

SECTION 7 SUMMARY

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

The results contained within this report are divided into two main sections, reflecting the parallel TIC Architecture and TIC User Interface evaluation activities. In this final section of the Evaluation Report, the evaluation hypotheses are considered in the light of the data collected and analyzed within the evaluation activities.

Five goals and a series of related objectives were identified by the evaluation team for the TIC Architecture and User Interface evaluation. The goals are presented in Section 4.1. In the completion of the various tasks described in the TIC Architecture and User Interface Evaluation Test Plan, Document #8464.ADV.00, included in this report as Appendix B, the evaluation team can report that these evaluation goals and objectives have been met.

In addition, seven hypotheses were devised for the evaluation of the *ADVANCE* TIC Architecture **and** User Interface evaluation. The first five hypotheses concerned the TIC Architecture, while the last two hypotheses related to the TIC User Interface. The hypotheses are listed in Section 4.1. The remainder of this summary section comprises a discussion of the evaluation hypotheses. Section 7.1 addresses the TIC Architecture hypotheses, while Section 7.2 addresses the TIC User Interface hypotheses.

7.1 TIC Architecture Hypotheses

7.1.1 Hypothesis 1

To reiterate, Hypothesis 1 is as follows: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test provides an acceptable level of performance, both in terms of the hardware and software as individual components, and as a complete system. Various aspects of the TIC Architecture were evaluated, including TIC functionality, reliability and maintenance requirements, efficiency and potential system design alternatives. These aspects were evaluated in order to ascertain whether Hypothesis 1 was verified.

Functionality (see Sections 5.2.1.2.8 and 5.2.1.2.9)

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

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

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

Reliability and Maintenance Requirements (see Section 5.2.2.5)

As outlined in Section 5.2.2, the various limitations of the reliability assessment should be borne in mind when considering the findings summarized in this section. In terms of the reliability and maintenance requirements of the TIC, the following conclusions have been made:

- The TIC hardware provided an acceptable level of reliability for the *ADVANCE* Targeted Deployment.
- The maintenance requirements of the TIC hardware proved to be reasonable, although it should be noted that the maintenance required the assistance of technical staff, and so continued access to these, or similar, staff should be ensured.
- The TIC software provided an acceptable level of reliability for the *ADVANCE* Targeted Deployment. Should the current system be utilized or adapted for use in a longer term or more extensive implementation, it is proposed that further effort would be required to ensure that, during unstaffed operations, the overall TIC MTTR is reduced from the current value.
- The maintenance requirements of the TIC software proved to be reasonable. However, as was the case with the TIC hardware, it should be noted that the maintenance action in response to software failures largely required the assistance of technical staff, and so continued access to these, or similar, staff should be ensured.

Efficiency (see Section 5.2.3.6)

In terms of the efficiency of the TIC; it is concluded that the volume of live data reports entering the TIC had very little impact on total time to process these reports within the TIC, at least for the numbers of live data reports that were habitually entering the TIC during Targeted Deployment.

Both the data captured during the live data test and the data captured during simulated data tests indicate that the major governing factor in the time taken to process data is the interval between the start of the TRF cycle and the start of the message scheduler cycle. It is therefore recommended that the TRF cycle and the message scheduler cycle be synchronized in order to optimize the time taken to process data reports. It is also recommended that the length of both cycles be reduced, again to minimize the time taken to process data reports. Further investigations need to be carried out in order to determine the ideal length of the two cycles which would optimize data report processing time while not creating an excessive processing overhead.

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

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

The time to process data reports which required manual input was also investigated. It was found that the maximum time to process these anecdotal reports was as high as 16 minutes, 38 seconds, demonstrating the effect that operator intervention can have on the total time to process anecdotal data reports. In extreme cases, this may have resulted in anecdotal data relating to incidents which were already cleared being entered into the TIC. It is concluded that, based on a worst case scenario for the total time taken to process anecdotal inputs, the automation of the entry of these inputs into the TIC database may be warranted.

