing a highly “zoomed-in” portion of the test area which corresponded to the last incident entered and no icons. This may signal the need for guidelines to be issued to the operators on the appropriate monitoring approach to take.

Again regarding the required monitoring approach to take, one operator reported that he never used any of the data windows accessed through the “Data Pop-up” menu. The same operator also commented that of all the log files available to him within the TIC Process Controller, he had only ever used the Startup and Shutdown log files. This would seem to result in this operator not being able to perform all the tasks required of him due to lack of information. This may be an area where more formalized training would assist the operators in being fully aware of what tasks are required.

6.2.9 Conclusions from Usability Findings

In terms of the assessment of MOE E.1.1, *the user perceptions of the level of ease with which TIC systems can be operated in everyday use*, operators assessed the ease of use of all the interface features as being either very easy, moderately easy, or neither particularly easy nor difficult. No features were rated as being either moderately or very difficult. It is therefore concluded that the user perceptions of the ease of use of TIC systems are substantially positive. However, given the large volume of operator comments and suggestions for enhancing the TIC systems usability, it is clear that there exists room for improvement in many of the features of the TIC User Interface. These suggestions are as summarized above in Section 6.2.8.

One issue which should be borne in mind when considering the usability assessment of the TIC User Interface is the prototypical nature of the interface developed for the *ADVANCE* operational test Targeted Deployment. For many innovative prototype systems such as that developed for *ADVANCE*, a focus on functionality rather than usability tends to be the norm. It is believed that this was the case during the development of the *ADVANCE* TIC systems. It is also the case that limited resources were available to the system developers for the usability aspects of system design. For example, no funding for usability testing during the design process was available. Given these circumstances, the operators' largely positive perceptions of the usability of the current interface are all the more notable.

In terms of the assessment of MOE E.1.2, *the number and type of difficulties reported by operators in everyday use*, the findings previously discussed translate into nine key areas where difficulties were experienced. Although it was not within the scope of this usability evaluation to identify possible solutions to all these difficulties, many suggestions were put forward by TIC operators and their manager. These are not repeated here, but are contained within Sections 6.2.4 to 6.2.7.6 where applicable. Again, due to the large amount of data which were gathered using the various data collection tools, it has been necessary to identify and focus upon what are considered the principal difficulties. The nine principal areas where difficulties were experienced are noted in the following paragraphs.

First, operators reported that the monitoring of the NWCD incident log to decipher which inputs required entry into the TIC system was made more difficult by the need to scan a large number of log entries to ascertain if any updates to a previously received and entered incident had been subsequently received. In addition, the rapid scrolling of NWCD log entries to the last item in the log when this window is first accessed also created some difficulties for operators.

Second, operators experienced difficulties in dealing with NWCD incidents displayed on the log file that had no precise location identified.

Third, in the event of the status buttons on the TIC Process Controller and the TIC Subsystem Controller displaying different colors for the same process, no indication was provided by the system as to which controller was reporting the correct status.

Fourth, operators could not identify when a remote data source had stopped providing data to the TIC. The process status buttons on the TIC Process Controller and the TIC Subsystem Controller displayed caution and warning conditions only when the processes were experiencing difficulties in executing.

Fifth, the time that the TIC systems took to process data or commands introduced delays into the completion of TIC operators' tasks. This tended to occur mainly during peak periods, though the timing of some such delays appeared to be random.

Sixth, the need to wait for the anecdotal input facility to open each time an operator needs to input anecdotal data introduced delays in the completion of this task.

Seventh, problems were experienced by the operators when certain data windows which needed to be utilized in conjunction obscured each other.

Eighth, operators experienced some difficulties in monitoring both the updates to the NWCD incident log file and the status of processes via the TIC Process Controller status displays using the visual cues provided by the interface. No use of aural cues for the user was made within the current interface.

Ninth, it was reported that the buttons which denoted that options in the data input windows were selected were too small to be easily distinguished.

Though many, more minor, difficulties were experienced by operators, the above list of nine key areas represents those difficulties which it is recommended be addressed as the first priority in any future releases of the *ADVANCE* TIC systems.

6.3 Objective E.2 - Evaluate TIC User Interface Functionality

For MOEs E.2.1, *the difference between desired and actual functionality of the TIC User Interface,* and E.2.2, *the number and type of interface functions not utilized during TIC operation,* data collection took place using the TIC Evaluation Questionnaire, the TIC Operator Observation Log, and the TIC Evaluator Observation Sheet. These are contained in Appendix C of this report. The data collection tools and procedures of the functionality evaluation were as described in Section 6.2 above relating to the usability evaluation.

