EDAPTS
Smart Transit System

Task Order 6403

Cal Poly Pomona EDAPTS Test Deployment

Final Report

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DISCLAIMER

This work was performed as part of the California PATH Program of the University of California, in cooperation with the California Department of Transportation and Federal Transit Administration.

The contents of this report reflect the views of the authors who are responsible for the statements and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the State of California and the Federal Transit Administration. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

TERMINOLOGY

APTS	Advanced Public Transportation System
APC	Automatic Passenger Counter
AVL	Automatic Vehicle Location
Bronco Express EDAPTS Demonstration	Stage 5 Test Deployment of Efficient Deployment of Advanced Public Transportation Systems (EDAPTS) at Cal Poly Pomona
Bronco Express EDAPTS system	The APTS solution deployed using the EDAPTS approach at the Bronco Express shuttle bus system
Caltrans DRI	California Department of Transportation; Division of Research and Innovation
Cal Poly Pomona	California State Polytechnic University at Pomona, California
Cal Poly SLO	California Polytechnic State University at San Luis Obispo, California
COTS	Commercial Off-The-Shelf
EDAPTS	Efficient Deployment of Advanced Public Transportation Systems
EDAPTS Spec Generator	Software that can generate performance specifications for an EDAPTS deployment
FTA	Federal Transit Administration
FHWA	Federal Highway Administration
GPS	Global Positioning System
MDT	Mobile Data Terminal
Modified V-Model	An EDAPTS modification of the FHWA Systems Engineering V-Model in which the detailed design and testing steps of the procured COTS solution are done by the supplier or vendor without specific knowledge or overview of the procuring agency.
RID	Roadside Information Display

RMS	Roadside Message Sign
RFP	Request for Proposal
Validation	The process of testing and rating the compliance of the installed Bronco Express EDAPTS system to the features described in each operational scenario listed in the Cal Poly Pomona Test Deployment EDAPTS Operations Description report.
Verification	The process of checking the compliance of the installed Bronco Express EDAPTS system to the system and performance requirements described in the Cal Poly Pomona Test Deployment EDAPTS Request for Proposal document.
V-Model	The Federal Highway Administration's (FHWA) System Engineering V-Model. FHWA requires that federally funded projects using Highway Trust Funds use this model to maximize the opportunity for success.

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ABSTRACT

In the late 1990's the California Department of Transportation (Caltrans) and the Federal Transit Administration (FTA) embarked on a research program entitled "Efficient Deployment of Advanced Public Transportation Systems" (EDAPTS) to help lower the cost of deploying advanced public transportation systems (APTS) at small transit agencies. The Stage 5 Test Deployment of Efficient Deployment of Advanced Public Transportation Systems demonstration at California State Polytechnic University, Pomona (Bronco Express EDAPTS Demonstration) is a continuation of this research seeking to determine if the EDAPTS concepts for procuring and deploying low cost Intelligent Transportation Systems (ITS) are optimized for small transit agencies and if they can be successfully transitioned to the commercial marketplace.

This final report documents the procurement, installation, verification, and validation processes associated with the Bronco Express EDAPTS Demonstration effort. It provides a summary of all previous reports and provides insights, recommendations and lessons learned stemming from the demonstration results.

The report first summarizes the procurement process and explains its use of a modified version of the Federal Highway Administration (FHWA) Systems Engineering "V-model". This modified V-model helped the research team and the stakeholders coalesce with a clear understanding of expectations of what the procured system needed to do. The EDAPTS procurement process used by Bronco Express demonstrated a practical procurement and bidding methodology useful to small and medium transit agencies when acquiring ITS solutions.

The report then summarizes procedures that are effective in installing and testing lower-cost ITS systems and provides a practical methodology for verifying and validating them. Additionally, it highlights the outcomes of using that methodology on the installed Bronco Express system and compares the results with the user needs and the performance specifications requested in the Bronco Express EDAPTS RFP.

Finally, it provides a detailed discussion on the effectiveness of using the EDAPTS approach for the procurement, installation, and operation of the Bronco Express EDAPTS system. This discussion concludes with a summary of lessons learned during the demonstration and recommendations for possible future enhancement of the EDAPTS approach to help assure the efficient procurement and deployment of APTS solutions in a small transit environment.

Keywords: EDAPTS, Procurement, Systems Engineering V-Model, System Verification, System Validation, Intelligent Transportation Systems, Advanced Public Transportation System

EXECUTIVE SUMMARY

The California Department of Transportation (Caltrans) and the Federal Transit Administration (FTA) embarked on a research program entitled "Efficient Deployment of Advanced Public Transportation Systems" (EDAPTS) in the late 1990's. The Bronco Express EDAPTS Stage 5 Test Deployment Efficient Deployment of Advanced Public Transportation Systems demonstration at California State Polytechnic University, Pomona (Cal Poly Pomona) seeks to determine if the EDAPTS concepts for procuring and deploying low cost Intelligent Transportation Systems (ITS) are optimized for small transit agencies and if they can be successfully transitioned to the commercial marketplace.

This final report documents the procurement, installation, verification and validation processes associated with the Bronco Express EDAPTS Demonstration. It provides a summary of all previous reports and provides insights, recommendations and documents the lessons learned during the demonstration.

The Bronco Express EDAPTS Demonstration project utilized a modified version of the Federal Highway Administration (FHWA) Systems Engineering "V-model" and deployed the Bronco Express EDAPTS system through simplified procurement, installation, verification, and validation processes.

The EDAPTS test deployment for the Bronco Express EDAPTS system resulted in an operational APTS. The deployed APTS solution helps Bronco Express better manage their bus service operations and provides improved service to riders by displaying expected bus arrival time at bus stop signs and on the internet. The APTS functions deployed at Bronco Express and the identified benefits to each stakeholder group are as follows:

1) Transit Management Functionality at Cal Poly Pomona

The Bronco Express system provides managers with a comprehensive set of fleet management tools. Using these tools, Bronco Express managers can now monitor the real-time location of all buses on a map-based AVL display at dispatch consoles. They can also generate customizable reports on vehicle schedule adherence and passenger loading. The transit service managers have characterized the installed Bronco Express system as the transportation system with "intelligent transit goodies."

