# Multi-Modal Traveler Information System

## *Lessons Learned*
## *Working Paper # 19210.01*

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# 1.0 INTRODUCTION

## 1.1 PURPOSE

The purpose of this working paper is to provide an information base of lessons learned from activities similar to the design of the Gary Chicago Milwaukee (GCM) Corridor Architecture and the Gateway Traveler Information System (TIS). Many similar activities have taken place in the Intelligent Transportation Systems (ITS) community and there is no need to repeat individual efforts or proceed in a direction which may not prove necessary to achieve the goals of this project. It is in the best interest of the GCM Corridor that the lessons learned from similar ITS projects be documented, studied, and incorporated into the Multi-Modal Traveler Information System (MMTIS) Project and specifically the GCM Corridor Architecture and Gateway TIS design.

### 1.1.1 Goals of this Working Paper

The goals of this working paper are as follows:

- To summarize lessons learned from similar ITS activities.
- To present previous experiences so that they can be used in the development of the design of the GCM Corridor Architecture and Gateway TIS.

### 1.1.2 Intended Audience

This working paper is intended to serve as a resource and a guide to the members of the GCM Deployment Committee, the Architecture Communications & Information (ACI) Work Group, project managers, system designers, system developers, and system integrators.

### 1.1.3 Working Paper Organization

This working paper is organized to present technical and institutional lessons learned from several ITS projects which are similar to the efforts of the MMTIS project. A summary presents an aggregated set of critical lessons learned and how they relate to the MMTIS project.

## 1.2 PROJECT OVERVIEW

### 1.2.1 MMTIS Project Overview

The MMTIS project revolves around the concept of a GCM Corridor TIS. It involves identification of ITS systems in the Corridor which are currently deployed and proposed systems identified in regional strategic plans or early deployment studies. This information will be used to develop a corridor architecture which best suits the characteristics of the diverse resources within the Corridor. Along with the corridor architecture, a corridor strategic plan will be developed. Another key component of the MMTIS project is the design of the Gateway TIS. The Gateway will be the collection and distribution hub for traveler information in the GCM Corridor. Specific tasks identified in the MMTIS project include developing the following documents for the Gateway: System Definition Document, Functional Requirements, and Interface Control Requirements.

### 1.2.2 Role of Lessons Learned from Other Projects in MMTIS Design

One of the goals of the MMTIS project is to detail the requirements for the Corridor Architecture and Gateway TIS through a thorough analysis of corridor, regional, and agency specific needs. Many of the areas which are the focus of the MMTIS design have been addressed in similar ITS projects. The intent of this paper is to document those lessons learned from other similar ITS projects and then incorporate that base of knowledge into the design of the GCM Corridor Architecture and Gateway TIS.

## 1.3 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

Document #17100-1, MMTIS Project Glossary, contains all definitions, acronyms, and abbreviations associated with this project, as well as ITS, communications, computer programming, and other standards in general. A few definitions are listed below for the reader's convenience.

BBS- Bulletin Board System - A computerized bulletin board that can be accessed by members to post and download messages.

DLL- Dynamic Link Library -A program library written in C or assembler that contains related functions of compiled code. The functions in a DLL are not read until runtime (dynamic linking).

GPS- Global Positioning System - A government-owned system of 24 earth-orbiting satellites that transmit data to ground-based receivers. GPS provides extremely accurate latitude and longitude ground position.

Link ID- Link IDentification - A unique identifier for a specific roadway link.

T1- A communication line conditioned to provide data transmission rates up to 1.544 Mbps.

TCP/IP- Transmission Control Protocol/Internet Protocol - The standard network protocols in UNIX environments.

PDA Personal Data Assistant - A hand held computer that provides functions like a notepad or messagepad. PDAs often include data transmission capabilities.

## 1.4 RELATED DOCUMENTS

This working paper is part of a series of documents and working papers produced to support the design of the GCM Corridor Multi-Modal Traveler Information System.

Related documents and working papers include:

- Document #17100-1 - MMTIS Project Glossary
- Document #17150 - Gateway TIS System Definition Document
- Document #17200 - GCM Corridor Architecture Functional Requirements
- Document #17250 - Gateway TIS Functional Requirements
- Document #17300 - GCM Corridor Architecture Interface Control Requirements

- Document #17350 - Gateway TIS Interface Control Requirements
- Working Paper #18250 - Cellular 911 - State of the Practice
- Working Paper #18380 - GCM Corridor User Needs and Data Exchange Requirements
- Working Paper #18400 - Regional Strategic Plans
- Working Paper #18500 - GCM Corridor Strategic Plan
- Working Paper #18520 - Performance Criteria for Evaluating GCM Corridor Strategies and Technologies
- Working Paper #18550 - Alternative GCM Corridor Technologies
- Working Paper #18555 - Alternative GCM Corridor Strategies
- Working Paper #18600 - System Interfaces and Information Exchange
- Working Paper #18700 - Information Clearinghouse - Initial Administrative Network
- Working Paper #18790 - Information Clearinghouse - Final Network
- Working Paper #18830 - Weather Detection System Standard Message Sets
- Working Paper #19140 - Gateway TIS Phased Implementation Plan
- Working Paper #19220 - Gateway TIS Design Options
- Working Paper #19840 - Variable Message Signs/Highway Advisory Radio State of the Practice
- Working Paper#19845 - Variable Message Signs/Highway Advisory Radio Suggested Guidelines.

## 1.5 REFERENCES


- *The ADVANCE Project: Formal Evaluation of the Targeted Deployment*, Argonne National Laboratories

- *The Atlanta Olympic Experience, Lessons Learned from Deployment*, L. Stapleton, Jr. Georgia Department of Transportation, et al, May 15, 1996

- *TravInfo Evaluation: Value Added Reseller (VAR) Study Phase 1 Results*, D. Loukakos, California PATH, et al, March 1996

- *TravInfo Evaluation: Institutional Element Phase 2 Results*, R. Hall, California PATH, et al, August 1996

- *Lessons from Case Studies of Advanced Transportation and Information Systems*, J. Dahlgren, California Path, et al, July 1996.

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## 2.0 LESSONS LEARNED

Several ITS projects that have functions similar to those of the proposed Gateway TIS, where information is collected from various sources and distributed to a diverse set of users, were studied and some of the lessons learned from designing, developing, implementing, and operating the systems associated with these projects are described in the following sections.

### 2.1 *ADVANCE*

The Advanced Driver and Vehicle Advisory Navigation Concept *(ADVANCE)* project was a joint public-private partnership between the Illinois Department of Transportation (IDOT); the Federal Highway Administration (FHWA); Motorola; the Illinois Universities Transportation Research Consortium (IUTRC) (Northwestern University and the University of Illinois at Chicago); and the American Automobile Association (AAA). These five Parties had overall responsibility for funding, design, development, implementation and evaluation of the project. Several organizations were contracted to assist the original Parties. IDOT was responsible for coordination and management of the project. De Leuw, Cather & Company, assisted by the IBI Group and Castle Rock Consultants, served as the lead systems engineer as well as provided engineering support services to the project manager. The MITRE Corporation was contracted by the FHWA to assist and guide in the development of the initial evaluation methodology of the project. Argonne National Laboratory was the evaluation manager. Volpe National Traffic Systems Center was involved in the safety evaluation of *ADVANCE*.

The development phase of the *ADVANCE* Project was an ITS field operational test focusing on the evaluation of the potential benefits of an in-vehicle, dynamic route guidance system in a market that comprises drivers who are, in general, familiar with the area in which they undertake most of their daily traveling. The project involved over seventy-five vehicles operating within a three hundred square mile area in the northwest suburbs of Chicago, Illinois.

The basic concept of *ADVANCE* is as follows:

- The *ADVANCE* vehicles have equipment installed that is capable of determining the vehicle location, selecting the "best" route to the driver's destination, and providing route guidance instructions to the driver.

- Actual travel times are to be determined by these probe vehicles as they traverse the test area and this information is transmitted over a radio system to the Traffic Information Center (TIC).

- Revised estimates of travel times are transmitted by the TIC to the probe vehicles.

- The on-board equipment determines if the traffic information received affects the route that has been selected. If there is an impact, the driver is then presented with a better route to select in order to avoid a traffic incident or congestion.

- As the *ADVANCE* probe vehicles collect additional information, the updated travel times are used to improve the knowledge of travel conditions in the test area.

### 2.1.1 Technology Issues

Many of the technology issues that were faced during *ADVANCE* TIC design and development are relevant to the MMTIS project, especially the design of the Gateway. Following are summaries of lessons learned which relate to technology or the use of technology.

#### 2.1.1.1 Hardware/External Connections Design

With the rapid changes in the computer industry, the TIC computer which was state-of-the-art at the time of its purchase, was comparatively slow once implementation began. This subsequently resulted in the procurement of new processors. Future systems that will reuse hardware need to be aware of the potential limitations that may be imposed.

The TIC had an electronic connection to Northwest Central Dispatch, a regional emergency 911 dispatch center for six communities within the *ADVANCE* project area. The data was received at the TIC as it became available, but was not automatically entered in the TIC database (the raw log files were temporarily stored, but not saved). The operators manually entered the incident information into the TIC for processing and inclusion in the system and database. This turned out to be very labor intensive and during peak times it completely inundated the operator. A better design would be to automate all connections and their entry of data into the database to the greatest extent possible. Sometimes the data needs to be filtered or pared into a more useful format or to protect privacy before being transmitted or committed to the database. Additionally, there still may be a need for an operator to verify or check the data.

The TIC experienced numerous instances where connections to data sources were lost due to noise on the phone lines. These lines were standard dial-up lines, as opposed to leased lines with line conditioning. It is recommended that conditioned leased lines be used wherever a permanent connection is established.

#### 2.1.1.2 User Interface

The user interface was displayed on X-terminals due to equipment considerations. These terminals did not have any internal processing power. All processing was performed within the TIC computer. This meant that all operator actions were processed through the same computer which was accepting data from modems, processing data, and storing data in its database. The load on the TIC computer was heavy and resulted in a loss of performance. The ideal configuration would consist of operator workstations containing all software and hardware sufficient to operate the user interface internally, with no degradation in overall system performance.

The design of the TIC allowed for a display showing the status of the various processes so system operators could monitor the system. At first, the implementation provided only a display which showed the status of the processes, not if data was being sent, received or processed. As a result, an improved display was created which showed the last messages sent and received for several major processes within the TIC. It is important to design features which are providing useful information to the system operators so they can make informed decisions.

Due to schedule constraints, the TIC interface was developed and installed with limited input from the users. Because of this, there were several instances where a large development effort was undertaken on something that was either scrapped or severely modified. It is these situations which lead to the conclusion that some rapid prototyping tool would be beneficial for user interface screen development. Future systems should provide sufficient details to produce an early prototype (paper markups of windows, etc.) which would be used to solicit responses from potential users.

Early requirements were to have the operator map display road names. This became an enormous software development task considering all of the road levels, zoom levels, and overlapping street names. The solution was to allow the operator to select a road segment and display the name in a separate window on the screen.

The lesson here is that some flexibility needs to exist to adjust requirements once the impact of a requirement is known.

#### 2.1.1.3 Software Design

The number of persons actually involved in the software design was very limited. This resulted in some misunderstanding of the intent of particular software processes. An earlier involvement by system operators, traffic engineers, etc., would enable quick recognition of design flaws and redesign and redirection can be started before major effort is expended in an improper direction.

Throughout the early project development, there were times when the TIC would fail and it would be difficult to identify the cause. As a result, a watchdog timer process was developed which saved the system log files to a disk file in the event of a process failure. Since *ADVANCE* was not staffed 24 hours per day, this watchdog timer process was designed to also restart the system after a system failure, assuming the restart is possible. This enabled system developers to later analyze the fault while minimizing the system down time during development, testing and operational phases. This illustrates the need to have a means available to developers and operators to fully analyze faults that may occur.

The requirements specification approach to preparing a detailed system design developed out of military software procurement processes. The approach may be briefly described as one of first describing the functional requirements for the desired system, and then making a detailed specification of the system requirements. This method envisages that the technology is relatively mature, and the challenge is to design a specific application. As discussed previously, these conditions were not present in the *ADVANCE* Project.