To reiterate, in the three evaluator observation sessions, a total of 188 observations were recorded. Of these, 3.2% were classified as type E - TIC functionality. TIC Operator Observation Log sheets were completed by TIC staff from August 8, 1995 and log sheets from that time up to and including December 28, 1995 were utilized for this Evaluation Report. A total of 60 observations were made by the various TIC operators during that time. Of this total, 10 observations were disallowed from the analysis as they related to the status of processes or the system hardware which should have been entered onto the TIC Real-Time Log sheet. Of the remaining 50 observations, 32.0% were classified as type E - TIC functionality.

The observations made by the TIC operators and the human factors evaluator regarding the functionality of the TIC, and the responses to functionality-related questions within the TIC Evaluation Questionnaire fall into two main categories:

- possible additional functions which would ease operator workload, streamline TIC processes or improve TIC efficiency; and
- functions not utilized during regular TIC operations.

6.3.1 Additional Interface Functionality - Findings

As part of the TIC Evaluation Questionnaire, operators were asked that if they could re-design the TIC system interface having used the present interface, what changes would they make that would make their tasks more easy to complete or that would ease their workload in any way. Operators suggestions included the following:

- The interface should provide an "Undo" button, for the reversing of incorrect or inappropriate commands mistakenly entered by operators.
- The interface should automatically process NWCD log file information.
- The interface should provide a menu item for the input of traffic signal malfunctions within the input of incidents data entry window, as this is a frequently received cause of events in the NWCD log. At present this cause has to be entered as an "Other/unknown" type of event.
- It was suggested that the interface should filter out "Ambulance call" and possibly "Activated fire alarm" events within the NWCD incident log, as these events were very rarely or never of sufficient impact to merit entry into the TIC system. In addition, these events tended to occur at residential addresses which cannot be entered into the TIC system.
- It was requested that a "Select Last Incident" option be provided in the "Select" menu, in order to streamline this frequently required task.
- Operators also requested that they be able to select the location of an incident by its address. It was commented that as the drivers of MNA equipped vehicles are able to input an exact address into the device, operators too would prefer to be able to enter information in this manner.

6.3.2 Additional Interface Functionality - Conclusions

In terms of the assessment of MOE E.2.1, *the difference between desired and actual functionality of the TIC User Interface*, it appears that the TIC User Interface functionality met the requirements of the TIC operators to a large degree, as is reflected by the relatively small volume of suggestions made by operators for additional features which would make their tasks more easy to complete or that would ease their workload.

It is considered that the implementation of two of these operator suggestions, that the interface should automatically process NWCD log file information, and that the interface should filter out "Ambulance call" and "Activated fire alarm" events within the NWCD incident log, would actually result in TIC operators' responsibilities and workload being greatly diminished, as the manual processing of NWCD input forms one of their main tasks within the TIC. It is of course possible that in future implementations of systems comparable to the *ADVANCE* TIC, that a fully automated system would be practicable, and perhaps even preferable. However, in the context of the Targeted Deployment of the *ADVANCE* TIC, it is considered that these suggestions are not cost effective.

Regarding the other four suggestions made by TIC operators for possible additional interface functionality, that is, an "Undo" button, a traffic signal malfunctions anecdotal data entry menu item, a "Select Last Incident" facility, and locating an incident by its address, it is recommended that further investigations be undertaken into the feasibility and implications of implementing these. It is considered that the inclusion of these features would significantly enhance the present interface.

4.3.3 Interface Functions Not Utilized by Operators

The TIC Evaluation Questionnaire contained various questions concerning the frequency of use of the various interface functions. These were designed to help identify those functions that were very rarely or never utilized by the TIC operators. If required, additional information on the features of the interface is contained in the TIC Console Operator's User Manual, referenced above. It should be noted that all the features discussed in the following paragraphs other than some of the features contained within the "Data Pop-up" menu were intended for the everyday use of the TIC operators, as opposed to being implemented to support the system integration and validation processes.

