Intelligent Transportation Systems
at the
2002 Salt Lake City Olympic Games
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Traffic Management and Traveler Information
Case Study

Prepared by
Iteris, Inc.

for
Utah Department of Transportation

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The principal authors of this report are Lawrence Jesse Glazer and Roberto Cruz, of Iteris, Inc., in Anaheim, California. Assisting in the study were S. Edwin Rowe and Mark Nuaimi of Iteris, plus Drs. Peter Martin and Joseph Perrin, of the University of Utah Traffic Lab.

All information, findings, and opinions expressed herein are the opinions of the principal authors and do not necessarily represent opinions or policies of the Utah Department of Transportation.

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1 Executive Summary

Utah Department of Transportation (UDOT) contracted for a series of evaluation efforts associated with the development, deployment, and operation of their Intelligent Transportation Systems (ITS) in the Salt Lake City Region, which are known as the CommuterLink system. The CommuterLink deployment efforts were accomplished to provide advanced transportation management and advanced traveler information capabilities in the SLC area. The 2002 Winter Olympic Games in Salt Lake City added some new functional requirements plus a very firm completion deadline for the deployment effort.

The CommuterLink Case Study was performed to examine UDOT's procurement and deployment efforts related to the ITS capability in the region. UDOT followed a unique approach to contracting this deployment and the Case Study provides an overview of the successes and lessons-learned that arise from that effort.

This report is written for UDOT staff and also for other agencies contemplating deployment of similar ITS elements. This report provides the reader with findings from the ITS "Case Study" which primarily focuses upon the deployment efforts ***before*** the 2002 Winter Olympic Games. A companion document – the Olympics "Event Study" – assesses how the CommuterLink system was used ***during*** the Olympic Games, for traffic management and traveler information. Readers who wish a more complete picture of the deployment and use of CommuterLink should peruse both reports.

1.1 Overview of ITS Deployment in Utah

The UDOT ITS deployment – CommuterLink – is an extensive network of traffic sensors, Closed-Circuit Television, Variable Message Signs, Highway Advisory Radio, Freeway Ramp Meters, Telephone Advisory System, Internet information site, and other traffic-management and traveler information services. All these functions are integrated into a Traffic Operations Center that provides for control and monitoring of these systems. In addition to the freeway operations, the arterial signals throughout the region are integrated as well into an arterial management system. Communications between these elements and the operations center is supported through an extensive fiber-optic backbone. This communications system provided excellent access to video data both to the operations personnel within UDOT as well as local media outlets in the region.

The Salt Lake City ITS installation is among the most comprehensive in the nation. Deployed largely over the past 5 years, it included the following ITS elements as of early 2002:

- 120 miles of instrumented freeways continuously monitoring traffic flow
- 218 closed-circuit television cameras (CCTV) on freeways and surface streets
- 63 variable message signs (VMS) spread across the region
- 12 highway advisory radio (HAR) transmitters
- 30 roadway-weather information system (RWIS) data-collection stations
- a centralized control system encompassing 608 traffic signals, with over a thousand special signal-timing plans for regular traffic plus Olympic venues and events
- freeway on-ramp metering at 23 locations

- 350 miles of fiber-optics cable, plus extensive telephone and wireless links
- the CommuterLink Web site delivering traffic, Olympics, and other information
- an innovative “5-1-1” telephone service delivering traffic and other information
- a new light-rail system (TRAX) with traffic-signal preemption and other ITS features
- a Traffic Operations Center (TOC) serving as the nerve center for all the above, linked to satellite Traffic Control Centers serving other transportation agencies.

1.2 Case Study Approach

The CommuterLink Case Study was conducted to assess the procurement and deployment process that UDOT followed as part of this ITS implementation. This assessment focused on Technical, Institutional, and Operational considerations and had an additional objective of describing the key lessons learned, for use by other agencies considering deployment of extensive ITS functionality.

The CommuterLink Case study was completed in parallel with the Olympics Event Study. This allowed for observations within the operations center during the 2002 Winter Olympics and provided an assessment of how the system worked under extreme traffic and system-usage conditions.

1.3 Key Findings and Recommendations

During the course of observations and interviews, a number of clear “Lessons” were captured that can prove quite useful for subsequent ITS deployments. This list is not intended to be an exhaustive summary of all the lessons learned from the deployment of the CommuterLink System (UDOT has tabulated a more extensive list). These are key lessons that would have mitigated the most challenging issues faced by UDOT and the deployment personnel. These Lessons are summarized below and detailed discussions follow on each:

- **Configuration Management**
- **Utah Isn’t Georgia**
- **Standardize the System Environment**
- **Need for a Strong System Manager Role**
- **Co-Located Development Team**
- **Need for Acceptance Test System**
- **Potential System Enhancements**

Lesson #1 -- Configuration Management

When deploying a highly complex system like CommuterLink, there exists a need for a disciplined Configuration Management process from the beginning of the deployment. Such a process would have established the documentation requirements, naming conventions, requirements traceability, and change-control practices early in the development process. In the case of the UDOT deployment, there were a number of characteristics of that deployment that further required a mature Configuration Management process. They were:

- ***Multiple contractors involvement in the deployment:*** The CommuterLink system was deployed through a series of contracts that included the Highway Construction, the System Manager, the TOC construction, and the Systems Integrator contracts.
- ***Urgency for Operation / Speed of Deployment:*** UDOT required that components be brought online as soon as possible for their use in operation. This often required that interim solutions be provided for communications.
- ***Instability of Communications Infrastructure:*** Given that much of the CommuterLink system was being concurrently developed, components were often brought on line prior to the final communications infrastructure being in place. This required interim solutions to be developed and resulted in frequent configuration changes between the methods in which data and control signals were brought back from field elements to the operations staff.

Based upon discussions with project personnel, one of the greatest challenges of the deployment was maintaining accurate information about the current configuration. On a frequent basis, the Highway Construction contractor would add components to the configuration and integrate those capabilities to the traffic operations center. There were also frequent changes in the communications channels as new backbone/distribution communications capability came on line. A Configuration Management approach should have been in place from the start that identified naming conventions, interfaces, and required protocols. This would have ensured consistency between the Highway Construction integration work and that of the Systems Integration contractor. It would have also allowed for the development of test apparatus (simulators) to effectively test the functionality of the deployed components without the need of having an operating ATMS system.

Lesson #2 -- Utah isn't Georgia

While the decision to utilize the Georgia DOT (GDOT) NaviGAtor ATMS software application provided a number of compelling advantages – reduced deployment cost, lower risk, faster deployment schedule -- to the CommuterLink System deployment, there were also some disadvantages that arose from that decision:

1. **Dependency on Operating System** – Given that the GDOT system was a Unix deployment, this mandated that the UDOT deployment also be Unix based. Based upon the inputs from project stakeholders, this yielded a more complex design than was probably necessary given the evolution of IT processing.
2. **Commercial-Off-The-Shelf (COTS) Package Changes** – One of the key components to the GDOT software application was no longer supported by the commercial vendor. Given the decision by the map vendor to no longer support their product, UDOT had to integrate a new mapping application to the ATMS software. However, another partner on the NaviGAtor ATMS development team (Oregon DOT) had already integrated a new mapping application to the NaviGAtor system and UDOT was able to port that functionality to their use.
3. **Operational Differences** – The role of the TMC operators is dramatically different in Utah as compared to Georgia –UDOT operators are empowered to make real time decisions relative to incident management approaches. In the Georgia application, the incident management capability of the system limits the ability of the operators to create VMS messages. The system proposes potential VMS messages from a pre-approved library of messages. In Utah, the operators are viewed as the specialists in the incident management activity and would have preferred an approach that allowed them more flexibility in creating messages to suit the situation.
4. **Lacking Diagnostic Information** -- The NaviGAtor system also does not currently provide diagnostic information to the operator about field element status. Staff with software development experience are required to access this information within the system – a simple user interface is not provided.
5. **Incident Management Tailored for GDOT** – There are a number of attributes / settings that are defined for the GDOT needs. One example cited is the incident management code for "road kill". There is no equivalent in UDOT or a desire to categorize "road kill."
6. **Functionality Tied to Hardware Configuration** – According to UDOT staff, they discovered that some of the functionality of the NaviGAtor system was tied specifically to the hardware configurations of the Atlanta ATMS system. Specific examples include the manner in which video switching / viewing / transport took place. In Utah, the communications design allowed for redundant fiber communication paths for transporting video from the field hubs to the TMC. The NaviGAtor system was designed to control only a single source feed and could not automatically switch control and viewing as the feeds shifted from primary to back-up conditions. This required UDOT staff to hardcode changes to the configuration when the primary feed was lost – changes were made to return the code once the feed was restored. While this demonstrates a software compatibility issue between NaviGAtor and the UDOT TOC configuration, it highlights a key need when reusing a software solution – ***determine the dependencies on hardware solutions and adapt the hardware design to match the software or customize the software to match the hardware.***

Lesson #3 – Standardize the System Environment

With a system deployed over the course of many years, one of the challenges is how to incorporate advancements in technology without ending up chasing technological fads. Interviews with UDOT staff identified concerns about how fragmented the technology is associated with the ATMS application. Without an extensive review of the technical design decisions, it is impractical (and unfair) to second-guess decisions made over the course of a four phase deployment effort. However, agencies should be cautioned in the future to be aware that every "new" innovation in "off-the-shelf" software comes with its own set of bugs, software licenses, languages, interdependencies, etc. A quick review of the Architecture Alignment document completed in Phase IV shows the varied software and development environments required to duplicate what is currently in place.

An example of this need to "standardize" the environment can be shown with a review of Phase IV development activity. Unified Modeling Language (UML) design methodology was utilized by the contractor for the design and development activity. UDOT staff indicated that they were not prepared to support such a change in methodology and did not have anyone on staff with that capability. This minimized the technical review provided by the agency staff. Therefore, it was recommended by staff that ***the agency determines their preferred design methodology and requires the contractor to support that approach***.

Lesson #4 – Need for Strong System Manager Role

Many of the issues identified during this assessment pointed to the need for an expanded System Manager role in this project. As was mentioned previously, there were a number of contracts awarded to yield the deployment of the CommuterLink system. The System Manager supported UDOT staff in the design and day-to-day activity of the project. The System Manager was also assigned Integration activity that was originally assigned to the Systems Integration contract. But more could have been done, earlier in the deployment process, to alleviate some of the issues that arose later:

- Given that the System Manager contract was competed and awarded prior to the Systems Integration contract, one of the initial tasks should have been the establishment of a Configuration Management system (refer to Lesson #2).
- With a more significant role, the Systems Manager contract could have been planning and executing Acceptance Testing. This would have provided a more independent assessment of the system performance.
- End-to-end integration activity was a challenge given the overlapping nature of the Systems Integration and Construction contracts. The System Manager activity could have provided the necessary bridge between those projects if it were responsible for the end-to-end integration of the system. This would have transformed the "Systems Integration" contract into a software development and deployment activity where the software applications are one of many components to the complete system.

This expanded role might have avoided some of the uncertainties in roles and responsibilities. It would also have focused accountability for overall system performance within the scope of a single contractor as opposed to the multiple contracts in place.

Lesson #5 – Co-Located Development Team

One of the major themes that arose in the discussions with UDOT staff was the need for better visibility into the design and development process of the CommuterLink software enhancements. What began as a local software development activity ended in a distributed engineering activity occurring in several sites across the country. This precluded having UDOT staff co-located with the development team and minimized their visibility into development progress and process.

A preferred approach that was discussed in interviews with UDOT staff would include the following features:

- Development staff is co-located at a single facility with an agency presence serving as "code review" staff. Assuming that the agency will take over responsibility for system maintenance, it was discussed that the same people who will maintain and enhance the system in the future, should be involved during the initial deployment to better understand the design methodology and code structure.
- A separate Test Environment (see lesson #6) would be included at this site. Acceptance tests would be conducted prior to deployment on the production unit.