Several problems were experienced in attempting to apply the requirements specification approach. Most problems centered on some participants having little experience with this approach, the capabilities of the hardware and software, and the wide range of desired functionality. Most participants questioned whether this approach was suitable for a system that requires solving many research problems during the design process.

The lessons learned here included the need to be able to have flexibility in the requirements as development occurs and not to specify "bells and whistles" or development based projects until the hardware and software components are more fully defined.

### 2.1.2 Institutional Issues

#### 2.1.2.1 Intellectual Property Rights

The negotiation of intellectual property rights was a perplexing issue, in part because the representatives of the parties, other than Motorola, had little experience with such matters. Because this is an issue rife with misunderstanding, the provisions of the Agreement between the Parties required significant discussion As a result, as issues arose throughout the project, reference was made to the Agreement provisions to resolve difficulties. This demonstrated the need to fully define intellectual property rights in writing before undertaking development projects.

2.1.2.2 Project Management

Over its six year duration, the managers of the *ADVANCE* Project have used various project management methods. Essentially, these methods are drawn from:

- construction contract management; and
- the computer science subfield of software development using the military requirements specifications approach.

Construction contract management methods ranged from highly detailed critical path analysis methods to more generalized procedures involving milestones. Typically, several hundred specific tasks were defined, related and monitored through monthly progress reports. Motorola and IUTRC, as well as De Leuw, Cather & Company and the project office, each devoted significant manpower to these tasks throughout the project.

In a large-scale project such as *ADVANCE*, detailed management of personnel and budgets are clearly necessary. The time-honored method of dividing large tasks into smaller subtasks and even sub-subtasks is clearly an appropriate management strategy. How much effort should be expended in monitoring this system is a difficult question that tends to bring managers into conflict with the designers being managed.

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 their task and discuss deadlines and progress towards them in a meaningful way and required greater inter-agency cooperation and communication. Whether the more detailed description of tasks provided any useful insights or measures of progress was continuously debated.

Clearly, the *ADVANCE* Project is not the first project to face these questions. Although project management was identified early by both IDOT and Motorola as a difficult issue, the interviews with six prospective project management consultants provided no assurance that anyone knew how to manage such a project in a public-private partnership.

*ADVANCE* used various traditional and non-traditional project management methods. Undoubtedly, experience and a willingness to keep the whole project in focus and perspective are important ingredients of success. The use of milestones rather than detailed procedures worked reasonably well. However, one could argue that this was a result of most problems being defined and addressed by the time this technique was used.

2.1.2.3 Design Team/Leadership

The development and deployment of *ADVANCE* occurred over a six year period. Few of the persons that attended the initial meetings were actively involved in deployment. Equally important, the supervisors of many of the leaders of the project have changed. This project illustrates that technology development efforts require a long time to bring to fruition, and therefore, they require unusual focus and persistence to achieve positive results. Many of the leaders of this project found this length of time to be extremely long in terms of their previous professional experience.

Equally important, supervisors typically evaluate the success of projects under their purview on an annual basis or an even longer time frame; likewise, their success as managers is evaluated on the same basis. A long term development effort of the nature of *ADVANCE* is in conflict with this time scale. Everyone involved in this project had prior experience in related efforts; however, no one had the experience in all facets of the project or large scale technology development and implementation effort involving a public-private partnerships. All of the parties to the *ADVANCE* Agreement committed significant resources to the project. All parties 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 who were brought into *ADVANCE* by the parties.

The lesson learned from ADVANCE was that on long term projects, staff will change and it is imperative that efforts be fully documented and a willingness exist between all Parties to work together.

#### 2.1.2.4 Consensus Building

There were five parties that were the main members of the *ADVANCE* Project as noted in Section 2.1. This diverse group of organizations had varied interests in the project and also particular areas of expertise in which to aid in guiding the project through concept, design, development and deployment. Each of the organizations involved had its own agenda and elements which it deemed critical to the project. Consensus building was performed through a hierarchy of committees and subcommittees. While an overall committee provided policy direction, smaller committees tackled specific technical problems. This organizational structure was beneficial in arriving at mutually acceptable solutions to sometimes difficult technical and institutional issues.

#### 2.1.2.5 Agreements

A written and signed agreement for the *ADVANCE* Project established the mutually agreeable terms to engage in this cooperative demonstration to design, develop, implement and evaluate *ADVANCE*. The agreement outlined overall policy and program goals, individual Party responsibilities, committee structures, project management roles, project length and funding terms, and other basic contractual provisions.

This agreement proved useful for identifying responsibilities and providing a framework for the legal constraints regarding the project. This type of agreement can be used as a prototype for similar agreements between the three states of the GCM Corridor with respect to sharing of traveler information, Variable Message Signs (VMS) / Highway Advisory Radio (HAR) policies, and joint control of border located field devices.

#### 2.1.2.6 Liability

Because the design of the *ADVANCE* Project provided for placing route guidance systems in private vehicles, there was substantial concern about the liability of the Parties in the event of accidents involving these vehicles. Other than providing for sensible procedures in screening drivers during the recruitment process, it was concluded that there were no workable mechanisms for limiting the liability of the Parties. In the end, each

Party agreed, in effect, to be responsible for its own liability, and not to be liable to the other Parties. As the project developed, these issues continued to be raised where Parties were anxious to protect themselves from liability. In fact, no liability claim against any Party resulting from the conduct of *ADVANCE* have been made through development and operation of the in-vehicle testing.

## 2.2 CORRIDOR TRANSPORTATION INFORMATION CENTER

The Corridor Transportation Information Center (C-TIC) is an expansion of the TIC which was used in the in-vehicle phase of the *ADVANCE* Project. The C-TIC has been expanded beyond the TIC, however, to include new sources of transportation information. These sources are located within the three state GCM Corridor and encompass a variety of jurisdictions and information types. The C-TIC is the prototype of the Gateway Transportation Information System and will continue to operate throughout the development of the Gateway.

The C-TIC is designed to be a pass-through between various information sources in Illinois, Indiana, and Wisconsin. It is not designed to control and/or monitor traffic control devices but rather to facilitate the sharing of information between various agencies, control centers and private firms and to provide transportation related information to the public. This information includes travel times on selected routes, weather information, incident locations, construction and maintenance information.

### 2.2.1 Technology Issues

Many of the technology issues that were faced during C-TIC design and development are relevant to the MMTIS project, especially the design of the Gateway. Discussions of these technology issues are presented in this section.

#### 2.2.1.1 Design

The C-TIC design was limited due to re-use of *ADVANCE* hardware and software packages. Usually, a design specification is completed and then a system is developed to meet the design specifications. In the case of the C-TIC it was important to base the design on the existing hardware and software, being careful not to exceed the capabilities of the system. Additionally, when it was noticed that the C-TIC software was memory intensive and excessive swapping of programs in and out of memory was slowing system performance, additional memory was added to the system to alleviate this problem.

Throughout the development of the C-TIC, it proved useful to re-use interfaces (modems, communication software, protocols, and C-TIC receiving processes). This resulted in substantial savings of design and coding time. Additionally, it assured proper operation by using a proven method and decreased uncertainty that could have resulted from use of unproven technologies and protocols. Conversely, it did establish restrictions in architecture, processing speed/capability, and database organization on the C-TIC design.

The C-TIC design is based on centralized processing. All processing is performed within the C-TIC computer. The C-TIC operator workstations do not have any processing capability. This has a direct impact on the performance of the operator interface, since operator requests are served through the C-TIC computer. This decreased available memory for other C-TIC processes. Overall, the lack of computing capability in the operator workstations impacted the speed of the overall system and the user interface. Future design should provide for operator workstations to have their own processing capability.

The C-TIC employed an object oriented database in its design. Object oriented databases are becoming more widely accepted in the industry and offer an easy method of mapping data into the database through the use of objects and the ability to re-use code. Another aspect of the database was the use of one large database to store all C-TIC data and the GCM road network. As the amount of stored data grew, it became more difficult to manage the data in the database and the process of removing old data became slower as the number of records to search through grew. Historical data held in the database was therefore reduced from 14 days of data to only holding the current set of data. This has dramatically reduced the processing time of updating the database since current files are being overwritten and no actual cleaning occurs.

Throughout C-TIC development, there was a five step process for implementing new software processes. The first step was for a developer to create a document which described the purpose of the new process and detailed its design. Next, was a review by other developers, the systems integration team, and the C-TIC manager. The third step was an updated document which reflected comments and/or changes brought forth by the design review. The fourth step was software coding and the fifth step was integration testing. The use of this structured methodology allowed widespread access to the design before any code was written, and therefore assured that the design was in line with the objectives of the entire project. By performing reviews early in the development process, misdirection was kept to a minimum which let software development efforts proceed without intermittent design changes. The increased involvement of non-programmers resulted from the experiences previously noted in *ADVANCE*.

The C-TIC has two ways of displaying its information. The operator corridor map and the Internet web pages. System developers spent significant amounts of time creating these interfaces and showing prototypes to the operators. This was not rapid prototyping, however, and future design efforts could reduce their redesign time significantly through the use of rapid prototyping.

Situations arose initially in the C-TIC development where one developer would write a process which did not interact properly with other processes. This problem occurred because there were several software developers working separately on the various processes. It became clear that each developer must be involved in a code review process. This involvement provides each developer with the definitions of certain variables available and their specific format or data structure. The lesson learned is that each developer must understand all processing that is being performed so that they can write their own code accordingly.

#### 2.2.1.2 External Interfaces

For the duration of *ADVANCE* and C-TIC development, a T1 leased line connection existed which linked the C-TIC to the University of Illinois at Chicago (UIC) computer network. The T1 enabled the UIC software developers to gain remote access to the C-TIC for development and testing. As part of the C-TIC project, an Internet Homepage was developed and served out of the UIC computer network. All communication with the server was performed over the T1 connection. The T1 connection was proven to be a reliable and cost effective means of transferring large amounts of data over long distances.

The Illinois State Toll Highway Authority (ISTHA) is deploying an electronic toll collection system throughout its highway network. The electronic toll collection system is currently deployed on about 40% of the ISTHA network. In relation to this, a prototype system was installed which gathered information from the toll plazas and transmitted the information to a computer located at the C-TIC facility. Two sequential readings from the same transponder were used to calculate travel times on Sections of I-355. The data was transmitted using the X.25 protocol. For the most part, the concept of using electronic toll collection as a means of measuring travel times was proven. However, most of the time there were problems with the X.25 communications protocol that prevented real-time data transfer.

The C-TIC uses the Navigation Technologies (NavTech) road network database for its internal location standard. The database is also used to generate the graphical image for the operator corridor map and the Internet web page maps. Each of the segments of roadway within the NavTech database has an associated link ID. The C-TIC uses these link IDs to anchor specific loop detectors to the roadway at a particular location. The problem is that the NavTech link IDs are not necessarily constant and are subject to change periodically. Although strides have been made to separate hard ties to a specific database, some ties still remain and could potentially cause problems if link IDs were to change in the future. It has been noted that NavTech is going to be transitioning to permanent link IDs, but changes may occur in the transition and it is still preferred practice to separate the hard ties from a particular vendor.

A connection to Northwest Central Dispatch (NWCD), a suburban police and fire dispatch center provided the C-TIC with timely and accurate incident information. The connection was provided through a buffering PC at NWCD. This PC was used to filter non-traffic related incidents and also sensitive information such as names and other details. The use of filtering enabled the C-TIC to receive only relevant information and saved processing time at the C-TIC. NWCD also utilizes alias tables to categorize incident types. The large variety of incident types at NWCD does not make a one-to-one correspondence with the incident types at the C-TIC. This lack of exact matches is a recurring problem which was also seen when *999 was connected to the C-TIC.

In Chicagoland, the *999 Cellular Express Line receives calls from cellular phone users who report mainly traffic incidents. Until recently, the calls were received by operators who recorded all information using a paper based system. Currently, a computerized database system enables operators to record the information which can be later sorted and statistics can be kept more accurately. The *999 system ultimately transfers incident information to the C-TIC. Development of this entire system uncovered several noteworthy lessons:

- The transition from a paper based system to a computerized system can be difficult and a large amount of training is needed, both in general computer use and actual system use.