Test Area Map

A series of questions concerned the operators' usage of the various items within the test area map menus. Operator responses were as follows:

- The "Monitor" menu can be used by the operator to select various events to monitor. Operators were asked if there were any items in this menu that they very rarely or never used. Menu items very rarely or never used by all operators included the Loop Detector Data and Incidents items.
- The "Display" menu controls which items are displayed on the test area map. Menu items very rarely or never used by all operators included the Road Names and Congestion items.
- The "Select" menu is used to select roadway segments and links on the test area map without having to use the mouse to click on the map. Operators were asked if there were any items in this menu that they very rarely or never used, and it was found that no items fell into this category for all operators.
- The "Locate" menu is used to locate and display a portion of the road network. Menu items very rarely or never used by all operators included the Loop Detector and Latitude / Longitude items.
- The "View" menu is used to create or remove map displays. All operators reported that they had never used any of the items on the "View" menu.
- The "Input" menu is used to enter incidents and road closures on selected links, link updates on selected links, TRF parameters and map properties. Menu items very rarely or never used by all

operators included the Fused Data, TRF Parameters, and the Map Properties items. However, it should be noted that the TIC operators do not have the required permissions to edit TRF parameters, and therefore the TRF Parameters item within the Input menu was not designed to be used by operators.

- The "Plot" menu on the test area map window had originally been intended to be used to provide the operators with various system data in graphical format. However, as part of the Targeted Deployment of the *ADVANCE* project, it had been decided by project participants that this feature need not be implemented. However, the interface utilized for the Targeted Deployment still displayed this menu and the menu items though they performed no function.
- Once an operator selects a map object, such as a segment, group of segments, or a link, various types of information could be queried from the system database on these objects. These capabilities were available to the operator though the "Data Pop-up" menu. However, the majority of items on this menu had been very rarely or never used by all operators, these items included the MIF File Contents, Static Profile, Probe Reports, Link Updates, Loop Detectors, Incidents, and the Node Information items.

Operators were then asked to estimate how frequently they used each of the various data windows contained in the test area map window. As was outlined above in relation to the usage of the "Data Pop-up" menu, it was found that the majority of these data windows were not used by operators. The two data windows which had been used by operators were the Link Network Attributes data window and the Segment Network Attributes data window. The frequency of use of these windows is illustrated in Figures 6.19 and 6.20 respectively. The Link Network Attributes data window was only used a few times per month by one operator, while the Segment Network Attributes data window was used more than once per day by two operators.

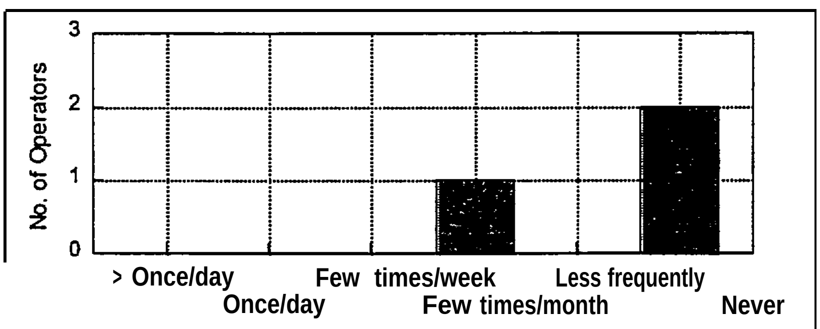


Figure 6.19 Frequency of Use of Link Network Attributes Data Window

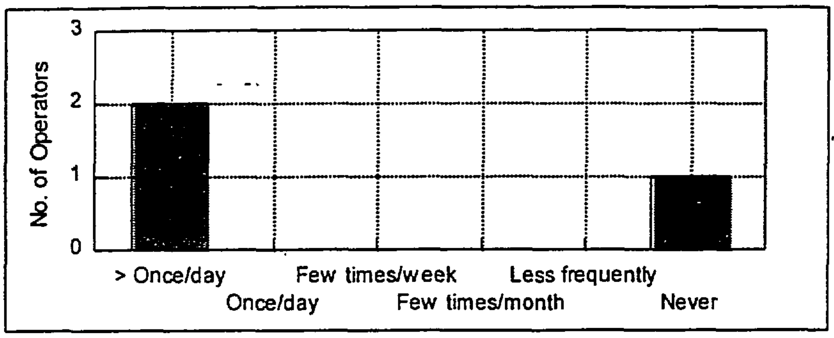


Figure 6.20 Frequency of Use of Segment Network Attributes Data Window

Data Entry Windows

The TIC User Interface also provides various data entry windows. These are the Incident Reports and Road or Lane Closures data input window, the Link Updates data input window, and the Map Properties data input window. The Incident Reports and Road or Lane Closures data input window was used more than once per day by all operators, as illustrated in Figure 6.21.