It is concluded that in order to prevent the efficiency of TIC functions being compromised by system failures when full log files continued to be written to, the "advance1" data directory back-up cycle should be executed daily in order to maximize the efficiency of the user interface. In addition, the "advance8" data directory back-up cycle should be performed at least every five days.

It is concluded that the NWCD anecdotal input represents a highly valuable data source for the *ADVANCE TIC*, and that the efficiency of the TIC in providing a full coverage information service without the entry and utilization of this data would be negatively impacted.

It should be noted that the findings presented here are of course dependent on maintaining the same system parameters utilized for the Targeted Deployment and the same typical range of data reports which habitually entered the TIC during Targeted Deployment. Therefore, the conclusions drawn from the findings should not be taken out of the context of the *ADVANCE* Targeted Deployment.

Potential System Design Alternatives (see Section 5.3.2)

A peer review team examined the above findings in order to identify any potential system design alternatives. The feedback received from the peer reviewers indicated three key areas which they considered could be streamlined, as follows.

- It was suggested that an architecture which incorporated the GUI within full-function workstations instead of on the main server could perhaps improve system performance and reduce the complexity of the software, while incurring minimal extra cost for the more expensive operator workstations.
- It was suggested that, in a fully deployed operational system, provision for central system hardware redundancy should be provided, such as in the case of the TIC server and disk storage.
- It was suggested that the TIC system's omission of an automated procedure for discontinuing non-critical activities in order to maintain real-time performance of critical activities could have a potentially negative impact on the efficiency of the TIC in a fully deployed operational system. It was suggested that access conflict prioritization routines should be incorporated to ensure that any negative impacts are not experienced.

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

Therefore, it was found by the evaluation team that the TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test provided an acceptable level of performance, both in terms of the hardware and software as individual components and as a complete system. Consequently, Hypothesis 1 was verified. However, the various comments and recommendations outlined in the above paragraphs should be taken into account should further development on the existing TIC take place, or for any future systems which are based either partly or wholly on the *ADVANCE TIC* concept.

7.1.2 Hypothesis 2 (see Section 5.4.2)

To reiterate, Hypothesis 2 is as follows: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test is expandable to cover additional services within the current test area. The actual functionality of the implemented TIC was reviewed by a peer review team in order to ascertain whether Hypothesis 2 was verified.

In terms of the expandability of the TIC Architecture, the feedback received from the peer reviewers indicated four key areas where they considered that potential existed for expanding the functionality of the TIC.

- Peer reviewers suggested that the TIC/TRF software algorithms designed to utilize the in-bound MNA communications may be adaptable for additional types of probe vehicles, such as AVI-equipped vehicles, which could then provide data for the TIC.
- It was suggested that future systems may be enhanced to incorporate real-time adaptive control of signal systems based on data received from the loop detectors and the probe vehicles.
- The provision of personal emergency services and notification services were also suggested as possible areas for expansion of the current functionality of the TIC.
- It was suggested that the inclusion of weather related and surface condition data would be of significant benefit to the drivers of the MNA equipped vehicles.

It is concluded that these four key areas should be investigated further to ascertain the potential advantages and disadvantages of their implementation. In the case of the fourth suggestion above, the provision of weather-related data had initially been intended for inclusion in the *ADVANCE* TIC, and indeed during the Targeted Deployment data fed from a weather information supplier and was provided at the interface in a logfile. It is considered that minimal additional effort would be required to have this data entered automatically into the TIC database. Consequently, Hypothesis 2 was verified. However, based on the input received from the peer reviewers, it is concluded that the expandability of the *ADVANCE* TIC to incorporate additional services is largely constrained due to inherent system limitations resulting from Targeted Deployment.