2) Internet-based Traveler Information to Bronco Express Riders

The EDAPTS solution provides students, faculty, and staff with real-time traveler information to assist them in catching and riding Bronco Express shuttles. Through the Bronco Express web site, riders can access a real-time map that displays current Bronco Express bus locations on routes, as well as predicted bus arrival times at any designated stop in the system. Bronco Express riders can also access these same mobile maps using Internet-enabled cell phones and can request predicted bus arrival times through a text message service.

3) Commercially Deployed Solar Powered Roadside Information Displays

A significant result of the Bronco Express EDAPTS Demonstration is the installation and operation of its commercial solar-powered roadside information displays. These displays, which provide passengers waiting at stops with predicted bus arrival times, may be the first commercially available, solar-power only, dynamic messaging signs for use at transit bus stops having no access to utility AC power.

4) Serviced-Based EDAPTS Solution

The deployed EDAPTS solution at Bronco Express is different from many other typical transit APTS systems in that it is a service-based system. Under the contractual agreement, the system supplier is completely responsible for the installation of the system, as well as its ongoing maintenance, support, and operation similar to other APTS installations. However, this deployment differs from other installations in that it required only a small initial capital expenditure on the part of Bronco Express, with an on-going monthly operating cost payment for the vendor's services. The Bronco Express EDAPTS solution has truly been a turnkey system with all operational needs provided by the contractor. Existing Bronco Express personnel have therefore been able to focus on the overall operation of the transit service and are not required to hire or contract for highly specialized technical support for the system.

The careful observation of the Bronco Express EDAPTS deployment by the research team resulted in a set of technical reports that can be utilized by transit properties to simplify and potentially make their deployment process less difficult and more thorough. These technical reports are:

1) Cal Poly Pomona EDAPTS Test Deployment Operations Description Version 6.0

2) Cal Poly Pomona EDAPTS Test Deployment Procurement Documentation Package Version 7.0

3) Cal Poly Pomona EDAPTS Test Deployment Installation and Technical Review Report Version 5.0

1. INTRODUCTION

1.1 Background

In the late 1990's, the California Department of Transportation (Caltrans) and the Federal Transit Administration (FTA) embarked on a research effort "Efficient Deployment of Advanced Public Transportation Systems" (EDAPTS). The goal was to make lower cost, easily deployed Intelligent Transportation System (ITS) solutions more available to the small transit community. Its mission was to determine if EDAPTS concepts for procuring low cost ITS solutions could be optimized for small transit agencies and if they could be successfully transitioned to the commercial marketplace.

The EDAPTS research project initially focused on developing a low cost, easily configurable, and non-proprietary Advanced Public Transportation System (APTS) suitable for deployment by small, medium and rural transit properties. Researchers from California Polytechnic State University, San Luis Obispo (Cal Poly SLO), through research grants from Caltrans and FTA, designed and deployed the EDAPTS test system at San Luis Obispo (SLO) Transit.

The SLO Transit EDAPTS System was a unique prototype design that integrated commercially available components, parts and products to implement ITS technologies such as Automatic Vehicle Location (AVL), schedule adherence tracking, and real-time bus arrival notification. The system utilized wireless data communications links, open source designs, and solar powered dynamic messaging signs to improve transit services and safety for passengers and drivers. This system demonstrated that it is possible to construct and deploy a lost cost, non-proprietary APTS that can maximize user benefits while minimizing initial and recurring costs. Since that time, many private sector companies have developed and offer similar self-contained APTS systems for transit use, though almost all of those offerings retain proprietary designs and communications protocols.

Having completed the initial research tasks of this project (hereinafter referred to as Tasks I and II), EDAPTS was ready for proof testing to show it was ready for commercialization and deployment. In 2005, Caltrans and FTA initiated three additional research tasks that focus on how to efficiently deploy APTS systems. These three tasks were (1) the Benefit/Cost Evaluation of the EDAPTS system at San Luis Obispo Transit (Task III of the EDAPTS project), (2) the Development of Performance-Based Specifications for EDAPTS (Task IV of the EDAPTS project), and (3) the Bronco Express EDAPTS Demonstration for the university bus system at California State Polytechnic University, Pomona (Task V of the EDAPTS project). The collective goal of these projects was to solidify the business case for EDAPTS and demonstrate to the transit community that using the EDAPTS approach is just "smart business practice". Figure 1.1 shows the relationships of the EDAPTS research tasks within the overall project.