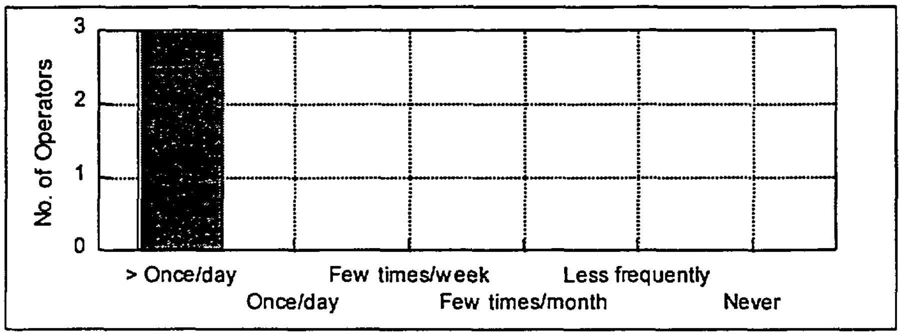


Figure 6.21 Frequency of Use of Incident Reports and Road / Lane Closures Data Input Window

However, all operators responded that they only used the Link Updates and the Map Properties data input windows either less frequently than a few times per month or never, see Figures 6.22 and 6.23. This finding suggests that operators do not need to utilize these data input windows as part of their regular workload, though the data input windows may well be necessary to fulfill tasks ordinarily completed by system administrators.

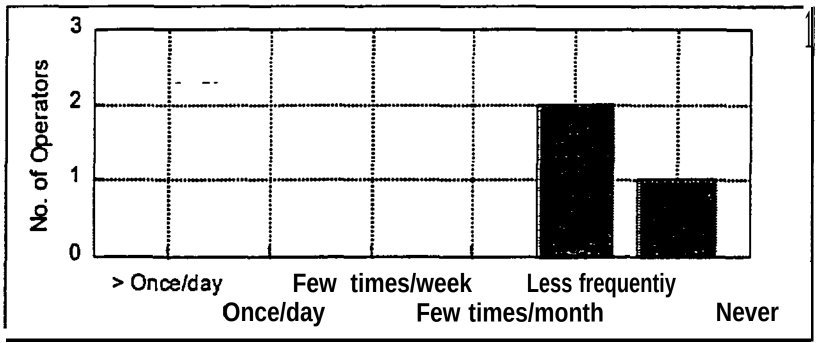


Figure 6.22 Frequency of Use of Link Updates Data Input Window

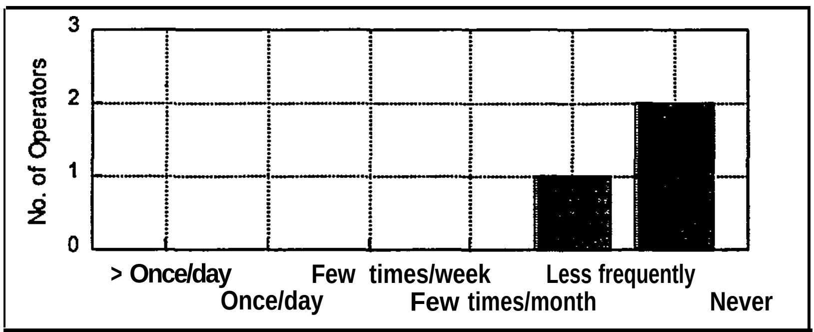


Figure 6.23 Frequency of Use of Map Properties Data Input Window

Internet Sites

Operators were asked how frequently they accessed the Expressway Map and the Gary-Chicago-Milwaukee (GCM) Project Home Page on the Internet via the TIC User Interface. The Expressway Map program provides a graphical view of the congestion levels on detectorized expressways in the Chicago urban area. Responses varied from more than once per day, to less frequently than a few times per month to never, see Figure 6.24. It was also found that the Expressway Map, although provided as a menu option within the main TIC menu, could not be accessed through this menu by TIC operators. It appears that the Expressway Map had been moved to the UIC-EECS Internet site after the design of the interface, so its menu item was made redundant.