7.1.3 Hypothesis 3 (see Section 5.5.2)

To reiterate, Hypothesis 3 is as follows: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test is transferable to other geographic areas. The actual functionality of the implemented TIC was reviewed by a peer review team in order to ascertain whether Hypothesis 3 was verified.

In terms of the transferability of the TIC Architecture, the feedback received from the peer reviewers indicated two key areas where they considered that potential could exist for such system transferability.

- It was thought that the techniques developed, tested and proven *within ADVANCE* for the distribution of real-time traffic and traveler information to vehicles could be of use to other corridors and metropolitan areas. These techniques include, for example, travel time prediction techniques, map database integration methods and data fusion processes for various real-time data sources including anecdotal sources.
- It was noted that the implementation of the TIC User Interface offers the opportunity to expand current knowledge of the interaction between the system and the operator in combining automatically generated information, anecdotal information and subjective judgement to establish predicted roadway conditions and travel times.

It is concluded that the knowledge and expertise gained by project participants during the *ADVANCE* operational test in terms of the lessons learned from the implementation appear to be the major transferable elements of the *ADVANCE* TIC Architecture created for the Targeted Deployment. Consequently, Hypothesis 3 was verified. Further information will be available by late 1996 within the "Lessons Learned from the *ADVANCE* Project", Document #8465.ADV.01. As was noted by the peer reviewers, it must be concluded nevertheless that the *ADVANCE* project produced a unique technical solution that, as an entire system, will have limited application in meeting local requirements in other areas. To maximize future transferability potential, it is proposed that further investigations be carried out into a change in focus for the *ADVANCE* TIC, from ATIS to a combined approach incorporating both ATIS and ATMS.

7.1.4 Hypothesis 4 (see Sections 5.6.1.3 and 5.6.2.2)

To reiterate, Hypothesis 4 is as follows: The TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test provides acceptable cost efficiency. The development, implementation and operation costs of the implemented TIC were reviewed by a peer review team in order to ascertain whether Hypothesis 4 was verified.

The TIC equipment costs were calculated at \$129,562; however, it should be noted that this figure represents significant contributions from various project participants. The labor and miscellaneous costs for TIC development and implementation were calculated at \$2,293,532, resulting in total costs for TIC development and implementation of \$2,423,094. The costs accrued on a monthly basis for the continuing operation of the TIC were calculated at \$8,352. This figure includes the costs for technical support personnel.

The peer reviewers noted that capital cost avoidance was not possible as the system had already been implemented. However, reviewers considered all equipment costs to be reasonable. It was also remarked that although the system development costs were significant, given the complexity of the data sources, including the probe vehicles, these labor costs were in line with the overall TIC complexity.

Reviewers also assessed the monthly TIC operating costs as reasonable, given that the system was providing an essentially full-time information service. However, a potential area where ongoing cost savings could be made was identified as a fully automated TIC system, which would not require staffing

by operators. It was recommended that this proposal, for enhancing TIC capabilities to include fully automated information processing, be investigated for any future TIC systems either partly or fully based on the *ADVANCE* TIC concept. However, it is concluded the TIC Architecture as implemented for the *ADVANCE* Targeted Deployment operational test provided acceptable cost efficiency. Consequently, Hypothesis 4 was verified.

7.1.5 Hypothesis 5

To reiterate, Hypothesis 5 is as follows: The operational practices in place at the *ADVANCE* TIC enable acceptable system operation and ensure reasonable operator workload. Various aspects of the policies, procedures, and staffing levels at the TIC were assessed in order to ascertain whether Hypothesis 5 was verified.'

Policies and Procedures (see Sections 5.7.3 and 5.7.4)

In terms of the assessment of the TIC Policies and Procedures, two key areas were identified where revisions to TIC policies or procedures could be made. These areas are described in the following paragraphs.