- It is critical that the system developer have intimate knowledge of the operation which is going to be computerized. Several days on-site aid in gathering the needed information to understand the needs of the system users.

- Never underestimate the importance of the user interface. Its design must be driven by user needs, as this is the only means with which the user will interact with the system. The layout must be logical and flow in the same manner as the workload. It was important to not change the concepts followed by the operators, just change the means of recording the information.

- It was important to clearly document the communication protocol and data to be transmitted from *999 to the C-TIC. Initially there were some problems in communicating between the two systems. The way in which the user interface was structured initially was that a new record was inserted after the location information confirmed a new incident and at the end of an incident entry there would always be an update record inserted into the database, even if there were no updates. First, a process monitored the database at *999 and checked for new records that were inserted into the database. These records were then packaged and sent to the C-TIC. The process also checked for updated records in the database, packaged them and sent them to the C-TIC. The end result was a duplication of transmission which falsely created duplicate incidents at the C-TIC. Minor reprogramming was needed to correct the duplicate messages. Second, the NavTech database is being used in both the *999 system and the C-TIC. Incident locations can be identified by road and crossroad, or by a NavTech specific identifier (each roadway segment has a unique numerical identifier). Since both systems use the same roadway database, it was easier to transmit the segment ID. In order for the *999 system to allow for entering of locations beyond the NavTech database coverage, location verification needs to be manually performed by the operator. It has been noticed at the C-TIC that some incident information is arriving without segment IDs. The C-TIC software was written expecting to receive a segment ID for determining location and when all incidents from *999 were not arriving with segment IDs, modifications needed to be made within the C-TIC.

### 2.2.2 Institutional Issues

Throughout the development of the C-TIC special attention has been paid to providing a system which addresses the needs of the entire GCM Corridor. An Operations Committee held bi-monthly meetings which allowed all three states to provide input into the system development. Issues regarding overall system operations were discussed. This Committee met with particular agenda items which needed to be addressed but also maintained an open forum discussion at the end of each meeting for all attendees to air their concerns or provide insight beyond the meeting topics. By means of the Operations Committee, the C-TIC Internet and operator interface were approved through a consensus of all members. This type of decision making process where system operations personnel are involved assures a project which meets the expectation of the future users.

The technical direction of C-TIC development was guided by the GCM ACI Work Group. The ACI meets every other month and makes policy decisions on technical matters relating to GCM projects. The decisions to include National Transportation Communications for ITS Protocol (NTCIP) standards into specifications and to work jointly on the FHWA sponsored national location referencing standard were upheld at these meetings. The C-TIC developers and consultants often presented recommendations on development direction at ACI meetings. Due to a large turn-out at most of these meetings, the development of the C-TIC proceeded in a manner consistent with the views of the GCM Corridor stakeholders.

## 2.3 MONITOR

The MONITOR freeway traffic management program was initiated to mitigate the increasing impacts of traffic incidents and recurring congestion along the Interstate and primary highway network within the Milwaukee area (encompassing Milwaukee, Waukesha, Ozaukee, and Washington Counties). Initial activities focused on operational and management improvements instead of increasing capacity. These improvements involved installing ramp meters and establishing closer liaisons with various enforcement agencies within the region. As recommended in the Southeastern Wisconsin Regional Planning Commission (SEWRPC) Planning Report

(No. 39), MONITOR consists of traffic detectors, closed-circuit television (CCTV), additional ramp metering with High Occupancy Vehicle (HOV) exclusive lanes, variable message signs, additional freeway patrols, and related infrastructure such as a communications network and a control center. MONITOR's primary objectives are to reduce congestion, improve safety, enhance freeway operations, and facilitate increased vehicle occupancy rates.

MONITOR is being built in stages, with each stage being a section of freeway. The first two of five stages of implementation have been designed and constructed, with the third stage currently under construction. MONITOR is currently operating on approximately 50 centerline miles of freeway in Southeastern Wisconsin. Along these freeways, a subsystem of traffic detectors provides real-time data about traffic conditions through a leased communications network to an operations center. Computer hardware and software at the control center analyzes and presents the freeway traffic information graphically for system operator usage. Nearly 60 entrance ramps are equipped with ramp signals, or ramp meters, which can be managed from the control center to maximize traffic flow on the freeways. Fourteen variable message signs, eleven on the freeway system and three on arterials leading to the freeway, are also controlled from the operations center. The signs are used by system operators to provide real time traffic information to freeway and surface street travelers. In addition to the signs, the operators will be able to utilize Traveler Advisory Radio (TAR) to broadcast traveler information concerning freeway traffic directly to the motorists' AM radios.

By the year 2000, MONITOR will manage traffic on over 100 centerline miles of freeway, as well as provide information to the Gary-Chicago-Milwaukee C-TIC/Gateway, and will be a resource for expanded freeway corridor management, incident management, and traveler information services.

### 2.3.1 Technology Issues

#### 2.3.1.1 Central Hardware

The central hardware selection for the MONITOR system involved a compromise between the original desires of the developers and that of the Wisconsin Department of Transportation Central Office Bureau of Automated Services (BAS). The basis of the compromise was that the developers were in the process of developing a system on Sun UNIX workstations with OS/2 PCs as Operator Interface machines. BAS was not experienced in the operation of Sun UNIX, nor with OS/2. They did have experience on Hewlett Packard (HP) UNIX workstations and requested that the platform for the central servers be changed to HP workstations, while keeping the OS/2 PCs as the operator interface. Although at the outset the switch from Sun UNIX to HP UNIX workstations appeared to be a minor change, two major obstacles were uncovered later.

Firstly, the HP UNIX C and C++ compilers were not 100% compatible with the Sun compilers creating incomplete code and secondly, the object oriented database (Versant) that was the foundation of the system was available on the Sun platform, but only a beta version was ready for the HP. The differences between the Sun and HP versions, and the constant upgrades of the beta version required a number of extensive revisions to the system during development.

The lesson that can be learned from this experience is that a careful risk analysis must be completed prior to any system level changes. The downside to not fully completing and understanding this risk analysis (both for the developers and the users) will usually be in the form of additional system costs and a delayed system implementation and integration. In addition, consideration needs to be given to the design requirements of departments/agencies which may not be directly involved in the design and operation of the ultimate system.

#### 2.3.1.2 Data Communications

The MONITOR system's data communications are routed through a communications server which is responsible for compiling the outgoing commands and post processing the data from the field equipment prior to insertion into the central data bases and distribution throughout the system. The communications server is a Versa Model Europa (VME) based system with a Motorola MVME147S central processor board and Heurikon HK68/VSIO boards. The Motorola processor is the primary gateway to the system network for the Heurikon boards. The Heurikon boards perform the main communication function by communicating directly to the field devices.

This communications server was based on similar servers and currently performs very well. Heurikon, however, announced that they discontinued production of the HK68/VSIO board shortly after the server elements were procured. The initial procurement for the communications server included two HK68/VSIO board, or capacity for 32 data channels. The basic design feature of the communications server was its modularity, therefore boards for only the first few implementation stages were included in the initial procurement. The options that are currently available are to determine a source for used or reconditioned HK68/VSIO boards, or redesign the server to use a currently available board.

The lesson that can be learned from this experience is that every attempt should be made to implement system components which are hardware independent. If there must be some hardware dependence, then it is vital that sufficient numbers of individual hardware elements are procured initially to allow for all expected expansion and redundancy for maintenance purposes.

#### 2.3.1.3 Video Communications

The MONITOR system is one of the few systems that currently utilizes leased analog video services from the local telephone company for all CCTV surveillance cameras. The local telephone company installs all video transmitters, receivers, and additional fiber optic cable. The service enables each field camera to receive a National Television Standards Committee (NTSC) video signal, as well as transmit a full motion analog video image to the Control Center, where it is then converted back to an NTSC signal.

This arrangement was possible because the local telephone company was in the process of installing fiber optic cabling throughout the MONITOR system's area. Although the telephone company's plan is to ultimately utilize this fiber optic cabling to provide expanded digital services in the area, they had not yet fully implemented these services and therefore had spare capacity on their fiber optic cabling.

This video communications arrangement was not originally considered because it is typically the case that the local telephone companies will be able to provide digital services and not analog. However, during the preliminary engineering for the system, an informational meeting was held where system options were presented and comments were requested. After the meeting, representatives of the telephone company offered the analog video transmission services as an option for consideration. Because of the aggressive and cooperative nature of several of the key players within the telephone company and the Department, it was determined that the analog video services were actually the most cost effective alternative for the 0 - 5 year time frame.

The primary lesson learned was that there are advantages gained by including the private sector early in the system design process. By being open and straightforward in presenting the perceived options, and then being willing and able to cooperate, the Department was able to implement full motion video surveillance with analog video transmissions to the control center without the up front cost and time required to install a user owned fiber optic network.

### 2.3.2 Institutional Issues

#### 2.3.2.1 Video / Data Sharing

During the system definition process, a number of one-on-one interviews were conducted with local media representatives. During these interviews the primary functionality of the MONITOR system was described as being the collection and distribution of traveler information. Several alternative methods of distributing the information were discussed including distribution by fax, text based data broadcast, and system graphics terminals. It was agreed that video images, travel time and incident information was desirable on the part of the media, but there were some concerns about the distribution methods. Originally, two video images were allocated for each media outlet distribution. However, because communications connections to transmit the images from the Traffic Operations Center (TOC) to the individual media outlet rested with the media, the majority only implemented a single video image.

As far as the distribution of the travel times and incident information, the general consensus was that periodic fax transmission of the information was the preferred alternative. The primary determining factor was that the information would be in a text format which did not need to be converted or interpreted to be read over the air. However, there was some interest in the system graphics terminal which would allow the broadcaster to interpret the overall system status (i.e., big red sections, or all green) at a glance during the actual broadcast, although the graphics were rated as having a much lower priority.

The lesson learned was to present the end user, in this case the media broadcaster, with a range of alternatives and be willing and able to accommodate their reasonable requests. With the case of MONITOR, it actually resulted in the initial implementation of the fax server and delaying the implementation of a media based system graphics terminal which would have required significant software resources.

#### 2.3.2.2 System Access

The MONITOR system consists of a series of operator interface PCs networked together with two HP UNIX workstations, communications server, fax server, and traveler information systems server. The system can operate as an isolated self contained network, or as in the current case of MONITOR, a gateway can be implemented between the MONITOR network and the DOT's statewide governmental network.

The advantage of this gateway is that it allows the MONITOR operator interface PC to also operate as the user interface for any and all resources on the statewide network (i.e., DOT email, etc.). This actually allows the integration of the two systems onto a single PC on an employee's desk. However, it also creates a system where security is a very large concern for any entity attempting to gain access to the MONITOR system.

The two primary areas where security issues have affected the MONITOR system are maintenance, software corrections and sharing of system information with the existing C-TIC.

In regard to the maintenance and software corrections, typically the system developers researching a reported software error would dial-up and form a SLIP network connection. Through this connection the developer would have access to the system to complete testing, and load and implement corrective software. Because of the issue with network security, the use of a SLIP or network connection was greatly discouraged. There have been instances where a network connection has been established, but typically it is implemented for only a short time frame.

The second area of concern is sharing system information with the C-TIC. The initial concept of the C-TIC was to gather information from many individual systems throughout the Corridor, combine all the information, and share the combined information with the individual systems. This type of two-way data sharing requires access to the MONITOR system on a network basis and due to security, this type of connectivity is not allowed. Therefore, the MONITOR to C-TIC interface currently consists of a one-way data broadcast. The C-TIC will combine the data with the rest of the available information and display the combined data on an Internet web page. The MONITOR system plans to use this Internet web page to receive data back from the C-TIC. Although this is a workable solution, it does violate the concept of integrating data sharing into the systems.

The lesson that should be learned is that care and forethought must be given during the system development process to determine where there are concerns such as the State's security issues, and attempt, to the extent possible, to develop a system that is not limited in functionality or in maintainability.