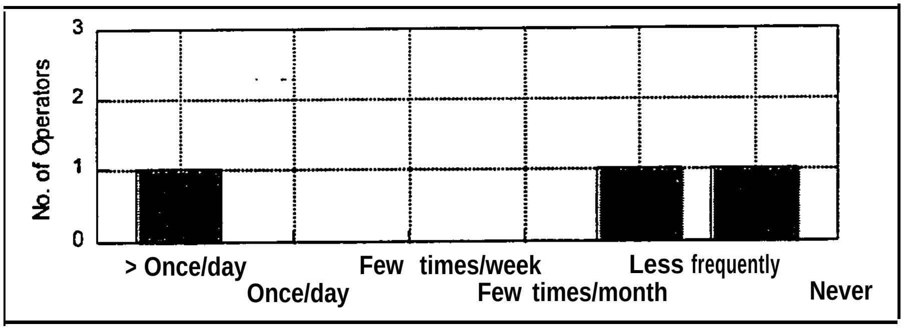


Figure 6.24 Frequency of Internet Expressway Map / GCM Home Page Access

Static Update Utility

Operators reported that the frequency with which they utilized the Static Update utility was either less frequently than a few times per month or never, see Figure 6.25. Although this utility was used several times during the Targeted Deployment by other Project Office staff, it appears the operators themselves were required to use it very infrequently. This finding suggests that operators do not need to utilize this utility as part of their regular workload during Targeted Deployment, though the utility may well be necessary to fulfill tasks ordinarily completed by system administrators. It has also been established that in a full deployment operators would be required to use the Static Update utility.

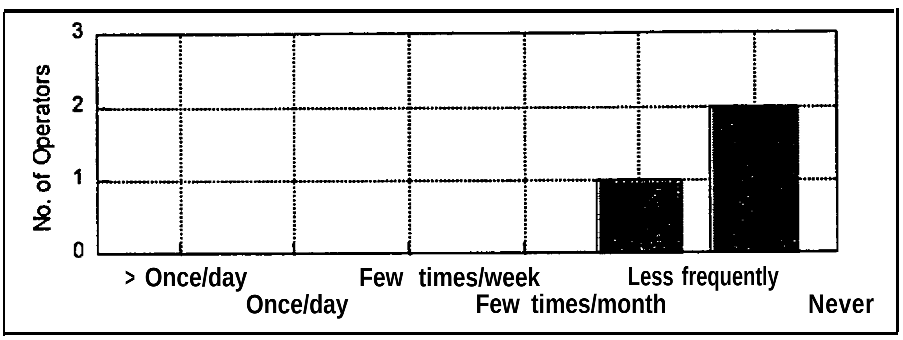


Figure 6.25 Frequency of Use of Static Update Utility

TIC Subsystem Controller

The TIC Subsystem Controller offers an alternative means by which operators may monitor the status of TIC processes. Its structure is for the most part similar to that of the TIC Process Controller, though the TIC Subsystem Controller displays nested groups of related processes and the operator may chose to display the status of all the processes within a subsystem, or solely the status of the overall subsystem. Operators were asked how frequently they used the TIC Subsystem Controller. The usage of this feature varied considerably, as can be seen from Figure 6.26. Operators variously reported that they utilized this feature more than once per day, a few times a month, or never.

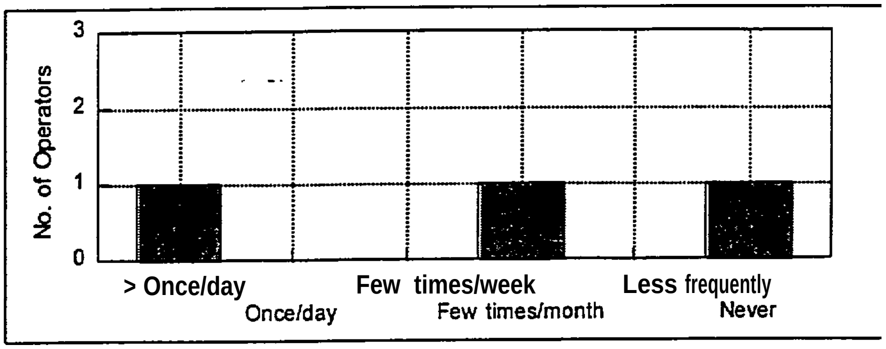


Figure 6.26 Frequency of Use of TIC Subsystem Controller

TIC Back-up Utility

Operators stated that they utilized the TIC Back-up Utility either once per day, a few times per week, or less frequently than a few times per month, see Figure 6.27. This difference in usage can be explained by the patterns of shifts worked by the operators, as system back-ups were performed during the morning shifts only.

