THE ADVANCE PROJECT:
Formal Evaluation of the Targeted Deployment

Volume I

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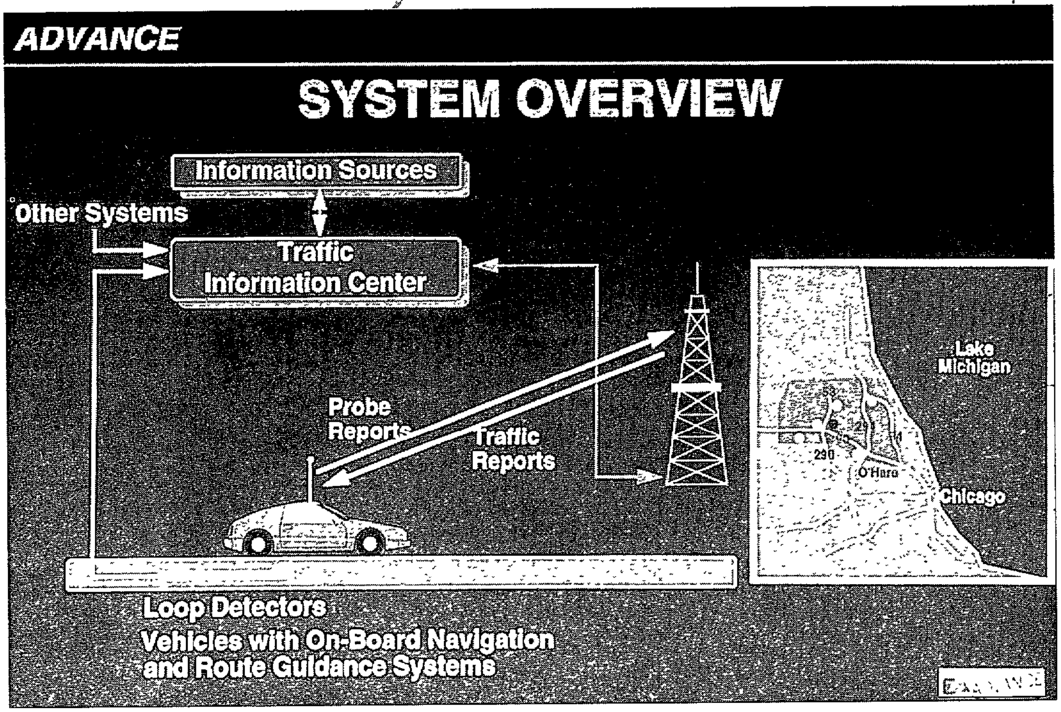
Volume 1



ADVANCE

ADVANCED DRIVER AND
VEHICLE ADVISORY
NAVIGATION CONCEPT

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THE *ADVANCE* PROJECT:

FORMAL EVALUATION OF THE TARGETED DEPLOYMENT

VOLUME 1

by

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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.l	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
MMI	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 & V Plan	Verification & Validation Plan, Document # 8300
V & V Team	Verification & Validation Team
VNIS	Vehicle Navigation and Information Systems
YD	Yoked Driver

THE *ADVANCE* PROJECT: FORMAL EVALUATION OF THE TARGETED DEPLOYMENT

EXECUTIVE SUMMARY

The Advanced Driver and Vehicle Advisory Navigation ConcEpt ***(ADVANCE)*** was an in-vehicle advanced traveler information system (ATIS) that operated in the northwest suburbs of Chicago, Illinois. It was designed to provide origin-destination shortest-time route guidance to a vehicle based on (a) an on-board static (fixed) data base of average network link travel times by time of day, combined as available and appropriate with (b) dynamic (real-time) information on traffic conditions provided by radio frequency (RF) communications to and from a traffic information center (TIC). Originally conceived in 1990 as a major project that would have installed 3,000 to 5,000 route guidance units in privately owned vehicles throughout the test area, ***ADVANCE*** was restructured in 1995 as a "targeted deployment," in which approximately 80 vehicles were to be equipped with the guidance units — Mobile Navigation Assistants (MNAs) — to be in full communication with the TIC while driving the ***ADVANCE*** test area road system.

Originally to have been evaluated formally as a fully deployed field operational test (FOT), ***ADVANCE*** by early 1995 required a modified evaluation scheme be developed in order to be realized as a targeted deployment. Such a plan was constructed by Booz-Allen & Hamilton, FOT support contractor to the FHWA Joint Program Office. The ***ADVANCE Evaluation Management Plan*** identified the roles and responsibilities of the test program participants, delineated the data management requirements, provided a resource management plan for the test vehicle fleet, and included detailed schedules for the completion of each evaluation task. This document, in concert with the ***ADVANCE Evaluation Program Plan,*** served as the foundation upon which test plans were developed, through extensive cooperation between staff and the evaluators, to direct data collection and management, analysis, and task management efforts for each of the individual tests.

Three of the four ***ADVANCE*** subsystems were formally evaluated; focused evaluations were also made of the performance of the system in its entirety. The evaluated subsystems were Traffic Related Functions (TRF), Mobile Navigation Assistant (examined in the context of its user friendliness/acceptance and its performance in route guidance), and Traffic Information Center. The interaction of these subsystems in concert with the RF communications subsystem (COM) was performance-tested by the dynamic route guidance and incident detection field evaluations.

The TRF algorithms used by ***ADVANCE*** were resident in the central computing facilities of the TIC. Their primary purpose was to screen, validate, and then process incoming real-time data from loop detectors (traffic volume and detector occupancy), MNA reports (travel times of probe vehicles on the various links), and any anecdotal information (such as emergency vehicle dispatch reports) to generate near-term estimates and predictions of travel time along any arterial link. These reports and the resulting link travel time estimates were compared with values in the stored data base of historical average travel time for that day of week (measured for normal weekday vs. normal weekend vs. Friday/holiday) and time of day (five total time periods). If certain criteria were met, a travel time update was included in a message bundle for RF transmission to MNAs.

The purpose of the TRF subsystem field tests was to evaluate the performance of the components of the subsystem and the relative usefulness of probe-equipped vehicles (called "probes"), in-pavement loop detectors, and anecdotal incident reports to provide real-time traffic data. Specific questions to be answered were

- How well did the static profile, data screening, detector travel time conversion, data fusion, incident detection, and travel time prediction components of the TRF perform?

- How accurate were the initial travel time estimates generated by the Network Flow Model, which was used prior to system deployment to simulate traffic activity in the ***ADVANCE*** area?

- What was the relative value of the fixed detectors and the probe vehicles as sources of information for the incident detection and travel time prediction algorithms?

- What frequency of probe reports was needed to obtain reliable estimates of current link travel times and identification of (nonrecurrent) congestion?

- What was the accuracy of the probe travel time reports?

To answer these questions, paid drivers operating up to 15 *ADVANCE*-system-equipped vehicles four days per week (Monday-Thursday) drove predetermined routes for which their traversal times and other indicators of network performance (e.g., distances traveled at speeds less than 22.5 mph and time spent at less than 5 mph) for each link of the route were recorded at the TIC, along with arterial loop detector data. Performance indicators were analyzed to assess response, accuracy, and usefulness of the key TRF components, including fusion of data received from probes and detectors into a travel time prediction algorithm, construction of both the default static forecasts and the on-line dynamic forecasts, estimation of the number and frequency of probe traversals required for reliable travel time updates, and the relationship among vehicles' travel times on a link as a function of turning movement and direction.

The MNA hardware configuration installed in ADVANCE-equipped vehicles included a display unit, located next to the driver, with a memory card (PCMCIA); a speaker for audio messages; a gyrocompass and transmission pickup for dead reckoning navigation, mounted inside the vehicle frame; antennas, attached to the rear exterior of the vehicle, for transmitting and receiving

RF messages and for receiving global positioning system (GPS) signals; and a navigation computer, sensor controller, RF modem, GPS receiver, and CD-ROM drive, all mounted in the trunk (or rear of a minivan's passenger compartment).

It had always been intended that drivers who reside in the study area be given the opportunity to experience the look, feel, and capabilities of the ***ADVANCE*** MNA for an extended period in their own cars and trucks. A focused test using study area residents was devised for the purpose of providing drivers familiar with the ***ADVANCE*** test area an opportunity to use the ***ADVANCE*** system in their normal driving behavior for a relatively extended period of time. It was expected that these drivers could contribute useful perspectives on the characteristics and performance of the ***ADVANCE*** system and help guide the design and development of future ATIS services.

The TIC, located at the ***ADVANCE*** project office, provided all centralized computing resources for the system, including processing, distribution, and archiving of system descriptive (static) and real-time-generated (dynamic) data. The purpose of the TIC evaluation conducted under the targeted deployment was to analyze the TIC hardware and software as a combined system, documenting reliability, examining system staffing and operation requirements and overall cost efficiency, and assessing system design alternatives from the perspective of system portability (to other sites and applications), maintenance needs, and ease and effectiveness of use by operators.

Two tests were more focused on all subsystems of ***ADVANCE*** operating as an integrated whole. In the dynamic route guidance (DRG)/yoked driver (YD) tests, a group of three equipped vehicles operated by paid drivers were driven, starting at approximately identical times, between a preselected origin and destination. Two members of each group followed routes planned and updated in real time through the communications link with the TIC, while the third followed a fixed (or static) route defined by the in-vehicle navigation unit by using only its embedded map and travel time data (i.e., no TIC communications). Two dynamically guided vehicles were used to ensure success of the test even if equipment in one vehicle malfunctioned. Eighteen equipped vehicles acting as probes departed ahead of this pair along alternative routes between each planned origin and destination to provide frequent travel time updates to the TIC. The objective of the test was to determine whether and how frequently the members of the pair that had full communication were given a route that was different from that provided by static guidance only ***and*** that saved time or had a ***potential*** time-saving benefit relative to the static route. In the incident detection (ID) evaluation, prestaged and roving field vehicles from a deployed fleet of up to 12 were dispatched in real time to the scene of either a reported incident or a known, actual (or simulated) construction delay. If an actual delay condition was found, these probe-equipped vehicles traversed the affected area repeatedly to measure travel times. Later, the vehicles returned to the incident sites to record travel times under normal conditions. The reliability of the algorithm that identified (a) nonrecurring incidents and construction and (b) incident delays by means of loop detector data and data fusion was evaluated with data collected from these traversals.

RESULTS

Reports from 50,620 probe traversals were collected during the TRF field tests and examined. Of these, 88 had unacceptably high speed, 95 had unacceptably high congested distance (longer than the link itself), and 115 had an unacceptable match between congested distance and congested time (i.e., time on the link spent at speeds at or less than 10 m/sec — about 22.5 mph). Of those 115 reports, 11 were also in the set of unacceptable speed reports. Thus, 287 reports were found to be suspect, or about 0.6 percent of the total, and many of these were traceable to a single faulty MNA. Further, when 776 of these probe-reported values were compared to manually recorded values observed at the same time, 87.6% of values were within plus or minus five seconds and 94% within plus or minus ten seconds, with substantial clustering within two seconds or less. The overall conclusion is that MNA data proved a reliable indicator of traffic conditions in ***ADVANCE*** and thus could provide a valuable resource for traffic monitoring and analysis in future ATIS deployments.

After two or three updates based on probe traversal data, the static (average) profiles of travel times by time of day in the ***ADVANCE*** network became very accurate. Updated algorithms performed well against occasionally idiosyncratic probe reports, and data were screened appropriately, eliminating many reports from malfunctioning MNAs. Profiles based on probe data only were found to be more accurate than those based on both probe and detector data.

In most instances, three probe reports per five-minute interval were adequate to provide reasonable travel time estimates and predictions on the arterial system. Increasing this probe rate produced very little change in the output forecasts, a result consistent with an evaluation of probe frequencies, which found that the variance of arterial travel time estimates never approaches zero regardless of the number of probes, and that the quality of estimate essentially stops improving above relatively few traversals per five-minute interval. These factors argue strongly that very high levels of probe deployment are probably ***not*** necessary for an effective probe-based ATIS. However, all prediction algorithms would be enhanced by the inclusion of traffic signal timing data on the network roadways.

The user features of an in-route guidance system, such as those of the MNA units deployed for ***ADVANCE,*** must be able to accommodate a reasonably broad range of technological sophistication and network knowledge among the population likely to pay for and regularly use such a system and its associated services. Specifically, the capability should exist to “train” the system to learn the user’s preferred routes, then provide timely and relevant information about available time savings on alternative routes (especially those which may be “counter-intuitive” to a user familiar with the area road network). In general, users who regularly drive in a road network and know its normal traffic and congestion patterns tolerate recurrent time-of-day delays in the network on the links with which they are familiar and comfortable; thus, only a route guidance system capable of providing reliable real-time data about non-recurrent congestion is likely to find a market base beyond very specialized, very limited applications.

For successful identification of instances of nonrecurrent congestion, results of testing the ***ADVANCE*** incident detection algorithms were mixed. Although the composite results of the evaluation called into question the ability to generally apply previously estimated freeway/ expressway incident detection algorithms without complete recalibration of parameters, they revealed substantial potential for further development of reliable arterial incident detection algorithms based on volume and occupancy data from fixed detectors and/or link traversal data from probe vehicles. A modified algorithm based on probe and detector data in the arterial system that used data from three probe traversals per fifteen minutes detected nine of nine incidents without false alarms.