One of the benefits to this approach of co-locating the development team and providing agency staff presence is schedule adherence. The agency representatives would not be dependent on the contractor to provide the latest in project schedule. It also allows the agency to better understand some of the issues and challenges with their requests of the contracting firm.

Lesson #6 – Need For Acceptance Test System

Currently, there is a development environment and a production environment. For much of the functionality, it was not possible to test the new software code until after it was installed in the production setting. This has inherent risk in that new applications are not tested extensively before being introduced into operation. A separate test environment would allow for extensive testing to eliminate bugs in the software application prior to being introduced into production.

One of the elements proposed in the Phase IV activity was the development of a separate Acceptance Test environment. This system would mirror that of the production unit and would have devices or simulators available to exercise the functionality of the system. This type of an approach does require a significant investment on the part of the agencies. While this may prove cost-prohibitive to some agencies, the ability to fully test "enhancements" prior to activation is a very effective risk mitigation approach.

One potential alternative to agencies facing a similar deployment might be to establish a relationship with a local university. As was the case in Utah, the local university worked with the state transportation agency and supported many of the on-going initiatives.

Lesson #7 – Potential System Enhancements

Overall, the system performed well given the extreme demands of the 2002 Winter Olympics. It is highly unlikely that the CommuterLink System will ever be required to function to the high level of usage as occurred during the Olympics. This extensive usage did highlight potential enhancements to the system as well as some technical issues with the current configuration. These included:

- Variable Message Sign User Interface enhancements – the current design of the VMS control allows for the modification / command of a single VMS at a time. With over 60 permanent signs, it would have been much easier to simply command a change in content that could then be broadcast to multiple signs at once. Also, the VMS control did not appear to allow for Time-Of-Day scheduling of messages or a default messaging feature.

- Highway Advisory Radio – communications to the HAR utilized cellular telephone systems to upload new messages. Given the cellular phone traffic in the area during the Olympic Games, there were times when connection with the HAR unit could not be made to update the messages. In addition, the HAR units were battery powered with a solar recharge capability. These HAR units were transmitting for extended periods of time during the games. At times, power to the HAR was lost due to consumption exceeding the available charging capacity of the solar panels.

While some of these issues were largely unique to the heavy demands of the Olympic Games, similar issues could occur in other urbanized areas where extensive incident management and/or traveler information services are in place. Similar extreme demands could also occur in the instance of a catastrophic event.

1.4 Conclusion

The deployment of the CommuterLink system was successful through the use of innovative contracting approaches, the leveraging of transportation management software capability, and the cooperation of several agencies throughout the deployment effort. This success was not had without some challenges. However, the flexibility of the agency staff and the capabilities of the various contractors were sufficient to yield a successful deployment and a capable Advanced Transportation Management and Traveler Information System.

2 Introduction

2.1 Study Purpose and Report Structure

The goal of the Case Study was to assess the effectiveness of the CommuterLink deployment process. The Case Study included a review of the project documentation plus a series of agency interviews, and culminated in a review of System Impacts and Lessons Learned from the development and deployment process. The topics contained within this study included Technical, Institutional, and Operational assessments. This qualitative study sought to answer some basic questions: How effective was the CommuterLink deployment process? What worked well in the process? What could have been improved? How well does the system satisfy the original intent of the procurement? Specific objectives include the following:

I. Technical Issues
- A. Effectiveness of the procurement process in defining UDOT expectations/requirements
- B. Correspondence of the delivered system with specified requirements
- C. Effect of ITS Standards upon the system design
- D. Accuracy and reliability of system data
- E. Maintainability of the system

II. Institutional Issues
- A. Agency expectations and satisfaction
- B. Comparison of procurement process to ATMS/ATIS deployments elsewhere
- C. Intellectual-property issues
- D. Inter-jurisdictional integration

III. Operational Scenarios
- A. Incident-detection and incident-management performance
- B. Traveler-information performance
- C. Event-management performance
- D. Center-to-center integration
- E. Perceptions of other agencies regarding system operation and impacts

IV. Perceptions of ATMS/ATIS Performance
- A. Evaluator perceptions
- B. System manager and operator perceptions
- C. Transportation-planner perceptions

V. Site-Specific Issues
- A. Deployment activities by UDOT and Construction Contractor
- B. NTCIP initiation in ramp metering
- C. Integration of freeway and arterial management
- D. Use of multiple types of traffic-signal controllers
- E. Compliance with National ITS Architecture

This assessment study is written with the primary purpose of assisting other agencies that are considering deployment of ATMS/ATIS functionality. The lessons learned contained within this document are a compilation of evaluator observations, opinions of UDOT staff, as well as suggestions from current system engineers and operators who interact with the system on a daily basis.

2.2 The Transportation Context – the SLC Region

The area included in this study includes a three county area known as the Wasatch Front region of Utah, which includes the developed regions of Salt Lake, Davis and Weber Counties plus the relatively undeveloped Morgan and Tooele Counties. (see Figure 2. 1). This fast growing region's borders include the Great Salt Lake and the Oquirrh Mountains to the west, and the Wasatch Mountains to the east. The Utah County line forms the region's southern border. The line between Weber and Box Elder Counties forms the northern border.

Figure 2. 1 Regional Map

According to the 2000 Census, Utah's population has reached 2.23 million. Of that total, approximately 76% live in the Wasatch Front Region. With the nation's highest birth rate, lowest death rate and youngest median age (26.7), Utah expects to exceed 3 million residents by the year 2030 with a projected 2.1 million in the Wasatch Front Region. Counties in the Wasatch Front are all projected to undergo rapid population growth in the coming years. According to the State of Utah's Long Term Economic and Demographic Projections, 1.4 million people were employed in the state in 2000, of that total, 895,000 were employed in the Wasatch Front Region.

The region's unique geographic features have shaped a region that runs approximately 60 miles from north to south while only 15 miles wide at its widest point. This dictated the creation of a transportation system that heavily favored north-south routes dominated by Interstate 15. (See Figure 2. 2)

The area's current roadway network includes several major interstate freeway systems including, I-215, I-80 and I-84 which provide east-west travel. I-80 extends east-west across the southern portion of Salt Lake City and the Wasatch Mountains to the Park City area. I-215 serves as a beltway around Salt Lake City and I-84 serves as a second east-west connection in the northern part of the region connecting the city of Ogden and Echo Junction. The area is also served by several principal arterials, which provide connections to the downtown areas of regional cities as well as the University of Utah, the Salt Lake City International Airport and major recreation areas.[1] (See Figure 2. 3.)

Figure 2. 2 Regional Freeway Systems

[1] *Wasatch Front Urban Area Long Range Transportation Plan 1998-2020,* Wasatch Front Regional Council, 1999

Figure 2. 3 Downtown SLC Arterial Roadways

2.3 Overview of ITS Deployments – ATMS, ATIS, and Related Elements

The Salt Lake City ITS deployment is among the most comprehensive in the nation. It included the following ITS elements:

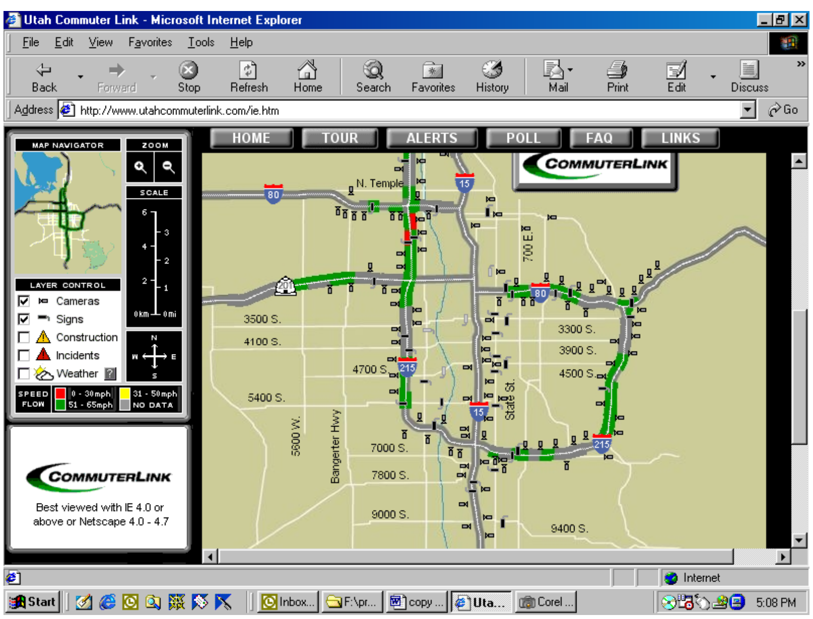
- 120 miles of instrumented freeways continuously monitoring traffic flow
- 218 closed-circuit television cameras (CCTV) on freeways and surface streets
- 63 variable message signs (VMS) spread across the region
- 12 highway advisory radio (HAR) transmitters
- 30 roadway-weather information system (RWIS) data-collection stations
- a centralized control system encompassing 608 traffic signals
- freeway on-ramp metering at 23 locations
- 350 miles of fiber-optics cable, plus extensive telephone and wireless links
- the CommuterLink Web site delivering traffic and other information
- an innovative "5-1-1" telephone service delivering traffic and other information
- a new light-rail system (TRAX) with traffic-signal preemption and other ITS features
- a Traffic Operations Center (TOC) serving as the nerve center for all the above, linked to satellite Traffic Control Centers serving other transportation agencies.

2.4 The Deployment Process in Salt Lake City

The development of ITS in Utah began in 1994 with the initiation of an ITS Early Deployment Plan (EDP) for the Salt Lake City metro area by UDOT. The EDP was prioritized for elements supporting the Olympics and included Incident Management, Advanced Traveler Information, Parking Management, ATMS Expansion, and Automated Vehicle Location. ITS elements specific to the Olympics listed in the EDP included CCTV installations, incident management expansion and training, and variable message signs. These items were to be redistributed throughout the state following the Olympics.

The State Senate passed legislation in 1995 that established a Traffic Management Committee to work with UDOT and local jurisdictions to create advanced traffic management strategies. Key projects spearheaded by this committee included a Traffic Operations Center, a coordinated signal system along the Wasatch Front, and the public traveler information system that is delivered from the TOC.

The UDOT Traffic Operations Center (TOC) was opened in the summer of 1999. The TOC is able to receive traffic conditions from the areas freeways through the use of loop detectors and closed circuit television (CCTV). The TOC also controls 63 variable message signs (VMS) in the region as well as highway advisory radio stations, roadway weather information stations, and incident management vehicles. The system also includes ATMS elements on most major surface streets including the interconnection of over 600 arterial traffic signals, CCTV cameras, and VMS signs. The TOC has direct communications links to control centers operated by Salt Lake County, Salt Lake City and the UTA. The TOC also houses the Utah Department of Public Safety dispatch center, and a radio broadcast studio that broadcasts traffic conditions to several local radio stations. Commuterlink provides real-time traffic information to the traveling public at home, work and on the road via VMS, HAR, the Commuterlink website, and information on TV and radio.[2]



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[2] U.S Department of Transportation website, *ITS in Your State.* (Quantities updated to January 2002)

Transportation System Improvements

In the years leading up to the Olympics, the Utah Department of Transportation worked with regional partners to develop a list of transportation infrastructure projects that would be needed to meet travel demands during the Olympics and beyond. The state invested heavily in transportation projects, including a large portion directly related to the Olympics ($100 million in federal highway discretionary funding for Olympics related projects). These projects are listed below:[3]

- **I-15.** I-15 was reconstructed and expanded from Sandy to north of Downtown Salt Lake City. Additions to the freeway include a general-purpose lane, a high occupancy vehicle lane and an auxiliary lane between ramps in each direction. ITS capabilities were also added along I-15 and within the I-215 belt loop.
- **I-80.** In 1999, a portion of I-80 was repaved and safety improvements were added. ITS was also installed in the form of vehicle and speed detection, pavement sensors, CCTV and fiber optic cable. The system was connected to the ITS system on I-15 and is controlled through the TOC.
- **UTA North-South TRAX Light Rail Service.** This new service consists of a 15-mile transit line on a dedicated right-of-way from Sandy to Downtown Salt Lake City.
- **UTA East-West TRAX Light Rail Service.** The new light rail service was extended 2.5 miles east from downtown to the University of Utah, and includes four stops.
- **Venue Access Improvements.** New access roads were constructed at several Olympic venues in order to meet the expanded capacity and safety needs.