## 2.4 ATLANTA ADVANCED TRAFFIC MANAGEMENT SYSTEM

The Atlanta Advanced Traffic Management System (ATMS) monitors traffic flow along 60 miles of I-75 and I-85 and provides congestion and incident detection. The basic system consists of a fiber optic communications backbone, real-time radio communications spurs, detection cameras and surveillance cameras. The system operation allows near real time traffic management by polling the detection cameras every 20 seconds for average speed, volumes, occupancies and stopped vehicles. This data is then sent to the Traffic Management Center (TMC) where it is processed and disseminated. Dissemination can be via changeable message signs, Highway Advisory Radio (HAR) or other means used in the Traveler Showcase project.

The system deployed over 300 detection cameras, 60 surveillance cameras, 100 miles of fiber optic cable 107 radio links for video transmission and 41 changeable message signs. As such, the Atlanta ATMS is the largest integrated installation of video detection and traffic management in the world.

### 2.4.1 Technology Issues

#### 2.4.1.1 System Requirements

As with all large-scale system deployments, agreement and early establishment of system requirements provides developers with a clear design path. In Atlanta, the ATMS requirements were not written down or distributed to critical team members until after design had already begun. Since system requirements were established late in the process, the involved parties did not have time to fully comprehend all their implications. As time went on, both designers and owners discovered requirements that had to be altered or broadened to provide needed additional capabilities. This necessitated redesign of some aspects and greatly affected the design schedule.

Another aspect of system requirements is that all requirements should be listed. Developers should not assume any inherent functions will be provided without asking for them. Additionally, a peer review would be helpful to point out deficiencies in the Requirements Specifications.

The integration of Autoscope with the Incident Detection System was another area where system requirements played a key role. Because of a lack of understanding of some of the Autoscope system requirements, at least two major design flaws arose. In order to explain these design flaws, a brief discussion of the Autoscope unit and its original usage follows.

Autoscope utilizes video based intelligent detectors to perform intersection detectorization and control. In intersection control, there are 4 Autoscope cameras which can be input into one Autoscope controller. In published literature, each Autoscope camera can have up to 16 detection zones, or 64 detection zones per controller. The Atlanta ATMS utilized the Autoscope intelligence for freeway incident detection. The difference in application necessitated a system redesign which was performed by a third party vendor. The first design flaw that came up was that the vendor coded in more than the maximum 64 detection zones per controller. When the system was deployed it did not operate. The vendor mistakenly used greater than 64 zones because there was an Autoscope unit in the design phases that could handle up to 100. This greater capacity, however, was not available on the unit that was being used for deployment. The vendor did not fully comprehend the system requirements of the unit that was being deployed.

An additional error occurred mainly due to the differences in applications. When the Autoscope unit is deployed at an intersection, the unit and cameras are generally powered by a single power source. Autoscope has a system requirement that the cameras must be in-phase when they are received at the controller unit. A camera can get out of phase if its power source is not in-phase with a power source of another camera. In the Atlanta ATMS, the distance between the four cameras that were connected to the Autoscope unit was so vast that the four cameras were not all powered by the same power source. This led to the cameras being out of phase from one another. The Autoscope unit could not handle it and would not boot up.

The lesson learned from Atlanta about System Requirements is that each system requirement of each component in the system deployment must be discussed and fully understood by the entire design team.

#### 2.4.1.2 Project Management

Because of the large scale deployment of the Atlanta ATMS project, Project Management became a key technical issue. In Atlanta, it was difficult to find a Prime Contractor that had experience in all aspects of an ATMS (communications, system integration, client-server networks, and transportation technology) as well as an understanding of the operational requirements of the ATMS owner. Atlanta was able to approve personnel who were to work on the project and found this to be helpful to gain experienced team members.
Other management difficulties pertained to a specific aspect of the deployment. It was difficult to manage the scheduling, quality control and testing of the communications infrastructure due to the fact that there was a multitude of contractors involved in the installation. For example, a different contractor was responsible for installing the communications equipment at each hub. Within each hub there were several subcontractors; there

was a separate subcontractor for routing installation, head-end equipment, and connections. With so many different limits of responsibility, it was difficult to determine accountability for correcting problems.

2.4.1.3 Incident Management

The Georgia Department of Transportation Traffic Management Center (TMC) was responsible for generating incident response plans. These were generated automatically by the Incident Management Software (IMS) or manually by the operators. One problem that was noted involved the time an incident was declared cleared. When an incident was identified, an incident icon was posted to the system. The icon served several purposes. Firstly, the icon was used in the Advanced Traveler Information System (ATIS) system to notify travelers or potential travelers that an incident exists. Secondly, the absence of the icon terminated any ATMS actions. The incident icon was taken off the system when an incident was moved from the travel lanes to the shoulder. In the cases of those incidents that had created extensive traffic backups, the icon removal cancelled further ATMS actions, including impact mitigation efforts, and therefore incident conditions were not fully treated. The lesson learned was that there must be a separation of when an incident is declared cleared and when incident mitigation efforts are declared complete.

2.4.1.4 Software Development

The Atlanta ATMS found that concept Graphical User Interface (GUI) screens should be used up front to aid in defining the operational characteristics desired by the owner/operator. Without these prototyping screens, much time was spent on designing features that were later dropped for new features.

2.4.1.5 Data Processing

System designers developed a unique manner in which data was passed from the field to the TMC and thence to the automatic incident detection system. For the Atlanta ATMS, the first half of the data flow (field to TMC) is accomplished by a direct link between the video detection system and a communications server at the TMC. It is not uncommon in other systems that there is an intermediate connection to a field controller. System designers eliminated this intermediate connection by using the distributed intelligence of the video detection system. The resulting transmission time was quicker. The second half of the transmission for the Atlanta ATMS (TMC to Incident Detection System) used a client server network. In this way a distributed processing network was used for faster incident response. In other words, instead of using one computer to communicate with the field as well as process the data for incidents, the Atlanta ATMS distributes the two tasks to a network to increase processing capabilities.

The lesson learned here was that designers should be encouraged to utilize approaches other than those used in the past in order to improve performance, etc.

### 2.4.2 Institutional Issues

2.4.2.1 Partnerships

The Atlanta ATMS forged partnerships where none existed before between media outlets, utility companies, technology vendors, defense contractors and public agencies (counties, police departments, 911 agencies, and DOT staff). These private sector partners were unfamiliar with transportation in general while some of the public agencies were unfamiliar with the benefits of ITS. The ATMS provided an opportunity for various traffic management groups to work together and share resources to improve traffic operations. Communications and agreements were not forthcoming initially because the various agencies did not fully comprehend the capabilities of the ATMS and had no prior experience with working together.

The lesson learned is that the concept must be sold to the various agencies, providing them with proof when possible. In the case of the Atlanta ATMS, as the capabilities of the TMC were exhibited and proven to the various parties, the communications efforts improved and data quality and timeliness also improved.

#### 2.4.2.2 System Integration.

System integration was found to be a major issue in the Atlanta ATMS. Designers and operators found it was absolutely essential to have a planned series of system integration steps that would enable isolation of problems or malfunctions. By not having a step-by-step procedure that would enable the determination of errors, the installation schedule was not met. Additionally, the focus of the system integration that was performed was on integrating the hardware and software but, as was learned, it was just as important to integrate the functions of the various owners/operators with the system.

## 2.5 TRAVELINK (ATLANTA KIOSKS)

TraveLink, a link between the high technology world of traffic engineering and the general public, was developed to be fully operational prior to the 1996 Olympic Games in Atlanta. The TraveLink project was sponsored by the Georgia Department of Transportation (GDOT) and was a component of the ATIS of the Atlanta Regional Advanced Transportation Management System (ATMS). TraveLink provided a system of approximately 130 public access kiosks for distributing advanced traveler information to improve the mobility of travelers in the state of Georgia and the metropolitan Atlanta region. The system served as an information link to the traveler, providing:

- Real-time traffic and incident data from the Atlanta Regional ATMS
- Point-to-point vehicle routing
- Metropolitan Atlanta Rapid Transit Authority (MARTA) schedules and itinerary planning
- Information on Amtrak, Greyhound, and Cobb Community Transit
- Tourist information, including hotel reservation services
- Atlanta Regional Commission's Commute Connections information
- Weather information
- Airport facility information
- Airline schedule information and
- Special event information.

The Georgia Department of Transportation was the contracting agency for the kiosk project as well as the Atlanta Regional Advanced Traffic Management System, from which the kiosk system received data. FHWA served in an advisory role and provided funding for the project as an ITS Demonstration Project. The MARTA was linked to the kiosk project by providing schedule and routing information via its new ITS control center. The Georgia Department of Industry, Trade, and Tourism (GDITT) provided and maintained the database for travel and tourism related items on the kiosks. To sustain and expand the kiosk system in the future, the Department teamed with the GeorgiaNet Authority. GeorgiaNet was formed in 1990, as a State authority, to centrally market and sell, on-line or in volume, authorized public state information. GeorgiaNet procured the kiosks and maintained and operated the kiosk system after it was installed.

### 2.5.1 Technology Issues

#### 2.5.1.1 Hardware

The original TraveLink hardware configuration included Windows NT operating on both the PCs in the kiosks and the central server. To reduce costs by approximately $300,000, the kiosk's PCs were converted to operate using Windows 95 rather than NT. The central server remained configured with Windows NT. The use of both NT and 95 allowed comparison of the two operating systems. It seems that the use of Windows 95 caused many service calls to repair non-operational or locked up kiosks because of system memory errors. Windows NT was seen as a more stable operating system because the server did not have the system memory errors as did the machines operating with Windows 95.

A running theme within the Atlanta experience was that all of the projects had a very definite deadline (i.e., the Olympics). The start dates and delays within the projects allowed only limited time to complete the projects. Because of this, several typical project tasks were combined or completed "in progress." One of these tasks was to complete and obtain approval of a detailed design of all the required equipment to be contained within each kiosk. During development and testing, time was lost due to several minor redesigns required to include needed equipment that was not anticipated. The lesson learned is that ultimately time and effort are saved with the completion of a detailed design.

A primary goal of the kiosk project was to utilize COTS (commercially off the shelf) hardware and software as much as possible. Because of this several problems became apparent.

First with hardware, a typical problem concerned the printers. The printers were provided with Windows 95 compatible drivers. However, the printer's DLL device drivers did not support all of the features indicated by their sales literature. An example was the reporting of the printer status back to the system. Because of the Wide Area Network configuration of the Kiosk system the reporting of the printer status was a very important element in trouble shooting errors and maintenance issues. Unfortunately this feature was one that was not implemented as indicated in the literature.

The same type of problem was encountered with COTS software. Many times during the integration and testing it was discovered that certain features of the software package either were not implemented at all, or were implemented slightly differently than indicated or anticipated. With either situation, a workaround design change was required.

The primary lesson is that much of the COTS hardware and software did not contain expected features, some required features did not work or they worked differently than was documented. All features of COTS hardware and software should be verified prior to using them in the system design. Perhaps penalties should be imposed on the vendor if expected features are not included.

Another problem concerned installing equipment in the field that was not environmentally rated for the installation location. There were premature equipment failures due to heat and humidity. This type of problem should be thoroughly investigated and environmentally hardened equipment should be used. If environmentally hardened equipment is not available for the necessary elements, then additional design is required to modify the environment by either relocating the kiosks or modifying the housing design to better protect the equipment.

2.5.1.2 Communications

The kiosk system used high-speed, leased telephone lines operating at 56 kbps with frame relay, to communicate between the server and the individual kiosks. This type of communications allowed all the connections (kiosks) to appear as if they were on a single network (i.e., a WAN). The operating State agency was required to order all the leased lines. The ordering went smoothly, but there needed to be an agreement with owners of kiosk locations to provide telephone service to the kiosks. This could be accomplished by providing telephone connection lines from the primary communication terminal blocks, or they could provide conduit for the telephone company to install all the cabling from the terminal blocks to the kiosk locations. Communications problems occurred at many locations. For those locations which opted to have the telephone company provide the connection all the way to the kiosk, any reported problems were repaired promptly as the telephone company was responsible for completing all repairs. In those cases with divided responsibility for the communication lines, blame was passed between the location owner and the telephone company rather than the problem just being corrected as it was when there was a single point of responsibility. The lesson learned then would be that a single point of responsibility is preferred, especially when installing equipment.