In the DRG/YD tests, it was established that route diversions and travel time savings are sometimes associated with the use of real-time data for route planning, but in an arterial network like that of ***ADVANCE,*** in which DRG is subject to key functionality limitations, large time savings may not be a typical outcome. Where substantial time savings occurred during the test, the cause appeared to be availability of less congested (but, paradoxically, ***(onger or orthogonal)*** links proximate to highly congested routes. ***Such alternative routes, in the absence of DRG, are likely in most instances to appear illogical to drivers on the congested route and thus unlikely to be found and followed without a route planner using real-time information for the entire network.***

Evaluation of the TIC confirmed that the TIC architecture as implemented provided an acceptable level of performance for the demands made on it by the targeted deployment with respect to both hardware and software as individual components and as a complete system. Moreover, it provided an acceptable cost efficiency for the scope of its mission, enabled successful system operation, ensured reasonable operator workload with its procedural practices, and provided an acceptable level of usability and functionality of user interface (although operator comments about unused features and suggestions for additions and enhancements indicated that many features of this interface might be improved). However, it was found that the architecture as implemented for the targeted deployment operational tests is not directly or immediately expandable to cover additional services within the current test area due to inherent system limitations deriving from reduced project scope. Nor is it directly transferable to other geographic areas because it was a unique technical solution that, as an entire system, has limited application and capability to meet local requirements in other areas. The prospects for transferability of its major system components are very good.

CONCLUSIONS

From a practical standpoint, a number of lessons were learned about operating an FOT, whether full-scale or otherwise; these lessons are discussed in depth in a series of “Insights and Achievements” white papers. While it is true that the scope of testing of dynamic route guidance capabilities, the effect of the system on “familiar” drivers, and the ability to assess long-term operational and maintenance aspects of the system were far more limited than the original ***ADVANCE*** concept stipulated, there is clearly a subset of results of the ***ADVANCE*** evaluation that would not change regardless of its scale of deployment. Probably chief among these is that, although real-time guidance on arterial networks can be provided (at significant public expense) in the absence of equipped vehicle probes, its quality and usefulness will be much diminished relative to what even a very limited deployment of probes could achieve. The ***ADVANCE*** targeted deployment tests argue that probe data constitute such an essential component of reliable arterial dynamic travel time information that traffic management agencies in large urban areas should actively undertake to recruit a small population of commercial and private vehicles to serve as automatic vehicle locator (AVL) probes for operation on arterials and expressways. (Such AVL deployment has already occurred in the San Francisco Bay area and is being contemplated elsewhere.) In this way, without the need for specifically identifying individual vehicles, a vital, generally unprecedented, and perhaps ultimately indispensable stream of travel time information for the ***total*** network would begin to flow into regional traffic management centers.

The decision to adopt a targeted deployment approach for ***ADVANCE*** was a logical step in developing and advancing ITS technology. The dynamic route guidance concept which was central to ***ADVANCE*** was tested, the project infrastructure developed was enhanced to support a broader range of ITS deployments, and multistate corridor activities were supported and given a more central focus. The public and private participants in the project gained highly useful information from systems development and evaluation testing that has helped positively and productively to guide further ITS concept and product deployment pursuits.

THE ***ADVANCE*** TARGETED DEPLOYMENT: THE EVALUATION MANAGER'S OVERVIEW REPORT

1 GENESIS OF THE TARGETED DEPLOYMENT AND ITS FORMAL EVALUATION

The Advanced Driver and Vehicle Advisory Navigation ConcEpt ***(ADVANCE)*** was an in-vehicle advanced traveler information system (ATIS) that operated in the northwest suburbs of Chicago, Illinois. It was designed to provide origin-destination shortest time route guidance to a vehicle on the basis of (a) an on-board static (fixed) data base of average network link travel times by time of day, combined, as available and appropriate, with (b) dynamic (real-time) information on traffic conditions provided by radio frequency (RF) communications to and from a traffic information center (TIC). A schematic diagram of the information flow in the ***ADVANCE*** system is shown in Figure 1.

ADVANCE, which pioneered many of the public/private organizational arrangements and technical features now considered commonplace for Intelligent Transportation System (ITS) deployments across the United States, was unique in its use of "probe" vehicles to dynamically generate travel time information for arterial and local streets.

During the summer and fall of 1995, the ***ADVANCE*** system underwent a series of formal evaluation tests of the performance of its subsystems, as well as of the most important aspects of the system overall. The impetus for these tests, as discussed below, was the decision to deploy the ***ADVANCE*** concept as a limited but very focused demonstration of the system's capabilities and thereby conserve considerable public resources.

Originally conceived in 1990 as a major project that would have installed 3,000 to 5,000 route guidance units in privately owned vehicles throughout the test area, ***ADVANCE*** was restructured in 1995 as a "targeted deployment." Late in 1994, it was concluded that the technological capabilities and user features of the ***ADVANCE*** system, though state-of-the-art, might be difficult to combine in a package that consumers could reasonably afford. In addition, actual sales for other products with similar but nondynamic and less comprehensive features were smaller than expected. The lack of a logical, assured product development and rollout path prompted the decision to deploy ***ADVANCE*** in a manner that could test its effectiveness and performance, without committing millions of public and private dollars to the installation and long-term operation of 3,000 navigation units in private vehicles. Thus was born the idea of a targeted deployment, in which approximately 80 vehicles would be equipped with the navigation units — Mobile Navigation Assistants (MNAs) — to be in full communication with the TIC while driving the ***ADVANCE*** test area road system. The parties developing ***ADVANCE (see*** the ***ADVANCE*** participants, page V l-xi)

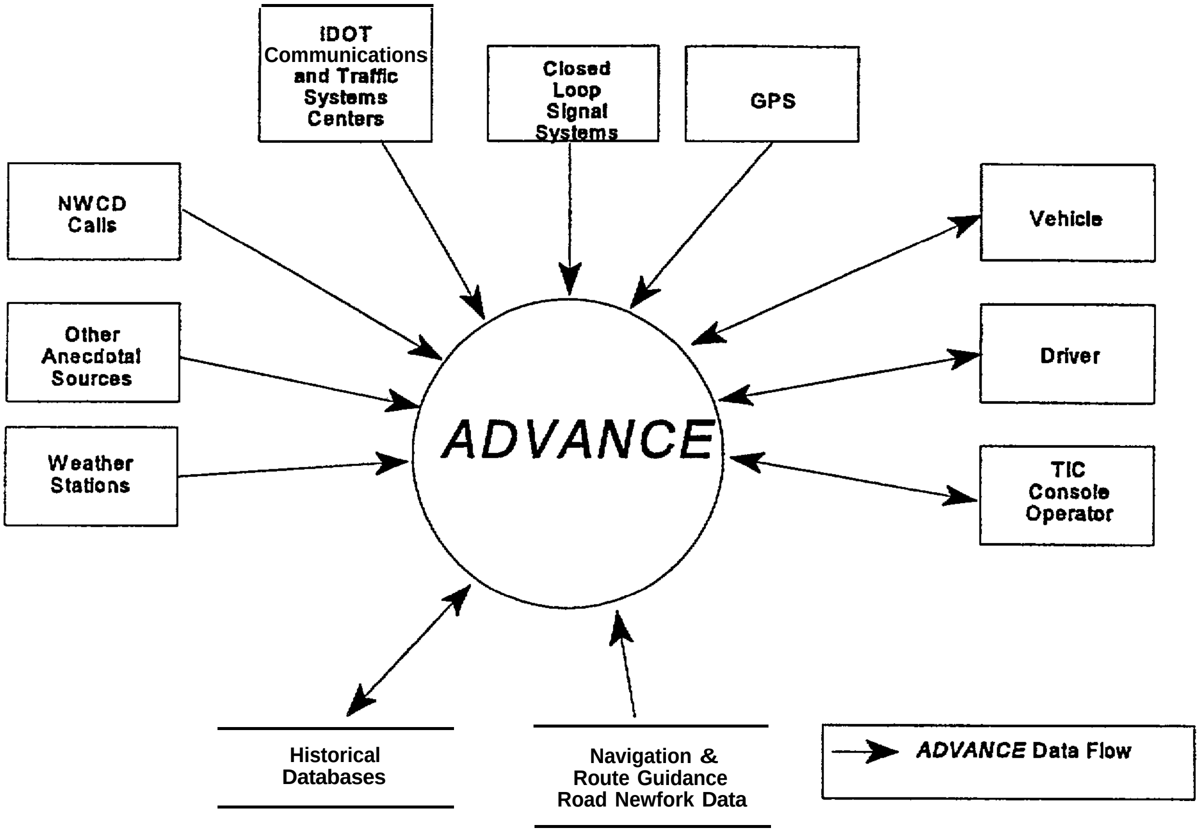

FIGURE 1 Dynamic Information Flow in *ADVANCE*

also agreed that the *ADVANCE* dynamic route guidance testing had produced significant technological accomplishments having future potential governmental and commercial application, and that documentation of these technologies and accomplishments needed to be made available to the public and to commercial enterprises more quickly than would have been possible under full deployment.

Deployment of new ITS technology demands verification that the purposes of the deployment are achieved and that *results* of development and deployment are commensurate with *resources expended.* The original planning for the *ADVANCE* deployment called for compilation of a large evaluation data base throughout the expected four-year project lifetime. This data base would have provided the basis for broadly informative and reliable tests of the various features of the project's systems and subsystems with respect to their capability to perform their stipulated missions. It became apparent early in 1995 that the resizing of the *ADVANCE* project to a smaller, targeted deployment, would necessitate development of an evaluation program and management plan different from what had earlier been drafted for full deployment. Moreover, the contract for evaluation manager had not yet been signed with Argonne National Laboratory (Argonne), the organization selected to fulfill that responsibility. Because the needed reformulation of the evaluation testing and management scheme could not be postponed until such a signed contract was in place, the Federal Highway Administration (FHWA) requested Booz-Allen & Hamilton, already under an FHWA contract, to assume the role of interim evaluation manager. In this role, Booz-Allen was tasked with directing the expeditious completion of evaluation and test planning requirements.

In developing plans for assembling an evaluation data base, objectives changed primarily in scope: although sample sizes and the number of data points were significantly diminished, it was still possible to collect adequate data to inform others about expected performance of and user response to similar system deployments. This philosophy motivated the developers of the ***ADVANCE*** evaluation plan, in concert with the evaluators, to devote considerable attention to redefining the objectives and resources necessary to conduct useful tests, then to deriving a feasible schedule under known time constraints for conducting all needed activities in the field and at the ***ADVANCE*** TIC. As applicable, the evaluation test plans that were ultimately prepared identified

- Data to be collected and the procedure for their collection,
- Hypotheses about system performance to be tested using these data,
- Chronological window(s) (calendar dates) during which data would be collected, and
- Resources required to perform the tests.

The ***ADVANCE Evaluation Management Plan*** (Document #8450) identified the roles and responsibilities of the test program participants, delineated the data management requirements, provided a resource management plan for the test vehicle fleet, and included detailed schedules for the completion of each evaluation task. This document, in combination with the ***ADVANCE Evaluation Program Plan (Document*** #8400), and extensive cooperation between staff and each of the evaluators, served as the foundation upon which test plans were developed to direct data collection and management, analysis, and task management efforts for each of the individual tests.

Early in May 1995, the evaluation management contract was signed with Argonne. By prior agreement, the Booz-Allen team remained in place to fulfill its responsibilities and conduct an orderly transition to Argonne's management; this transition was accomplished by mid-June. Argonne, in its position as evaluation manager, subsequently endeavored to ensure that all tasks were conducted in complete consistency with the scope and schedule of the plans developed by Booz-Allen & Hamilton and the respective evaluators. This endeavor was successfully completed.

2 SCOPE AND STRUCTURE OF THE EVALUATION

As described below, testing was conducted in the field and at the TIC in support of performance evaluation for each of three major ***ADVANCE*** subsystem features. These features are described in this section.

2.1 TRF SUBSYSTEM

The Traffic-Related Functions (TRF) algorithms used by ***ADVANCE*** were resident in the central computing facilities of the TIC. Their primary purpose was to screen, validate, and then process incoming real-time data from loop detectors (traffic volume and occupancy), MNA reports (link travel times of probe-equipped vehicles called "probes"), and any anecdotal information (such as emergency vehicle dispatch reports) to generate near-term estimates and predictions of travel time along any link. These reports and their resulting link travel time estimates were compared with values in the stored data base of historical average travel time for that day of the week (measured for normal weekday vs. normal weekend vs. Friday/holiday) and time of day (five total time periods). If certain criteria were met, a travel time update would be included in a message bundle for RF transmission to MNAs.

The base travel time values against which real-time data were compared had been generated by either a network equilibrium flow model or a static profile update incorporating real traversal time measurements. The navigation network used by ***ADVANCE*** for real-time travel updates contained 7,253 directional segments with 1,580 intersections, of which 699 were signalized. To code this network for appropriate representation as a data base, 274 boundary segments were defined around the test area, while every approach segment to an (eligible) turning movement was expanded to add a turning movement segment (this latter modification alone increased the number of coded links by a factor of 2.5). Turning movements and arterial signals were abstracted as delay functions.

In every 5-minute interval, TRF screened incoming data, then executed the following tasks:

1. Determined the presence of a lane-blocking or flow-retarding condition on any link by comparing probe traversal time and loop detector volume and occupancy reports with the static profile or by directly incorporating an anecdotal incident report; if time difference criteria were met, an incident report/flag for that link was generated.

2. Estimated current travel time on the basis of ***fusion*** of detector (where available) and probe data, or *individually* if either source were missing or had failed screening criteria. When both sets of data were available and screened as acceptable, the travel time estimator fused them in an equation

incorporating adjustment factors weighted according to (a) the standard deviations of the average travel time estimates from each source and (b) how influential the detector travel time should be in the combined estimate.

3. Computed travel times on the link for the next four 5-minute intervals (i.e., up to 20 minutes into the future). Probe and fusion data were used in this computation except where an incident had been confirmed, in which case the expected incident duration was applied. Data for the link were standardized by mean and standard deviation of the combined probe and detector values, and travel times were predicted in a function that gradually "decayed" back to the static average time after the last 5-minute interval. The outgoing message contained all four 5-minute computed values.

The *purpose* of the TRF subsystem field tests was to evaluate the performance of the components of the subsystem and the relative usefulness of probe-equipped vehicles, in-pavement loop detectors, and anecdotal incident reports in providing real-time traffic data. Specific questions to be answered were

- How well did the static profile, data screening, detector travel time conversion, data fusion, incident detection, and travel time prediction components of the TRF perform?

- How accurate were the initial travel time estimates generated by the Network Flow Model, used prior to system deployment to simulate traffic activity in the ***ADVANCE*** area?