[3] *Olympic Transportation Plan,* SLOC, March 2001

3 Study Methodology

3.1 Study Objectives

The ATMS Case study has the primary objective of assessing the effectiveness of the procurement and deployment process that UDOT followed as part of this ITS implementation. This assessment focused on Technical, Institutional, and Operational considerations and had the secondary objective of providing lessons learned for use by other agencies considering deployment of extensive ITS functionality.

3.2 Work Tasks

This section summarizes the Case Study work tasks and sub-tasks that were performed. This work plan evolved as information was discovered or found to be lacking. It included extensive review of system and procurement documentation[4] along with a series of interviews and observations during several visits to the operations center (during and after the Olympics).

TASK 1. TECHNICAL EVALUATION –

The technical evaluation is intended to answer the question "How well does the CommuterLink system satisfy the original intent of this procurement?" In order to answer this question effectively, an understanding of what was originally required and the current capabilities of the system is required. To accomplish this effort, the following subtasks were performed:

a. ***Review original RFP / Submitted Proposal*** **–** The study staff reviewed the original RFP. This review also included examination of the project contract and amendments to understand the intent of the planned work activity as they relate to the deployment of the ATMS.

b. ***Traceability of Requirements to Deployed System*** **–** The current deployed system was evaluated against the identified requirements. This evaluation occurred through observation of actual performance of the system. Additionally, system documentation ("as builts") was used to aid in this assessment.

c. ***System Design Review / COTS vs Custom*** **–** The system design was examined for use of Commercial-Off-The-Shelf solutions versus the need for customized, specialized applications. Additionally, the design was assessed for vendor independence and platform independence.

d. ***Standards Adoption*** **–** This part of the evaluation examined the interfaces designed and implemented as part of this ATMS and contrasted these interfaces with the emerging standards.

e. ***Ease of Integration*** **–** One of the greatest challenges facing many public agencies deploying ITS solutions is "how can I integrate to the system?" This part of the evaluation examined the documentation available or planned to assist in the integration to the ATMS. This included the various data definitions, instructions on establishing connection, and the utility of this information.

f. ***Quality of Documentation*** **–** Deployments across the country have a wide range of documentation available – from none to fully documented designs, users manuals,

[4] List of documents reviewed as part of this study are detailed on page iii.

maintenance manuals, software source code, acceptance test plans and results, etc. This task evaluated the available documentation for consistency and ease of access and use.

g. ***Data Quality / Accuracy Observations*** – Throughout the Event study, Iteris staff had access to ATMS MOE and video data as well as observations from field personnel. Based upon the information gathered during the event study, the Iteris team assessed the level of accuracy for the ATMS data. This was a qualitative assessment based upon the notes and feedback from the Olympics Event study. This assessment did not include any calibration or independent data collection activity.

h. ***Maintainability Issues*** – The Iteris staff evaluated and identified significant maintenance issues associated with the CommuterLink deployment. Based upon interviews with operations staff as well as observations from the Olympics Event study, this evaluation documents significant maintenance requirements. This effort also assessed qualitatively the availability of the system – assessment was limited to the timeframe associated with the Olympics Event study. This evaluation did not get into detailed analysis of logs or complex computations on Mean-Time-Between-Failure, Availability metrics, or comparable analyses.

TASK 2. INSTITUTIONAL EVALUATION -- The Case Study assessed the satisfaction of the institutional partners in the CommuterLink deployment. This assessment provided opportunities to highlight the successes and challenges associated with the CommuterLink deployment.

a. ***Agency Expectations*** – Through interviews with key institutional stakeholders, the evaluation team capture whether the agency expectations were satisfied with the deployment of the ATMS. These include satisfaction with inter-agency cooperation, communication among the stakeholders, as well as satisfaction with the deployment process.

b. ***Procurement / Contracting*** – The evaluation team reviewed the procurement process and contrasted that against procurement processes in other parts of the country. The process was assessed for flexibility, deliverables, and terms and conditions for their value-added results.

c. ***Ownership / Data Rights / Software*** – In a number of deployments across the country, there is contractual language that limits the rights of the public agencies to modify or share the deployed software. This study effort evaluated terms of software ownership, re-use, maintenance, etc.

d. ***Integration Across Jurisdictions*** – The case study process assessed the integration across jurisdictional boundaries that occurred as part of this deployment. The case study also evaluated the ability of the CommuterLink System to integrate to other ITS systems in the region.

TASK 3. OPERATIONAL SCENARIOS – The Olympics Event Study afforded the evaluation team to see the CommuterLink System in action in a variety of scenarios. This Case Study documents observations about the performance of the CommuterLink System in the following scenarios:

a. ***Incident Management Performance*** – The incident management scenario consists of the methods and solutions offered by the CommuterLink System to improve traffic flow and reduce travel time delays once an incident has been reported. The assessment was qualitative in nature and examined ease of use of the CommuterLink system, flexibility of the system, and the amount of automation provided in support of incident management.

b. *Traveler Information Performance* – An extensive traveler information network has been prepared in support of the winter Olympics. This part of the evaluation characterizes the success of the ATMS to support the traveler information mission.

c. *Event Management Performance* – Similar to incident management, event management performance provides both monitoring and traveler information dissemination to maintain the flow of traffic and reduce travel delays. The evaluation notes the effectiveness of the ATMS in this area of performance.

d. *Incident Detection Performance* – In conjunction with the incident management evaluation, the Case Study also evaluated the ability of the CommuterLink system to detect and validate incidents.

e. *Center-to-Center (C2C) Integration* – Center-to-center integration allows agencies to coordinate traffic management plans and automated incident responses. The Case Study assesses the level of C2C integration supported / provided by the current CommuterLink deployment.

TASK 4. SYSTEM IMPACTS – The Case Study summarizes the impacts of the ATMS on travel performance in the area. The primary source if information was the information gathered during the Olympics Event study.

a. *Conduct follow-up interviews/surveys* – Following the winter Olympics, the evaluation team conducted a series of telephone interviews with CommuterLink stakeholders to collect their impressions of the impact that the ATMS made on travel conditions in the region. The study team worked with UDOT staff to finalize the list of interviewees.

b. *Collect Anecdotal Examples* – Through the course of the Event Study, there were opportunities to collect and archive examples of ATMS performance to various scenarios that were representative of typical performance. The effects of this performance were captured and included in the draft and final Case Study report.

TASK 5. LESSONS LEARNED – Both the Event and Case studies provide recommendations that can serve as lessons learned for elements that were done well and areas of improvement. To effectively capture these suggestions, they were separated between the variety of specialties – evaluation consultants and system operators. Additional perspectives are captured in the Olympics Event Study report.

a. *Evaluator Observations* – The study team has a variety of perspectives, having supported ITS deployments across the country. This experience was translated into general lessons learned pertaining to the arena of ITS in general, and ATMS specifically.

b. *Operator Observations* – The operations personnel have a unique perspective to how well the system operates in the various operational scenarios. These observations were documented to assist in identifying potential areas of enhancement for the ATMS as well as areas of emphasis for other agencies choosing to deploy ATMS solutions.

4 Case Study Findings

4.1 *Introduction*

The CommuterLink System Case Study reviewed elements of the ITS deployment in the areas of Technical, Institutional, and Operational Assessments. This review was not an exhaustive critique or "evaluation" of the CommuterLink system design, deployment, or operation. This assessment was intended to provide a macroscopic view of the deployment – identifying the successes and lessons learned from such an aggressive and highly visible ITS deployment.

4.2 *Technical Assessment*

It is quite difficult to step into an implementation as extensive as the CommuterLink System deployment to make an assessment of deployment experience. Completing this assessment "after-the-fact" required reliance upon available documentation as well as the information / opinions of the agency and contractor personnel involved in the deployment process. To the credit of the agency representatives, the interviews / discussions were very candid about the challenges and successes of the deployment relative to the technical performance. It is also important to note that this assessment is simply a snap-shot in time – there are on-going enhancements to the system that were underway at the time of this study.

4.2.1 System Requirements Review

The CommuterLink System deployment was completed over a series of phases and a number of contracts among the system manager, system integrator, and I-15 re-construction activity. Prior to awarding any implementation contracts, a series of requirements documents were developed and used in support of the Systems Integrator procurement. As subsequent phases of the Systems Integration contract have been awarded, new requirements have been developed relative to the desired implementation.

The most recent phase of deployment, Phase IV, generated a comprehensive System Requirements document[5] that addressed enhancements to the System GUIs, Data Collection, Data Dissemination, Congestion Management (including ramp metering), Event Management, System Maintenance, and System Reporting. A requirements traceability matrix was also developed to track requirements that were "carried over" from prior phases to distinguish them from newly developed requirements. The contractor then developed an Implementation Phasing Plan[6] that prioritized each of the necessary improvements and allocated available funding to these activities. Thus, all the requirements were not satisfied within the funding available in the current phase. This approach has been used in a number of deployments across the country. Assuming that the agency has independent evaluation of the cost estimates, this is an effective manner in which agencies can incrementally deploy ITS functionality while maintaining a close watch over project costs versus deployed capability.

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[5] DCN 1003ASRDR02 Automated Traffic Management System Phase IV INTEGRATION – System Requirements Document (Final), Revision 2.0, October 2001

[6] DCN 1003AIPPR02 Implementation Phasing Plan for CommuterLink Phase IV INTEGRATION, Revision 2.0, November 21, 2001

4.2.2 System Design Review

The purpose of this assessment was not to do an exhaustive review of the CommuterLink system design. However, as part of the completed assessment, there was the opportunity to capture some impressions of agency staff and contractor personnel relative to the System Design. The overall impression was that the decision to re-use the NaviGAtor ATMS software application saved considerable time for the UDOT deployment. Rather than having to go through what would have been a substantial design / implementation process, the initial porting of the existing Georgia system allowed for rapid deployment of ITS capability.

With that deployment decision also came some of the challenges associated with the design. There were database issues, networking issues, software porting issues, system stability issues, and configuration management issues. The system delivered from GDOT had not been fully debugged and so the decision facing UDOT was whether to stabilize the system or continue to expand the functionality. Due to the fixed deadline of the Olympics, the decision was typically to expand the functionality. This included the addition of new field elements and the addition of the 511 telephone advisory system as a couple of examples. Now that the Olympics have passed, much of the emphasis of UDOT staff is focused on stabilizing the configuration and performance of the system.

The other key observation relative to the CommuterLink system design was that the software application was closely coupled to the hardware design / implementation in Georgia. While the ATMS software was being "ported", the reality was that it not only needed to be ported but also required customization to match the hardware configuration present in UDOT. Without this customization, some of the strengths of the hardware design would be lost. However, the more customization that occurred, the less likely that enhancements would be able to be ported to other agencies. So while the GDOT NaviGAtor application was used as the baseline for operation, there are significant changes to that configuration that will preclude widespread "sharing" between the public agencies that have the system deployed. The phenomenon was also noted during a recent evaluation of deployed ATMS throughout Florida. While a number of those systems also initially deployed "NaviGAtor" software, the resulting systems were unique enough to negate much of the potential benefits of leveraging the software. From this discussion, the key finding is that the software application is not a simple layer of functionality that integrates to the hardware. The functionality of the software is tightly coupled to that of the hardware configuration.