**2.5.2 Institutional Issues**

The primary institutional lesson learned is that developing agreements to share data must be accompanied by clear and proven benefits to the agencies involved. For the kiosk system, data sharing agreements were made between:

- State Agencies
- Private Companies
- Transit Systems, and the
- Airport.

There were a number of types of agreements that were developed for the kiosk project that had not previously been developed. The ultimate reason why the agreements were able to be completed for the Atlanta project was the Olympics. A special event of that magnitude created an atmosphere where each of the agencies and entities perceived a common goal and worked in unison to achieve that goal.

The kiosk's purpose was to receive travel data and present that data to travelers. The primary design of the kiosk system allowed that the format for each incoming data source was maintained and presented to the users. Since the kiosk system did not alter any data formats, responsibility for data accuracy remained with the data source. The lesson learned here was that by keeping a single point of responsibility, it was easier to maintain accountability for data accuracy.

Another institutional lesson dealt with coordination. During the development of the kiosk system, many of the information providing systems were also in development (i.e., Georgia ATMS, MARTA, etc.). Each of the systems were intended to interface in some manner and therefore each needed to be kept up to date with the status of all the projects. It was vitally important to know that one system was either not going to collect data or to change the way it manipulated the data. All changes to individual systems created a ripple effect, requiring redesign and modification of many of the other systems, specifically, the kiosk system that was ultimately receiving the data. Therefore, a process to limit the number of design changes or at least to efficiently coordinate any changes, is critical.

One method utilized was to attend coordination meetings to discuss the progress of each of the systems. Although coordination meetings are important, care should be given in conducting these meetings. First, these types of meetings need to be able to work on two levels at the same time. The first level is the true technical level. The accuracy and detail of each of the systems presented at the meetings should be consistent with the most current events. This typically means including a technical lead for each project; someone who knows the facts and details of the current implementation. The second level is the management level. During discussions at these meetings, conflicts can arise over the manner in which two systems are manipulating the same data. The most efficient method of resolving these issues is to allow management the ability to decide on the course of action to be taken by all parties at the meetings. Care should also be taken in these types of meetings to discuss only those details of the systems that need to be coordinated.

## 2.6 ATLANTA TRAVELER INFORMATION SHOWCASE

The Atlanta Traveler Information Showcase project along with the TraveLink Kiosks project and various other ITS projects comprise the Advanced Transportation Management System in Atlanta. The ATMS is housed in the Transportation Management Center in Atlanta and provides fiber optic communication links to the Transportation Control Centers in each of the five counties of the region as well as the Metro Area Rapid Transit Authority and the City of Atlanta. All of these systems then have access to each other's surveillance cameras and other information. The Showcase takes the data collected by the ATMS along with data provided by the other projects, performs data fusion and distribution to the traveling public. The primary goal of the Showcase was to demonstrate a variety of technologies which could be used for data dissemination including cable TV, an Internet Home Page, Personal Communications Devices (PCD), in-vehicle navigation devices and Interactive Cable TV.

It should be noted that the Showcase system proved helpful to the users. In fact, during system evaluation, it was found that more than 40 percent of all users adjusted their travel pattern based on the information they received. Additionally, it was noted that route planning and current traffic conditions were found to be the most useful data provided to Showcase users. As far as the means in which the data was disseminated, it was noted that if the opportunity arose, in-vehicle devices would be purchased more often than a PCD or access to Interactive TV. Similarly, data was more often received over the Internet than over a PCD.

### 2.6.1 Technology Issues

The showcase developed a standard to present information to the travelers. A standard was necessary due to the great differences in the technologies used to disseminate the data. The dissemination device capabilities ranged from low resolution to high resolution images and from color to black and white. Project designers experimented with road width sizes, colors, font types and font sizes. The end result created a similar look and feel of data on all devices; similar icons represented speed data, incidents, road construction, and road maintenance. The result was that data source changes and project jurisdictional boundaries were transparent to the users.

During the course of the Showcase, it was determined that the in-vehicle navigation system needed to access a more detailed database than was originally designed. More local roads (arterials and surface streets) were added in order to provide better routing options and a better overview of traffic conditions in the area.

Three types of communications between the TMC and the vehicles were used throughout the project: FM subcarrier, ARDIS packet radio and SkyTel 2-way paging. The ARDIS packet radio network proved to have spotty coverage of the region and the Sky-Tel paging system proved to be expensive. The FM subcarrier, although having a limited message structure, allowed near real-time data to be available in the vehicle for reasonable costs. The lesson learned is that not all mobile communications providers will be able to meet the project's needs and system developers will need to do an analysis of each one. A combination of providers may need to be used.

### 2.6.2 Institutional Issues

The Showcase developed software links to communicate transparently with the ATMS to receive travel data. Although this was accomplished technologically, the project found that it was important to have agreements between the various agencies that their data would need to be posted in a timely manner if the real-time aspects were to be of use.

On another note, the objectives and functionality of the on-line services were not clear to each of the agencies providing input. Problems arose mid-project that necessitated agreements on what services will be supported.

The Internet Web Page was very successful but maintenance of the page was time consuming. The cable television system necessitated program production time and money while distribution of the program to the residents necessitated a large amount of negotiations with cable television providers.

## 2.7 I-95 CORRIDOR COALITION INFORMATION EXCHANGE NETWORK

The I-95 Corridor Coalition is a partnership of the major public and private transportation agencies within the Northeast Corridor. The overall goal of the Coalition is to enhance mobility, safety, and efficiency across all modes and transportation facilities that serve the Northeast Corridor. The I-95 Corridor Coalition has sponsored several projects in response to this goal, including the development and deployment of an Information Exchange Network (IEN).

The objective of the IEN is to facilitate communications and information sharing among Coalition member agencies with private entities. This shared information supports coordinated transportation management and traveler information on a regional and corridor-wide basis. Some examples are: alerting other agencies and the traveling public of major incidents and their impacts; using VMS and HAR belonging to one agency to describe an unusual condition on another agency's facilities; maintaining a library of standard operating procedures and guidelines for access by IEN users; and creating an integrated clearinghouse of real-time multi-modal travel information. The Information Exchange Network provides access to transportation agency databases, and provides the communications backbone for exchanging information.

During the initial portion of the project, through custom software development and workstation deployment (the current phase of the project), both technical and institutional issues needed to be addressed. The institutional issues were more complicated simply because more people (from the consultant's and the customer's side) were involved in making decisions involving policy. Also complicating the resolution of institutional issues was the fact that a resolution for one client did not necessarily work for a different client with the same or a similar issue. Examples of this are discussed in the Agreements Section, 2.7.2.2.

### 2.7.1 Technology Issues

Several decisions needed to be made early in the project:

- What computing environment (hardware and software platforms) would be deployed at customer sites?
- What development system would be used to implement the custom software applications?
- What communications methods would be used to move information between the deployed workstations?

Each of these is discussed below.

#### 2.7.1.1 Computing Environment

For the I-95 Corridor Coalition Information Exchange Network, the "end" computing environment is Microsoft Windows NT 3.51, running a custom application supported by Microsoft Office Professional. The workstation software runs on a Dell Pentium Pro 200 with 64 MB of RAM and a large hard disk drive. Several factors influenced the decision on the computing environment. The most important factor, was that the environment had to be able to support the solution to the problem; economical and timely conveyance of incident and construction schedule information between agencies. The second factor was that the workstation had to fit into the customer's environment (whatever computing environment prevails in the customer's office). The third factor was that the solution had to fit into the project's budget.

In terms of providing an environment suitable for problem solution, the Microsoft Windows NT environment was most applicable although, the project did not start out using Windows NT but rather Windows 3.1. Windows 3.1 proved to be inadequate for the IEN simply because it does not provide a real-time, multi-tasking, preemptive scheduling environment. The Windows 3.1 system was unreliable in alerting the users of incoming incident information. Sometimes the information would arrive on time and at other times the user would be alerted 20 minutes after the information had arrived on the workstation. The lack of predictable message arrival and alerting was resolved after the system was implemented using Windows NT.

To determine how to fit into the customers computing environment, information regarding operating systems, word processing/office automation suites, and networking standards in use at the agencies was requested. Most agencies were not based on a Microsoft environment, although enough were Microsoft capable or had some experience with a Microsoft environment that choosing Microsoft was logical.

The final factor considered at the beginning of the project was the cost of the workstation. The choices were PCs running Windows, PCs running OS/2, some hardware running UNIX, or some other platform. The range of cost for these systems varied, so to be safe, a high estimate was used for the platform. The low end of the candidate solutions was ultimately chosen.

The Dell PC was not the first choice of hardware. A different PC manufacturer was originally chosen, however several of the machines did not work when they were delivered. With this experience and stories in the trade journals about the selected vendor having "quality" problems, Dell was chosen. There were no problems with the quality of the Dell equipment but there were long (5 weeks) lead times for the delivery of equipment.

The lesson learned here was that even after a decision is made on a particular hardware or software product, it may still be necessary to use other products for one reason or another.

#### 2.7.1.2 Development Environment

The development tool used for most of the IEN custom application was Visual Basic. Visual Basic allowed full functioned, complex, user interface based applications to be built without concerns about performance. More importantly, the Visual Basic language is easy to use and therefore was able to be learned quickly by many different levels of developer to produce useful system components.

#### 2.7.1.3 Communications

Choosing the proper blend of communications services to support the IEN proved to be a challenge both technically and institutionally. The technical challenge involved providing the best solution given the constantly changing communication services environment. The institutional challenge was, after choosing the technical solution, getting the coalition members to pay for it. In the end, the economics won and the solution that provided minimally acceptable system performance, with the costs being borne by the project, won.

The original technical solution connected all workstations via frame relay. Although this provided the best technical solution, two institutional issues arose: coalition members balked at the $500 per month charge for frame relay; and it was unclear if all agencies could procure frame relay services from a single pre-determined frame relay vendor which was a requirement. Given these constraints, a solution using dial-up telephone was chosen. The costs of this are the monthly charge for an analog telephone line and the long distance charges for the phone calls between the workstations and servers. To reduce the cost to the agencies where the workstations were located to the cost of a monthly line charge, an 800 number was set up for the workstations to call. This means that all long distance charges from the workstation to the server and from the server to the workstation are paid for by the project. The effect of this consolidation of communication costs is that the system is slower than it could be via full time connection through frame relay. The lesson learned here is that while a solution may be technically acceptable, it may not be cost efficient.

### 2.7.2 Institutional Issues

As mentioned in an earlier section, institutional issues as well as technical issues needed to be handled throughout the project.

#### 2.7.2.1 Consensus Building

Consensus building for the I-95 IEN was handled by a related, separate, I-95 Corridor Coalition project. Much of the consensus required in this project revolved around how incidents are managed in general, and how incidents are handled when they are managed across jurisdictional boundaries in particular. Additionally, the project that was developing the software system was helped immensely by a separate project that addressed ways of managing incidents. The incident management project resolved most of the "incident management" problems before the IEN project ever encountered them. In addition, the incident management project provided the development team a means to learn what was required of the system, how it was being used, and a forum for presenting new features/proper use of the system.

The lesson learned here was that by building a consensus on a particular common problem, it is possible to expand the consensus to other areas.

#### 2.7.2.2 Agreements

Most of the time spent on institutional issues was spent making modifications to the Memorandum of Understanding that was set up to provide a framework for the proper environment for and use of the IEN workstation. The document addressed what the hardware was to be used for, the environment for the hardware (secure, heated, plugged in to both power and a dedicated telephone line), software licensing issues, etc. One agency did not like the name of the document nor the language (not legal enough). Another agency required copies of all of the standard software license agreements for the software included on the workstation. Because the workstation is provided under a federal program, one agency was concerned whether or not accepting the workstation would impact their ability to charge tolls (accepting federal funds).

The lesson learned here is that what may be agreeable to most participants, may not be agreeable to all.