- What is the relative value of the fixed detectors and the probe vehicles as sources of information for the incident detection and travel time prediction algorithms?

- What frequency of probe reports is needed to obtain reliable estimates of current link travel times and identification of (nonrecurrent) congestion?

- What is the accuracy of the probe travel time reports?

The *procedures* developed for the seven interrelated TRF field tests, managed by the University of Illinois at Chicago Urban Transportation Center (UIC-UTC) faculty, used paid drivers operating up to 15 ***ADVANCE*** system-equipped vehicles four days per week (Monday-Thursday). The vehicles were driven along predetermined routes for which traversal times and other indicators of network performance for each link (e.g., distances traveled at speeds less than 22.5 mph and time spent at less than 5 mph) were recorded at the TIC, along with arterial loop detector data. Figure 2 shows the primary route used. Performance indicators were analyzed to assess (1) response,

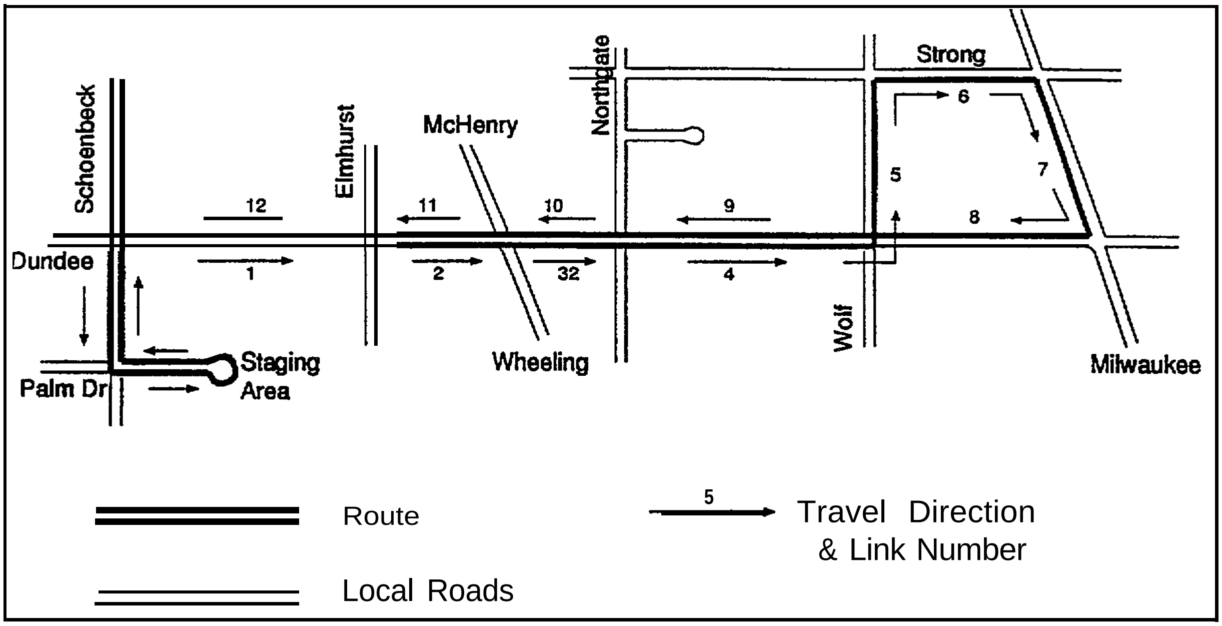

FIGURE 2 Primary Route Used in TRF Field Tests

accuracy, and usefulness of the key TRF components, including fusion of data received from probes and detectors into a travel time prediction algorithm; (2) construction of both the default static forecasts and the on-line dynamic forecasts; (3) estimation of the number and frequency of probe traversals required for reliable travel time updates; and (4) the relationship among vehicles' travel times on a link as a function of turning movement and direction.

A more detailed description of the field testing activities and protocols of the TRF evaluation is provided in Section 4 of this overview. The results of the analysis of data arising from these tests are presented in the evaluation reports accompanying this evaluation manager's report as

Appendix A: Base Data and Static Profile Evaluation Report (#8460-01.0l)
Appendix B: Data Screening Evaluation Report (#8460-02.02)
Appendix C: Quality of Probe Reports Evaluation Report (8460-03.01)
Appendix D: Travel Time Prediction and Performance of Probe and Detector Data Evaluation Report (#8460-04.01)
Appendix E: Detector Travel Time Conversion and Fusion of Probe and Detector Data Evaluation Report (#8460-05.01)
Appendix F: Frequency of Probe Reports Evaluation Report (#8460-06.01)
Appendix G: Relationships among Travel Times Evaluation Report (#8460-07.02)

One of the principal purposes of TRF and TIC functions was to generate, in real time, link travel time updates that could be broadcast to MNAs and enable them to determine a near-optimal (least-time) point-to-point route at a given time interval. A test was constructed to determine whether, and to what extent, dynamic route guidance (DRG), as implemented in the *ADVANCE* system, could significantly improve travel times for drivers. The test had two central facets: yoked-driver (YD) timing and incident detection (ID) timeliness.

In the dynamic route guidance/yoked driver (DRG/YD) tests, a group of three equipped vehicles operated by paid drivers were driven, starting at approximately identical times, between a preselected origin and destination. Two members of each group followed routes planned and updated in real time through the communications link with the TIC, while the other followed a fixed (or static) route defined by the in-vehicle navigation unit, using only its embedded map and travel time data (i.e., no TIC communications). Two dynamically guided vehicles were used to ensure success of the test even if equipment in one vehicle malfunctioned. Eighteen equipped vehicles acting as probes departed ahead of this pair along alternative routes between each planned origin and destination to provide frequent travel time updates to the TIC. An example of one of these origin-destination networks and possible routings is shown in Figure 3. The objective of the test was to

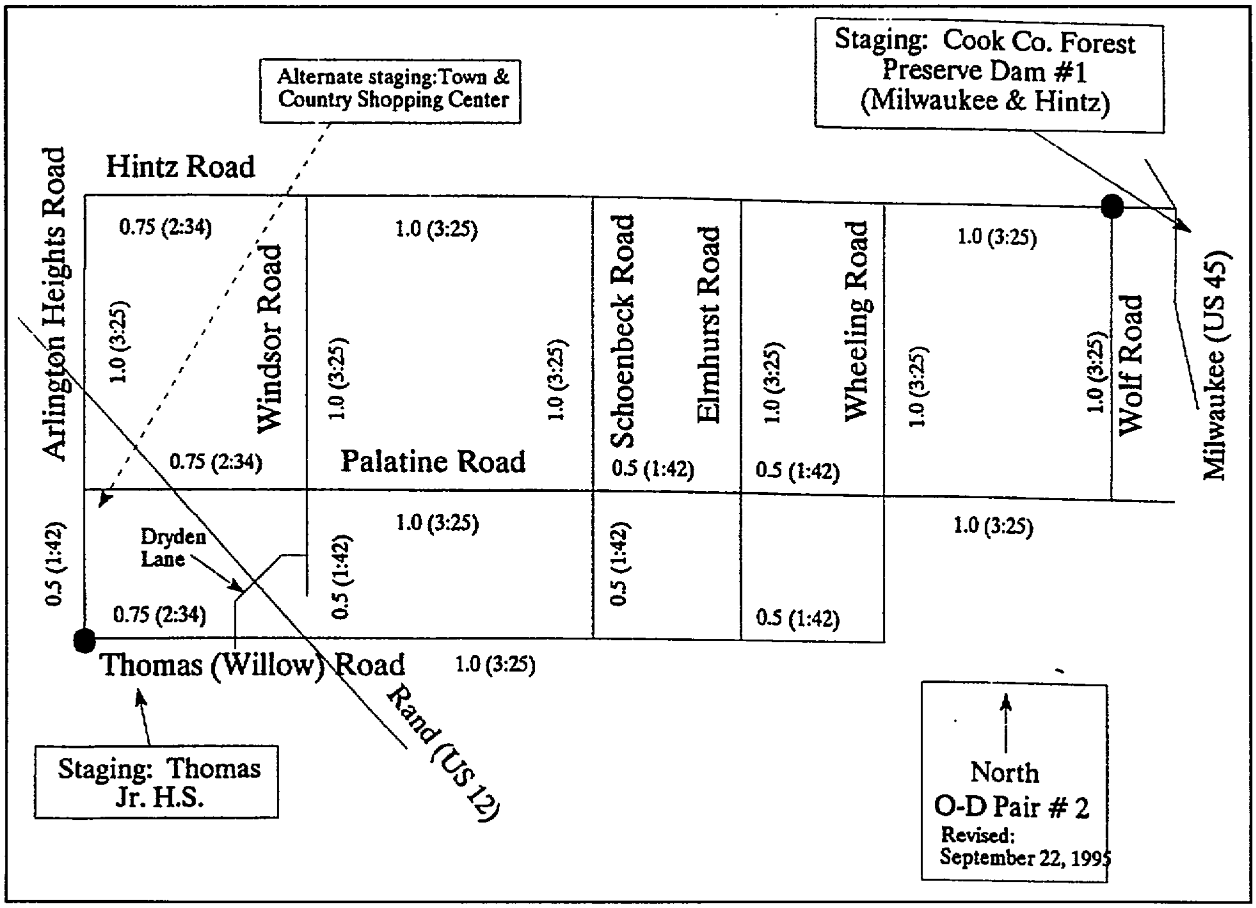

FIGURE 3 Example Origin-Destination Pair for Yoked Driver Test

determine whether and how frequently the members of the pair that had full communication were given a route that was different from that provided by static guidance only *and* that saved time or had a *potential* time-saving benefit relative to the static route. These tests, managed by faculty of Northwestern University Transportation Center (NUTC), were conducted weekdays and early evenings by using drivers hired by Northwestern University throughout the month of September 1995.

In the ID evaluation, prestaged and roving field vehicles from a deployed fleet of up to 12 were dispatched in real time to the scene of either a reported incident or a known, actual (or simulated) construction delay. If an actual delay condition was found, these probes traversed the affected area repeatedly to measure travel times. Later, the vehicles returned to the incident sites to record travel times under normal conditions. The reliability of the algorithm that identifies (a) non-recurring incidents and construction and (b) incident delays by means of loop detector data and data fusion was evaluated with data collected from these traversals. Tests were conducted by NUTC during weekday periods of recurrent, nonrecurrent, and incident-related congestion (both naturally occurring incidents and staged incidents were used) during summer and autumn 1995.

A more detailed description of the field testing activities and protocols of the DRG and ID evaluations is provided in Section 4 of this overview. The results of the analysis of data arising from (1) the ID and (2) the DRG test are presented in the evaluation reports appended to this document as

Appendix H:	Evaluation of Arterial Probe Vehicle, Fixed Detector and Expressway Fixed Detector Incident Detection Algorithm Evaluation Report (#8461.01)
Appendix J:	Field Test of the Effectiveness of ***ADVANCE*** Dynamic Route Guidance on a Suburban Arterial Street Network Evaluation Report (#8463.01)

2.2 MNA SUBSYSTEM

Look, Feel, and Capabilities. The MNA hardware configuration installed in ***ADVANCE***-equipped vehicles included a display unit, located next to the driver, with a (PCMCIA) memory card; a speaker for audio messages; a gyrocompass and transmission pickup for dead-reckoning navigation, mounted inside the vehicle frame; antennas, attached to the rear exterior of the vehicle, for transmitting and receiving RF messages and for receiving global positioning system (GPS) signals; and a navigation computer, sensor controller, RF modem, GPS receiver, and CD-ROM drive, all mounted in the trunk (or rear of a minivan's passenger compartment).

The navigation computer was activated when the vehicle was started, becoming functional after about a one-minute warmup, and shut down after safely closing out all its active functions when the ignition was turned off. It was designed to function in ambient temperatures ranging from -40°C to +85°C and was capable of operating effectively in a rough-service environment with respect to impact shock, vibration, and voltage spikes.

The display head to the driver's right contained a 5.7-inch diagonal screen featuring an infrared-based touch panel with backlit color LCD. A memory card slot housed a 2MB PCMCIA card (formatted to 1.44 MB) that stored link traversal data and other messages transmitted to and from the TIC. The purpose of this memory card was to assist in retrieval and storage of data to be used in the evaluation. Buttons to the right of the screen or touch prompts on the screen itself could be pressed to bring up one of the following principal displays:

1. A selection menu for route planning, network/location map, or user interface adjustment.

2. ***Route planning mode***: an option to select destination by address or intersection; up to seven addresses can be stored for future use and accessed from a screen linked to display 3 below.

3. Following display 2, an alphanumeric touch keypad to enter destination street names, address numbers, and/or towns in the ***ADVANCE*** data base (a choice of streets or towns is offered by pressing "ENTER" on the touch pad).

4. Following display 3 and the "best" route computation by the system (which uses the static network data on the CD-ROM and/or real-time information transmitted from the TIC), the LCD displays a straight-ahead, left-, or right-turn arrow indicator of the distance to the next required turn (onto the street listed at the top), supplemented by an auditory cue as the turn approaches. The street on which the vehicle is *currently* traveling is printed at the bottom of the display, which refreshes with a new direction and street name as each turn maneuver is accomplished, until the destination is reached.

5. ***Map*** mode: a "zoomable" north-up portion of the map network approximately centered on the vehicle's current location; this location is indicated by (a) the name of the street currently occupied (at the bottom) and the next street to be intersected (at the top), (b) a solid circular icon based on the GPS locator, surrounded by an orange ring if the vehicle position is receiving GPS range correction from the TIC (if the color of the solid circle changed from green to yellow, the GPS signal was being received from only three satellites; upon further loss of the signal, no circle whatsoever is shown), and (c) a red triangle

indicating the vehicle's position according to the MNA's map-matching and dead-reckoning computer function.

6. ***"ADJ"*** mode (accessed by a button on the display head): a prompt to change display brightness or volume of the auditory cue.