A specific example of this can be found in the manner in which video switching / control was deployed in UDOT. Video switching allows the operations personnel to place video images on monitors/ displays and to control the video camera. As part of the communications design, redundant control and data paths were implemented as much as possible. If a primary communication link was lost, the secondary source would activate and provide the video data for viewing. However, the ATMS application in GDOT apparently was not designed with a redundant control capability and hence the ATMS software could not detect and switch control of the video as communications was lost from the primary source. This required UDOT staff to modify the system software to activate the secondary control path. This was successful until such time that the primary control communication path returned. The software change was then reversed.

4.2.3 Standards Adoption

Given the lack of widespread, established ITS standards during the years over which the CommuterLink system was deployed, it is safe to say that standards adoption was not practical as part of the UDOT deployment. Having said that, it is clear that one of the key success stories for the UDOT deployment was the decision by local agencies to "standardize" on 2070 controllers and to integrate into a centrally managed, regionwide arterial traffic management software application. It was equally important that UDOT chose to deploy the NaviGAtor ATMS application instead of developing their own software application. This decision to leverage the investments of Georgia DOT was based upon the fact that other agencies were choosing that software application and there was a belief that economy of scale and leveraged improvements would be realized.

4.2.4 Ease of Integration

The CommuterLink system is viewed as the Regional Transportation Management and Traveler Information system for UDOT. While there have been additions made to the capability, there has been little need to "integrate" to the CommuterLink system. As part of the review of available documentation, there was no completed Interface Control documentation that defines how an "outside" interest might interface with the CommuterLink system to access data. There are specific interface documents mentioned relative to the 511 and Event Tracking System interfaces but neither of those documents were available at the time of this assessment. Nonetheless, the staff at UDOT have demonstrated a strong desire to integrate the CommuterLink system to outside interests for purposes of traveler information. As interest has arisen, the project team has supported those needs and implemented interfaces to provide both data and control (e.g. media interfaces, 511 interface).

4.2.5 Data Quality / Accuracy

One of the greatest challenges to an effective ATMS deployment is the quality of the data being collected / displayed. This is especially true when that data is also being heavily relied upon in order to support Advanced Traveler Information Systems (ATIS), as was the case in the CommuterLink deployment. There were three primary types of data collected: video, freeway speed / volume, and incident information. All three sets of information were made available to the traveling public in one form or another.

4.2.5.1 Video Data

There are over 210 Closed Circuit Television Cameras located across the region. Most were on freeways, at approximately one kilometer (0.62 miles) spacing. A small number of these locations were temporary installations for the Olympics Games only. Almost all CCTVs were connected via high-speed, fiber-optic communications lines, allowing full-motion displays and full control (pan/tilt/zoom). However, a few cameras at remote locations were connected via telephone lines (dedicated and dial-up), allowing only "slow-scan" images to be transmitted. However, these dial-up cameras are used sparingly due to the recurring communications costs associated with their operation. Snap-shots from most of these camera sites were made available to the general public and were updated on a 3-5 minute basis. This provided both timely and quality images for the traveling public.

4.2.5.2 Freeway Speed / Volume

There were traffic monitoring stations (TMS) throughout the region connected to the TOC via communications links. Almost all were on the freeway system, at approximately half-mile spacing. Each TMS generally consisted of a detector in each mainline lane, plus detectors on the on-ramps. In almost all cases, each mainline lane detector consisted of two in-pavement loops, to allow it to measure volume and speeds. The detectors at the 23 metered on-ramps generally included several loops in each lane to detect calls, clearance, and queue backup. Detectors at non-metered on-ramps included fewer loops.

From the perspective of data accuracy, there were two traffic-detector problems that had a minor impact on their functions:

1.) Speed detection errors – Early during the Games, observers noted that several of the detector stations were producing speed measurements that were noticeably inaccurate. UDOT staff and contractors performed diagnostic tests and felt that this could be a result of a bug in the "firmware" code of some of the 2070 Controllers. There were three versions of this firmware installed in the controllers, and the problem was isolated to one of those versions. Because the re-installation of this firmware was very time-consuming, TOC staff decided that the situation did not require an immediate remedy and the updates were scheduled for after the Games. At the time of this report, there was an on-going investigation into the cause of these speed detection issues. During the investigation, several problems have been identified that may be leading to the inaccuracies in speed measurement. These issues include hardware configuration settings (amplifier sensitivity), power supply filtering, and potential crosstalk issues due to cable routing.

2.) Data gaps – In addition to reporting speed, the detector stations also reported traffic volumes in each lane, plus some data about vehicle lengths (e.g. to classify and count cars versus trucks). For a number of the TMS, communications were removed in order to integrate the ramp metering system to the arterial management software application. This resulted in a number of data gaps in the network.

4.2.5.3 Incident Data

Incident data was entered into the CommuterLink system through the efforts of the operations personnel. When an incident was reported in the DPS CAD system, it would appear on the "incident" consoles within the TOC. The operator would then enter that information as an Incident into the CommuterLink system. Given the widespread availability of video data, the operators would use the CCTV imagery to assess the impact of the incident, potential duration, and incident management strategies. This allowed for significant information to be entered into the incident report. However, the double entry required at times allowed for the introduction of human error. On a number of occasions, the preliminary incident details were inaccurate and required update.

Also, the incident closure process at times allowed for stale information to remain on the CommuterLink website and the 511 telephone advisory system.

4.2.6 System Performance / Maintainability / Documentation Level

During the course of Event Study and Case Study observations, the CommuterLink system was operating in extreme conditions and some problems were encountered during the Olympics. However, none of these problems prevented any essential functions from being performed in a timely fashion. Specific issues relative to performance were:

- Traffic Monitoring Station Data Availability – The TOC system utilized two primary and different software applications to manage traffic. The ATMS software, which was developed in Atlanta and transplanted to Salt Lake City, provided the functionality to manage the freeways. The ICONS software is used to manage traffic signals on surface streets. The NaviGAtor software did not provide the functionality needed to operate traffic signals at the 23 metered on-ramps, so the signals at these on-ramps were put under the control of the ICONS software. However, this required that the communications lines from the TOC to those signals be dedicated to performing the ICONS communications instead of carrying data from the nearby Traffic Monitoring System (TMS) sites back to the TOC. Thus, a number of TMS sites near the metered on-ramps did not report volume or speed data back to the TOC. In addition to these losses of TMS sites, there are also issues related to the TMS sites reporting incorrect speeds. This anomaly was random in nature and was being investigated at the time of this writing.

- Gaps in TMS archived data. With the few exceptions described above, data from all TMS sites was flowing back to the TOC continuously, and was being stored in a "buffer" in the TOC computer every twenty seconds. This data was used by the TOC computer to perform the "real-time" traffic management and traveler information functions. Afterwards, the data was stored ("archived") in the computer for use at a later date. There were recurring problems during the Olympics with the archiving of this data for later use, with numerous periods of hours or days during which the data was not archived. While UDOT has not yet begun to use the archived data, this is an area of functionality that will play a significant role in future activity of UDOT.

- System Instability. From both observations in the TOC and interviews with UDOT staff, it was determined that the system stability was suspect. On a number of occasions, system processes "froze" – example, loss of camera control process precluded TOC personnel from accessing and controlling CCTVs. UDOT staff developed an operational procedure to re-boot the entire application every evening in the later hours. Through interviews with UDOT staff, it was determined that the original GDOT application exhibited some operational "bugs" and that these issues were not fixed prior to transporting the software to UDOT. Thus, UDOT inherited an application with some operational bugs and then modified and enhanced that base configuration. Speculation from staff was that the system instability was possibly related to memory leakage[7] from some of the more processing intensive functions. It has also been speculated that system instability might be related to CORBA / Smart Sockets interaction. A "bridge" had to be created to connect processes in the system including the operator map,

[7] Memory Leakage is a phenomenon where a software application will allocate internal memory when launched. The application is supposed to release that memory allocation once completed. However, some inefficient software applications fail to release all the allocated memory, thereby causing the system to run out of available memory.

creation of XML files used for 511 operation, and data collection used for data delivery to the Internet site. The "bridge" or VIDS servers have to be restarted frequently, as often as twice a day. UDOT staff is focusing effort into isolating these causes of system instability and correcting the system design.

The level of documentation for the CommuterLink System is limited. Based upon interviews with staff and review of available documentation, it appears that the original GDOT NaviGAtor system had minimal documentation. With much of the emphasis of contractual activity focused on porting of the system and designing / developing enhancements to the system prior to the Olympics, the issue of limited documentation continues. There are a number of documents that are pending completion under the Phase IV activity.

4.3 Institutional Evaluation

4.3.1 Agency Expectations – Based upon review of contracting documents and discussion with UDOT staff, the expectations of the stakeholders were as follows:

- ☐ Deploy an integrated Freeway and Arterial Management system that could support the regional transportation needs of the SLC area.
- ☐ Deploy an ATMS/ATIS system that could provide the required functionality in time to support the 2002 Winter Olympics.
- ☐ Deploy an ATMS/ATIS system that could serve as a foundation for future enhancements for the region
- ☐ Deploy an "off-the-shelf" system whereby UDOT investments could focus on development / deployment of new functionality while leveraging investments made by other agencies.

Overall, the expectations of the project stakeholders were satisfied as a result of the deployment of the CommuterLink system. As evidenced by the findings of the Olympics ITS Event Study (draft completed August 2002), the UDOT ATMS/ATIS performed well during the 2002 Winter Olympics and provided the UDOT personnel with the necessary command and control capability to effectively manage an event as demanding as the Olympics. While a few of the systems did not always function as expected, the deployed capability did provide the necessary information that allowed UDOT personnel to make informed decisions about traffic management alternatives.

In addition to the basic requirement to deploy the NaviGAtor ATMS and Icons Signal Systems applications, the original Systems Integrator RFP included additional goals for enhancements in subsequent contract phases. These goals and their status are summarized in the table below.

Goal / Feature	Status
Modified GUI Screens	Implemented
Incident Detection Algorithms	Not Implemented
Wide Area Ramp Metering	Currently Under Development
Integration with Public Safety CAD	Integration includes shared incident status log; requires manual intervention to integrate incident data with ATMS
Integrate Road Weather Information System	UDOT RWIS not integrated; TATS Data Available to traveling public via CommuterLink website
Implement Traveler Information Systems	www.commuterlink.com completed 511 Telephone system operational (TellMe) ATMS dissemination devices operational (Variable Message

	Signs, Highway Advisory Radio), media interfaces supported, automated paging systems
Implement AVL on Incident Management Vehicles	Not Implemented

4.3.2 Procurement/Contracting

Deployment of the UDOT ATMS/ATIS was achieved through a series of contracting activities. Throughout the deployment of this system, there were individual contracts awarded for the following activities:

- System Manager – The System Manager contract supported the Requirements Specification and System Design of the ATMS/ATIS. The System Manager contractor also supported agency staff in the evaluation and selection of the Design/Build consultants, the Systems Integrator activity, and subsequent deployment activity. The System Manager has also been expanded to complete activity that was originally envisioned to be the responsibility of System Integration contract.
- Systems Integration – The Systems Integration contract supported the implementation of the ATMS/ATIS software system. This included the deployment of the NaviGAtor ATMS system as well as the Icons Arterial Management System. A series of contract modifications were utilized to introduce new system features or modify capability of the deployed system.
- I-15 Corridor Reconstruction Design/Build – The I-15 Corridor Reconstruction Design/Build contract removed and replaced 17 miles of the urban Interstate Highway through Salt Lake city. A component of this design/build activity was the deployment of ATMS infrastructure throughout the corridor and valley.
- TOC Construction – The TOC Design/Build Construction contract built the Traffic Operations Center. This construction activity included the development of the Operations Center and communications infrastructure within the facility. The contract was modified to include the design, furnishing, and installation of all the TOC operator consoles and video systems, including procurement of the video switch, video wall, and other conference room electronics.

4.3.2.1 Overall System Deployment Responsibility

One of the greatest challenges to this CommuterLink deployment project was the inter-relationship between the various contracting activities. Aside from project management provided by UDOT staff, there was no single unifying contract responsible for the CommuterLink deployment. Field and communications infrastructure was the responsibility of I-15 Reconstruction contract, software and "integration" was the responsibility of the Systems Integrator, and system design was the responsibility of the System Manager. These varying roles led to some challenges when it came to answering the question of, "why isn't a function operating correctly?"