#### 2.7.2.3 Cultures

A technique that is employed to reduce any cultural differences that may arise between agencies is to have periodic user's group meetings. In the beginning of the project, when the population of workstations was small, a single user's group meeting was held at a single location that included all users of the system. One manager and one hands-on user from each site was invited to the meeting. At the meeting, topics were discussed such as what was good about the system, what needed updating, and how the different users were using the system (what was being entered, why certain things were being entered). When the population of workstations became greater than 20, regional user's group meetings were held in the different regions of the Corridor. Because this environment does not address interregional issues, facilitators are present at the regional meetings to convey corridor issues to the other regional meetings.

## 2.8 SEATTLE ADVANCED TRANSPORTATION MANAGEMENT SYSTEM

The Seattle Advanced Transportation Management System (ATMS) began in 1967 with the installation of closed circuit television cameras to monitor the reversible lanes on I-5. Since that time, the system has been expanded numerous times to include the installation of vehicle detection stations (1978), centralized ramp control (1981), variable message signs and highway advisory radio (1986) and most recently a complete system upgrade that included the replacement of the central control computer and operator consoles as well as the central and user interface software. This last upgrade began in 1989 and was completed in June 1993. Lessons learned are addressed in the following sections.

### 2.8.1 Technology Issues

#### 2.8.1.1 Design

Detailed software design requirements and specifications were not developed in advance of system coding. The lack of system requirements and detailed software design afforded Washington DOT (WSDOT) the opportunity to keep pace with the ever increasing computing and software capabilities over the duration of the project as well as tailor the system operation to very specific user needs. Conversely, project schedules and budgets were impossible to maintain due to shifting requirements. High level design issues had to be frequently revisited to meet new conditions and system requirements. The lesson learned then was that while a lack of system requirements enabled flexibility in design, the problems this flexibility created outweighed its benefits.

#### 2.8.1.2 Order of Work

The identification and definition of a system requirements document is absolutely critical in order to successfully manage a software development project. From the requirements, a high level design including the system architecture should be developed. Once the requirements are documented and a high level design document created to support the system requirements, a detailed design should be developed to sufficient detail as to allow software modules to be split off and developed independently. Modification of the requirements through the course of the development effort can be tolerated to an extent, so long as the high level design and architecture are not violated.

#### 2.8.1.3 Operator Console

WSDOT had over 20 years of traffic monitoring and 10 years of traffic control experience prior to the project start date. As such, they had a good feel for the system operations and every day realities of managing a transportation system. The operator consoles were designed to meet the following four goals:

- integrate all operator functions into each console such that multiple operators could simultaneously have access to the same traffic data and status information;
- utilize standard communications interfaces between the central computer and the operator consoles;
- utilize a low-cost, commonly available micro-computer with graphics display; and
- select a micro-computer that was commonly used within WSDOT such that maintenance and upgrades could easily be supported.

#### 2.8.1.4 Operating Systems

Microsoft Windows was just becoming available as the project was getting underway and there was tremendous excitement in the industry over this new user interface. However, software development within the Windows environment was much more difficult than anticipated. Several different versions of Windows from Windows/286 to Windows 3.1 were marketed by Microsoft during the development effort. All versions were encompassed into the software development effort. The user interface software was developed in approximately 5,800 hours and took a little over 3 years.

The lesson learned here was that while it may be desirable to utilize the latest product, it may have an impact on development costs and schedule.

### 2.8.1.5 Central Computer

The central computing system was also replaced as part of the ATMS upgrade project. A DEC VAX 6000-420 was selected for the central computing hardware which was designed to handle all communications requests, database development and maintenance, and real-time data collection and analysis. This platform proved to be very reliable and no hardware failures that would have disrupted the traffic management mission of the system were reported for the entire time the system was used for software development. Redundant hardware was included in the architecture design to pick up system management in the event of a primary system failure. On-line diagnostic software was successfully employed to identify 85 percent of all system degradation prior to system failure.

### 2.8.1.6 Applications Software

The central software required approximately 16,000 man-hours and over three years to develop. A total of 130,000 lines of code were developed. Several time critical sequences were identified and the response times had to appear almost instantaneous to the users.

The first time-critical sequence was in the use of joy sticks to control the pan-tilt-zoom features of the CCTV. The code to accomplish this task was written in assembly language. Response times between affecting an input to the joy stick and recognizing movement of the camera was approximately 75 msec. This exceeded expectations and the operators had no perception of sluggish operation.

The second time-critical sequence was in the retrieval of information from the VAX for display on the user console. The criteria was set at 2 seconds for all data and graphics to be displayed. This required that the data could not be stored on disk. All key databases were kept memory resident on the VAX. The net result was an almost instantaneous display of requested information at the user console ranging from 40 to 70 msec.

### 2.8.1.7 Team Size

The software development team consisted of the following individuals:

- two WSDOT engineers familiar with system operation and operation requirements as well as all subsystem components
- two senior software engineers
- two junior software engineers
- one documentation engineer
- project managers from WSDOT, Fluor Daniels, and HNTB.

All work was done locally with the exception of one senior software engineer who spent 50% of his time telecommuting. The proximity of the team eased project communications and facilitated impromptu working meetings and discussions which netted a superior end product. Direct communications among the key technical staff was cited as key to the project success.

The lesson learned here was that the use of a small team, primarily onsite, was beneficial to system development.

2.8.1.8 Team Continuity

Staff turn-over can be disastrous in a software development project. The knowledge base lost when an individual leaves prior to completing documentation can be difficult to recover. As well, training new staff to fill vacancies particularly in specialized fields such as transportation systems is time consuming and wastes valuable development time. The Seattle ATMS upgrade project was fortunate to keep the core team together throughout the entire project duration with the exception of two individuals. This lesson is particularly important when the core team is fairly small.

2.8.1.9 Project Manager

Any transportation systems project involving software development brings together engineers and specialists with a wide range of talents and experience. Each expert is critical to the success of the project, but often they have tremendous difficulty communicating with one another. The project manager must be versed in all areas of expertise to help ensure the project moves along as required and all team members' skills are maximized.

2.8.1.10 Standardization

Communications protocols vary widely across all subsystem components as well as between different manufacturers of similar components. Worse yet, protocols often vary between different models of the same manufacturer. The impact of non-standardized communication protocols on software development is tremendous, not only in terms of the total number of lines of codes, but also in the complexity of the software design and integration requirements.

## 2.9 TRAVINFO

The TravInfo system began in November 1995 as a two year Field Operational Test (FOT) approved by the Federal Highway Administration. TravInfo is an Advanced Traveler Information System (ATIS) for all modes of surface transportation in the San Francisco Bay Area. TravInfo is centered around a Traveler Information Center (TIC) which houses the database that is available to both the public and commercial vendors through phone, data server and data broadcast systems.

TravInfo is implemented as a public/private partnership. The project is set up with a two tiered level of management; a Management Board and a Steering Committee. The Management Board is entirely made up of Public Agencies, including the Federal Highway Authority, Federal Transit Authority, Metropolitan Transportation Committee, California Highway Patrol & Caltrans. The Steering Committee is almost exclusively private corporations with the exception of two City Engineers. These two management factions were often in conflict with one another on design issues and direction of the project, but were able to successfully resolve all conflicts for the sake of the project.

The publicly funded TIC provides data to transportation users and providers (public/private agencies) and private Independent Service Providers (ISP). The ISPs help perform data dissemination. There are currently over 40 ISPs who have agreed to participate in the project. Several of these ISPs have developed actual products that are being tested as part of the project.

One of the goals of TravInfo was to provide a system architecture and framework that could be reapplied in other metropolitan areas. The following sections briefly present the system architecture and hardware configurations that were developed for TravInfo as well as the lessons learned.

### 2.9.1 Technology Issues

#### 2.9.1.1 System Architecture

The TravInfo TIC is the hub for system operation, housing the database and operator workstations. The TIC utilizes a fully distributed architecture. The database workstation houses the static, periodic, and dynamic data acquired from outside sources, TravInfo software and database functions. Being fully distributed, each of the operator workstations also has TravInfo software and database functions. The operator workstations access and display the database, perform system administration, execute TravInfo software functions and view and modify the database. In this manner, the processing is distributed among the operator workstations.

Additionally, there are two TIC nodes. Each node has the same basic equipment described above which allows redundancy in processing in case of system failure. It also allows distributive processing on a regional basis. One lesson learned regarding system architecture was that system redundancy was required in order to be able to provide information to the travelers on a 24-hour basis.

There are three major subsystems within the TravInfo System Architecture. These are Data Acquisition, Data Processing and Data Dissemination. Within the Data Dissemination Subsystem, there are three dissemination means: Landline Data System (LDS), Data Broadcast System (DBS), and the Traveler Advisory Telephone System (TATS). During the design of each of these subsystems, conflicts arose between the two major management factions, the Management Board and the Steering Committee.

#### 2.9.1.2 Data Acquisition

TravInfo accepts data from a variety of sources in various data formats. The following table provides a brief description of these sources, data format and how the data enters the database.

| SOURCE | DATA TYPE(S) | COMMUNICATION (Interface Method) | ENTRY (Data Translation Method) |
|---|---|---|---|
| California Highway Patrol Computer Aided Dispatch Interface | incidents | leased line modem | Semi-automated: Manual input via a graphical interface which prompts inputs. |
| California State Automobile Association and Caltrans fleet dispatches | speed, congestion, incidents, roadway closure and maintenance | leased line modem | Semi-automated: Manual input with a data entry terminal at data origin; Electronic transfer to the database. |

| SOURCE | DATA TYPE(S) | COMMUNICATION (Interface Method) | ENTRY (Data Translation Method) |
|---|---|---|---|
| Caltrans CCTV | speed, congestion, incident verification | video feed into TIC | Manual entry with operator terminal. |
| Freeway Service Patrol Automated Vehicle Location Interface | speed | leased line modem | Automatic: electronic data feeds directly into database. |
| Caltrans mini Traffic Operations System | speed, volume, congestion | frame relay router | Automatic: electronic data feeds directly into database. |
| Regional Transit Database | routes, schedules, stops | BBS via dial-up modem | Manual entry, menu-based input screens. |
| Transit Agencies | delays, incidents | telephone, fax, BBS via modem | Manual entry, menu-based input screens. |
| Internet | weather | modem | Manual entry, menu-based input screens. |
| Local agencies and event operators | incidents, congestion, major events | fax, mail, telephone, modem | Manual entry, menu-based input screens. |
| Electronic Toll Collection | speed | modem | Manual entry, menu-based input screens. |

As can be seen in the data acquisition table, much of the data was obtained from Caltrans. One conflict that arose was that much of this data was to be received through one interface, the Caltrans new Traffic Operations System (TOS). However, during the beginning phases of the project, the California legislature passed a law that resulted in halting the design and construction of the TOS. Faced with this dilemma, the Management Board decided to build a mini-Traffic Operations System for Caltrans. This was ultimately agreed upon by the Steering Committee as well, although it took some negotiating. There were two lessons learned from this experience. Firstly, do not put too much reliance on one data source, especially if that data source has not been built yet. And secondly, once a major change needs to occur in the project direction due to unforeseen events, all project participants must be involved in the redirection process.

2.9.1.3 Data Processing

As TravInfo is set-up as a public/private partnership, responsibilities of each partner needed to be defined. Final agreements cited the public partners as being responsible for data collection, data processing and operation & support for the database. The private partners were responsible for development of products and services to disseminate data to travelers including data broadcasts.

One problem that arose was defining when data processing was complete; when was it in an appropriate format to give to the private partners. It was the private sector's responsibility to repackage the data for dissemination. The lesson learned was that clearer definitions were needed that cited specific interface requirements.

It was eventually agreed that acquired data is viewed, processed and stored using TravInfo/TIC Software whereupon operators are able to view and modify the database. The database and operator workstations are SunSPARC 20 with 32 MB RAM. The operator workstations are connected to the Database Workstation with a LAN and communicate using TCP/IP. As there are two TIC nodes, all data acquisitioned by any node is sent to all nodes via a Wide Area Network (WAN). The WAN uses Pacific Bell's high-speed frame relay network. This frame relay network is also used to obtain data needed by the Caltrans mini traffic operations system (speed, volume, congestion).