A few additional screens in the "MORE" mode, also accessed by button, enable users to identify or re-specify the trip starting point, enter their user identification and password, and modify other system control parameters. These screens were rarely accessed by the paid or volunteer drivers who operated project cars during the targeted deployment.

The display could not be toggled between route planning and map modes. However, a route plan could be canceled in navigation mode, and a stored destination could then be selected for route recomputation or the map could be accessed.

In ***ADVANCE,*** the planned route was not highlighted in map mode. The user could review an entire route in navigation mode by repeatedly pressing the "next maneuver" panel on the turn arrow display until the destination screen appeared. It was also possible to display the selected route length in miles (from origin to destination only, not from some intermediate point). If a driver deviated from a planned route in navigation mode, an "off-route" indicator appeared, accompanied by a warning chime and a query as to whether a route to the destination should be replanned from the current location. Touching the "YES" display button would reactivate the route planner, and the turn-arrow display would shortly reappear with the first maneuver in the new route sequence.

As applicable, real-time information passed from the TIC would indicate that a route different from that originally plotted could save at least two minutes. At this point, the display would chime and a window would pop up to provide the user the predicted total time savings and ask whether the new route should be taken; if "YES" was touched, the turn-arrow display would return with the first maneuver of the new route from the vehicle's current location.

Volunteer Driver Experience. It had always been intended that drivers resident in the study area be given the opportunity to experience the look, feel, and capabilities of the ***ADVANCE*** MNA for an extended period in their own cars and trucks. The targeted deployment reduced the opportunity for such an immersion experience to two weeks in a project vehicle. Nevertheless, evaluators believed that such a brief volunteer driver acquaintance with a prototype system could nevertheless generate much useful information for ***future*** development of in-vehicle navigation products and services. Thus, a focused test using study area residents was devised that had the purpose of providing drivers familiar with the ***ADVANCE*** test area an opportunity to use the ***ADVANCE*** system in their normal driving behavior for a relatively extended period of time. It was expected that these drivers could contribute useful perspectives on the characteristics and performance of the ***ADVANCE*** system and could help guide the design and development of future ATIS services.

This series of tests began in late July, with the most intense activity occurring from October through early December 1995. The tests involved families living in the test area that had volunteered to drive *ADVANCE*-equipped, project-supplied vehicles for a two-week period. These volunteer drivers completed both baseline and post-test surveys and maintained logs that noted malfunctions, problems, reroutes, and the drivers' responses. Subsequently, 30 percent of these drivers participated in focus groups that examined their experiences and reactions. This test and the follow-up focus groups were managed by Northwestern University. The results of the analysis of data arising from this test are presented in the evaluation report appended to this document as

Appendix I: Familiar Driver Perspectives on ***ADVANCE*** and Future Dynamic Route Guidance Systems Evaluation Report (#8462.01)

In addition, a formal study of the inherent safety of the MNA display and its potential for driver distraction relative to other means of route guidance was conducted by the University of Iowa under separate contract. Results of that analysis will be presented in a report to be separately submitted to the Volpe National Transportation Systems Center and the FHWA Joint Program Office.

2.3 TIC SUBSYSTEM

The TIC, located at the ***ADVANCE*** project office, provided all centralized computing resources for the system, including processing, distribution, and archiving of system descriptive (static) and real-time-generated (dynamic) data. The central computer was a Sun SPARC 670 multiple-processor server having 128-MB dynamic random access memory available, along with a 13.6 gigabyte disk drive, a 5.0-GB capacity off-line tape drive (for storage and archiving), and a CD-ROM drive. The rack modem for receipt of external data supported 16 slots (for the two 16-port synchronous interface cards) at 14,400 baud rates. The main operator consoles were Sun SPARC X-Windows terminals linked to the server by 10 BaseT Ethernet cabling.

All TIC software modules (including TRF processes, described below) interacted with the TIC data base and each other, using inter-process communication protocols without interrupts. Static data included the digital map data base of the road network, including link-by-link average travel times by time of day based on either the results of a network flow model or an updated (static profile) value derived from actual measurement. Dynamic data included expressway and arterial loop detector reports, vehicle probe travel time reports, incident reports from a regional 911 system, and any relevant weather data. Inbound message processes validated and managed reception and storage of reports from the Traffic Systems Center (expressways), Dundee Road loop detectors, and probe vehicles (MNAs), while the outbound processes involved a message scheduler that grouped updated dynamic data into packets for RF transmission to MNA-equipped vehicles. During the targeted deployment, these updates were transmitted at 4-second intervals, every fourth message being a differential GPS range correction. Outbound link update messages contained the IO-digit link identifier and travel time predictions for the current and ensuing 5, l0-, and 15-minute intervals. These messages (for any given link) were transmitted as frequently as the volume of updates permitted.

In general, during the targeted deployment, data were very infrequently lost (i.e., failed to be added to a scheduler bundle). The critical threshold was approximately 13 updates per message; if this total was exceeded in any update, messages were transmitted in a subsequent bundle, but if all bundles were at or above the threshold for five minutes, any unsent message(s) was erased. At any given time the TIC was simultaneously (a) receiving inbound information by RF on an almost continuous basis; (b) sorting and directing this information to log files, display windows, and/or TRF processing algorithms; and (c) preparing and scheduling for RF transmission outbound messages to project vehicles (about 15 times per minute). Up to 10 windows could simultaneously be displayed on the TIC console for operator viewing, use, and monitoring of system functions.

The purpose of the TIC evaluation conducted under the targeted deployment was to analyze the TIC hardware and software as a combined system, documenting reliability, examining system staffing, operation requirements, and overall cost efficiency, and assessing system design alternatives from the perspective of system transferability (to other sites and applications), maintenance needs, and ease and effectiveness of use by operators.

This evaluation began with a pilot test in September 1995, with the most intense activity occurring from October through early January 1996. Following a thorough review of system specifications, evaluators assembled data by means of the TIC real-time log, in which recorded known times and dates when malfunctions occurred were recorded. When a malfunction was identified, this log provided information on cause and remedial actions taken. Other automated logs created by the system describing separate processes were also examined, as were logs of such nonautomated functions as the entry of police dispatch and anecdotal traffic incident reports. Time stamps on each of these logs indicated how long it took for the TIC to formulate and transmit dynamic traffic messages, with and without operator intervention. Tests were performed to ascertain the maximum amount of data that could be entered into the system before incoming data were lost due to system overload. These tests determined if the TIC was adequate for the amount of data that required processing during the targeted deployment. In addition, measurements were made of the duration of the back-up cycle necessary to avoid compromising TIC functions.

Data were collected on the operational efficiency of the TIC in the absence of human intervention. This information was obtained by computing the amount of data entered *manually* as a percentage of total data used by the TIC (most data enter and are processed by the system automatically). To evaluate whether elements of the TIC architecture could be simplified without compromising system performance, there was an ongoing consultation process with a knowledgeable peer review team. These peers, familiar with the transportation situation in the Chicago area, also participated in a review process to consider the additional services that could be incorporated into the TIC operation by using functionality review documentation. TIC architecture capital and operating costs were assessed on the basis of all the available expenditure information provided by project partners and the ***ADVANCE*** project office.

The effects of policies, procedures, and staffing levels on efficient TIC operation were investigated by means of a structured questionnaire, observations, and informal discussion sessions with TIC operators and supervisors. The questionnaire was administered very late in 1995 to provide for maximum exposure of the operators to procedures in place at the TIC. In addition, a manual TIC-operator observation log was available at all times during the TIC architecture evaluation period to enable operators or the supervisor to note any issues relevant to operational practices. TIC operators and their supervisor were briefed at the outset of the evaluation period on the purpose and scope of the operational practices evaluation, informed of the purpose of the TIC-operator observation log and evaluator observations, and notified that they would be interviewed near the end of the evaluation period.

A structured questionnaire, evaluator observation sessions, and related log sheets were used to assess various aspects of the usability and functionality of the TIC user interface. The usability evaluation considered such elements of the interface as workstation layout, screen format, task and menu structure, demands made on the operator by the system for data input and process monitoring, and degree of feedback provided by the system to the operator. The functionality evaluation involved an assessment of interface features to identify additional features that might be required or desirable, as well as any features already provided that were superfluous.

The TIC Architecture and User Interface evaluation tests were conducted by DeLeuw, Cather & Company, with the assistance of Castle Rock Consultants. The results of the analysis of data arising from this test are presented in the evaluation report appended as

Appendix K: TIC Architecture and User Interface Evaluation Report (#8464.03)

2.4 COM SUBSYSTEM

Because a proven product was employed, no formal testing of the fourth subsystem, the RF communications (COM) component, was conducted as part of the targeted deployment. The successful functioning of the other three components was always dependent on the efficient functioning of COM, so to the degree that these other subsystems performed according to specification and fulfilled their desired objectives during the targeted deployment, COM was also successful. Moreover, no weaknesses or malfunctions of any of the other subsystems during testing were ever attributed to a failure of COM as an independent operation (i.e., when its response performance, such as for providing differential GPS corrections, was unaffected by the response time delays for other MNA functions).

It should also be noted that a high-speed communications system was developed for application in the full ***ADVANCE*** deployment. Although targeted deployment did not require use of this system, details about its initial concepts are available in Section 4 of the System Definition ***Document, #8020.ADV,*** in the Insights & Achievements White Paper B of ***Document #8465*** appended to this report, and in a series of technical reports on RF COM design and acceptance testing that can be downloaded from the ***ADVANCE*** Internet page at the URL **http://ais.its-program.anl.gov/.**

3 EARLY RESOURCE, PHYSICAL, AND INSTITUTIONAL CHALLENGES TO EVALUATION

As scoped, some of the evaluation tests scheduled to begin in August 1995 required up to 22 vehicles to be in the field at any one time. Conduct of routine maintenance combined with the occasional necessity of unplanned repairs dictated that the pool of equipped vehicles at the project office exceed this requirement by at least two vehicles. At the outset of testing in June, 15 to 18 equipped vehicles were fully under the project's control. The evaluation manager secured eight additional vehicles in mid-July through a rental agreement, such that the project "motor pool" had sufficient change-out flexibility by the commencement of the most resource-intensive tests, to enable all tests to be conducted with full vehicle complement. Also in late August, six additional vehicles were obtained from the Ford Motor Co. for use in the field tests. Thus, ***ADVANCE*** reached the full population of 30 fully deployable vehicles. These 30 vehicles remained in service from late summer to the completion of field testing on December 14. From this experience it was learned that a daily procedure was required to assure that availability of test vehicles match the resource requirements of the test(s) to be run on that day.

In 1995 the Chicago region experienced one of its hottest summers on record. Although the discomfort of drivers could be alleviated by using air-conditioned vehicles, some of the electronic components of the in-vehicle systems, specifically the CD-ROM drives, were mounted in locations (such as the trunk) that were not cooled from the passenger compartment. As a result, these drives experienced functional difficulties, attributed largely to the high-temperature environment in the trunks of some of the vehicles. These components were frequently exposed to temperatures in excess of 65 degrees Celsius, although the drives themselves were not certified for functioning above 60 degrees. Late in June, all test vehicles received replacement drives that operated successfully up to at least 65 degrees Celsius, and systematic drive failure and degradation of MNA performance ceased thereafter when reasonable precautions were taken to keep the trunks cool (e.g., parking cars in shaded areas and opening trunk lids during breaks).

The project required drivers participating in the ***ADVANCE*** tests to meet certain insurance requirements. During the driver recruitment phase, it was the recommendation that paid drivers provide their own insurance. This option would have proved difficult for a number of potential drivers who did not own automobiles. Ultimately, ***ADVANCE*** assumed the insurance coverage cost for the paid drivers, and this ceased to be a problem before even driving began. However, ***ADVANCE*** legal counsel suggested that paid drivers sign a waiver limiting the liability of the ***ADVANCE*** project for any accident that happened when the drivers were on duty in the field. The language of this waiver was legalistic and not well understood by most drivers. Early in the test process, several of the drivers became quite concerned about the liability risks they faced in their daily work. This became a topic of discussion among the group of drivers and ultimately resulted in several of the drivers quitting because the perceived risk was unacceptable. To preclude loss of more drivers, the Northwestern team arranged for the university's Risk Management Office to conduct a detailed review of insurance coverage provided to drivers employed by the university. The review made clear that the drivers were protected by three levels of insurance: the university's own insurance (as Northwestern was the employer of record); insurance carried by the Illinois Universities Transportation Research Consortium; and the policy carried by *ADVANCE.* The risk managers determined that drivers were amply covered — a point the waiver form failed to make clear, thus giving rise to the perception of hazard.

4 DATA COLLECTION ACTIVITIES AND PROTOCOLS OF THE EVALUATION FIELD TESTS

4.1 EVALUATION OF TRF

The objective of field data collection by paid drivers in support of the TRF evaluation was to have a series of structured driving activities over a route defined by a sequence of links. After the completion of each route, the drivers would pass through a staging area, where they received further instructions. The problems encountered in selecting the staging area and the route are discussed in this section.

Characteristics of the Staging Area. In order to properly coordinate driving activity, a staging area was necessary. The staging area needed to be close to the route (in distance and travel time) and of sufficient size that several probe vehicles could be parked at one time for short durations. The ideal staging area would be a quiet street just off the main route, where it would be possible to turn around safely and proceed back to the route.

After eliminating several unsatisfactory candidates, two principal staging areas were finally selected, one near a cul-de-sac with small office buildings and the other in a residential area. Research staff notified police officials in the municipality where tests were being conducted, and the law-enforcement community was made well aware of activities beforehand. However, concerned citizens called the police near both staging areas. There were no complaints from the businesses near the cul-de-sac. While most of the residents near the other staging area were curious and, after being briefed about the work and its purpose, very supportive of it, the members of one household expressed a strong desire for the tests to be conducted elsewhere. Although drivers were instructed to comply with the speed limit in the residential area (in fact, they drove slower than the other vehicles on the street), the additional traffic was not welcomed by some households. When activities were relocated to another residential staging area where approval of the neighbors in the immediate area had been obtained in advance, yet another unhappy home owner was encountered. His reaction was prompted by the presence of technicians who were called to check a few vehicles that were having problems with their MNAs. The home owner objected to the conduct of such testing and repair on the nearby street. When the repairs were subsequently conducted in an off-street open area away from homes, complaints ceased. In general, complications cited above were resolved without problems.