The first area relates to the levels of operators training and expertise. Given that operators seemed to possess varying perceptions of some of the tasks required of them, it is suggested that more comprehensive system feedback be provided in order to provide prompts for operators. Alternatively, the variances in perceptions of tasks required could be eliminated by the implementation of comprehensive and standardized initial training procedures, supported by full documentation, or by periodic "refresher" training sessions to be provided for all operators in order to ensure that they remain fully aware of their responsibilities.

It is also possible that TIC operations could be streamlined by employing operators with higher levels of technical experience and knowledge which would enable them to diagnose technical problems arising with the TIC systems and to judge the appropriate action to take. However, it was found that in the scenarios in which operators had not been able to diagnose or resolve problems experienced with TIC systems, that technical support from the systems developers had always been readily accessible. Should operators with more technical background not be employed at the TIC in the future it must be ensured that continuing access to systems developers' technical staff is available.

The second area relates to workload. Operator workload was lessened by the non-adherence to the procedures described in the TIC Policies and Procedures Manual for the release of data to *ADVANCE* project participants. However, the potential for breach of data privacy or integrity was minimal during the Targeted Deployment and therefore the procedures described in the Manual, solely in terms of internal project requests, could be eased. It is recommended that these procedures be revised to permit operators to release project information requested verbally by those project participants approved by the *ADVANCE*

Steering Committee. However, it is believed that in a permanently operational system, the procedures contained within the Manual relating to release of information were appropriate.

Staffing Requirements (see Section 5.8.3)

In terms of the TIC staffing requirements, it was found that the staffing levels in place for the *ADVANCE* Targeted Deployment were reasonable and did not result in undue pressure being placed upon operators; second, no adverse impacts were experienced by operators due to the system manager not being present throughout the entire period of daily staffed TIC operation. It should be noted that the system manager, UIC-EECS staff and De Leuw, Cather staff could be contacted by mobile telephone or pager should operators have required assistance.

It was found that the majority of the TIC operators' workload, including both administrative tasks and anecdotal data input, occurs from between 6:00 am and 9:00 am, and 4:00 pm and 7:00 pm. Therefore, it is recommended that further investigations be undertaken into the feasibility of staffing the TIC during these hours only. It should be recognized that unless some automation of NWCD anecdotal data is implemented, part-time staffing of the TIC would result in some loss of real-time data when the TIC is unstaffed. However, it is believed that during normal system operations, when the operators would not be involved in other *ADVANCE* related tasks, such as TRF data collection and dealing with test drivers, no significant reduction in the level of service provided by the TIC would result from part-time staffing of the TIC.

To conclude, it was found by the evaluation team that the operational practices in place at the *ADVANCE* TIC enabled acceptable system operation and ensured reasonable operator workload. Consequently, Hypothesis 5 was verified. However, the various comments and recommendations outlined in the above paragraphs should be taken into account should the *ADVANCE* TIC be recommissioned for longer-term operation, or for any future systems which are based either partly or wholly on the *ADVANCE TIC* concept.

7.2 TIC User Interface Hypotheses

7.2.1 Hypothesis 6 (see Sections 6.2.8 and 6.2.9)

To reiterate, Hypothesis 6 is as follows: The TIC User Interface as implemented for the *ADVANCE* Targeted Deployment operational test provides an acceptable level of usability. Various aspects of the usability of the TIC User Interface were assessed in order to ascertain whether Hypothesis 6 was verified.

Operators assessed the ease of use of all the interface features as being either very easy, moderately easy, or neither particularly easy nor difficult. No features were rated as being either moderately or very difficult. It is therefore concluded that the user perceptions of the ease of use of TIC systems are substantially positive. However, given the large volume of operator comments and suggestions for

enhancing the TIC systems usability, it is clear that there exists room for improvement in many of the features of the TIC User Interface.