TIC Operators perform data fusion, remove duplicate data, and remove inconsistencies in the data. They also associate data from multiple sources within discrete events. Once all data is entered a "model" is created of the transportation situation. The LDS and DBS output is generated automatically. A TATS operator generates the TATS messages from available data.

2.9.1.4 Data Dissemination

One of the unique aspects of TravInfo is that they are not developing end user devices. Instead, independent service providers (ISP) receive the data via either the DBS or the LDS. One lesson learned was that agreements need to be generated between the ISP and the agency in order to ensure there will be a means of providing data to the travelers. In TravInfo, the ISP and the agency sign an agreement that allows free access to the database in return for a promise from the ISP to look into developing products to provide the data to the end user.

Perhaps an even greater lesson was that the agreements between the partners need to be clearly understood by all members. As stated earlier, it was agreed that the private partners would be responsible for data dissemination. The public sector felt it necessary to also provide some dissemination since public funds were used to develop the database. This lesson is discussed in Section 2.9.2.2 below.

<u>2.9.1.4.1 Landline Data System (LDS)</u>

Once the data has been acquired and processed it is ready for distribution to travelers in the region. For transmission over landlines or regular unconditioned phone lines, a separate workstation is used. The LDS Workstation houses an LDS Database which is a duplicate of the TravInfo Database stored on the Database Workstation.

One lesson learned was it was important to provide a means of obtaining data from various sources without allowing security breaches. For this reason the LDS Workstation is on a separate Local Area Network (LAN) than the data acquisition and processing subsystems. The two LANs communicate via a frame relay network (WAN) and routers. The routers are considered firewalls in that they prevent 2-way data flow. That is, users who log-on to the LDS Workstation can only receive data and in that way a router prevents outside users from altering the LDS database. Similarly, there is one-way data flow between the database Workstation and the LDS Workstation. In this way, a router prevents any corruption to the TravInfo Database. The LDS design allows users to access static, periodic, and dynamic data in ASCII format. The system is flexible enough to allow users to select only the data they want to receive. ASCII allows users the ability to read the data without special programs as well as to run a computer program to format the data as they need. Assessing LDS, users will find a tree structure. Actual data resides at the leaf nodes while intermediate nodes are directories corresponding to categories of the data.

The users themselves can be value added resellers (VARs) or transportation agencies. The interface simultaneously supports 5 dial-up lines and 10 leased lines per node.

#### 2.9.1.4.2 Data Broadcast System Dissemination

This system, housed on the database Workstation, automatically outputs data via a landline modem to radio stations. The radio stations convert it to FM Subcarrier for transmission. In addition to radio stations, the data is also sent to VARs who convert it and transmit it to their subscribers. The subscribers have equipment in their vehicles that display the information.

This dissemination technique is one-way and allows no user interactivity with the TIC. The data format for the DBS follows the International Traveler Information Interchange Standard (ITIS) not ASCII.

#### 2.9.1.4.3 Traveler Advisory Telephone System

The TATS is connected to a regional telephone number that provides information on transit, traffic, ridesharing, bicycling, parking, etc. Callers press relevant keys (touch tone) to navigate through tiered menu options for information they want. The system is set up as the same telephone number with each of the four area codes for the region. Hearing or speech impaired calls and non-English calls are also handled by the operators.

The Operator Workstations are used by the TATS Operator to access the Database Workstation to help formulate or edit the TATS announcements and prioritize the messages. The TATS actually records and edits the TATS announcements on the phone system as well as fields overflow calls (callers do not have touch tone service or are unable to access the service themselves). Up to 20 hours of speech can be recorded.
The team learned that the TATS hardware was needed to be accessed by different personnel at the same time as the TIC node equipment. For this reason the TATS equipment is not collocated with the TIC node equipment for easy access and maintenance. The TATS system accommodates 48 voice grade telephone lines and allows calls to be forwarded to individual data sites (Regional TOCs).

### 2.9.2 Institutional Issues

Communication was a problem between the agency and the designer. The TravInfo system was developed by TRW, Inc. for the Metropolitan Planning Organization (MPO) for the region. The MPO, was not familiar with developing projects of this type and soon after the project began they realized they would need to contract with a Systems Integrator. Additionally, during Acceptance Testing, it was discovered that the designer had interpreted the Requirements differently than the intentions of the Agency. The requirements and tests were developed by the MPO prior to their contracting with a Systems Integrator. As such, the wording of the requirements and tests were not tight enough or detailed enough. When the MPO felt a test had been failed, TRW was able to demonstrate that the product met the letter of the requirements. The lesson learned here is that significant practical experience in projects of this type is needed to generate the requirements specifications and testing requirements.

2.9.2.1 Consensus Building

There are over 40 ISPs currently involved in the TravInfo project. Some of these ISPs have developed actual products that can be used by travelers to receive the TravInfo data. Potential ISPs were involved early in the planning process to contribute their ideas to the development of TravInfo. There is a valuable lesson here, allow ISPs enough time to have their board of directors or other necessary chains of command make a decision about what new products to develop. Product development generally takes a long time.

2.9.2.2 Agreements

With the TravInfo public/private venture, the two sides were not always in agreement on how the project should be designed. There was one direct conflict that arose in regard to the TIC database. As previously stated the TIC database was developed with public funds so the public interests in TravInfo felt the database should be available to individual travelers while the private interests felt this would violate their TravInfo Agreement that only private parties would disseminate data and that the public parties should not allow this competition. The problem was resolved by allowing only registered users to have access to the database. By limiting competition, the private sector interests were satisfied and by providing a venue to the traveler, the public sector interests were satisfied. This issue will still be debated as the numbers of registered participants increases.

Another institutional issue was the wording of the Agreement. The MPO wrote the Agreement such that they would own the "software" after the project was complete. The MPO was asking for the computer code for the database. TRW interpreted the word "software" as the executable files only. The problem was resolved by putting the computer code into an escrow account that the MPO can access if they desire to make changes, but that otherwise is owned by TRW. The lesson learned here is that open lines of communications are necessary early in contract negotiations and cultural differences need to be resolved to ensure that all parties involved understand what is being agreed upon.

2.10 TRILOGY

The Minnesota Department of Transportation (MnDOT) Advanced Traffic Management System includes extensive vehicle detection systems, video surveillance ramp meters and changeable message signs on over 70% (170 miles) of the freeways within the Twin Cities Metropolitan Area. The system has been designed to optimize the operation and management of freeway access, incident management and real-time traveler information. The Trilogy project was sponsored by the FHWA as a Field Operational Test and was conducted in the metropolitan area. The in-field data collection components of the Trilogy project has been in operation since July, 1995. The three principle components of the Trilogy system are outlined below:

Software for the first component, data entry user interface, was developed and employed the ITIS. This standard was developed by ENTERPRISE which is a group of governmental transportation authorities who pool funds to jointly research and deploy Intelligent Transportation Systems. The Trilogy software was developed around this standard which was also used as a framework to establish the basic message structures for motorist dissemination.

Three new operators were hired at the TMC to manually capture and key incident data into the user interface. The operators work on rotating shifts Monday to Friday from 6:00 AM to 6:30 PM and use the surveillance tools to verify incidents and/or congestion. The information is then keyed into the user interface software for broadcast to the Trilogy participants.

The Trilogy project was divided into two separate phases that would build on one another. In the first phase, Radio Broadcast Data System (RBDS) technologies were employed to transmit traffic information keyed into the user interface to commercial vehicle operators. The second phase builds on lessons learned from the first phase and will include private citizen commuters.

The second phase will employ a high speed FM subcarrier (HS-SCA) as the transmission equipment technology. This technology offers greater bandwidth than RBDS and will be used to carry incident information, road construction, link speeds, ramp meter status, weather reports and personal paging. As of the date of this publication, the FM subcarrier technology has not been implemented for testing.

The final components of the Trilogy system were the in-vehicle receivers. Several technologies were tested including:

- Volvo Dynaguide
- Indikta Traffic Information Device
- Genesis Paging Device
- High Speed Dynaguide device (Phase II only).

Each device displays or presents the transmitted traffic information in different and unique ways.

### 2.10.1 Technology Issues

#### 2.10.1.1 Data Dissemination

VMS and HAR are popular and effective but have limitations. For instance, traffic updates may not be available when needed; your route may not be discussed; or you must listen to a lot of information, most of it for someone else, before getting what you need.
Digital traveler information provides an alternative to VMS and HAR information dissemination techniques. Broadcasting information digitally enables information providers to supply a larger quantity of continuous real-time data. When combined with intelligent receivers, information can be presented in many formats and can be filtered by the user so that only relevant information is presented.

Verifiable information of many types is transmitted to the project participants. The core of this information is recurring congestion levels. It was decided to broadcast recurring congestion so that a driver, unfamiliar with daily traffic problems throughout the city, would always have needed information available. Additionally, messages are created to describe incidents and planned events such as road construction. Since the devices used in Trilogy have the ability to filter information based upon impact, all verified incidents and planned events are transmitted regardless of the impact on traffic.

2.10.1.2 Message Content

The operational philosophy of all the motorist information programs in MnDOT is to provide information in the most useful manner for the user. This approach required an understanding of the relative importance, from the driver's perspective, of the various components of information being provided in the Trilogy Operational Test. Based upon the experience gained through the other traveler information programs at MnDOT, Trilogy operational philosophy is based upon level of service, impact on freeway capacity, and incident cause.

Level of service is the primary information that is being disseminated. It is believed to be the piece of information most necessary for a driver to have when making a decision to alter time of departure or route of travel. This information is being provided in a series of four scales ranging from "heavy traffic" to "stopped traffic." These scales are described in training materials for the drivers and are related to freeway speeds. During Trilogy, the traffic flow will be generated in two ways. During the RBDS-TMC phase, the operator will be using surveillance tools to assist them in determining the flow of traffic. During the high speed phase, the data from freeway loop detectors will be transmitted directly to the high speed end user devices and displayed graphically. These two approaches will be evaluated for useability, consistency and reliability.

Freeway capacity also provides a driver with valuable information. Knowing whether all lanes are open can help a driver make a travel decision. This information is not as important as level of service since lanes could be closed and the traffic might still be free flowing. Yet, when combined with level of service, this provides very useful information. Much effort is spent keeping this information accurate. This allows a driver to watch the progression of an incident from one or more lanes blocked, to all lanes open.

The cause of the incident is certainly important, but is less important than knowing the impact. The cause is important in the determination of the expected duration of the incident. Algorithms can be developed based upon input such as "multiple vehicle accident" or "long term road construction" which would determine the time it will to take to clear an incident.

2.10.1.3 Standard Message Structure

The International Traveler Information Interchange Standard (ITIS) was very beneficial to the Trilogy Project. ITIS allowed for the deployment of RBDS devices to occur quickly. These standard documents were used by in-vehicle device manufacturers and traffic workstation developers to create the necessary software. The standard description lists and location tables insured that consistent information was being sent to the project participants.

The Trilogy Project is testing and evaluating two of the ITIS Bearer Application Protocols (BAP). Phase I of the project used the ENTERPRISE ITIS RBDS-BAP. Phase II of Trilogy will be using the Seiko HSDS-BAP. For Phase I, versions 2.2 and 2.5 of the ENTERPRISE ITIS RBDS-BAP were used. RBDS-BAP version 2.2 describes basic traffic information such as incidents, weather, and construction. Version 2.5 focuses on getting real-time status (link speed and ramp meter delay) information to end user devices. Trilogy is implementing only a portion of the functionality available in the RBDS-BAP documents. Only simple RBDS-TMC driver information messages are being broadcast. This is due to the availability of end user devices and to the hypothesis that this simple traffic information will contain enough detail to be beneficial to the drivers. A single group RBDS-TMC message consists of five main elements:

- **Description**. This element describes the traffic situation occurring on the roadway.

- **Location**. Where a situation is occurring is described with the location field.

- **Extent**. Related to the location field is the extent.

- **Duration**. The duration field is estimated by the operators to help the drivers by trying to predict how long a given situation is expected to last.