Characteristics of the Route. Several factors needed to be considered in defining the route used in the analyses. The route had to be sufficiently short so that a high density of vehicular coverage could be achieved. There were a variety of tests to be performed and each had its own requirements. The density of coverage could be varied by using different fleet sizes. The largest number of probe vehicles necessary was fifteen. These probe vehicles needed to travel a route that included a variety of link types, loop detectors for signal actuation, and detectors for volume and occupancy data. The arterial selected (Illinois Route 68, shown as Dundee Rd. on Figure 2) had detectors at all of the key intersections, but the detectors recording volume and occupancy information did not provide coverage that would have been considered optimal for data collection. For example, it would have been desirable to have detectors collecting volume and occupancy data for two sequential or at least closely separated blocks along the same roadway to permit link-to-link correlation of data. However, one of the project's goals was to rely on the utilization of existing systems for additional input to the TIC. This being the case, major changes to the normal "closed-loop" signal system and detector configuration on Dundee Rd. were not undertaken.

Given the elements described above, actual choices were very limited. Some prospective routes were very long, not in distance but in travel time. For example, the link on Dundee Rd. just east of Illinois Route 2 1 (shown as Milwaukee Rd. in Figure 2) looked very promising, but during the peak period, it was so congested that more than five minutes were typically required to complete a traversal. The other problem with this link was the lack of a safe place to turn the vehicles around.

Approximately 60,000 miles were driven in urban traffic. Driver safety was very important — hundreds of routes would be driven each day. There was to be a basic route and another for conducting tests on turning relationships. The initial expectation was that a selection would be made from several alternatives. In reality, it was impossible to identify a route that met all expectations. Thus, the process of choosing a route ultimately eliminated, for one or more of the reasons discussed above, all but the route that was selected. With a much larger driving fleet and a smaller range of tests, a broader final choice of routes would have been available.

4.2 DRGND AND ID EVALUATIONS

A typical day in the TIC during the DRG/YD and ID tests began at 2:00 PM. Drivers signed in and were assigned vehicles for the yoked test or chose a vehicle for the ID test. Route assignments and any other special messages or instructions were given. Generally the drivers were on the road by 2:30 PM. Vehicles were tracked and drivers were called if MNA reports were not received every 10 minutes. When called, drivers were asked about their MNA and traffic conditions. A decision was made in the TIC as to the likelihood of a probe reporting malfunction, and drivers were given instructions to reset the MNA if there appeared to be a malfunction or to standby otherwise.

For the YD test (vehicles starting at identical times over the same route), probe vehicle drivers were divided into six teams of two or usually three (dependent on driver or vehicle availability), plus two dynamic yoked vehicles and one static yoked vehicle. Each driver was given a booklet of route plans that showed each origin-destination (OD) pair, the staging area for each run, and the route to be taken. Captains were appointed for each team; each captain was given a form that listed dispatch times for each team at each OD pair. A field manager, appointed for the test, was present on-site to start the test for each assigned OD pair and to oversee the dispatching of probe and yoked vehicles. The field manager used a watch synchronized as closely as possible with the TIC clock to determine the time for each test start. This time was also recorded in the TIC by the test manager. The field manager and all drivers were in contact with the TIC by cellular telephone.

When each driver finished a run, he or she called the TIC, and the finish time was recorded. Precise recording of the finish time was not critical for the test; however, early in the process it provided feedback on whether the route start times and lengths were appropriate. For example, yoked vehicles arriving well before some of the probe vehicles would be an indication that the probe vehicle launch time may have been designed to start too late. Calling in the finish time also established a communication channel between each driver and the test manager and served to improve driver performance and consistency.

Staging areas for the DRG tests were different from those for the TRF validation tests because that 2 1 or more vehicles were involved. This larger number required larger staging areas and advance permission from property owners to assure that the ***ADVANCE*** vehicles would be accepted. Vehicles were staged in parking lots of forest preserves, schools, and shopping centers of various sizes. In the case of school lots, prior arrangements for use were especially important because, on occasion, the timing of yoked driver tests placed 2 1 vehicles in a school lot while the school was still in session.

The choice of staging areas had a direct effect on the actual routing of yoked vehicles in the case of certain OD pairs. For example, when vehicles were staged in a large shopping center at the intersection of two major arterials, drivers might be routed into traffic by one of three or four exits separated by some considerable distance. In at least one case, some of the routes followed arterial streets at the edge of the subnetwork in which the OD pairs were laid out, and included local “collector” links not adequately covered by probe vehicle travel time reports. This situation suggests a need for careful on-scene supervision to understand exactly where drivers are staging and what routes they are following in and out of staging areas.

For the ID test, a computer log file was electronically transferred from the Northwest Central Dispatch (NWCD), a computer-aided police, fire, and ambulance dispatch center serving six communities in the middle of the ***ADVANCE*** test area. This file was monitored in the TIC to identify incidents deemed appropriate to observe. When an accident with injuries or accident with property damage occurred in the vicinity of the driver assignments for the day, the test manager called the appropriate driver, asked for his or her location and, if they were close enough, sent the driver to the incident location. The test manager fielded calls about the existence of the incident and the nature and location of the incident if it was sighted. The test manager then gave the drivers further instructions about the traversals they were to make. It was helpful to listen to the NWCD dispatcher’s band on the radio because often a more specific location or description of the incident was available. Logs were kept of each incident observed, both in the TIC and by the driver. At 6:45 PM, drivers were instructed to call the TIC to receive directions about finishing their routes and returning to the TIC. Drivers returned to the TIC between 7:15 and 7:30 PM. Upon their return, the test manager made sure appropriate forms were submitted.

4.3 REAL-TIME DATA RETRIEVAL TRACKING

Both the evaluators and the evaluation manager maintained procedures to minimize data loss while field tests were in progress. A set of forms for real-time "hard-copy" recording of information was developed to assure post-test capability to trace the time and cause of specific events having the potential to disrupt or even invalidate data collection. A tracking check-sheet was used to assure that probe reports from vehicles known to be active were arriving at the TIC at acceptably short intervals. If an automated report from a given vehicle had not been received at the TIC for 7 or 8 minutes, its driver was contacted by cellular phone to determine if a problem had developed. The tracking form was supplemented, if vehicular or system problems were encountered, by a "problems" log book entry for that day. Paid drivers for the TRF tests also maintained daily running logs, which were used to record specific run durations, as well as to document unusual occurrences, such as railroad grade crossing delays, signal cycle failures due to congestion, or other events that precluded completion of a route according to a stipulated test procedure. The logs also indicated when the drivers believed they had lost functionality of the in-vehicle navigation unit or were otherwise out of communication with the TIC.

Data forms for yoked vehicles in the DRGND tests showed the routes the vehicles had taken and any reroutes. (The test start and finish times for each vehicle were also recorded on a form in the TIC.) For the ID test, the data forms were a reconnaissance form and an incident form used by drivers and two forms used at the TIC. The reconnaissance form was used by drivers to record the location, date, and roadway impacts of construction activity. The incident form was used to record the date, type, and location of incidents that were observed by drivers. The test manager in the TIC used the incident data form to record NWCD log number, vehicles assigned, type, and date and time of incidents observed; the test manager recorded dates and link locations of planned construction lane closures on the construction data forms. A form that listed vehicles, drivers, and assignments was also completed in the TIC for both the DRG and ID tests.

4.4 DATA CAPTURE AND ARCHIVING: DAILY TEST LOGS

The complete set of daily logs of all electronic reports received by and dispatched from the TIC for each test day (covering the period approximately 6 AM to midnight) — MNA reports, loop detector reports, NWCD incident reports, TRF messages (travel time projections), and DGPS corrections — were retained on disk storage media on the TIC computer. Early on the morning of the next day, a process was automatically initiated to compress these logs into a tar_gz file, which was transmitted via a T3 telecommunications link to a data server/host at Argonne. The Argonne server automatically uncompressed the tar file and wrote the complete set of logs for the preceding day to a password-protected data page as the files for the current calendar date (the data page entries for "September 22" would all be September 21 field data). Time stamps were retained for all log records, permitting evaluators to re-create project vehicle routes, route sequences, and contingent events according to a precise chronology. Data on the Argonne server were made available by

Internet FTP or http links to remote locations where the evaluators conducted downloading and analysis.

4.5 DATA CAPTURE AND ARCHIVING: MEMORY CARD FILES

Every Friday during field tests, the PCMCIA cards containing link traversal data recorded on board each vehicle were removed from the project vehicle MNA display heads by project office staff and downloaded by card reader. None of these cards ever exceeded or even approached its 2-MB (formatted to 1.44 MB) capacity over a week of testing. In addition to time-stamped link traversals, the cards also recorded vehicle position at two-second intervals as referenced to a map grid developed by Motorola. These binary-coded files were converted to ASCII at the TIC, then both the original binary and new ASCII files were transmitted electronically to Argonne. The ASCII files were installed weekly on the data page as dated entries in a special subdirectory.

4.6 FAMILIAR DRIVER DATA COLLECTION INSTRUMENTS

Continuous monitoring of vehicle movements was neither necessary nor desirable during the two-week periods in which drivers familiar with the roads system in the ***ADVANCE*** test area used MNA-equipped project vehicles based at their respective residences. However, these drivers were asked to complete three different types of information recording instruments as part of their agreement to participate in the program:

1. Baseline survey, filled out prior to receiving a project vehicle, providing the characteristics, driving experience, and previous use of traffic information services (e.g., radio, cellular phone) of each participating driver (up to 2) in the household;

2. Re-route logs, to be filled out during the two-week period at any time that a driver decided not to use an *ADVANCE*-system-provided route or received an alternative routing option while following an MNA-preplanned route; and

3. Exit survey, recording each driver's overall end-of-test response to and reactions about the two-week route guidance experience.

Obtaining the completed first instrument was quite trivial in that no household would be issued a vehicle without it. Thus, data capture was 100 percent. Of 80 households participating, 74 completed at least one re-route log, while a few completed as many as 20. Obviously, there was no way to verify that all re-routes were recorded by each of the 74, or that no reroutes were actually presented to or undertaken by the remaining 6. Finally, 78 of the 80 households returned the exit survey.

5 EVALUATION DATA COLLECTED AND ARCHIVED

The following electronic data files were captured *daily* during the targeted deployment field tests and used subsequently by evaluators in support of their analyses.

mnarep.log (date): the previous day's link traversal reports by probe-equipped vehicles (including those not directly involved in the evaluation tests but which were used in updating the static profile), listed chronologically by MNA time stamp. Northwestern University used a version of this log specially modified by Argonne that incorporated the street name of the link and the historical (static profile or base data) average travel time estimate for that link at that time of day.

dundee log, tsc log (date): the previous day's five-minute average volume and occupancy estimates from, respectively, the Dundee Rd. (Ill. Route 68) and Traffic Systems Center (freeways) detector master controllers. Northwestern University used a specially modified version of these logs that provided one-minute estimates.

msgsch (message scheduler).out (date): raw output of all of the previous day's four-second message bundles, containing link travel time updates and GPS range corrections transmitted to all probe vehicles, ordered chronologically by TIC time stamp (these are very large files).

nwcd.out and incidentTracker logs (date): raw and operator-processed descriptive records, respectively, of the previous day's emergency vehicle dispatches by incident type and (subsequent) incident closeouts in the Northwest Central Dispatch area — covering a large portion of the *ADVANCE* study area — organized chronologically by TIC time stamp.

shortLinkResolver log: chronologically-ordered instances of execution of the short link resolver to explain an "impossible" link traversal (i.e., a very low traversal time or an instance of disconnected links in consecutive probe reports); this information was needed occasionally in reconstruction of probe vehicle routes.

tscO.out: raw freeway detector report data from the Traffic Systems Center. Rarely used.

ttp.out: output of the travel time prediction algorithms from probe and, as applicable, detector data, used to generate 5-minute-interval link travel times estimates for the current, the 5-minute-ahead, the IO-minute-ahead, and the 15-minute-ahead intervals; used by UIC-UTC during its evaluation of the performance of the traffic-related functions.

ssi.out: weather forecast output. Rarely used

dataServer log: used during the TIC architecture evaluation to track server up time and on-line functionality; also could indicate TIC instability.

The following data from the on-board PCMCIA memory cards were captured *weekly* from late July onward during the targeted deployment field tests and used subsequently by evaluators to complete their analyses:

- Link traversal file (listed chronologically by the modem identifier uniquely assigned to each probe vehicle) containing the travel time report and hexadecimal link identifier (plus actual street/segment name as translated by Argonne).

- Location identifier messages (in Motorola-supplied coordinates translated to latitude/longitude datum) written every two seconds by each probe vehicle's MNA.

All manually recorded instruments from the familiar driver tests — baseline surveys (130), reroute logs (74 sets, or about 400 individual logs), and exit surveys (110) — were coded and uploaded to the data page for ease of tabulation by NUTC staff.

Data capture and archiving were generally successful from early June through August, despite the brutal heat on most test days; after the overheating problems with the CD-ROM drives were mitigated, the only systematic log data losses occurred on those few days when the TIC went down for brief periods or was not properly started in the morning (resulting in the daily log storage process failing to execute and null files being generated for some logs). In most cases, after July, data lost in this manner could be reconstructed from memory card files.

Archiving success was somewhat more uneven during the autumn months. At one point in late September, both a loss of log data and a malfunction of PCMCIA functions in one or more vehicles (plus a possible failure to download data from one vehicle's card for a particular week) resulted in irrecoverable loss of some electronic yoked vehicle test records during the incident delay simulation phase of the DRG evaluation. Thus, much of the incident simulation portion of the DRG tests ended up relying on manually collected driver logs for route timing information. There was also electronic data loss in November during the post-construction traversal time follow-up field tests for incident detection, but consequences of this loss were somewhat less critical than for DRG.