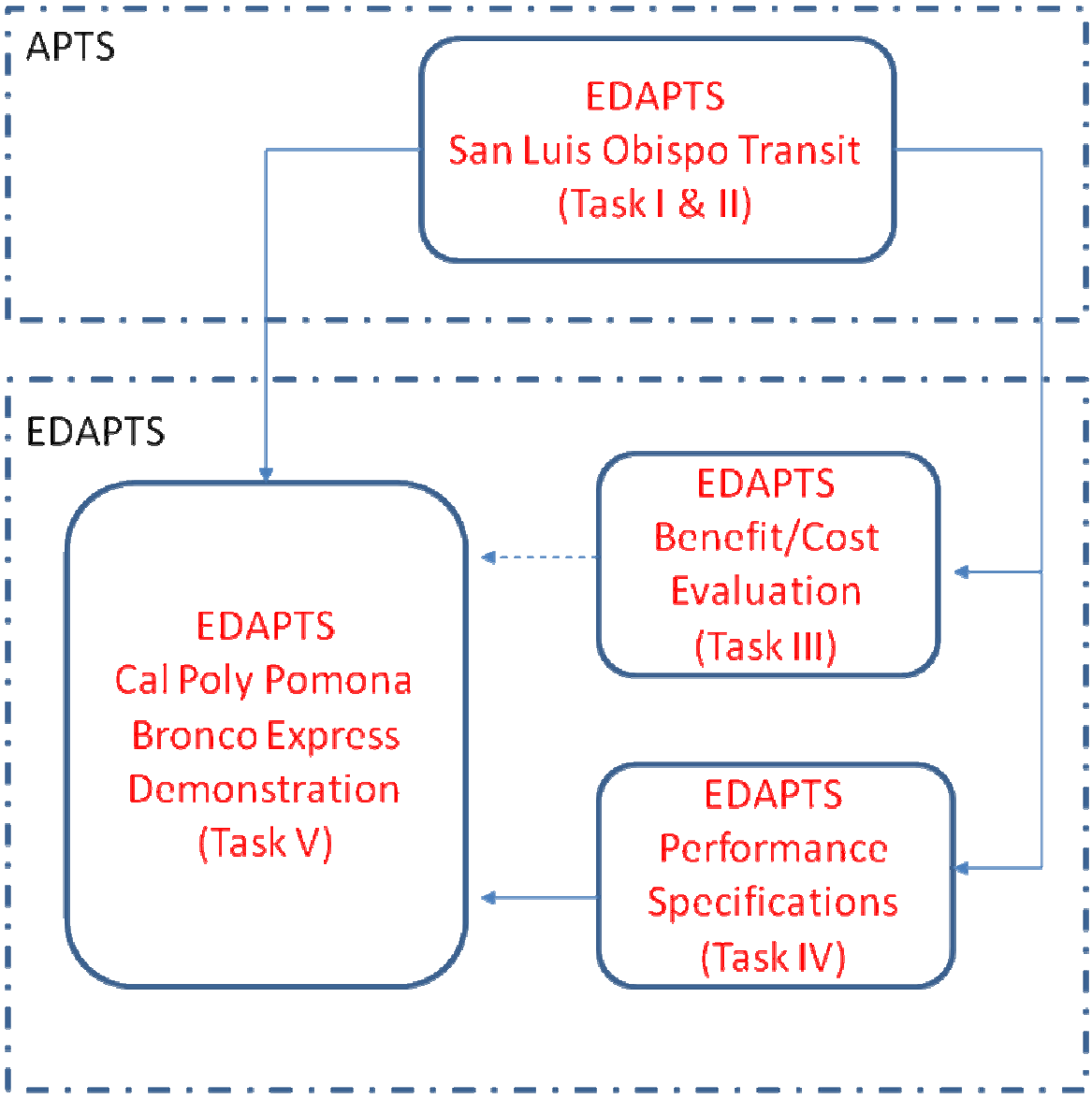

Figure 1.1 Relationships of completed EDAPTS Research Projects

1.1.1 EDAPTS Benefit/Cost Evaluation

The researchers on the EDAPTS Benefit/Cost Evaluation effort first conducted a literature review on benefit to cost studies done for Advanced Public Transportation Systems in general, then determined appropriate benefit and cost measures of performance (MOPs) for the EDAPTS ITS system. Using these MOPs as guidelines, the researchers developed an innovative evaluation method (based on stated preference analysis) to quantify the intangible benefits of the system.

This stated preference evaluation method uses the principle of *willingness-to-pay* to provide an aggregate measure of what surveyed passengers are willing to forego to obtain a given ITS service feature. This research could be the first application of quantifying benefits of ITS technologies using the stated preference evaluation method.

Using a passenger questionnaire, a boarding time survey, and interviews with SLO Transit drivers and administrators, the research team estimated the various benefits and costs of the SLO Transit EDAPTS system. On this basis, a benefit to cost (B/C) ratio analysis was performed. The team also performed a sensitivity analysis of B/C ratios considering different discount rates and assumed service lives of the EDAPTS system.

The study considered that there are two basic types of benefits generated by the SLO Transit EDAPTS system: conventional benefits and consumer surplus. Conventional benefits are the benefits directly measured using the "willingness to pay" principle for existing passengers, as well as for drivers and SLO Transit administrators. Consumer surplus is the difference between the price consumers (passengers) are willing to pay and the actual price charged by the SLO Transit.

The analysis used a 7% discount rate (as required by the US Office of Management and Budget (OMB) for public investment projects) for the B/C ratio analysis. The most conservative B/C ratio analysis excludes consumer surplus as benefits and shows B/C ratios of approximately 3.9 to 5.7. This indicates in general that every dollar invested in the SLO Transit EDAPTS system resulted in at least four dollars of benefits to the constituent groups. Considering consumer surplus as benefits makes the B/C ratios increase to between 4.8 and 7.0.

The B/C ratio sensitivity analyses indicated that the B/C ratios were not very sensitive to discount rates. The B/C ratios exceeded 1.0 in all cases and certainly provided economic justification for continuing efforts to commercialize EDAPTS ITS technologies (Jia et al, 2008). Detailed descriptions of the EDAPTS B/C ratios and their sensitivity analyses are provided in the final report of the EDAPTS Benefit/Cost Evaluation research task.

In summary, this research task conducted a comprehensive benefit to cost ratio evaluation for the SLO Transit EDAPTS system. The findings confirmed that using the EDAPTS ITS methodology provides low-cost, easily deployed, and economically sound ITS solutions for small and medium transit agencies.

1.1.2 EDAPTS Performance-Based Specifications Development

The EDAPTS Performance-Based Specification Development task, done concurrently with the EDAPTS Benefit/Cost Evaluation task, recognized that performance specifications for an EDAPTS compliant system are critical to a successful procurement by a small or medium sized transit property. The research objective was that these specifications, once developed, could be used to clarify the performance objectives a transit agency would like its APTS system to have. They also could provide system integrators with performance targets that they could use to procure, integrate, and install the hardware and data communications subsystems that make up their EDAPTS solution.