Based upon interviews with UDOT staff, it became apparent that "end-to-end" responsibility of the system needed to reside within one of the cited contracts. However, it appears that such was not the case. As the I-15 reconstruction contract deployed ATMS components / communications, they would "test" that functionality and transfer responsibility to the TOC operations. Yet there was not an ATMS capability deployed to actually test that functionality as it was "sold-off" to UDOT. As the CommuterLink system was deployed, much of the challenge became understanding the configuration of the deployed functionality and relating that configuration to the ATMS design.

Nonetheless, even with these challenges, the system was deployed and did provide all of the critical elements that were required during the Olympic Games. It was through the flexibility of the UDOT contracting and the capabilities of all the players that such a challenge was overcome. Examples of this flexibility can be found in the manner in which the Systems Integration contract was executed (multiple phases, re-negotiated statements of work, scope transfer between contractors, etc.).

4.3.2.2 Systems Integration Contracting Assessment

For purposes of this study, the critical contract that affected the deployment of the CommuterLink system was the Systems Integration contract. This project was introduced as a multi-phase effort where general requirements / expectations were known at the beginning of the process. For example, when the procurement occurred, UDOT had already made the determination that they wanted to deploy the GDOT NaviGAtor ATMS software application and focus their investment on enhancements to a "deployed" system. To accommodate their desires to expand and enhance the NaviGAtor software, UDOT entered into an phased development and deployment contract with the Systems Integrator using a cost plus fixed fee arrangement. This approach allowed each of the project phases to be managed as separate enhancement projects with their own requirements, development, deployment, and acceptance timeframe. This approach also allowed flexibility in adding and removing scope to the Systems Integration contract as the agency saw the need.

Traditionally, many ITS projects are procured on a Fixed Price basis. This is typically accomplished by the agency developing detailed requirements / expectations at the beginning of the procurement process and then evaluating the technical and cost proposals from the potential bidders. Many procurements are determined ultimately based upon overall program cost. UDOT selected based upon a value approach knowing that flexibility was required due the potential for change in requirements and deployment direction.

One of the key features to the contracting approach and execution was the use of Implementation Phasing Plans. A number of agencies have used this approach to allow for a systematic approach to prioritizing System Requirements / Features and then deploying the higher priority features first. This process begins with requirements building efforts between the consultant team and the project stakeholders. These requirements are then evaluated and the costs to implement these requirements are developed. Based upon available funding, the agency then picks from the "menu" the features that they can afford and includes those deployments within the scope of the project.

For this approach to be successful, the agency requires a solid technical knowledge of the type of deployment that is being contemplated in order to determine the appropriateness of the cost estimates as proposed scope. These are typically the services that a system manager contractor or experienced in-house staff would provide as part of the negotiation process.

4.3.3 Ownership / Data Rights / Software

An area of review for this evaluation was whether software ownership rights were addressed in the contracting language. This has been an issue for other deployments across the country and was included to see how UDOT's approach differed from other agencies. Review of UDOT contractual documentation shows that the specific issue of software ownership remains silent until Amendment #5 to the Systems Integration contract (effective June 8, 2001). Prior to this amendment, the only language pertaining to "ownership" referenced documentation (original contract effective November 20, 1997).

As has been the case in other ITS deployments across the country, the issue of software ownership involves whether the consultant "owns" the software and grants "license" to the agency or visa-versa. The original contract language appears to be silent to specific limitations or licensing provisions of the deployed CommuterLink software. However, the Amendment #5 language appears to grant ownership of the software to the state for software developed under the Systems Integration contract as well as consultant developed software (with the exclusion of the Icons software package). This amendment language does provide "a royalty-free, non-exclusive, irrevocable, perpetual use license" to the consultant for the benefit of the consultant.

4.3.4 Integration Across Jurisdictions

The development of the Salt Lake area CommuterLink required the cooperation of numerous agencies and jurisdictions in the Salt Lake Valley. This integration was accomplished through the development of the ATMS implementation plan and the execution of a number of interagency agreements. Much of the integration was achieved through the decision that the CommuterLink System would be a Regional Transportation Management Center. With this decision, a majority of the local agencies agreed to standardize and centralize traffic signal control operations within the state DOT Regional ATMS.

The Department of Public Safety (DPS) is also co-located at the Regional TOC allowing for the coordination of response activity and the sharing of data between the various functions. The integration between the DPS CAD and the CommuterLink system is not automated. However, the TOC operators have access to incident information through a workstation in the TOC. This allows them to view the incidents entered by dispatchers as well as input information themselves. Once an incident is escalated to their responsibility, they manually input the information into the CommuterLink application and the data becomes available to the traveling public.

4.4 Operational Scenarios

4.4.1 Incident Management Performance

In order to understand Incident Management performance, it is important to define an "incident." An incident is an unplanned occurrence that affects traffic flow within either the freeway or arterial network. During the Olympic games, for example, incidents also included suspicious packages, motorcades for dignitaries, in addition to the traditional accidents or weather related "incidents."

In general, incident management actions included three steps: incident detection, incident confirmation, and response planning / execution.

4.4.1.1 Incident Detection

In this context, "incident detection" is defined broadly to include all forms of information gathered at the TOC relative to potential delays on the roadway network. Based upon interviews and observations, the Control Room Operators were the "front-line troops" for incident management and were usually the first to become aware of an incident. They received surveillance information about incidents via a number of methods, including:

- Calls from the public – As mobile phones become more ubiquitous, motorists have played an increasing role in traffic surveillance. When a motorist dialed the *11 or 887-3700 number, the phone would usually be answered by one of the Control Room Operators. In most cases, the operator would then select and move one of the CCTV cameras to *verify* the incident.

- Monitoring CCTV images – A portion of the video wall screens were programmed to automatically cycle through a pre-established pattern of camera locations, generally moving sequentially along a freeway and holding each image for several seconds. Some incidents were detected initially by the operator seeing the problem on the screen, usually as a result of noting heavy queuing on the freeway when/where it does not occur normally.

- Messages from the DPS dispatcher / other emergency services – The DPS dispatcher is located in the TOC, in a small room adjacent to the Control Room. DPS dispatchers received 911 and *11 calls from motorists or other travelers. As part of the DPS dispatching process, they would enter descriptive data into their Computer-Aided Dispatch (CAD) system. The TOC operators have access to this incident log and monitor it regularly. Additionally, these operators also are able to enter incidents into the log and have that information shared with the DPS personnel. The Operators also had access to information from other emergency-services agencies in the region, by monitoring their 2-way radio transmissions.

- Radio messages from UDOT field units – During special events (like the Olympics), the Incident Management Team and the Service Patrols spent the bulk of their time on the freeways. When they encountered an incident, they would radio the information to a Control Room Operator. There were many other UDOT staff deployed on the roadways for other purposes, especially during the Games, and they also served a surveillance function.

- Weather and roadway conditions – Bad weather can itself be an incident – especially when it causes slippery pavement conditions – so the Control Room Operators monitored the weather via a screen on their workstation (or on the display wall) that displayed a variety of weather maps and other weather-related information.

While there were originally plans for automatic incident detection algorithms, such software was not deployed as part of the CommuterLink System activity. Given the better sources of incident detection that are now available, it is doubtful that such an algorithm would have a significant improvement on performance. Also, given issues with detection data accuracy (refer to section

4.2.5) it is unlikely that an automated incident detection algorithm would have operated as expected.

4.4.1.2 Incident Confirmation

With the widespread deployment of CCTV infrastructure, a majority of the Incident Confirmation occurred through the use of cameras by the TOC operators. This confirmation approach proved to be the most effective means by which response could be coordinated and assessed. When camera images are not available, TOC operators will work with other affected agencies to assess the nature of the incident, the potential impact, and possible solutions / management strategies to minimize the impact.

4.4.1.3 Response Planning / Execution

In general, the control room operators were responsible for handling minor traffic incidents and minor non-incident congestion, that is, traffic situations that did not require strategic traffic-management decisions or substantial interagency coordination. Most of the incidents that occur fit into this category and were handled entirely by the control room operators. They did so by assessing the situation and deciding upon a response plan. The CommuterLink software contained several-hundred of these response plans, which were pre-defined by UDOT staff prior to the Olympics based upon the type, severity, and location of the potential incident. The ATMS computer did not automatically display the response plan for the current incident; the operator had to request the computer to do so. In most cases, the operators were sufficiently experienced that they identified the appropriate response plan immediately, without requesting an Action Set.

In general, the response by the TOC Operators included the following actions:

- Notify the “responders” – This included any of the field units (DPS, IMT, paramedics, etc.).
- Distribute information – Likely including “broadcast” messages (e.g. CLW Alerts), or “targeted” techniques (e.g. VMS and HAR messages).
- Monitor the situation – Track progress until it is cleared, often using CCTV plus 2-way radio to communicate with IMT and DPS units on the scene.

The CCTV images could also be viewed – with full-motion video – by several local media outlets via a high-speed communications link to their studios. Static snapshots of the CCTV images could also be viewed worldwide through the CommuterLink Website by anybody with access to the Internet. The coverage of the CCTV cameras is so broad that most of the incidents are viewed using one or more cameras.

To illustrate how the incident-management approach was used, the following vignettes describe actual events that occurred during the Olympic Games and was documented in the Event Study report.

- ☐ <u>Freeway Crash, Day 1</u> – A moderate snowstorm passed through Salt Lake City on the morning of Day 1, making the roads slippery and resulting in a number of collisions on the freeway. One such crash occurred on the freeway adjacent to the E-Center, a major Games venue. One of the vehicles involved left the roadway and crashed through the chain-link fence surrounding the E-Center’s large parking lot. There were injuries, but none looked to be serious. To all appearances, this was just another incident among many that day. The Control Room Operators followed standard response procedures, which included issuing an Alert. The message in the Alert described that the vehicle breached the fence, and also mentioned that the fence was the "security perimeter" for the venue. When reading the message, an anxious media immediately assumed the worst – the security perimeter of a venue has been breached – and they inundated the TOC with phone calls seeking further information. Room 230 sprang into action to issue clarifications, and the issue quickly subsided. There was a brief discussion about possibly discontinuing the Alerts, but UDOT management decided that their value for traveler information justified the extra effort required to avoid misperceptions by the media.

- Presidential Motorcade – The President attended the Opening Ceremonies, arriving at SLC Airport around Noon on the first day of the Games and traveling via motorcade to the University of Utah area, near where the Opening Ceremonies took place at Rice-Eccles Stadium. For security purposes the exact arrival time and travel route were not disclosed to TOC staff until roughly one hour before the motorcade began. Plans were previously made by TOC staff to accommodate the several likely routes. Thus, to some extent, this was a "planned" incident, for which the incident-management actions included:
  - Law-enforcement officers closed all cross streets and freeways along the route as the motorcade passed.
  - TOC Control Room operators set traffic signals along the route to green indications, whenever possible.
  - Room 125 staff posted VMS signs to warn motorists of road closures ahead.
  - TOC staff (at all three levels plus Room 227) tracking the motorcade using CCTV.
  - TOC staff blocking those specific camera images from the media.