Both the daily field test logs, filed by (following day's) calendar date, and weekly memory card data, filed by vehicle modem identifier, are currently retained in compressed (tar_gz) form on a data sub-page of the ***ADVANCE*** Web page, accessible by user password. In due course, when all evaluators and the ***ADVANCE*** partners have completed the analyses they expect to perform using these data, the Steering Committee will approve opening the data page, with appropriate annotations, to access by the research community at large. It is expected that this will occur by January 1997.

6 LESSONS OF THE PARTNERSHIP AND THE TARGETED DEPLOYMENT TEST PROCESS

Four years of cooperative project experience and system development followed by seven months of field evaluation posed a wide variety of technical and management challenges for ***ADVANCE*,** alongside of which was the ongoing evolution and growth in understanding of public/private partnerships. The project's colorful and illustrative history has contributed valuable insights into approaches that are effective, and those that are less than satisfactory, in the deployment of an ATIS. We summarize below some of the most instructive of these insights.

All parties involved in the ***ADVANCE*** project had prior experience in related efforts. However, no one had the experience in all facets of such a project or in large-scale technology development and implementation efforts involving a *public-private partnership.* All of the parties to the ***ADVANCE*** Agreement of 1991 committed significant resources to the project and worked diligently in a spirit of cooperation, which was evident not only in technical areas but also in the commitment of public information, audit, and administrative staff brought into ***ADVANCE*** by the parties. As events transpired, without this degree of commitment by all parties, the project might well have failed and thus retarded both the prospects for and promise of public-private partnerships in transportation. Nevertheless, arduous efforts among project management staff and all public and private sector participants were occasionally necessary to resolve complex and delicate issues: such a development must be anticipated for any public-private partnership deployment.

ADVANCE had much in common with applied research, in addition to systems design. (Research often requires a creative process that is not conducted on a rigorous schedule, as much as managers wish to the contrary. This is especially true of the conceptual stages of a project.) ***ADVANCE*** applied the time-honored management structure of dividing large tasks into smaller subtasks and even sub-subtasks. The general experience with ***ADVANCE*** can be summarized by stating that more aggregated techniques proved to be more acceptable to designers than more detailed techniques. Given a milestone chart that highlights interfaces between parties, a group of project leaders could better visualize the task, discuss deadlines, and progress towards them in a meaningful way. However, it remained open to debate whether the more detailed description of tasks provided any useful insights or measures of progress. As with any administrative process, excellent communication and explicit, even-handed application of procedures can help facilitate resolution of the difficulties of this unusual institutional format.

Some general observations about management of public/private enterprises gleaned from the ***ADVANCE*** experience are as follows:

- Ensure that the project manager's role is distinct and separate from those of project partners;

- Take all necessary measures to retain key project leaders and legal and financial personnel from the point of project conception to its completion and require each participant organization to designate a certain position responsible for executing all contractual documents;

- Fully develop and understand all procurement processes with commercial enterprises before executing an agreement and ensure that the project adopts procurement and audit procedures meeting the internal requirements both of a private sector firm (with a commercial focus) and of governmental agencies (with a regulatory focus); and

- Organize administrative-type committees among the major parties to handle important non-engineering issues.

In developing an integrated ATIS involving an information center processing data streams in real time, an in-vehicle guidance system, and continuous center-to-vehicle communications, it is appropriate to (a) assure early and constant communication among the designers and developers, (b) develop standard guidelines for documentation that will be followed throughout any project, especially one of size and complexity comparable to that of ***ADVANCE*, *(c)*** assure access by system developers to information related to all subsystems, even if some subsystems contain proprietary information, (d) ease complexity of the integration testing effort by "freezing" the system release level while integration is occurring (i.e., perform all of Release 1 testing for all subsystems before proceeding to Release 2, and avoid "interim" releases of component subsystems that are out of synch with other subsystems), (e) thoroughly test all subsystems before they are submitted to integration testing, (f) design into the development process a channel to provide input and feedback from operations personnel so that designs do not proceed in an inappropriate direction, (g) ensure that system integrators have the capability to examine internal data flows and data values during testing, and (h) record and track any problems not fully resolved and requirements not met during testing.

The design of large demonstrations similar to ***ADVANCE*** should reflect what can be done with existing technology, rather than emphasizing the use of unproven technology. A specific example of this design philosophy in ***ADVANCE*** was the unavailability of low-cost, high-speed, industry-standard equipment to serve MNA/TIC communications during deployment. In the targeted deployment scenario, a 4,800-bps system was adequate. However, performance of this carrier technology, like that of some other subsystem components, would have been inadequate under full deployment. Hence, ***ADVANCE*** needed to make provision for a high-speed system during the development phase of the project. It is likely that technologically advanced integrated systems would have been needed under full deployment to enable the vehicles to function reliably in the wide range of environments encountered by moving vehicles and to meet high standards for vehicle positioning accuracy.

In carrying out field tests using hired drivers, unexpected situations are likely to occur. Whenever paid staff must be procured, problems will arise because of the time limitations in getting all particulars finalized, especially those relating to liability insurance coverage. Resolution of insurance issues should be given the highest priority before field testing protocols and schedules are finalized. Paid drivers for specific tests should be hired on the basis of an interview conducted no later than a few weeks before the start of the test. Other means of recruitment evaluation are likely to prove less satisfactory. With respect to vehicular resources, ensure before testing begins that availability of test vehicles will match the requirements of the test(s) to be run on any given day; account for vehicles scheduled for maintenance and repair under tracking procedures like those adopted for ***ADVANCE.***

If vehicle staging areas are located in residential areas during field tests, it is not likely that all potential objections from neighboring residents can be anticipated and allayed in advance. Nevertheless, prior clearance with local law enforcement and directly affected institutions (school, shopping areas) is essential for both logistical and diplomatic purposes. Moreover, even after testing begins, there may remain the need for careful on-scene supervision to know exactly where drivers are staging and what routes they are following in and out of staging areas.

Written logs should be maintained to document unusual events during field tests: paper trails are vital to attempting after-the-fact diagnoses of operational problems that resulted in lost or corrupted data. Where electronic data collection is used, a backup automatic data retrieval system should be considered for critical field testing.

While the quality of probe link traversal data reporting in the ***ADVANCE*** tests was very high — indeed, such data proved a more reliable basis of real-time travel-time estimation and prediction than data from arterial loop detectors — the quality of prediction of arterial travel times could be increased even more by including data on the timing and phasing of traffic signals. This finding may provide guidance for algorithm development for future ATIS deployments. However, such algorithm development must take into account the facts that probe-vehicle travel-time reports are not independent, (the condition of statistical independence is assumed in developing most statistical formulae), that travel times themselves are highly stochastic, and for some computations, the effects of nonindependence of reports and large variances in values for a given link can be great.

For tests involving volunteer drivers who will operate either project vehicles or their own vehicles as part of a test and later complete surveys, any pretest agreement should stipulate an explicit reward for timely completion of or penalty for nonresponse to survey instruments; otherwise, it is almost certain that the post-test survey response rate will fall short of 100 percent of the data base target. Moreover, never assume that in all prequalified, two-driver households, both drivers will drive the vehicle, unless instructions and incentives are offered to ensure that both drivers will participate in the test. Even if all households selected were two-driver units, it appears that only about 1.4 drivers per household will actually participate unless special steps are taken to ensure each driver uses the vehicle.

Volunteer driver recruitment involves a different set of considerations than paid driver recruitment and, depending on the number of volunteer drivers involved, may well require substantial resources and planning up-front to execute effectively. Focus groups and surveys can be effective tools in designing experimental conditions and participation agreements. Both paid and free advertising well in advance of testing will be required for volunteer solicitation, and specific attention to the content of solicitation materials is necessary to avoid under-representation of women, older drivers, and the physically challenged. Application forms and driving record checks are advised to ensure that candidates meet sampling and screening criteria. The recruitment process should be implemented by a knowledgeable and efficient single-point-of-contact agency representing the interests of all participating parties. The agency should employ an efficient and responsive computer data base for contract management in any test involving a large number (hundreds to thousands) of volunteer drivers. With respect to orientation of volunteer drivers, it was found in *ADVANCE* that one-on-one training in test vehicles quickly prepared the drivers for safe and efficient use of the MNA system.

In ***ADVANCE*** the paid driver field tests preceded those in which local residents (volunteers) used the project vehicles. Thus, virtually all system operational problems could be resolved prior to the time period allocated for most of the public use of the vehicles (i.e., by the volunteer drivers). It is recommended in future evaluations using a single set of equipped vehicles for both focused tests and more general public exposure applications that all paid-driver-system verification testing be completed before turning project vehicles over to volunteers.

The *ADVANCE* MNA-based route guidance system was found to be at least as safe as, and possibly safer than, use of paper maps or a typed list of instructions for drivers both with and without prior experience using the in-vehicle display. This finding was based on the comparative number of driver errors and "near misses" (driving proximate to a hazard present in the roadway environment) observed under each means of navigation by trained experimenters who accompanied these drivers in an MNA-equipped vehicle. However, no benefit to driver performance was observed by the auditory (voiced instruction) supplement to the MNA display, a finding which departed from that of at least one prior study (the TravTek demonstration in Florida) in which the auditory cues, while acoustically and aesthetically less pleasing than that of the ***ADVANCE*** MNA, did increase driving and navigation performance. Thus, there is evidence that designers of future ATIS navigation systems should devote further effort to exploration of the effects and value of voice message content, aesthetics, and timing, and their relationship to driver performance, safety, and preferences.

The design and implementation of ATIS projects will require people of profoundly different disciplinary backgrounds and even greater variations in institutional settings (corporate, government, and university) to work together cooperatively and effectively. Effective collaboration requires the institution of a defined committee structure; in ***ADVANCE,*** such a structure — the System Issues Subcommittee — was in place for purposes of algorithm development. This body ensured effective collaboration and, when necessary, enabled successful decisions to be made focusing the combined resources of all partners on commonly agreed objectives. In general, development of ***ADVANCE***-type multicomponent algorithms should be based on the use of a unified structure, preferably based on field rather than simulation data. However, it is reasonable and appropriate to use simulated data as a preliminary starting point, subject to validation and refinement when field data become available.

The ***ADVANCE*** development plan called for *parallel* development of the technology and the algorithms that would make the technology useful to drivers, and during much of the project, development did occur concurrently with implementation. While performing tasks simultaneously rather than sequentially enabled more rapid completion of the project than would otherwise have occurred, it also created difficulties. One such impediment to development of the travel-time algorithms was a lack of actual probe data for algorithm development, refinement, and validation prior to the commencement of testing. Future development programs should allow adequate time for such data collection, with the full technology in place, before finalization of the algorithms that will interpret data for traffic analysis.

Nothing revealed by the ***ADVANCE*** field tests refutes the conclusion reached in prior studies that reliable real-time information during periods of *nonrecurring* congestion has a very high value and usefulness and thus should be a key component of ATIS deployments similar to ***ADVANCE.*** To maximize the probability that real congestion reduction (and associated emissions improvement) will result from an ATIS deployment, the system should (a) communicate accurate information on link traffic conditions to ATIS users with the shortest possible delay and (b) offer an accurate, reliable route planner. In addition, would-be purchasers of ATIS services need to be convinced that real, measurable benefits *will* accrue. The road network in which this system is to operate must possess alternative route options that are faster and not too much longer (significantly greater length can mean higher emissions) than the original route of choice and that generally have excess capacity (mitigating the problem of diverted congestion). In general, the gap between system *potential* and actual system *performance* must be closed before the confidence of ATIS users can be won sufficiently to make them act consistently on ATIS guidance.

ADVANCE was able to achieve its basic goals at significant savings in time and money by adopting the targeted deployment strategy. As conditions changed from those in existence at the time of signing of the original agreement, project management and the project Steering Committee remained vigilant and appropriately redirected effort to achieve an overall benefit from the project, even though specific development targets were at least temporarily abandoned in favor of more promising and better-informed evolving projects. Given this experience, ***ADVANCE*** established that the use of a multiple decision point framework as a project progresses should be considered in all major operational tests.

7 THE EVALUATION TEST REPORTS: A SYNOPSIS OF FINDINGS

Eleven evaluation test reports and a twelfth report comprising a compendium of "insights and achievements" white papers were prepared under the evaluation test plans co-developed in May 1995 by Booz-AIlen & Hamilton and the evaluation teams at the UIC-UTC; NUTC; and DeLeuw, Cather & Co. This section summarizes the salient findings of the 11 test reports. Details regarding the design of each evaluation, the structure of field tests, and resulting data analyses are contained in the reports themselves, which are appended to this overview document.

7.1 BASE DATA AND STATIC PROFILE (#8460-01) (APPENDIX A)

The purpose of the base data and static profile evaluation was to assess the quality of the base data of link traversal times, estimated by simulation using a Network Flow Model (NFM), and the quality of the (approximately quarterly) static profile (SP) updates of these traversal times, estimated with actual probe and loop detector data collected at the TIC. Validation of both the NFM and the SP was based on data from a representative sample of links by comparing probe data to corresponding (time-of-day) values in the NFM and SP, respectively. In general, there was inconsistent correspondence between peak and off-peak traffic volume estimates as provided by the NFM and by the actual arterial traffic volumes recorded by in-pavement detectors, due to a wide variation in the quality of the NFM estimates (good to very poor) of speed and travel time on the subset of study area road links analyzed. The discrepancy was attributed to either inappropriate cost functions in the NFM or obsolescent origin/destination counts (which were based partially on 1990 data). Whatever the reason, it was found that, especially after a few updates, SP values for the same links were exceptionally accurate. The updating algorithms performed robustly against occasionally idiosyncratic probe reports. Profiles based on probes only were found to be more accurate than those based on both probes and traffic signal system detectors. Analysis results indicated that a recommendation to modify the SP algorithm into a continuous, rather than stepwise, function incorporating data on traffic signal timing would be appropriate for future applications.