Researchers began this project by documenting current best practices for determining performance specifications. Researchers then documented all EDAPTS system elements, developed a list of performance metrics applicable to EDAPTS, provided measures for these metrics on a per-element basis, and then documented the data format of all EDAPTS messages.

A detailed set of tables containing metrics, measures of the metrics, and other aspects of the performance specifications were created. A database-driven software program (known as the EDAPTS Performance Specification Generator Tool and hereinafter called the EDAPTS Spec Generator) was then developed to retrieve and cross reference material from the tables based upon functionality selected by user input. The tool provides an easy to use user interface in generating a transit agency specific performance specification document. This software is similar to TCIP[1] Implementation Requirements and Capabilities Editor (TIRCE).

Preliminary EDAPTS Data-Formatting Standards were also created as a complement to the EDAPTS Performance Specifications. These standards specifically defined low-level communications details of EDAPTS systems and were aimed at facilitating future EDAPTS deployments. Using the standards, the research team hoped to allow EDAPTS components to be procured as commodities (i.e. components that may be obtained from any source and should drop directly into the system by having commonality at the communications interface level). In doing so, the team believed that EDAPTS cost effectiveness could be maximized if system components had uniform interfaces as prescribed by the EDAPTS Data Formatting Standards.

The EDAPTS performance specifications and the data-formatting standard were used as inputs into the EDAPTS Spec Generator to create a procurement ready document for the Bronco Express EDAPTS Demonstration effort. This document provided a list of specifications and data-formatting standards specific to the Bronco Express system. It was anticipated that these project-specific specifications and data-formatting standards could guide the Bronco Express team and the winning contractor during procurement and installation of the EDAPTS system. It was also anticipated that these specifications and data-formatting standards could be verified

[1] TCIP –Transit Communications Interface Profiles, ITS standards developed by American Public Transportation Association (APTA) for transit industry.

and validated in the Bronco Express EDAPTS system to demonstrate their usefulness to the small transit agency (Gerfen et al, 2008).

The detailed description of the EDAPTS Specifications and their Development procedures is provided in the Performance-Based EDAPTS Specifications Development research task.

1.1.3 Bronco Express EDAPTS Test Deployment

The Bronco Express EDAPTS Demonstration research provided a final opportunity to monitor and evaluate the EDAPTS concepts as applied to the procurement, installation, and operation of the Bronco Express EDAPTS system at California State Polytechnic University, Pomona. The experience and knowledge gained from this test deployment effort was essential if EDAPTS is to become the useful tool envisioned by the research team and truly help small transit properties in California and the U.S. adopt the low-cost principles and concepts for their ITS procurements and implementation.

This report is the last of three reports that document the procurement, installation, verification, and validation processes associated with the Bronco Express EDAPTS Demonstration. It focuses on collecting and summarizing all previous reports in this project, providing insights, recommendations and documenting the lessons learned during the demonstration.

The first report in this series, entitled "Cal Poly Pomona EDAPTS Test Deployment Procurement Documentation Package," outlines the procurement of the Bronco Express EDAPTS system (Jia et al, 2009). It documents the Bronco Express EDAPTS system procurement process and is intended to be a guideline to help small/medium transit agencies establish a practical procurement and bidding methodology for acquiring their own unique EDAPTS enabled solutions. It also provides useful information about selecting the best value vendor(s) for an EDAPTS system.

The second report in this series, entitled "EDAPTS Installation and Technical Review Report," identifies and summarizes procedures that are effective in installing and testing a lower-cost ITS system (Jia et al, 2009). It provides a practical methodology for verifying and validating small transit ITS systems. The report documents outcomes of the installed system in and compares the results with the user needs and the performance specifications as requested in the Bronco Express EDAPTS Request for Proposal (RFP).

1.2 What is EDAPTS?

The research team has asked the question "What is EDAPTS?" several times since the start of the EDAPTS project in 1997. The best definition of EDAPTS, as developed during the Bronco Express EDAPTS Demonstration, is:

> *EDAPTS is a cost effective method for deploying Advanced Public Transportation System (APTS) solutions to small and medium size transit properties. It is a framework for development and deployment that allows members of the transit community to leverage the efforts of each other to mutual advantage.*
>
> *EDAPTS involves technical and institutional aspects for efficiently deploying APTS. The technical aspect focuses on APTS solutions. It seeks low-cost, off-the-shelf, open source, and easy to be deployed APTS solutions through performance-based procurement and deployment approach. Such APTS solutions are consistent with the National ITS Architecture and conformant to TCIP and therefore are entitled as EDAPTS systems.*
>
> *The institutional aspect focuses on how to efficiently deploy EDAPTS systems. It seeks the deployment of an EDAPTS system through a modified Systems Engineering "V-model" of Federal Highway Administration (FHWA). This modified model continues to incorporate early stakeholder involvement, concepts of operations, procurement, system verification and validation.*

In determining the above definition the Bronco Express EDAPTS Demonstration research team set out to incorporate a procurement process that followed a modified System Engineering "V-model" approach adapted to the procurement of a commercial off-the-shelf (COTS) solution. The modified V-model used for this approach is discussed in greater detail in Section 2 below.

1.3 Bronco Express EDAPTS Demonstration Objectives

The Bronco Express EDAPTS Demonstration is an important element of the overall EDAPTS project since it paves the way for full deployment of EDAPTS concepts to the general transit community. The Bronco Express EDAPTS Demonstration effort had a number of objectives. The most important objective was to test and validate the stated definition of EDAPTS above. This was done using the EDAPTS concepts of procuring small transit ITS solutions and by successfully completing a small transit ITS solution for Cal Poly Pomona's Bronco Express using the modified Systems Engineering "V-model". In order to accomplish this, the research team needed to evaluate how well an EDAPTS solution could be put out to bid, procured, integrated, and installed in the commercial environment. Furthermore, the team had the responsibility of analyzing and documenting the effectiveness of the deployment process and assessing the functional operation and capabilities of the installed the Bronco Express EDAPTS system.