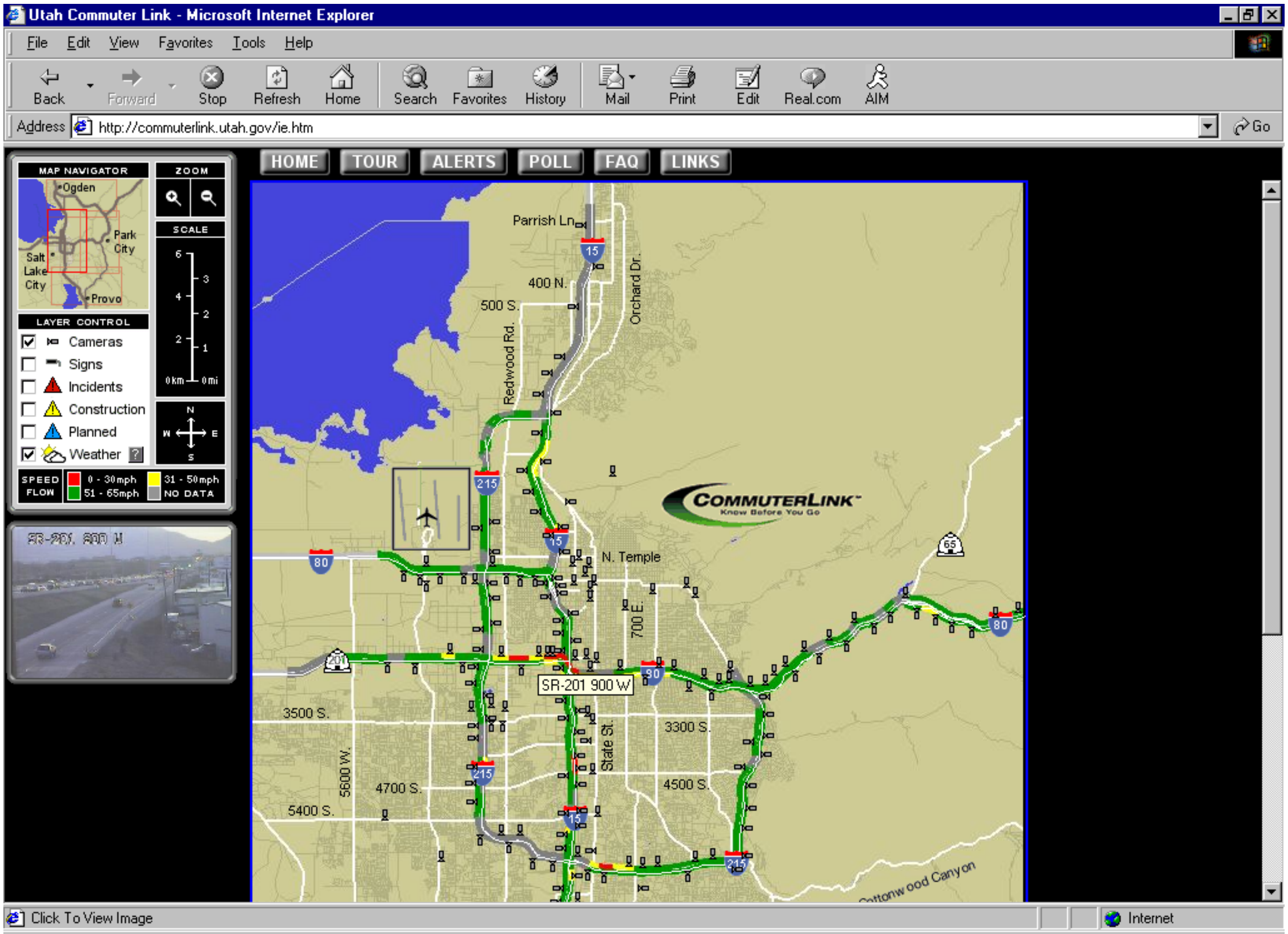
    Although there was a small "glitch" with the camera-control software earlier that morning, everything was in order at the time of the motorcade and it proceeded as planned. Similar actions were executed for the President's return to the airport, as well as for the Vice-President's trip from and back to the airport, when he attended the Closing Ceremonies. All went as planned.

4.4.2 Traveler Information Performance

Traveler information is made available to the public through a variety of dissemination channels. These include: Internet site, 511 telephone advisory system, automatic paging system, the media, and through devices along the roadway (including variable message signs and highway advisory radio). Information made available included video image snapshots, freeway speed information, incident information, weather information, alternate route information, transit information, and special event information.

4.4.2.1 www.commuterlink.utah.gov

The UDOT Internet site is a well-designed, easy to navigate, and comprehensive Internet traffic map. It provided the visitor with the video snapshots, freeway congestion, incident, weather, variable message sign, and construction information. The site was designed with predefined "views" that provided increased details on the arterial and freeway network. These predefined zoom areas also allowed for quick navigation within the site.



The site includes a preview pane that features the data from whatever device / icon is selected. For example, when a video camera is selected, the preview pane would include that image snapshot. Users could then further expand the video size by "double-clicking" on the image and a new window with a larger video image would result.

The Internet site also provides additional information that explains the various components included in the CommuterLink system, a virtual tour of the TOC, and links to other sites of interest within the state. The CommuterLink website also allows users to register for an Alert system that sends email notification when incidents are reported in the coverage area.

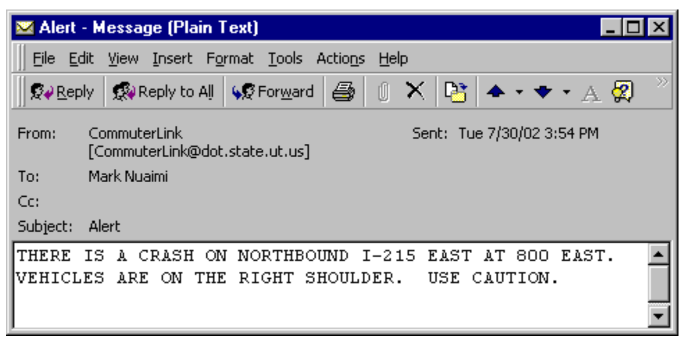
4.4.2.2 511 Telephone Advisory System

Travelers in the region can access information about incidents through a 511 telephone advisory system. The system (operated by TellMe) is a voice responsive system that came on-line just prior to the start of the Olympics. The 511 deployment was the third such deployment in the nation and was the first voice responsive implementation. While the system itself appears to have performed well, there were inconsistencies between the various CommuterLink databases that affected the overall accuracy of the information somewhat (refer to the Event Study for further detailed information).

4.4.2.3 Media Interfaces

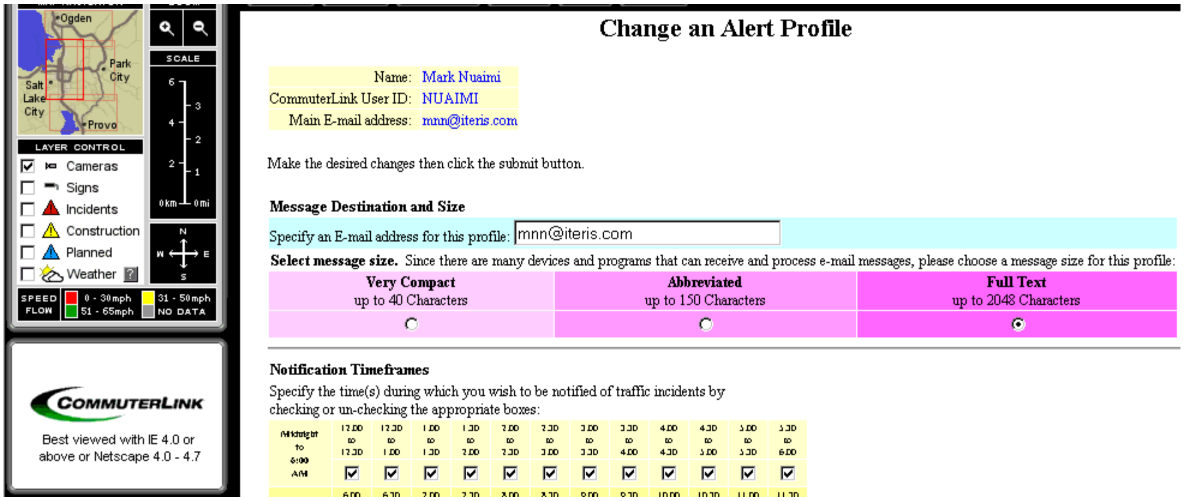
A number of the local media outlets also served to disseminate traveler information to the public. Several broadcast TV stations were provided links to video feeds from the TOC and the control to switch cameras of interest. The TOC facility monitored on their video wall the camera selections of the broadcast media and had the ability to "lock-out" specific cameras due to incident response issues, privacy, or security reasons. Radio broadcast information was also available with "on-air" personalities co-located in the operations center. Finally, UDOT personnel also generate a periodic "status" that gets emailed to the various media outlets. This alerts the motorists as to the incidents on the roadway, alternate routes, and other information that could prove useful to the traveling public.

4.4.2.4 CommuterLink Alerts



The CommuterLink System also included an email alert system that provided incident information automatically to users that had subscribed to data. The system allows for a rich set of filtering characteristics for the user to limit the number of alerts to only those that might impact the travelers' trips.

This capability provides a solid foundation upon which additional automated services could be deployed. As the CommuterLink system is enhanced, additional sources of incident information will further supplement that data stream to the travelers. Additional testing should also occur to ensure that the data requests / filter criteria are satisfied.



4.4.2.5 Roadside Elements

The most visible form of traveler information dissemination came from the various field elements deployed throughout the region (VMS & HAR). The VMS inventory was used extensively during the Olympics in response to event management and that experience has produced a rich incident management response plan as well when it comes to using VMS and the highway radio as dissemination devices (refer to the Event Study for further detailed information).

4.4.3 Event Management Performance

One of the highlights of the Winter Olympics was the manner in which UDOT staff used the CommuterLink system to facilitate and enhance Event Management. Through the use of CCTV, the TOC operators were able to assess the congestion in and around event venues and direct the traveling public accordingly. Once congestion was detected, the operators would utilize a variety of strategies to address the impacts. These included modifying signal timing to accommodate flow and the use of VMS and HAR to instruct motorists on conditions and alternate routes.

In addition to freeway and arterial congestion monitoring, the TOC operators were in constant contact with observers at the various Olympics Park-and-Ride facilities throughout the region. The VMS were used extensively to also direct travelers to the proper parking lots or to direct motorists away from full lots.

The traffic managers used the CommuterLink web site as a quick-look tool to check and confirm that the proper messages were on the VMS. This feature was used extensively as a result of the importance of the signs to the daily operation of the TMC during the Olympics.

A specific example of ITS implementation specific for Event Management involves the E-Center Event Management System. This deployment project included 5 CCTV and 11 Trailblazer signs deployed strategically around the E-Center. The Regional TOC used real-time information from both the cameras and local police to change instructions to the motorists (via the Trailblazers) and made modifications to signal timing to enhance travel conditions in the area of the arena.

4.4.4 Incident Detection Performance

Originally, the CommuterLink application was to include an Incident Detection algorithm. This feature was not deployed as part of the UDOT activity. Also, given the issues with Traffic

Monitoring Station data accuracy, such an algorithm would probably not have functioned well to begin with. As with a number of other agencies across the country, agency staff has come to the belief that there is today no quicker Incident Detection mechanism than the driver with a cell phone.

4.4.5 Center-to-Center (C2C) Integration

Since the CommuterLink system is viewed as the Regional Traffic Management center, there was little emphasis on the development and deployment of a Center to Center integration effort. The primary integration that took place occurred as a result of the actions of the TOC operations staff integration to the DPS data sources and inputting that information into the CommuterLink system. At the time of this document development, there was no documented interface that was consistent with the emerging C2C interfaces.

In addition to the Regional Traffic Management center, remote sites were established for Salt Lake City and County. While these systems played a more active role during the development and deployment of the CommuterLink system, they now provide remote monitoring locations for those agencies with much of the regional transportation management occurring at the TOC.

4.5 Site Specific Issues

In addition to the Technical, Institutional, and Operational considerations, there were specific areas if interest that UDOT staff wanted examined. Some of these issues have already been discussed. However, they are summarized here for ease of review.