7.2 DATA SCREENING (#8460-02) (APPENDIX B)

The purpose of the data screening (DS) evaluation was to assess the performance of the screening tests for on-line probe and detector data within the data fusion function. The goal of these components is to remove probe and/or detector reports that are unreasonable, probably attributable to malfunctioning detectors of MNAs, and/or inconsistent, attributable to the presence of incident conditions, according to preset criteria for acceptable minimum and maximum values. In order to test that these components were properly implemented in the TRF design, their limits were tested with simulated data. Then the actual performance of the algorithm was tested using real probe and detector reports. For the simulated data, the DS algorithm performed as designed. For actual data, there were several instances in which a report failed the screening test for inconsistency but no incident was present. However, in most of these cases, a malfunction of the MNA reporting process had apparently occurred. The overall screened-data-consistency success rate was 99% for probe reports and 92% for arterial detector reports. It was concluded that, while performance of the DS algorithm was not satisfactory with respect to identifying incident conditions on arterials, the DS screening was very effective in identifying the rare occasions when MNAs malfunctioned; for this reason its use was continued because the resulting data base was better with it than without it. Among recommendations for modifying the DS algorithm were (a) apply lane volume rather than total approach volume, possibly by dividing total approach volume on a link by the number of mid-block lanes as reported in the attribute data base and (b) relax the testing criteria for screening detector data consistency but tighten the restriction on maximum (permitted) probe link travel time.

7.3 QUALITY OF PROBE REPORTS (#8460-03) (APPENDIX C)

The purpose of the quality of probe reports evaluation was to systematically compare probe-reported values with "reasonable" values for each link and also with manually reported travel times and congested distances (distances traveled and speeds of 2.5 m/s [about 5 mph] or less). Some 50,620 probe reports were collected and examined, of which 88 had unacceptably high speed, 95 had unacceptably high congested distance (longer than the link itself), and 115 had an unacceptable match between congested distance and congested time (i.e., time on the link spent at speeds at or less than 10 m/s [about 22.5 mph]). Of these latter 115 reports, 11 were also in the set of unacceptable speed reports. Thus, 287 reports were found to be suspect, or about 0.6 percent of the total, and many of these were traceable to a single faulty MNA. Further, when 776 of these probe-reported values were compared to manually recorded values observed for link travel times, 87.6% of the probe values were within plus or minus five seconds and 94% within plus or minus ten seconds, with substantial clustering within two seconds or less. The overall conclusion was that MNA data as deployed in *ADVANCE* proved a reliable indicator of traffic conditions and thus could provide a valuable resource for traffic monitoring and analysis in future ATIS deployments.

7.4 TRAVEL TIME PREDICTION AND PERFORMANCE OF PROBE AND DETECTOR DATA (#8460-04) (APPENDIX D)

The purpose of the travel time procedures evaluation was to assess the quality of the travel time prediction (TTP) algorithm, which used both probe and detector data to generate link travel time estimates for each of four five-minute intervals: the current interval, and each of the three intervals beginning five, ten, and fifteen minutes into the future. Values of these predictions on four links of the study route (see Figure 1) were compared to actual electronically recorded travel times experienced by paid drivers, and the sensitivity of prediction accuracy to varying levels of probe deployment was also examined. Two links with detectors were selected for detailed examination. It was found that both detector and probe data performed reliably as a source of input to the algorithm during the off-peak period, but during the peak period the arterial detectors, whose primary function, as mentioned above, is to regulate traffic signal timing, quickly became saturated (i.e., overloaded with vehicles stopped in the queue spilling back from the link ahead) and yielded unreliable travel time predictions. Probe-based predictions were more accurate, but during peak periods, the probes also substantially underestimated actual travel times. This suggests that the prediction algorithm may have been calibrated too conservatively (i.e., somewhat too willing to ignore clusters of high probe travel time reports). Appropriately, the algorithm does ignore outliers when only one or two appear in a five-minute interval, and thus generally performed well in such circumstances. It was also found that in most instances, predictions changed substantially from one to three probe reports per five-minute period but changed very little with increasing numbers of probe reports. This finding is consistent with that of the frequency of probe evaluation (see below).

7.5 DETECTOR TRAVEL TIME CONVERSION AND FUSION OF PROBE AND DETECTOR DATA (#8460-05) (APPENDIX E)

The purpose of the detector travel time conversion and fusion of probe and detector data evaluation was to assess the quality of travel time estimates obtained from detector volume and occupancy observations and those obtained from the fusion of probe and detector data. This assessment was accomplished by comparing the detector-based and fused-data travel times to averages of probe reports over five-minute intervals. Performance of two algorithms was examined: that of the process that converted detector data to travel time estimates (detector travel time conversion or DTTC) and that of the process that fused these estimates (data fusion or DF), when available, with probe data to create link travel time updates for incorporation into the static profile. The evaluation examined only data from links on which the probe deployment level during the periods of interest were at least five vehicles per five-minute interval, in order to ensure a reasonable basis for computing mean probe travel times. The analysis showed that estimates of arterial link travel times produced by DTTC and DF appeared to be accurate except when over-congested conditions were present over a long period of time. This shortcoming was likely attributable to the saturation and "spillback" problems cited above. More data for calibration purposes would have been necessary to improve the performance of DTTC. With respect to DF, estimates for steadily increasing deployment levels (i.e., using probe traversal times based on one-, three-, and five-vehicles per interval means, respectively) suggested that the greatest improvement in fused data estimates when compared to DTTC alone occurs from a one- to a three-vehicle level, with considerably less net improvement between the three- and five-vehicle levels. However, even *one probe traversal per five-minute interval yielded more reliable travel time estimates than did DTTC output only,* especially in prolonged congestion conditions.

7.6 FREQUENCY OF PROBE REPORTS (#8460-06) (APPENDIX F)

The purpose of the frequency of probe reports evaluation was to determine whether a high frequency of probe link traversals would be *required* in order to obtain reliable estimates (and near-term forecasts) of travel times. In order to do this, a correlation function of travel times for links of the test route (Figure 1) by time of day and headway at various probe deployment levels was derived with a view toward estimating and analyzing travel time variances, while recognizing the statistical nonindependence of probe reports on the same or contiguous links in a given time period. A synthetic method to get around this lack of independence was devised to estimate the relationship between estimate quality (as measured by probe time variance) and the number of probe reports per time interval. It was shown that the variance of estimates never approaches zero regardless of the number of probes, and that the quality of estimate essentially stops improving at the point of a relatively few more traversals per five-minute interval. These two factors argue strongly that very *high levels of probe deployment are probably not necessary for an effective probe-based ATIS,* and that the approach taken with *ADVANCE* travel time algorithms — namely, not broadcasting update messages until dynamic estimates differ by a conservatively large margin from the static profile estimates — was appropriate for this deployment. Nevertheless, had signal timing data and the exit times of probes departing links been included in the algorithms used, the quality of estimates and thus of route guidance would have been considerably enhanced. Incorporation of these data into calibration procedures for travel time prediction functions is strongly recommended for future probe-based ATIS deployments.

7.7 RELATIONSHIPS AMONG TRAVEL TIMES (#8460-07) (APPENDIX G)

The purpose of the relationship among travel times evaluation was to investigate whether a systematic and identifiable relationship between through- and turning-movement travel times exists on arterial links by time of day (inferred traffic volume) and, if so, how it might be more effectively incorporated into travel time prediction for turning movements (in the absence of probe data) than the technique used in *ADVANCE* of adding a simple constant to the through travel time stored in the base data as computed by the NFM. Probe data of through and turning movements from one specific link on the test route (Figure 1) were intensively examined. Although this analysis was limited by lack of data on such relevant traffic variables as static profile update traversal times, flows on intersecting streets, protected left turn signal timing, and driver use of yellow and early red signal time to complete turns, the analysis showed that, in general, either applying a single constant value or adding a constant to the through travel time provided an adequate, but not uniformly reliable, estimate of turning travel time for the *ADVANCE* deployment, and in any case, the application of a more complex approach, such as a regression model, was not justified on the basis of the data analyzed.

7.8 EVALUATION OF ARTERIAL PROBE VEHICLE, FIXED DETECTOR AND EXPRESSWAY FIXED DETECTOR INCIDENT DETECTION ALGORITHM (#8461) (APPENDIX H)

The purpose of the arterial probe vehicle, fixed detector, and expressway fixed detector incident detection algorithms evaluation was to assess the quality and effectiveness of the procedures instituted in *ADVANCE* for flagging the presence of recurrent and non-recurrent roadway conditions leading to intermittent congestion and delay. Separate detection algorithms had been implemented for incident detection on *ADVANCE* study area freeways and arterials. Both algorithms used volume and occupancy data from in-pavement detectors, but the arterial algorithm was supplemented by probe data and verified in part by anecdotal incident reports from an emergency vehicle dispatching center (Northwest Central Dispatch). The freeway algorithm was a modified version of a procedure already in use in California that, once triggered, employed a decision tree sequentially categorizing observed detector-based states of traffic flow (key variables being the spatial and temporal differences between upstream and downstream detector occupancies) into a confirmed or tentative incident, or a compression wave. The arterial detector-based algorithm was estimated on a discriminant function employing the standardized values of the respective standard deviations of occupancy and volume at each detector. The arterial probe-based algorithm was estimated on a discriminant function employing link-specific ratios of, respectively, observed and mean average travel times and mean and observed average speeds. Parameter estimates for this function changed as the number of probe reports on the link during the possible incident time increased. Moreover, a Northwest Central Dispatch action could trigger an incident flag automatically.

In a limited test of the freeway-detector-based algorithm, the overall performance on the evaluated freeway (using parameter values estimated with data from another *ADVANCE* study area freeway) was generally poor, with a detection rate of less than 70 percent (with 1% false alarms) for a lenient false alarm penalty weight, declining to 20 percent (.02% false alarms) when the false alarm penalty was made stringent. However, the arterial fixed detector algorithm, which was subjected to more thorough testing, was modified following initially unsatisfactory performance to a formulation that detected 29 of 141 incidents with no false alarms. The probe vehicle algorithm based on the use of three sequential probe reports (in keeping with the adequate probe frequency identified in the various traffic-related functions test) identified 6 of 11 incidents without false alarms. A modification to this latter algorithm, which incorporated probe-reported congestion distance as a variable, improved this result to the detection of 9 of 9 incidents without false alarms. Thus, while the composite results of this evaluation call into question the generalizability of previously estimated freeway/expressway incident detection algorithms without complete recalibration of parameters for every expressway to which a given algorithm is applied, they reveal potential for further development of reliable arterial incident detection algorithms based on volume and occupancy data from fixed detectors and/or link traversal data from probe vehicles, a reliability which could in turn greatly enhance reliability of dynamic route guidance.

7.9 FAMILIAR DRIVER PERSPECTIVES ON *ADVANCE* AND FUTURE DYNAMIC ROUTE GUIDANCE SYSTEMS (#8462) (APPENDIX I)

The purpose of the familiar drivers evaluation was to examine the potential contributions of in-vehicle route guidance concepts to congestion avoidance in urban areas as evinced by the behavior and perceptions of, and valuation of ***ADVANCE*** follow-on concepts by, drivers resident in and familiar with the road network of the *ADVANCE* study area. Pre-screened volunteers representing 80 households in the area were given the opportunity to drive a vehicle equipped with the *ADVANCE* dynamic route guidance system (MNA) for a period of two weeks of normal use. A total of 110 drivers from these households used the *ADVANCE* vehicles and completed both baseline and post-test surveys as well as, in most cases, log forms recording each instance of and reason(s) for changing a planned route while driving; of this subset of drivers, 32 later participated in focus groups. The size of this population and the time frame point out the key limitations of the test: the test was based on a small, non-random, self-selected sample not (necessarily) broadly representative of the driving population at large or even within the study area; it took place over a very short time period; it could provide exposure only to limited functionality of the *ADVANCE* system; and it could only exploit real-time data generated sparsely and sporadically. 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. Among these are the following:

- Drivers reported that routes provided by *ADVANCE* were not particularly good and tended to be inferior to their own routes; this conclusion is consistent with the facts that the drivers were very knowledgeable of the entire network, that relevant real-time information was not always available, and that the route planning algorithm, by policy, emphasized collector and arterial streets and avoided "local" streets in route plans, some of which the drivers commonly used for parts of their trips.

- Drivers generally expressed a preference for having a greater degree of control over their choice of routes and route planning criteria (i.e., having the route guidance system *learn* their individual preferences as part of its functionality), but the drivers also showed a high level of interest in real-time traffic information, especially that concerning non-recurring congestion, for the purpose of blending that data with their own knowledge to plan routes.

- The idealized vision of the route guidance technology expressed by most drivers was as *an intelligent assistant* that could acquire and process real-time data, use these data to *evaluate* routes chosen by the driver and, where appropriate, recommend alternatives to those routes *capable of saving time.*

- Focus groups and survey results each revealed patterns of gender and personality differences in response to (a) the route guidance function and user interface of the *ADVANCE* MNA and (b) preferences for future system attributes; the articulation of these perspectives and preferences was of sufficient depth and clarity to inform conceptualization and development of future route guidance systems capable of offering the ***breadth*** of capabilities (and sensitivity to differences) that a successfully marketable product will require. However, it was also found that the willingness to pay for such a future product or service was more clearly associated with the characteristics and overall experience of the drivers themselves, rather than with their assessment of the characteristics of the *ADVANCE* system.