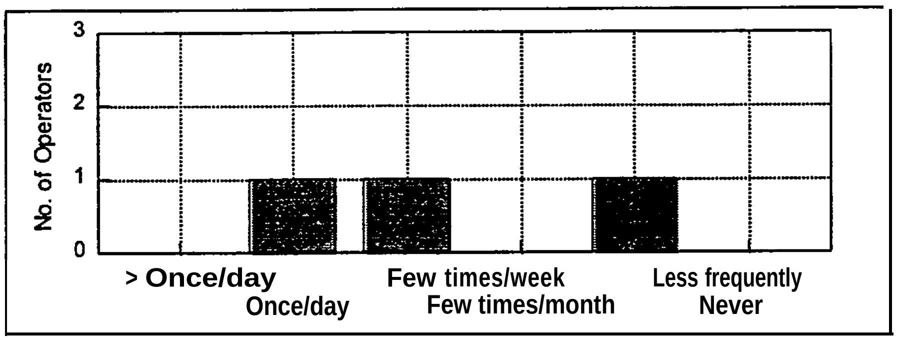


Figure 6.27 Frequency of Use of TIC Back-up Utility

6.3.4 Interface Functions Not Utilized by Operators - Summary and Conclusions

The following points summarize the key findings relating to the interface functions not utilized by operators. The fact that not all features of the User Interface had been used by one or more of the operators could be partly attributed to the difference between the operators' length of employment at the TIC, and the pattern of shifts worked by the operators. It should be borne in mind that should all operators have had the opportunity to gain more experience in using the TIC systems over a longer period, then more of these functions may have been encountered. For these reasons, only those functions of the interface which had never or rarely been used by all three operators are presented here.

In terms of the assessment of MOE E.2.2, *the number and type of interface functions not utilized during TIC operation,* the functions rarely or never used by all TIC operators included the following:

- The Loop Detector Data and Incidents items within the "Monitor" menu.
- The Road Names and Congestion items within the "Display" menu.
- The Loop Detector and Latitude / Longitude items within the "Locate" menu.
- All items within the "View" menu.
- The Fused Data and the Map Properties items within the "Input" menu.
- The MIF File Contents, Static Profile, Probe Reports, Link Updates, Loop Detectors, Incidents, and the Node Information data windows accessed via the "Data Pop-up" menu.
- The Link Updates and the Map Properties data input windows.
- The Static Update utility.

It should be noted that all the features listed above, other than some of the features contained within the "Data Pop-up" menu, were intended for the everyday use of the TIC operators, as opposed to being implemented to support the system integration and validation processes. It is recommended that all the above items undergo further investigation to ascertain their utility to operators in everyday use of the TIC systems. Although it is acknowledged that during a Targeted Deployment of limited duration there exists the possibility that operators did not have the need to utilize all the provided functions and thus these items could still be of utility in a permanently operating system, it is anticipated that some of these items could be eliminated without significantly restricting the functionality of the TIC User Interface.

Another possibility exists, which would result in the simplification of the TIC User Interface without sacrificing any of the above functions. It is recommended that the potential utility and benefits of a "dual interface" be investigated. This would in effect comprise a simplified interface for the everyday use of the TIC operators, which would allow them to fulfil all the tasks required of them, but which would not possess any of the above features which it could be determined they do not require. This interface could be automatically activated when any user possessing TIC operator status access permissions logs in to the TIC. A second, more advanced interface could be available to any user logging in who possesses system administrator permissions. This second interface could possess all the above functions for the use of staff needing to perform more advanced operations.

Alternatively, and if resources were available, a single TIC interface could be customized for each TIC operator. This would require extremely flexible set-up options, whereby the system administrator or TIC Manager could select all of the functions which should be made available to each individual operator, thereby tailoring the interface according to the level of operators' expertise or capabilities. The system administrators would, of course, have all features of the interface available to them.

In addition, there are certain features whose menu items are currently displayed on the TIC User Interface but which are not available to system users. These include all items within the "Plot" menu on the test area map menu bar, and the Expressway Map item within the main TIC menu. It has been established that it was decided not to implement these features of the interface as part of the system rationalization which resulted in the Targeted Deployment of the *ADVANCE* project. It is recommended that these non-functioning items be removed from the TIC User Interface.