- **Diversion Advice**. This one bit field can be used to alert the drivers of especially bad travel ahead, or to trigger the device to perform other functions, such as displaying alternate route information. The implementation of this field has varied from place to place. In Trilogy, this field has not been used.

It is noted, that the message structures chosen for dissemination to the motorist can be greatly optimized for a particular output device. By performing this optimization, the information can become much less useful for another output format. Listed below are four examples of different output devices tested and how operational choices can effect their utility.

- **Volvo Dynaguide**. The first device tested by Trilogy was the Volvo Dynaguide device. This is primarily a map based device that uses a series of maps at several scales. GPS is used to show the current position of the vehicle and to automatically change map frames when the vehicle transitions from one map to another. The traffic information is shown using series of symbols and icons. The symbols convey the level of service and are the first thing the driver sees. The hypothesis is that this is the core information that the drivers need and that it can be understood with a simple glance at the display. The next level of information is used for the impact on capacity or the cause of the incident. From these icons it can be seen that the level of service shown by the symbol is caused by an accident, a road closure, or just normal congestion. This information provides further detail for the driver to make a decision. The final layer of information is the text mode. Included is the situation, location, extent and the expected duration. For potential safety reasons, the drivers were not allowed to read the text while the vehicle was in motion. Since the Dynaguide represents traffic conditions as a point using a symbol, the extent is not visually displayed. Users may select a map view such that an incident that will affect their trip will not be displayed in that view. To insure that the traffic situation is displayed regardless of selected map scale, the operators create several messages when they must describe traffic conditions over a long stretch of congested freeway. Since the Dynaguide is so visual, it is logical to only show active incidents. When an accident occurs, the appropriate symbol and icon are displayed. Once the accident is cleared from the freeway, the symbol and icon disappear. The users are trained that if an accident icon is removed from the device there is no longer a problem. Since the level of service is the most valuable piece of information, all situations impacting traffic must include a level of service description. In all cases the priority of "level of service," "impact on capacity," followed by "cause of the situation" is used to determine the most appropriate description. The ITIS description list contains situations that combine two of the three above categories. As an example, if an accident is blocking a lane of traffic resulting in severe congestion, the operator would choose to use "stop and go traffic, roadway reduced to one lane." The description list does not combine all possible causes with level of service. When a situation occurs the level of service always takes priority. For example a car fire that is not affecting traffic will be broadcast as "car fire" while a car fire that is affecting traffic will be reported as "stop and go traffic, accident," since "stop and go traffic, car fire" is not available in the list. To send out only "car fire" would not tell the level of service, and to send out two messages would be wasteful of bandwidth and would begin to cause clutter on the Dynaguide display since there would be two or more sets of symbols and icons for each incident. To add level of service combination messages for all possible causes would make the list unmanageable.

- **Indikta Traffic Information Device**. Another in-vehicle device used in Trilogy was developed by Indikta Display Systems. This device uses speech to alert the driver to pending problems. The entire ITIS description list and location tables were recorded by a professional broadcaster and saved as computerized data files. This device takes the same information (event, location, extent, duration) and splices prerecorded speech segments together to form a sentence which is then played to the driver. A text display is also included for system configuration, and to display traffic messages in an abbreviated form. Since all the messages are not easily available at a glance, it is important that the driver is not overloaded with numerous spoken messages. To avoid this, a series of filters were implemented that allow the user to screen messages based upon route, region, type of incident, or severity of incident. Using these filters, a user should never be forced to listen to a large number of irrelevant messages. For this device to be effective, changes in messages must be presented to the driver. The best example of this is when an accident clears. For a user of a speech based system, they must hear "accident cleared" to know that something has occurred. With the Dynaguide described above, this was not necessary because the user would clearly see that the accident icon was gone. While the "accident cleared" message is required for the Indikta device, it causes clutter for the Dynaguide. Since it is important to keep the number of messages to a minimum with this device, all situations are best described by one message. Segmenting long stretches of congested freeway into multiple messages for the Dynaguide results in Indikta users listening to several messages describing one situation.

- **Genesis Paging Device**. The Genesis Operational Test used pagers and PDAs to provide traffic information to 400 participants. Virtually the same data was sent to these devices as well. The information included the same description, location and extent. The ITIS duration was not used, but the time of incident was substituted instead. The majority of the information broadcast is "level of service" related messages. In fact, the goal is to send enough information so that the map based device will have congestion status on all roads that are not free flowing. The alpha numeric pager also received information on news, weather and sports in addition to normal personal paging. The additional large quantity of traffic information messages overloaded the pager during peak traffic periods. If a person was trying to use the pager for anything other than traffic, they were interrupted by incoming traffic messages. The goal of trying to integrate the information dissemination of Trilogy and Genesis devices was achieved, but because the pager lacked the ability to filter information, it was overwhelmed with messages, and its usefulness decreased. Had an operator been optimizing just for pagers, fewer messages (only the most severe) would have been broadcast.

- **High Speed Dynaguide Device**. The last device to be deployed in Phase II of Trilogy is a more advanced Volvo Dynaguide device using the Seiko high speed subcarrier communications system. This device was deployed in the fall of 1996 and the Trilogy team needed to design a way to operate the system to make these devices compatible with the existing Dynaguide and Indikta devices. This was quite challenging because of the automated link speed information being broadcast solely to this device. The three Trilogy operators use general guidelines to work toward describing "level of service" consistently. Because the level of service information is being gathered based upon observations, it is the largest source of inconsistency in the information being broadcast. During Trilogy Phase II, link speed data from the loop detectors will be broadcast directly to the vehicle. This will greatly improve the consistency of the "level of service" data. This information will be transmitted every 30 seconds on each ½ mile segment of instrumented freeway and displayed on an in-vehicle graphical map as colored links. The operational challenge for this device is how to use the information currently being generated for the Phase I devices. Since the level of service for the Phase II devices is provided continuously by the loop detectors, the Phase I level of service information generated subjectively by the operator should not be broadcast because it is redundant information and could be delayed or contradictory. Moreover, the operator could more accurately reflect the cause of the situation by not being limited to descriptions containing level of service. Operations could also become more straightforward in that the operator would only need to focus on describing the cause of the situation without regard to the level of service. The Trilogy team is currently addressing how to achieve efficient operations, while keeping the goal of creating only one message for all devices.

### 2.10.2 Institutional Issues

The overall effectiveness of any traveler information initiative lies more in the timeliness and usefulness of the information provided than in the technology delivering it. Although the technology must function adequately, the information must be useful for a service to be successful. Information that is unreliable or inaccurate will not benefit the traveling public and could ultimately undermine the credibility of an entire program. Trilogy relies on three core principles for traffic information: accuracy, timeliness and consistency.

Only incidents and congestion that can be verified and visually inspected by the operator are sent to the end user. This includes any incident or congestion reported that is outside the surveillance coverage area. This policy eliminates the chance of broadcasting incomplete, inaccurate or inconsistent information. In Phase II of the Trilogy Project, an approach will be tested that will display messages such as "Accident Reported" or "Road Construction Planned" in areas not covered by video surveillance.

To enhance the consistency of the information produced by Trilogy, only a limited number of operators currently run the system. Since part of the position requires the operator to make subjective decisions based on personal observations, Trilogy believes that the quality of information is higher when there are fewer operators involved. This philosophy coupled with the ITIS standard guidelines allows operators to make judgements and send appropriate messages with a higher degree of consistency instead of sending information without any standard procedures in place. Trilogy operators have developed additional procedures and guidelines to ensure greater consistency in their performance.

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# 3.0 SUMMARY

Throughout this document, insight and lessons from other ITS projects have been described. This section will emphasize a few of the major themes that were discussed in detail in the previous sections. Overall, specific attention has not been directed to any particular sections in order to express the general lessons learned that are globally applicable and more importantly, specifically applicable to the GCM Corridor as it proceeds forward with the Multi-Modal Traveler Information System.

Areas in which special care is necessary to assure that the goals of the MMTIS project are achieved are included in the summary of technical and institutional issues below.

## 3.1 TECHNICAL ISSUES

### 3.1.1 System Design

A major theme throughout this paper is the need for a thorough review of the design. Included in this is the need to perform a risk analysis at the system level to assure that the design reflects the optimal configuration based on needs and potential risk (hardware, vendors, technology trends, etc.). Once the review has been performed, it is important to incorporate the following steps into the design process. Firstly, it was noted that the end-user needs to be involved in the design process to provide input relating to data requirements and flexibility. As well, there needs to be some oversight by a technical committee which will assure that a consensus is reached among the principal participants before a design is approved. One important iterative step that should not be overlooked is the tracking of changes in the design. This provides a traceable path to follow, should the design prove to need modification. System security should also be included in the design process and not be tacked on as an afterthought. Security is more of a concern now that many of the systems are connected to larger networks within State DOTs. Lastly, as part of the design, an integration plan should be documented so that the system can be tested according to the design elements.

On another note, designers should consider the end data dissemination products that travelers will be using to access the ATIS data. Different users have different needs so there could be a variety of dissemination media developed. In developing messages then, it must be noted that messages will need to be optimized for each device.

### 3.1.2 Software Development

It has been noted that a few items are critical to software development. First, the use of rapid prototyping is essential to get the application screens to the user in a timely manner so that they can be reviewed and any changes can be performed early in the process. Second, the user interface must be fast and the software which supports the user interface must be developed with this goal in mind. Third, software development should, wherever possible, be performed on the actual system. Moving developed software to another platform is usually not problem free, even if it is a platform by the same manufacturer. There are numerous configuration settings unique to each system installation and it is uncommon for two separate platforms to be set up identically. Fourth, in order to assure that the information in the system is reliable, there needs to be a mechanism which analyzes errors (i.e., in modem connections with telephone lines, database storage, network connections, etc.).

### 3.1.3 Standards

The use of standards is essential to keeping a system open and expandable. It is important to use system components that are hardware independent as much as possible. Components that are specific to one vendor's product could limit the capability of the system in the instance where a component is no longer manufactured or supported. Whenever a system is communicating with others and sharing information relating to locations, a common referencing system should be used to reduce ambiguity introduced when translating between referencing systems. A standard location referencing system also reduces the number of translation programs that need to be developed. The system should also be developed using standards to minimize custom development of communication protocols. Additionally, it is noted that the X.25 communications protocol did not perform in a satisfactory manner and it is recommended to avoid using it where possible.

## 3.2 INSTITUTIONAL ISSUES

For all of the ATIS projects presented in this document, it is clear that the institutional issues were significant. The institutional issues can be categorized as operational issues, management & control issues and project philosophy.

### 3.2.1 Operations

There were three significant lessons learned relating to operations. First, there is a need to standardize incident types, VMS messages, HAR messages, congestion levels, etc., across all agencies sharing this information. It is important to get everyone speaking the same language. Second, operators may or may not be staffing a system around the clock, so there needs to be an effort to minimize operator inputs into the system. Operators also may be busy with monitoring different aspects of a system such as the CCTV feeds, or responding to reported incidents and may be unable to enter information in a timely manner on a routine basis. Third, as many systems are displaying information on a Web site, it needs to be noted that maintaining a Web site and providing timely, up-to-date information is a time consuming task and requires significant effort from a variety of personnel.

### 3.2.2 Management and Control

Although technology is critical, proper project management and project control mechanisms are just as important to assure a project achieves its ultimate goals. The lessons learned on this topic can be simplified into the following key areas:

- use management committees to govern the project
- the project manager should act as a facilitator and should be technically knowledgeable
- it is best to keep the project team small and constant
- locate the project team in one facility
- milestones should be used for scheduling
- focus on single point responsibility and match responsibility to tasks
- define intellectual property rights and ownership upfront
- involve the private sector early in the project.

### 3.2.3 Philosophy

In order to be successful, a project needs to subscribe to a common philosophy or set of goals. For example, decisions need to be made up front on whether the project is focusing on advancing technology rather than using proven techniques, or the importance of achieving on-time, on-budget performance. Different philosophies are seen in the way in which projects are initially set up. Many of the projects reviewed herein obtained a common set of goals by setting a clear definition of the requirements. Project and system requirements help to corral the overall philosophy which then needs to be stressed by the project leaders.

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