4.5.1 Deployment activities by UDOT and Wasatch Constructor –

This report has documented some of the key characteristics of the manner in which the CommuterLink system was deployed. Through the use of multiple contractors, the UDOT deployment sought to utilize design/build contracting to expedite the deployment of the ATMS capability. With this approach came some significant challenges relative to configuration management and overall integration responsibility. However, proof is in the overall results – by the time the 2002 Winter Olympics began, UDOT had in place an expansive network of data collection and traffic management devices that minimized the delays and improved the traffic conditions during the 2002 Winter Olympics.

4.5.2 NTCIP initiation in ramp metering

Implementation of Ramp Metering control was a significant goal of the ATMS deployment. At the time of this writing, the Ramp Metering control had not been deployed within the ATMS software. However, UDOT personnel worked around those software issues and integrated the ramp meters with the traffic signal control system (Icons) to allow for coordination with the arterial network. This had some negative impacts relative to data collection on the freeway mainline but it was not evident from the Olympics Event Study that Ramp Metering was a major asset or hindrance to the traffic management operations.

4.5.3 Integration of freeway and arterial management

Integration between the freeway and arterial management systems was achieved through the co-location of the freeway and arterial operations staffing. The CommuterLink system and the Icons application are not integrated for automated operation. The operators have access to both applications at their workstation. This provides the operator access to both types of information to coordinate between the arterial and freeway operations. Additionally, the arterial management system was able to integrate to the freeway ramp metering operations to allow the Icons application to manage these devices until such time that the ATMS Ramp Metering system was developed, deployed, and tested.

4.5.4 Use of multiple types of traffic-signal controllers

The deployment of 2070 controllers brought forward considerable flexibility and performance capability. However, as part of the procurement process, multiple types of 2070 controller were deployed. While these various hardware devices satisfied the specification, they came with a variety of firmware packages that complicated configuration management. At the time of this writing, the issues with freeway mainline congestion data collection were still under investigation. It is unclear whether the variations in controller devices contributed to these issues.

4.5.5 Compliance with National ITS Architecture

The CommuterLink development and deployment began in 1994 with the initiation of an ITS Early Deployment Plan (EDP) for the Salt Lake City metro area by UDOT. The EDP was prioritized for elements supporting the Olympics and included Incident Management, Advanced Traveler Information, Parking Management, ATMS Expansion, and Automated Vehicle Location. ITS elements specific to the Olympics listed in the EDP included CCTV installations, incident management expansion and training, and variable message signs.

The EDP process included User Needs assessments, a mapping of User Services, and a development of an implementation plan. The initial system design methodology appeared to be consistent with the version of the National Architecture at the time. Elements of the overall CommuterLink deployment were mapped to subsystems and terminators in the National ITS Architecture. Interconnections between these elements were generally consistent with the National ITS Architecture, based upon the high-level diagrams that were examined.

While a Regional ITS Architectural Plan was undertaken by the Wasatch Front Regional Council (and funded by UDOT), this study focused only on CommuterLink system deployment and did not attempt to examine the Regional ITS Architecture. The study also did not attempt to examine any detailed architecture aspects of the system design, such as architecture flows, data flows, or process specifications.

There have been updates to the National ITS Architecture and the USDOT has recently issued the ITS Architecture and Standards Rule. As a result, the Regional Architecture for Salt Lake City should be reexamined to insure that it reflects the recent guidance from FHWA relative to Regional Architecture development and compliance with the Architecture and Standards Rule.

4.6 Lessons Learned and Transferability

During the course of observations and interviews, a number of clear "Lessons" were captured that can prove quite useful for subsequent ITS deployments. This list is not intended to be an exhaustive summary of all the lessons learned from the deployment of the CommuterLink System (UDOT has tabulated a more extensive list). These are key lessons that would have mitigated the most challenging issues faced by UDOT and the deployment personnel.

Lesson #1 -- Configuration Management

When deploying a highly complex system like CommuterLink, there exists a need for a disciplined Configuration Management process from the beginning of the deployment. Such a process would have established the documentation requirements, naming conventions, requirements traceability, and change control practices early on in the development process. In the case of the UDOT deployment, there were a number of characteristics of that deployment that further required a mature Configuration Management process. They were:

- ***Multiple contractors involvement in the deployment:*** The CommuterLink system was deployed through a series of contracts that included the Highway Construction, the System Manager, the TOC construction, and the Systems Integrator contracts. There were additional subcontractors associated with these deployments and improved communication between the prime and subcontractors was warranted as well. Poor coordination between the Systems Integration contractor and their subcontractor eventually affected the delivery of the NTCIP Ramp Metering System.
- ***Urgency for Operation / Speed of Deployment:*** UDOT required that components be brought online as soon as possible for their use in operation. This often required that interim solutions be provided for communications.
- ***Instability of Communications Infrastructure:*** Given that much of the CommuterLink system was being concurrently developed, components were often brought on line prior to the final communications infrastructure being in place. This required interim solutions to be developed and resulted in frequent configuration changes between the methods in which data / control were brought back from field elements to the operations staff.

Based upon discussions with project personnel, one of the greatest challenges of the deployment was maintaining accurate information about the current configuration. On a frequent basis, the Highway Construction contractor would add components to the configuration and integrate those capabilities to the ATMS operations. There were also frequent changes in the communications channels as new backbone / distribution communications capability came on line. A Configuration Management approach should have been in place from the start that identified naming conventions, interfaces, and required protocols. This would have ensured consistency between the Highway Construction integration work and that of the Systems Integration contractor. It would have also allowed for the development of test apparatus (simulators) to effectively test the functionality of the deployed components without the need of having an operating ATMS system.

<u>Lesson #2 -- Utah isn't Georgia</u>

While the decision to utilize the Georgia DOT (GDOT) NaviGAtor ATMS software application provided a number of compelling advantages – reduced deployment cost, lower risk, faster deployment schedule -- to the CommuterLink System deployment, there were also some disadvantages that arose from that decision:

1. **Dependency On Operating System** – Given that the GDOT system was a Unix deployment, this mandated that the UDOT deployment also be Unix based. Based upon the inputs from project stakeholders, this yielded a more complex design than was probably necessary given the evolution of IT processing.
2. **Commercial-Off-The-Shelf (COTS) Package Changes** – One of the key components to the GDOT software application was no longer supported by the commercial vendor. Given the decision by the map vendor to no longer support their product, UDOT had to integrate a new mapping application to the ATMS software. However, another partner on the NaviGAtor ATMS development team (Oregon DOT) had already integrated a new mapping application to the NaviGAtor system and UDOT was able to port that functionality to their use.
3. **Operational Differences** – The role of the TMC operators is dramatically different in Utah as compared to Georgia –UDOT operators are empowered to make real time decisions relative to incident management approaches. In the Georgia application, the incident management capability of the system limits the ability of the operators to create VMS messages. The system proposes potential VMS messages from a pre-approved library of messages. In Utah, the operators are viewed as the specialists in the incident management activity and would have preferred an approach that allowed them more flexibility in creating messages to suit the situation.
4. **Lacking Diagnostic Information** -- The NaviGAtor system also does not currently provide diagnostic information to the operator about field element status. Staff with Software development experience are required to access this information within the system – a simple user interface is not provided.
5. **Incident Management Tailored for GDOT** – There are a number of attributes / settings that are defined for the GDOT needs. One example cited is the incident management code for "road kill". There is no equivalent in UDOT or a desire to categorize "road kill."
6. **Functionality Tied to Hardware Configuration** – According to UDOT staff, they discovered that some of the functionality of the NaviGAtor system was tied specifically to the hardware configurations of the Atlanta ATMS system. Specific examples include the manner in which video switching / viewing / transport took place. In Utah, the communications design allowed for redundant fiber communication paths for transporting video from the field hubs to the TMC. The NaviGAtor system was designed to control only a single source feed and could not automatically switch control and viewing as the feeds shifted from primary to back-up conditions. This required UDOT staff to hardcode changes to the configuration when the primary feed was lost – changes were made to return the code once the feed was restored. While this demonstrates a software compatibility issue between NaviGAtor and the UDOT TOC configuration, it highlights a key need when reusing a software solution – ***determine the dependencies on hardware solutions and adapt the hardware design to match the software or customize the software to match the hardware.***

Lesson #3 – Standardize the System Environment

With a system deployed over the course of many years, one of the challenges is how to incorporate advancements in technology without ending up chasing technological fads. Interviews with UDOT staff identified concerns about how fragmented the technology is associated with the ATMS application. Without an extensive review of the technical design decisions, it is impractical (and unfair) to second-guess decisions made over the course of a four phase deployment effort. However, agencies should be cautioned in the future to be aware that every "new" innovation in "off-the-shelf" software comes with its own set of bugs, software licenses, languages, interdependencies, etc. A quick review of the Architecture Alignment document completed in Phase IV shows the varied software and development environments required to duplicate what is currently in place.

An example of this need to "standardize" the environment can be shown with a review of Phase IV development activity. Unified Modeling Language (UML) design methodology was utilized by the contractor for the design and development activity. UDOT staff indicated that they were not prepared to support such a change in methodology and did not have anyone on staff with that capability. This minimized the technical review provided by the agency staff. Therefore, it was recommended by staff that ***the agency determines their preferred design methodology and requires the contractor to support that approach***.

Lesson #4 – Need for Stronger System Manager Role

Many of the issues identified during this assessment pointed to the need for an expanded System Manager role in this project. As was mentioned previously, there were a number of contracts awarded to yield the deployment of the CommuterLink system. The System Manager supported UDOT staff in the design and day-to-day activity of the project. The System Manager was also assigned Integration activity that was originally assigned to the Systems Integration contract. But more could have been done, earlier in the deployment process, to alleviate some of the issues that arose later:

- Given that the System Manager contract was competed and awarded prior to the Systems Integration contract, one of the initial tasks should have been the establishment of a Configuration Management system (refer to Lesson #2).
- With a more significant role, the Systems Manager contract could have been planning and executing Acceptance Testing. This would have provided a more independent assessment of the system performance.
- End-to-end integration activity was a challenge given the overlapping nature of the Systems Integration and Construction contracts. The System Manager activity could have provided the necessary bridge between those projects if it were responsible for the end-to-end integration of the system. This would have transformed the "Systems Integration" contract into a software development and deployment activity where the software applications are one of many components to the complete system.

This expanded role might have avoided some of the uncertainties in roles and responsibilities. It would also have focused accountability for overall system performance within the scope of a single contractor as opposed to the multiple contracts in place.

Lesson #5 – Co-Located Development Team

One of the major themes that arose in the discussions with UDOT staff was the need for better visibility into the design and development process of the CommuterLink software enhancements. What began as a local software development activity ended in a distributed engineering activity occurring in several sites across the country. This precluded having UDOT staff co-located with the development team and minimized their visibility into development progress and process.

A preferred approach that was discussed in interviews with UDOT staff would include the following features:

- Development staff is co-located at a single facility with an agency presence serving as "code review" staff. Assuming that the agency will take over responsibility for system maintenance, it was discussed that the same people maintaining / enhancing the system in the future, should be involved during the initial deployment to better understand the design methodology and code structure.
- A separate Test Environment (see lesson #6) would be included at this site. Acceptance tests would be conducted prior to deployment on the production unit.

One of the benefits to this approach of co-locating the development team and providing agency staff presence is schedule adherence. The agency representatives would not be dependent on the contractor to provide the latest in project schedule. It also allows the agency to better understand some of the issues and challenges with their requests of the contracting firm.

Lesson #6 – Need For Acceptance Test System

Currently, there is a development environment and a production environment. For much of the functionality, it was not possible to test the new software code until after it was installed in the production setting. This has inherent risk in that new applications are not tested extensively before being introduced into operation. A separate test environment would allow for extensive testing to eliminate bugs in the software application prior to being introduced into production.

One of the elements proposed in the Phase IV activity was the development of a separate Acceptance Test environment. This system would mirror that of the production unit and would have devices or simulators available to exercise the functionality of the system. This type of an approach does require a significant investment on the part of the agencies. While this may prove cost-prohibitive to some agencies, the ability to fully test "enhancements" prior to activation is a very effective risk mitigation approach.