The general functional objectives of the Bronco Express EDAPTS Demonstration were to improve the operation and increase the service level of the Cal Poly Pomona's Bronco Express shuttle service through the EDAPTS ITS methodology. It was envisioned that Cal Poly Pomona students, staff, and faculty would have an easier time catching a Bronco Express bus due to up-to-the minute estimated arrival time information available at stops. It was also envisioned that dispatchers and coordinators of Bronco Express shuttle buses would be provided with live information regarding the status, location, and passenger load status of all vehicles, thus helping them to more effectively dispatch replacement buses and emergency assistance vehicles during breakdowns and emergency situations. The University Parking and Transportation Services (PTS) anticipated they would have better, more complete knowledge of actual Bronco Express operations and resource utilization, allowing them to make informed operational decisions and helping them provide the best possible service for the least possible cost.

2. BRONCO EXPRESS EDAPTS DEPLOYMENT

Cal Poly Pomona and Cal Poly San Luis Obispo researchers utilized the modified Systems Engineering "V-model" and an inclusive set of actions and milestones for this demonstration. These included (1) early involvement of system stakeholders, (2) a full understanding of the needs, the problems, and envisioned ITS solutions for the Bronco Express shuttle bus services, (3) development and documentation of the Bronco Express EDAPTS Operations Guidelines, (4) procurement of the Bronco Express EDAPTS system using a Request for Proposal (RFP) process, (5) installation and operational testing of the Bronco Express EDAPTS system, and (6) verification and validation of the installed EDAPTS system.

2.1 Steps to Bronco Express EDAPTS Deployment

The Bronco Express EDAPTS Demonstration was carried out using the key steps shown in Figure 2.1.

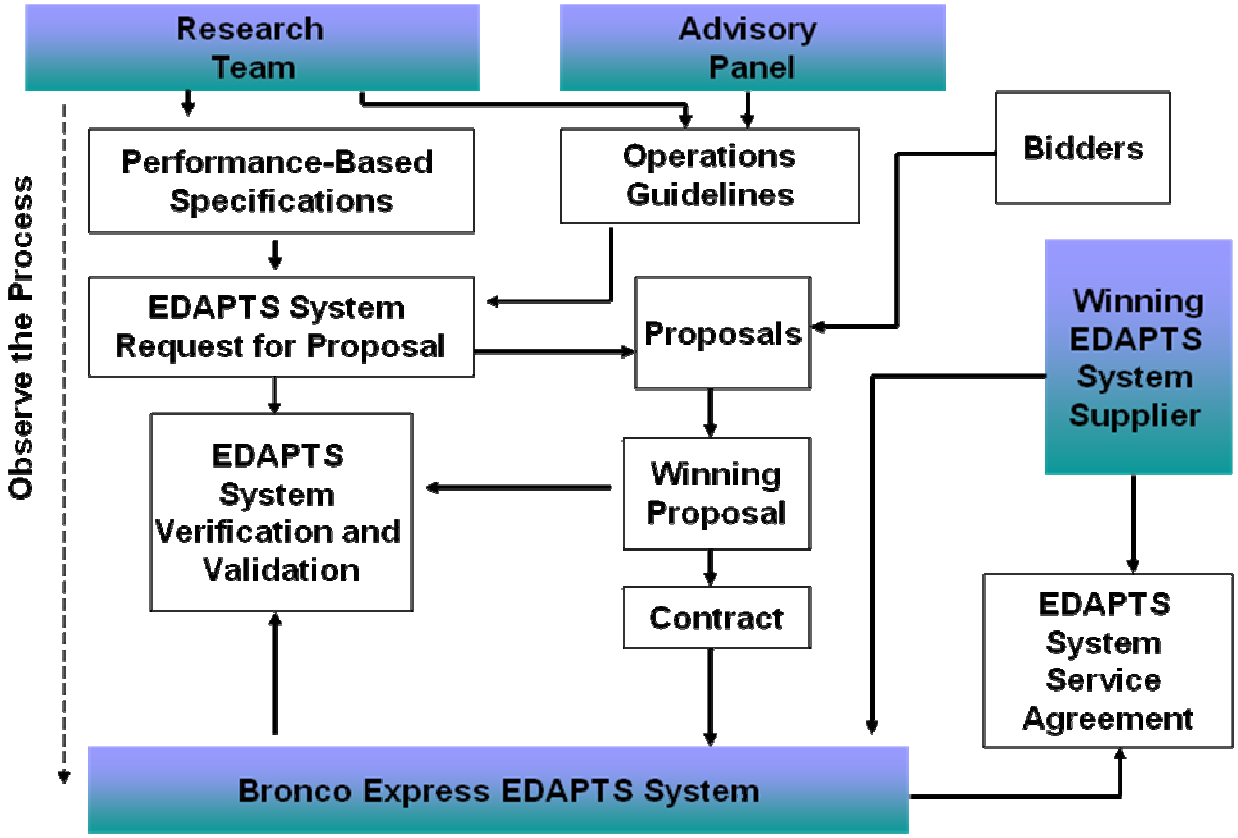

Figure 2.1. Cal Poly Pomona Bronco Express EDAPTS Deployment Steps

2.1.1 System Engineering Approach – A Modified V-Model

This task utilized a modified version of the Federal Highway Administration (FHWA) Systems Engineering "V-model" (see Figure 2.2 below) to aid procurement of the Bronco Express EDAPTS system. In this model, the Detailed Design, Software and Hardware Development, and Unit Device Testing steps of the FHWA V-model are left to the system supplier and are outside the purview of the procuring agency (Cal Poly Pomona and the research team in this procurement). This is referred to as the "modified V-model" from this point forward. It is not necessary for these steps to be seen by the procuring agency since the systems supplier is installing Commercial Off-the-Shelf (COTS) system elements. The interested reader may wish to refer to California PATH report, System Installation and Technical Review Report for additional information regarding the modified V-model (Jia et al, 2009). The key steps in the Bronco Express EDAPTS Demonstration are mapped to the modified V-model (see Figure 2.2).