7.10 FIELD TEST OF THE EFFECTIVENESS OF *ADVANCE* DYNAMIC ROUTE GUIDANCE ON A SUBURBAN ARTERIAL STREET NETWORK (#8463) (APPENDIX J)

The purpose of the dynamic route guidance evaluation using yoked (trip-start synchronized) vehicles was to determine whether, and the extent to which, DRG as implemented for the *ADVANCE* targeted deployment could provide useful route guidance to drivers on the basis of information about current travel times that differ non-negligibly from historic (average) travel times for that time of day due to recurrent or non-recurrent (incident-induced) congestion. The test utilized 18 probe vehicles for generating current link-travel-time estimates and three yoked vehicles, of which two were always capable of receiving real-time travel time and route guidance updates from the TIC (dynamic vehicles) while the third (except during the incident simulation phase of the tests, when all three were in RF communication with the TIC) had access only to data from the static travel time map on the CD-ROM on-board the vehicle. The 18 *ADVANCE*-equipped vehicles drove alternative routes between the start and end points of one of a set of five predefined (by arterial intersection) OD pairs in the study area. These routes were designed to provide coverage, and thus traversal time reports, for all links that might be part of a ***reasonable*** path between the selected OD pair. The yoked vehicles were then deployed from the origin at a common start time after a lag adequate to have received updated travel time information from the probe vehicles via the TIC. Drivers of the yoked vehicles manually recorded their travel time and route followed to destination; in most cases, this information was also recorded electronically on the MNA memory card. It was hypothesized that a successful DRG implementation would result, on average, in shorter OD travel times for a dynamic-equipped than a static-equipped vehicle, because in a significant number of cases the dynamic driver would be guided to a faster route.

In the actual test, 73 runs over the five OD pairs (at least 14 runs per pair) and 19 incident simulation runs, in which the probe vehicle drivers were instructed to slow to minimum safe speeds on defined links to simulate nonrecurrent congestion, were conducted over a five-week interval. Predominantly on the basis of driver-recorded information, dynamic vehicles were found to experience significantly shorter mean travel times than static vehicles for two of the five OD pairs (t-statistic at 90 percent level or greater). For the other three pairs, mean dynamic times were greater than or equal to static times on average but not with comparable statistical significance. Examination of the limited computer data base showed that on three of the OD pairs, dynamic cars had statistically significant mean time savings for both (a) entire routes and (b) contiguous links that were part of each route. When comparison was limited only to cases in which the static and dynamic vehicles took different routes, dynamic time advantages were seen on four of five pairs (though none of these comparative results was statistically significant). Due in part to the need to maintain safe driving practice, incident simulation runs generated probe link traversal times that in many cases were not sufficiently different from the average times (i.e., around one minute greater) to trigger an update through DTTC and DF (see above), and thus for only one OD pair was a substantial proportion (76%) of yoked vehicle diversions off the incident link.

In general, the test established that route diversions and travel time savings are sometimes associated with the use of real-time data for route planning, but in an arterial network like that of *ADVANCE,* in which DRG is subject to key functionality limitations as cited above for the familiar driver tests, large time savings may not be a typical outcome. Where substantial time savings occurred during the test, the cause appeared to be availability of less congested (but, paradoxically, *longer)* links proximate to highly congested routes. *Such alternative routes, in the absence of DRG, are likely in most instances to appear illogical to drivers on the congested route and thus are unlikely to be found andfollowed without a route planner providing real-time information for the entire network.*

7.11 TIC ARCHITECTURE AND USER INTERFACE (#8464) (APPENDIX K)

The purpose of the evaluation of the architecture and user interface of the TIC was to assess the degree to which the implemented *ADVANCE* TIC architecture and operational practices met the needs of all agencies and users involved in or affected by the system operation. To achieve this purpose, several aspects of the performance of the various TIC subsystems were examined individually and collectively as a system, while the acceptability of the TIC console display unit was assessed in the context of the effectiveness of its user interface and responsiveness to human factors. A series of seven hypotheses about the TIC's performance and user interface as implemented was tested by determining in each case whether the TIC hardware and software had both met preset operational goals and shown the ability to meet objectives relating to expansion, transferability, and refinement of its capabilities and/or simplification of its architecture. The evaluation confirmed the following hypotheses:

1. The TIC architecture as implemented provided an acceptable level of performance for the demands made on it by the targeted deployment with respect to both hardware and software as individual components and as a complete system.

2. The TIC architecture as implemented provided an acceptable cost efficiency for the scope of its mission, an efficiency that could have been significantly improved only by having fully automated the TIC system.

3. The operational practices in place at the *ADVANCE* TIC during the targeted deployment test enabled successful system operation and ensured reasonable operator workload.

4. The user interface of the TIC as implemented provided an acceptable level of usability, although operator comments and suggestions for enhancement suggest that improvement is possible in many features of this interface.

5. The user interface of the TIC as implemented provided an acceptable level of functionality; certain functions as well as nonfunctioning display features that were almost never accessed by operators may be expendable in future system development, while some missing features that operators indicated would prove valuable to their capabilities should be added.

The following findings represent rejections of or modifications to pre-assessment hypotheses:

6. The TIC architecture as implemented for *ADVANCE* targeted deployment operational tests is not directly or immediately expandable to cover additional transportation management functions within the current test area because of inherent system limitations due to reduced project scope.

7. The TIC architecture as implemented for *ADVANCE* targeted deployment operational tests is not directly transferable to other geographic areas because it was a unique technical solution that, as an entire system, would have limited application and capability to meet local requirements in other areas; however, transferability of major system components is very likely.

8 THE EFFECTIVENESS OF PROBES: A KEY TEST OF THE TARGETED DEPLOYMENT

Its uniqueness as an ATIS, heavily dependent on probe-provided link traversal times for real-time information about travel conditions, made it incumbent on *ADVANCE* to establish whether GPS-locator-equipped probe vehicles can be a reliable and cost-effective source of data for developing such real-time travel time estimates and projections for an arterial network. If the *ADVANCE* experience has established the usefulness of probes, are any of the direct benefits to the relatively small number of (present and near-term) ATIS product users in probe-equipped (or even DRG receiver-only-equipped) vehicles transferable to other motorists in the network?

Bearing in mind the key limitations of the targeted deployment — (a) a TIC that was never stressed (except using synthesized data inputs during the TIC architecture evaluation) by having to process travel time estimation functions and RF messages at rates and volumes representative of a 3,000-probe deployment; (b) an in-vehicle guidance system whose planned functionality was not fully realized with respect to features or data processing rates; and (c) a study area network for which reliable average link traversal time estimates by time of day were not available for many arterial links in the static profile prior to the start of testing — the results of probe-related testing were nevertheless very gratifying, even exciting. As discussed above, of 50,620 probe reports collected and examined over almost three months of testing, only about 0.6 percent were found unreliable, and many of these were traceable to a single faulty MNA. Moreover, the great majority of the satisfactory 99.4% of reports provided traversal time estimates within 5 seconds of manually recorded values (themselves occasionally unreliable), with most of these falling within 2 seconds. Given the conservative modulation of the DF and TTP algorithms, such differences would be acceptably small to ensure consistent reliability in the generation of travel time updates. In the sequential updating process of the static profile, it was found that profiles based on probes only were found to be more accurate than those based on both probes and detectors. It was also found that in most instances three probe reports per five-minute interval are adequate to provide reasonable real-time estimates and predictions; increasing this probe rate produced very little change in the output forecasts — a result consistent with the statistical finding that the variance of link traversal time estimates never approaches zero regardless of the number of probes, and thus the quality of estimate essentially stops improving above relatively few traversals per five-minute interval.

These results argue strongly that GPS-locator-equipped probe vehicles *can* provide reliable data for developing real-time travel time estimates and projections in an arterial network and, because very high levels of probe deployment are probably not necessary, can do it cost-effectively. Thus, it is unequivocally recommended as a result of the *ADVANCE* analysis that traffic management agencies in large urban areas actively undertake to recruit a small population of commercial and private vehicles to serve as automatic vehicle locator (AVL) probes for operation on arterials and expressways. Such AVL deployment has already occurred in the San Francisco Bay area and is being contemplated elsewhere. In this way, without the need for specifically identifying individual vehicles, a vital, generally unprecedented, and perhaps ultimately indispensable stream of travel time information for the ***total*** network would begin to flow into regional traffic support centers.

9 ARE THE TARGETED DEPLOYMENT'S RESULTS VALID AND TRANSFERABLE?

The decision to restructure *ADVANCE* as a targeted deployment meant that some of the project's original objectives were not fully met. A large-scale field test with 3,000 vehicles acting as probes was never realized. The scope of testing of DRG capabilities, the effect of the system on "familiar" drivers, and the ability to assess long-term operational and maintenance aspects of the system were far more limited than the original concept stipulated. Commercial trucking operations and fleets were not involved in the deployment, and experience gained in driver recruitment and training and vehicle installations of the MNA system represented less than 5% of original expectation. In emphasizing specific corridor and sub-area concepts rather than area-wide performance, due to deployment limitations, the project tests had a much-reduced ability to estimate the *overall* effectiveness of probes in conveying actual traffic conditions to a public information source. The project could not achieve the statistical reliability, attributable to the large accident and incident data base that could be potentially assembled under full deployment, of a comprehensive evaluation of MNA use by and distractions of drivers; thus, the findings of the more limited safety tests with recruited drivers soon to be released may not be as conclusive.

Also, the volume of data collected from the targeted deployment field tests, which would have been limited in any case, was further diminished by still-unaccounted-for losses in the transmission and archiving of electronically collected records. This problem impaired even some tests with relatively modest objectives.

However, test results might have been more conclusive overall had it not been discovered during testing that the benchmark against which travel time data was being evaluated — the network flow model's link traversal times — was itself impaired by large estimation errors, such that the far more reliable basis of comparison generated by every successive update of the static profile was actually developed during the testing phase itself and was thus unavailable until too late to serve as the testing platform. Until testing was completed, it was also unknown how important having data on signal timings in the arterial network would have been in estimating reliable formulas for travel time prediction and quantification of travel time relationships between through and turning movements at a given intersection.

Nevertheless, a subset of results of the *ADVANCE* evaluation would not change regardless of the scale of deployment:

- The user features of an in-route guidance system, such as those of the MNA units deployed for *ADVANCE*, must be able to accommodate a reasonably broad range of technological sophistication and network knowledge among the population likely to pay for and regularly use such a system and its associated services. Specifically, the capability should exist to "train" the system to learn the user's preferred routes, then provide timely and relevant information about available time savings on alternative routes (especially those which may be "counter-intuitive" to a user familiar with the area road network).

- Users who regularly drive in a road network and know its normal traffic and congestion patterns tolerate recurrent time-of-day delays in the network on the links with which they are familiar and comfortable; thus, only a route guidance system capable of providing reliable real-time data about *non*-recurrent congestion is likely to find a market base beyond very specialized, very limited applications.

- Although real-time guidance on arterial networks can be provided, at significant public expense, in the absence of equipped vehicle probes, its quality and usefulness will be much diminished relative to what even a very limited deployment of probes could achieve.

- The quantity and timeliness of data flowing into *a properly functioning* traffic information center (that is, a center capable of fast and reliable message processing and turnaround) argues strongly that such a center will not achieve its full potential unless it is integrated directly with a traffic *management* center having the ability to intercede directly in modifying network flows.

- Route guidance algorithms that use probe data can be improved by including traffic signal timing data from the arterial system. The probe data itself significantly improves static (archival average) link travel time estimates by time of day.

- Automated incident detection algorithms for expressways do not yet possess sufficient reliability and transferability for stand-alone deployment. Probe- and detector-based incident detection on arterial networks show promise for improved performance and reliability.

Other less comprehensive findings of the *ADVANCE* experience and evaluation would be equally applicable to other deployments as "lessons learned" (see Section 6) but are not repeated here because they relate more directly to applied practice. In larger-scale deployments, project practices would have to be adjusted to accommodate different sets of needs and goals. Such adjustments may yield broader, perhaps more fundamental, discoveries about the limits, proper role, and driver acceptance of ATIS. However, on the basis of the project's seminal investigation of properties and performance of important ATIS concepts deployed in a limited yet focused manner, the evaluation manager for *ADVANCE* defends the position that most of the findings have wide-ranging implications and that present and future deployments cannot afford to ignore any of them.

10 THE LEGACY OF *ADVANCE*: THE GCM CORRIDOR AND BEYOND

Significant benefits resulted from the implementation and evaluation of *ADVANCE* as a targeted deployment. Probably the most important transferable benefit was gaining knowledge and experience of the operation of a real-time traffic information center sufficient to permit transition to full-scale transportation center operations for the Gary-Chicago-Milwaukee (GCM) tri-state corridor, obviating "shakedown" delays and setbacks that might otherwise have occurred. Progress in GCM corridor development is occurring faster than originally anticipated under a concept fully endorsed by responsible authorities in all affected states (Illinois, Indiana, Wisconsin) and is opening the tri-state region to opportunities for other public and private initiatives.

Obvious and significant fiscal savings resulted from the plan to use fewer test units over a shorter time span than originally envisioned. Compensating for the reduction in scope was a faster turnaround (just over a year) of analysis completion, report preparation, and availability of findings to the interested public than would have been possible with a two-year test. As discussed above, though testing was limited, some results are capable of broader generalization

In January of 1996, the *ADVANCE* TIC was decommissioned and in its place rose a Corridor Transportation Information Center (C-TIC), now providing real-time travel information to a broad multistate spectrum of interests. That is, the *ADVANCE* Corridor Transportation Information Center has expanded beyond the original *ADVANCE* test area to include expressways and major arterials in all three states throughout the GCM Corridor. The prototype center is operational. The practical architecture of the network of information sources feeding this center is now being demonstrated, and a full deployment scenario that will incorporate many features of an approved national infrastructure, including a standardized location referencing system and the National Transportation Communication and Information Protocol, is being reviewed as part of the GCM Multi-Modal Traveler Information System effort. Several information sources and media not used in *ADVANCE* will be a part of this multi-modal system; in fact, the only data source from the targeted deployment that will *nut* be processed through the GCM C-TIC (at least in the near term) is GPS-based vehicle-locator probes.

The decision to adopt a targeted deployment approach for *ADVANCE* was a logical step in developing and advancing ITS technology. The dynamic route guidance concept that was central to *ADVANCE* was tested, the project infrastructure developed was enhanced to support a broader range of ITS deployments, and multistate corridor activities were supported and given a more central focus. The public and private participants in the project gained highly useful information from systems development and evaluation testing that has helped positively and productively to guide further ITS concept and product deployment pursuits.