One potential alternative to agencies facing a similar deployment might be to establish a relationship with a local university. As was the case in Utah, the local university worked with the state transportation agency and supported many of the on-going initiatives. Agencies may wish to partner with their local university to provide a test-bed for new functionality or to provide a limited Acceptance Test capability.

<u>Lesson #7 – Potential System Enhancements</u>

Overall, the system performed well given the extreme demands of the 2002 Winter Olympics. It is highly unlikely that the CommuterLink System will ever be required to function to the high level of usage as during the Olympics. This extensive usage did highlight potential enhancements to the system as well as some technical issues with the current configuration. These included:

- Variable Message Sign User Interface enhancements – the current design of the VMS control allows for the modification / command of a single VMS at a time. With over 60 permanent signs, it would have been much easier to simply command a change in content that could then be broadcast to multiple signs at once. Also, the VMS control did not appear to allow for Time-Of-Day scheduling of messages or a default messaging feature.

- Highway Advisory Radio – communications to the HAR utilized cellular communications to upload new messages. Given the cellular phone traffic in the area during the Olympic Games, there were times when connection with the HAR unit could not be made to update the messages. In addition, the HAR units were battery powered with a solar recharge capability. These HAR units were on for extended periods of time during the games. At times, power to the HAR was lost due to consumption exceeding the available charging capacity of the solar panels.

While some of these issues were largely unique to the heavy demands of the Olympic Games, similar issues could occur in other urbanized areas where extensive incident management / traveler information services are in place.

4.7 Conclusion

The deployment of the CommuterLink system was successful through the use of innovative contracting approaches, the leveraging of transportation management software capability, and the cooperation of several agencies throughout the deployment effort. This success was not achieved without some challenges. However, the flexibility of the agency staff and the capabilities of the various contractors were sufficient to yield a successful deployment and a capable Advanced Transportation Management and Traveler Information System.

List of Reference Documents

Regional Traffic Management System for the Salt Lake City Area (Final Report), April 1994

Salt Lake Valley ITS Early Deployment, Technical Memorandum No. 1, Part A, Transportation System Inventory, February 1995

Salt Lake Valley ITS Early Deployment, User Service Plan, March 1996

Initial System Concept and High Level System Requirements, May 1996

Traffic Operations Center, Architectural Program Study, May 1996

Early Deployment Planning Study, Strategic Deployment Plan Development (Phase II), September 1996

Salt Lake Area I-15 ATMS Traffic Signal Requirements, September 1996

Salt Lake Area I-15 ATMS Design Requirements, September 1996

Salt Lake Area I-15 ATMS Communications System Requirements, September 1996

Early Deployment Planning Study, ITS Strategic Deployment Plan, Executive Summary, February 1997

Request For Technical Proposal, Salt Lake Area ATMS System Integrator, July 8, 1997

I-15 Corridor Reconstruction Project, Design/Build Contracting (Initial Report), Special Environmental Project 14, October 1997

ATMS Expansion, June 1998

I-15 Corridor Reconstruction Project, Design/Build Evaluation, 1998 Annual Report, Appendix 1 RFP Evaluation & Selection Procedure, Special Experimental Project 14, October 1998

Incident Management Expansion Plan, November 1998

I-15 Corridor Reconstruction Project, Design/Build Evaluation, Special Environmental Project 14, December 1998

Salt Lake Area Intelligent Transportation System Olympic Expansion, March 1999

I-80 East ATMS Expansion Concept Design Report, April 1999

“E” Center ATMS Expansion, November 1999

Salt Lake Area ATMS Central Business District Expansion, February 2001

Salt Lake Area ATMS Surface Street Expansion, February 2001

Scope of Work for CommuterLink System Integrator Phase IV, April 4, 2001

DCN 1003ASRDR02, Automated Traffic Management System Phase IV INTEGRATION, System Requirements Document (Final), Revision 2.0, October 2001

Scope of Work for CommuterLink Traveler Advisiory Telephone System, Final, October 31, 20010

DCN 1003AIPPR02, Implementation Phasing Plan (Final) for CommuterLink Phase IV Integration, Revision 2.0, November 21, 2001

DCN 1003AHLDR01, Architecture Alignment for CommuterLink Computing Environments (Draft), Revision 1.0, November 27, 2001

Advanced Traffic Management System Design Manual, December 2001

DCN 1003AATPR01, Acceptance Test Procedures for CommuterLink Phase IV INTEGRATION, Revision 1.0, Final, January 24, 2002

DCN 1003AHLDR01, Architecture Alignment for CommuterLink Computing Environments, Revision 2.0, Draft, May 9, 2002

Various Systems Integrator Contract documentation

ITS Acronym List

Acronym	Definition
AASHTO	American Association of State Highway and Transportation Officials
ABS	Antilock Brake System
AD	Archived Data
ADA	Americans with Disabilities Act
ADMS	Archived Data Management Subsystem
ADUS	Archived Data User Service
AFD	Architecture Flow Diagram
AHS	Automated Highway System
AID	Architecture Interconnect Diagram
AMPS	Advanced Mobile Phone System
ANSI	American National Standards Institute
APTS	Advanced Public Transportation System
ASP	Application Service Provider
ASTM	American Society for Testing and Materials
ATC	Automatic Train Control, Advanced Transportation Controller
ATIS	Advanced Traveler Information System
ATM	Asynchronous Transfer Mode
ATMS	Advanced Traffic Management System
AVCS	Advanced Vehicle Control System
AVI	Automated Vehicle Identification
AVL	Automated Vehicle Location
AVO	Automated Vehicle Operation
CAA	Clean Air Act
CAD	Computer Aided Dispatch
CASE	Computer Aided Systems Engineering, Computer Aided Software Engineering
CCTV	Closed Circuit TV
CD	Compact Disc
CDMA	Code Division Multiple Access
CDPD	Cellular Digital Packet Data
CD-ROM	CD Read Only Memory
CMS	Changeable Message Sign (see also DMS, VMS), Congestion Management System
CMP	Congestion Management Plan
COTR	Contracting Officer Technical Representative
CSP	Communication Service Provider

Acronym	Definition
CV	Commercial Vehicle
CVAS	Commercial Vehicle Administration Subsystem
CVCS	Commercial Vehicle Check Subsystem
CVISN	Commercial Vehicle Information Systems and Networks
CVO	Commercial Vehicle Operations
CVS	Commercial Vehicle Subsystem
DAB	Digital Audio Broadcast
DC	Double Click (or District of Columbia)
DD	Data Dictionary
DDE	Data Dictionary Element
DFD	Data Flow Diagram
DGPS	Differential Global Positioning System
DMS	Dynamic Message Sign (see also CMS, VMS)
DMV	Department of Motor Vehicles
DOD	Department of Defense
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
DTA	Dynamic Traffic Assignment
DVD	Digital Video Disc
E9-1-1	Enhanced 9-1-1
ECPA	Electronic Communications Privacy Act
EDI	Electronic Data Interchange
EDP	Early Deployment Plan
EMC	Emergency Management Center
EMMS	Emissions Management Subsystem
EMS	Emergency Management Subsystem
EPA	Environmental Protection Agency
ESMR	Enhanced SMR
ETA	Expected Time of Arrival
ETS	Emergency Telephone Services
ETTM	Electronic Toll and Traffic Management
EVS	Emergency Vehicle Subsystem
FARS	Fatal Accident Reporting System
FCC	Federal Communications Commission for the U.S.
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standard
FMC	Freeway Management Center
FMCSA	Federal Motor Carrier Safety Administration

Acronym	Definition
FMS	Fleet and Freight Management Subsystem
FOT	Field Operational Test
FPR	Final Program Review
FTA	Federal Transit Administration
FTP	File Transfer Protocol
GIS	Geographic Information System
GPS	Global Positioning System
HAR	Highway Advisory Radio
HAZMAT	HAZardous MATerial(s)
HOV	High Occupancy Vehicle
HRI	Highway Rail Intersection
HSR	High Speed Rail
HTF	Highway Trust Fund
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
HUD	Head-Up Display
IBC	International Border Clearance
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IFB	Invitation for Bid
IP	Internet Protocol
IPR	Interim Program Review
ISO	International Standards Organization
ISP	Information Service Provider
ISTEA	Intermodal Surface Transportation Efficiency Act
ITE	Institute of Transportation Engineers
ITI	Intelligent Transportation Infrastructure
ITS	Intelligent Transportation Systems
ITS-A	Intelligent Transportation Society of America
IVHS	Intelligent Vehicle Highway Systems
IVIS	In-Vehicle Information System
JPO	Joint Program Office
LAN	Local Area Network
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LEO	Low-Earth Orbit satellite system
LPD	Liability and Property Damage
LRMS	Location Reference Messaging Standard
MAN	Metropolitan Area Network

Acronym	Definition
MCMS	Maintenance and Construction Subsystem
MCO	Maintenance and Construction Operations
MCVS	Maintenance and Construction Vehicle Subsystem
MDI	Model Deployment Initiative
MIS	Major Investment Studies
MMDI	Metropolitan MDI
MMI	Man-Machine Interface (or Interaction)
MOE	Measure Of Effectiveness
MOU	Memorandum of Understanding
MPA	Metropolitan Planning Area
MPH	Miles per Hour
MPO	Metropolitan Planning Organization
NAV	Navigation
NEMA	National Electrical Manufacturers Association
NHPN	National Highway Planning Network
NHTSA	National Highway Traffic Safety Administration
NII	National Information Infrastructure (aka Information Superhighway)
NPRM	Notice of Proposed Rule Making
NTCIP	National Transportation Communications for ITS Protocol
OEM	Original Equipment Manufacturer
OSI	Open Systems Interconnection
OTP	Operational Test Plan
PC	Personal Computer
PCS	Personal Communications System
PDA	Personal Digital Assistant
PIAS	Personal Information Access Subsystem
PMS	Parking Management Subsystem
PSPEC	Process Specification
PSTN	Public Switched Telephone Network
PTS	Positive Train Separation
R&D	Research and Development
RDS	Radio Data Systems
RDS-TMC	Radio Data Systems incorporating a Traffic Message Channel
RFP	Request For Proposal
RFQ	Request for Quotation
RS	Roadway Subsystem
RTA	Regional Transit Authority
RTP	Regional Transportation Plan

Acronym	Definition
RTS	Remote Traveler Support Subsystem
SAE	Society of Automotive Engineers
SC	Single Click
SDO	Standards Development Organization
SIP	Statewide Implementation Plan
SMR	Specialized Mobile Radio
SNMP	Simple Network Management Protocol
SONET	Synchronous Optical Network
SOV	Single Occupancy Vehicle
SOW	Statement of Work
SQL	Structured Query Language
SSR	Standard Speed Rail
STIP	Statewide Transportation Improvement Program
STMF	Simple Transportation Management Framework
STMP	Simple Transportation Management Protocol
TAS	Toll Administration Subsystem
TATS	Telephone Advisory Traveler System
TCIP	Transit Communications Interface Profiles
TCP	Transport Control Protocol
TCS	Toll Collection Subsystem
TDM	Travel Demand Management
TDMA	Time Division Multiple Access
TEA-21	Transportation Equity Act for the 21st Century
TIP	Transportation Improvement Program
TM	Traffic Management
TMA	Transportation Management Area
TMC	Traffic Management Center
TMDD	Traffic Management Data Dictionary
TMS	Traffic Management Subsystem
TOC	Traffic Operations Center
TRB	Transportation Research Board
TRMC	Transit Management Center
TRMS	Transit Management Subsystem
TRT	Technical Review Team
TRVS	Transit Vehicle Subsystem
UDP	User Datagram Protocol
USDOT	United States Department of Transportation
USR	User Service Requirement

Acronym	Definition
VMS	Variable Message Sign (see also DMS, CMS)
VRC	Vehicle/Roadside Communications
VS	Vehicle Subsystem
WAN	Wide Area Network
WIM	Weigh-in Motion
WWW	World Wide Web