2.1.2 Operations Guidelines, Performance Specification, and Procurement

Early in the demonstration, the research team formed an EDAPTS Advisory Panel to sit down with key stakeholders from Cal Poly Pomona and understand the needs and wants of the future APTS system for Bronco Express services. This process was accomplished through a series of meetings in which the researchers introduced stakeholders to APTS technologies and concepts, and then helped them assess the importance of various features, e.g. map-based dispatch displays, roadside information displays, etc., to accomplishing their objectives. A final list of desired functionalities for the Bronco Express EDAPTS system was then developed using a prioritization and down selection process.

Upon stakeholder articulation of desired functionalities the project researchers used the EDAPTS Spec Generator to create a performance specification which could be incorporated in the RFP for the Bronco Express EDAPTS Demonstration (Gerfen et al, 2008). Interested readers may refer to the California PATH report entitled "Development of Performance-Based Specifications for Efficient Deployment of Advanced Public Transportation Systems (EDAPTS)" for more information.

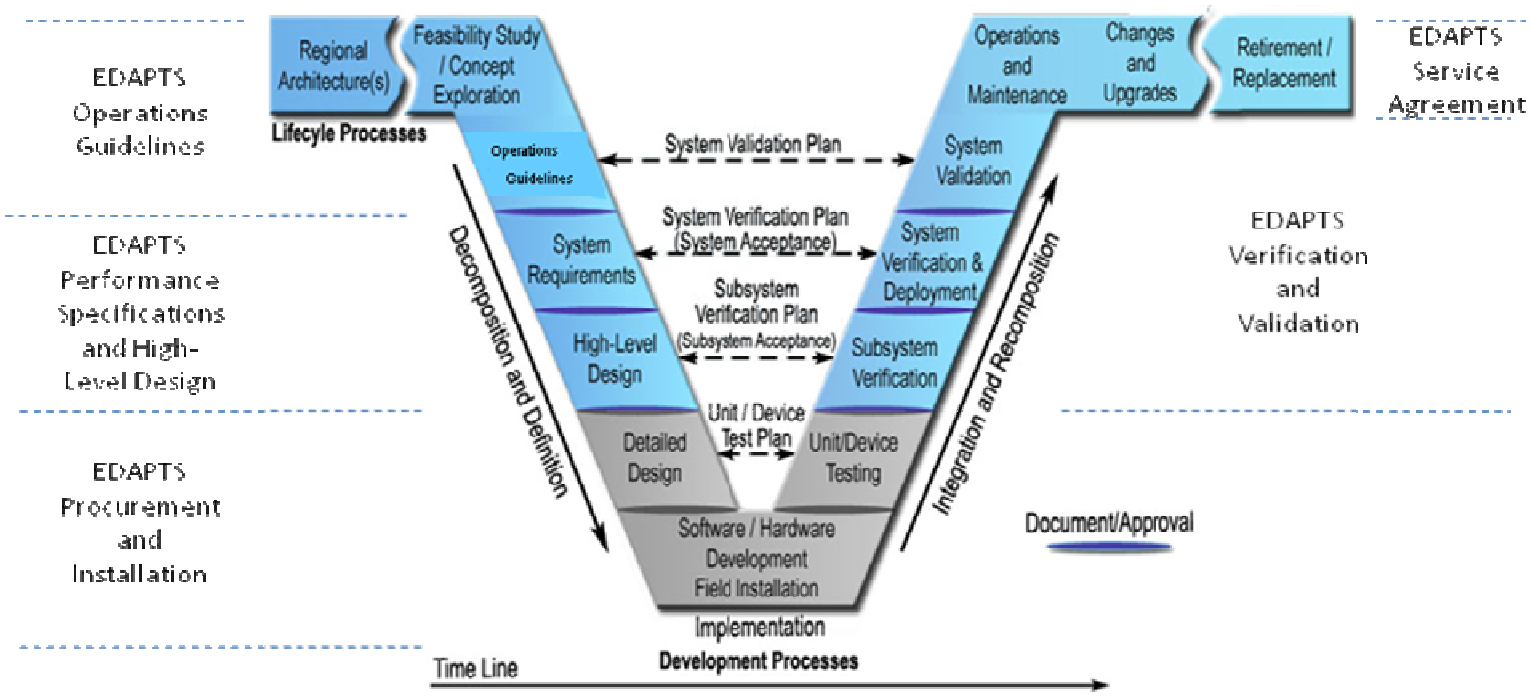

Figure 2.2 Relation of Bronco Express EDAPTS Demonstration to Modified FHWA Systems Engineering V Model
(Source: Systems Engineering for Intelligent Transportation Systems, US DOT, 2007)

Please note that items in blue were completed as part of the procurement process while the items in gray were not.

The Advisory Panel then coordinated with Cal Poly Pomona's Procurement Office to develop a formal RFP describing the APTS solution desired. The RFP was advertised and sent to more than 40 potential APTS system integrators and suppliers. Four proposals from interested vendors were received, all of which were limited in their response to one or more specific areas of the RFP and in all cases the interested system suppliers were proposing a unique COTS system solution. These four proposals were evaluated based on several pre-established measures and the final system supplier was then selected. The California PATH report entitled "Cal Poly Pomona EDAPTS Test Deployment Procurement Documentation Package" documents the RFP and procurement process.

2.1.3 System Installation, Verification, and Validation

System installation was carried out jointly by the system supplier, Bronco Express, and other Cal Poly Pomona facilities personnel. The system supplier made the necessary and appropriate accommodations to ensure minimal disruption to on-going Bronco Express operations. A full description of this effort can be found in the California PATH report entitled "Bronco Express EDAPTS System Installation and Technical Review report.