One issue which should be borne in mind when considering the usability assessment of the TIC User Interface is the prototypical nature of the interface developed for *the ADVANCE* operational test Targeted Deployment. For many innovative prototype systems such as that developed for *ADVANCE*, a focus on functionality rather than usability tends to be the norm. It is believed that this was the case during the development of the *ADVANCE TIC* systems. It is also the case that limited resources were available to the system developers for the usability aspects of system design. For example, no funding for usability testing during the design process was available. Given these circumstances, the operators' largely positive perceptions of the usability of the current interface are all the more notable.

Though many minor difficulties were experienced by operators, a list of nine key areas was prepared which it is recommended be addressed as the first priority in any future releases of the *ADVANCE TIC* systems. This list, relating to NWCD monitoring, controller data source status indicators, process delays and display particulars, is not reproduced here, but is presented in Section 6.2.9.

It is concluded that the TIC User Interface as implemented for the *ADVANCE* Targeted Deployment operational test provided an acceptable level of usability. Consequently, Hypothesis 6 was verified. However, the various comments and recommendations outlined in Section 6.2.8, 6.2.8.1 and 6.2.9 should be taken into account should further development on the existing TIC take place, or for any future systems which are based either partly or wholly on the *ADVANCE TIC* concept.

7.2.2 Hypothesis 7 (see Sections 6.3.2 and 6.3.4)

To reiterate, Hypothesis 7 is as follows: The TIC User Interface as implemented for the *ADVANCE* Targeted Deployment operational test provides an acceptable level of functionality. Various aspects of the functionality of the TIC User Interface were assessed in order to ascertain whether Hypothesis 7 was verified.

It was found that the TIC User Interface functionality met the requirements of the TIC operators to a large degree, as is reflected by the relatively small volume of suggestions made by operators for additional features which would make their tasks more easy to complete or that would ease their workload.

Four suggestions made by operators for possible additional interface functionality were identified as key areas for further study. The operator suggestions for additional functions are as follows: an "Undo" button, a traffic signal malfunctions anecdotal data entry menu item, a "Select Last Incident" facility, and locating an incident by its address. It is recommended that further investigations be undertaken into the feasibility and implications of implementing these as it is considered that the inclusion of these features would significantly enhance the present interface.

Various functions had been never or rarely used by all three operators. These include several items within the test area map menus, and several data windows accessed through the "Data Pop-up" menu. It is recommended these items, which are listed in full in Section 6.3.4, undergo further investigation to ascertain their utility to operators in everyday use of the TIC systems. Although it is acknowledged that during a Targeted Deployment of limited duration there exists the possibility that operators did not have the need to utilize all the provided functions and thus these items could still be of utility in a permanently operating system, it is anticipated that some of these items could be eliminated without significantly restricting the functionality of the TIC User Interface.

It is also recommended that the potential utility and benefits of a "dual interface" be investigated. This would in effect comprise a simplified interface for the everyday use of the TIC operators, which would allow them to fulfil all the tasks required of them, but which would not possess any of the features which it could be determined they do not require. This interface could be automatically activated when any user possessing TIC operator status access permissions logs in to the TIC. A second, more advanced interface could be available to any user logging in who possesses system administrator permissions. This second interface could possess all the above functions for the use of staff needing to perform more advanced operations. Alternatively, and if resources were available, a single TIC interface could be customized for each TIC operator based on their technical knowledge and experience.

In addition, there are certain features whose menu items are currently displayed on the TIC User Interface but which are not available to system users. These include all items within the "Plot" menu on the test area map menu bar, and the Expressway Map item within the main TIC menu. It has been established that it was decided not to implement these features of the interface as part of the system rationalization which resulted in the Targeted Deployment of the *ADVANCE* project. It is recommended that these non-functioning items be removed from the TIC User Interface.

It is concluded that the TIC User Interface as implemented for the *ADVANCE* Targeted Deployment operational test provided an acceptable level of functionality. Consequently, Hypothesis 7 was verified. However, the various comments and recommendations outlined in the above paragraphs should be taken into account should further development on the existing TIC take place, or for any future systems which are based either partly or wholly on the *ADVANCE* TIC concept.