The system installation involved four phases: (1) Web Service Establishment, (2) Vehicle On-Board Subsystem Installation and Integration, (3) Solar-Powered Roadside Information Display Installation and Integration, and (4) System Acceptance Testing. The system supplier identified, acquired, and tested the required COTS hardware and software components before the components were integrated into the Bronco Express EDAPTS system.

Since solar-powered roadside information display signs meeting the Bronco Express EDAPTS system requirements and specifications were not commercially available at the time of contract award, the system supplier could not install the signs at the same time as the Automatic Vehicle Location (AVL), Automatic Passenger Counter (APC), and Mobile Data Terminal (MDT) subsystems were installed. The supplier had to design, build, test, and deliver its own solar-powered sign product to Bronco Express separately from the rest of the installation and integration process. Upon delivery of this newly designed sign, Cal Poly Pomona facilities personnel then installed the signs at the designated sites around campus.

The research team tackled the verification and validation of the system after system installation and acceptance testing by the vendor was complete. System verification was based on the EDAPTS performance specification included in the RFP, since this was the original basis for the Bronco Express solution. Each performance metric in this specification became the basis for an item to be verified. Each performance metric was verified, either through manual inspection, system testing, or certification by the system supplier.

System validation was carried out by the research team to compare the installed Bronco Express EDAPTS system against the features described in the Bronco Express Operations Guidelines. A validation test plan was developed and validation tests were completed to determine if each operational scenario could be successfully demonstrated using the installed EDAPTS system. The complete results from the verification and validation efforts are incorporated in the previously mentioned System Installation and Technical Review report. A final comparison to the RFP was done to determine the extent of overlap with the initial goals.

2.1.4 ITS Business Model and Services Agreement

An "ITS service model" was used by the supplier in this research project. This meant that Bronco Express did not physically acquire, own, and operate all of the elements of the Bronco Express EDAPTS system solution. Instead, it acquired only selected hardware components for the system and the supplier provided all other operations and maintenance for a monthly service cost. The hardware elements directly paid for by Bronco Express included vehicle mounted MDTs, APCs, GPS-based AVL subsystems, and the campus deployed Roadside Information Display (RID) signs. The system supplier provided the other components of the core APTS services through the service agreement. These services allowed Cal Poly Pomona to receive information, such as vehicle location tracking, schedule adherence, expected bus arrival time, and real-time status reporting, but did not need to actually operate or maintain the communications links, servers, or performance databases used in the system.

The service model leveraged the centralized technical resources of the system supplier and eased the burdens upon Bronco Express. Bronco Express management did not need to worry about tasks such as maintaining schedule adherence databases or hiring knowledgeable personnel for system troubleshooting and system upgrades. The system supplier handled these tasks and allowed Bronco Express and Cal Poly Pomona personnel to focus on just using the installed EDAPTS solution.

2.2 Cal Poly Pomona Bronco Express EDAPTS System– A Carefully Observed Deployment

The Bronco Express EDAPTS Demonstration was unique from other ITS deployments in the following areas:

1) The team had dual roles during this EDAPTS system procurement and deployment: (a) to perform the role of an ITS consultant to guide the Cal Poly Pomona staff through this process, (b) to carefully monitor the process to determine if an EDAPTS small-transit solution could be successfully obtained at a cost effective price.

The consultant role of the research team during this deployment resulted in some useful procurement tools and system verification and validation procedures that may be of help to other entities deploying EDAPTS solutions. In addition, through the careful monitoring and documentation of the deployment process, the project researchers endeavored to make the procurement, system verification, and validation process transparent to potential system suppliers bidding on the job and, most importantly, to the system supplier selected by the Advisory Panel.

2) The research team set out to purchase a commercial solution for the Bronco Express EDAPTS system and in order to ensure proper functionality of EDAPTS subsystems the research team developed a unique set of Bronco Express EDAPTS performance specifications. These performance specifications were critical to the procurement process and were useful for developing system verification plan for this deployment.

3) The research team did not find a lot of examples of ITS procurements that could be used as a framework for the comprehensive system specification, procurement, installation, verification, and validation envisioned for the EDAPTS methodology. The team found that the modified V-model could be the framework for efficient deployment of advanced public transportation systems. The use of the modified V-model in this project resulted in a commonly shared vision among stakeholders, a COTS based procurement package, and a verifiable and validated APTS.

Bronco Express, as would any transit property wishing to deploy an APTS solution, found the deployment needed to be started from scratch. This was a fairly daunting task for them and the research team. Obviously, if this task is difficult for a team of researchers with a solid background in ITS and APTS, it might be an insurmountable and prohibitively expensive climb for a small transit agency on its own. The research team realized that the use of the modified V-model could facilitate this process, helping small transit agencies quickly and accurately zero-in on ITS solutions that resolve their unmet needs and problems.

3. RESULTS

The EDAPTS test deployment for the Cal Poly Pomona Bronco Express system resulted in an operational APTS solution and a set of technical reports that document the deployment process undertaken in this research. The deployed EDAPTS solution now helps Bronco Express better manage their bus service operations and provide improved service to riders by displaying expected next bus arrival time at bus stop signs and on the internet. The EDAPTS deployment reports can be used as reference documents to aid future procurers of small transit management systems in California and the United States.

3.1 Deployed EDAPTS Solution at Cal Poly Pomona

The Bronco Express EDAPTS solution has been installed and is operational at Cal Poly Pomona, giving system stakeholders options not previously available. Despite some failures in meeting some expectations set forth in the Operational Guidelines, users on both the management and ridership sides of the system are now getting benefits which meet or surpass many of their initial expectations.

Before the EDAPTS solution was installed, the Bronco Express services were characterized by users as having uncoordinated and somewhat random pick-ups at stops, with a noticeable lack of available information on bus arrival times. It also required a labor intensive, manual reporting process to collect and analyze information on operational parameters. The bottom line was that Cal Poly Pomona had a strong need to employ APTS technologies to improve Bronco Express services. The deployed EDAPTS solution uses ITS to help resolve many of these problems and fill unmet needs.

The following paragraphs summarize the EDAPTS functions deployed at Bronco Express and the benefits to each stakeholder group.

3.1.1 Transit Management Functionality at Cal Poly Pomona

The Bronco Express system provides managers with a comprehensive set of fleet management tools. Using these tools, Bronco Express managers can now monitor the real-time location of all buses on a map-based AVL display at dispatch consoles. They can play-back a vehicle's travel history for a specified time period and day if they need to evaluate the operational performance of a specific Bronco Express route or vehicle. They can also view predicted and actual arrival times of all transit vehicles at stops, passenger loading of each bus, and the mechanical status of each bus. The transit service managers now characterize the EDAPTS-powered Bronco Express as the transportation system with "intelligent transit goodies."

While this solution does not have the full complement of schedule management or

schedule adherence reporting originally envisioned, it does provide detailed customizable reports on vehicle stop departure times and passenger loading. This EDAPTS deployment brought Bronco Express transportation management into the 21st century by removing most of the manual data collection and analysis necessary to get detailed performance reports on system operation. Additionally, the system allows drivers to report on-board emergencies to dispatch, and enables Cal Poly Pomona or local law enforcement to locate and intercept a bus in real-time if necessary. This is a major safety improvement and protects both riders and drivers in event of a major emergency.

3.1.2 Internet-based Traveler Information to Bronco Express Riders

The EDAPTS solution provides students, faculty, and staff with real-time traveler information to assist them in catching and riding Bronco Express shuttles. Through the Bronco Express web site, riders can access a real-time map that displays current Bronco Express bus locations on routes, as well as predicted bus arrival times at any designated stop in the system. Bronco Express riders can also access these same mobile maps using Internet-enabled cell phones and can request predicted bus arrival times through a text message service.

3.1.3 Commercially Deployed Solar Powered Roadside Information Displays

A significant result of the Bronco Express EDAPTS Demonstration is the installation and operation of its commercial, solar-powered roadside information displays. These displays, which provide passengers waiting at stops with predicted bus arrival times, may be the first commercial, solar-power only, dynamic messaging signs for transit use at remote bus stops. They are certainly the first to be based on an EDAPTS procurement process. The original EDAPTS research concept solar-powered signs were deployed in San Luis Obispo in 2002 and formed the historical foundation for this element.

The solar-powered signs are ADA compliant, receive information from the deployed EDAPTS system over a cellular link and accommodate both sight-challenged and hearing challenged passengers. They utilize a text-to-speech engine and a user enabled push button to allow waiting passengers to hear an on-demand audible announcement of estimated bus arrival times. This is in addition to the normal visual display of bus arrival information using ADA compliant Light Emitting Diodes (LEDs).

3.1.4 Low Cost Serviced-Based Deployment

As discussed previously in section 2.1.4 above, under the contractual agreement, the system supplier is completely responsible for equipment procurement, system installation, maintenance and operation of the system. This permits existing Bronco Express personnel to focus on the overall operation of the transit service. They are

relieved of the responsibility of hiring or contracting for highly specialized technical support for the system. This service-based deployment model has resulted in both lower initial capital costs and reduced estimated cost of ownership over the expected operational lifetime of the system. The Bronco Express EDAPTS solution has truly been a turnkey system, with most day-to-day operational needs provided by the contractor.

3.2 Technical Reports for EDAPTS Deployment

The careful observation of the Bronco Express EDAPTS deployment by the research team provided them with an opportunity to create a set of technical reports that may be utilized by transit properties to simplify and potentially make their deployment process less difficult and more thorough. The summaries of these reports are as follows:

3.2.1 Cal Poly Pomona EDAPTS Test Deployment Operations Description

This document identifies important stakeholder needs and desired system characteristics of the final Bronco Express EDAPTS solution through the use of operational scenarios. The operational scenarios, initially developed through workshops with stakeholders, are down selected based on their priority or score. Scenarios with medium or high priority were considered worthy of deployable elements. The scenarios that were most critical to Bronco Express were included in the published RFP for the system.

The report provides small transit agencies with examples that help stakeholders prioritize their most important needs and wants for an advanced public transportation system solution. Following the procedures and methods documented in this report, a small agency will be able to functionally and operationally describe desired performance characteristics. It allows stakeholders and vendors to clearly understand how the APTS functions will be used in daily activities. Also, transit agencies can characterize the benefits to be realized by the APTS solution and can clearly define any limitations that may need to be accommodated when the system is actually implemented.

3.2.2 Cal Poly Pomona EDAPTS Test Deployment Procurement Documentation Package v7.0

This report documents the entire Bronco Express EDAPTS system procurement process using the modified V-Model and the EDAPTS procurement approach. The EDAPTS procurement approach gave the research team a clear understanding of expectations of what the procured system needed to do. It demonstrated a practical procurement and bidding methodology for small and medium transit agencies to acquire their own unique EDAPTS solutions.

The procurement is documented in this report with two phases: (1) the pre-procurement evaluation and definition processes and (2) the Request for Proposal (RFP) process. In the pre-procurement processes, the Bronco Express EDAPTS Operations Guidelines were used to help the research team identify the high-priority operational needs and wants that were eventually incorporated in the RFP document. The RFP process involved the RFP document development and the selection of a winning contractor.

This documentation package also includes several other reports, as detailing sections 3.2.3 and 3.2.4 below.

3.2.3 Cal Poly Pomona EDAPTS Test Deployment User Features, Operational Needs and Performance Parameters

This report describes the user features, operational needs and performance parameters that had to be considered during the procurement and deployment of the Bronco Express EDAPTS system. It summarizes the results of the stakeholder workshops and assessment of operational scenarios included in the Cal Poly Pomona EDAPTS Test Deployment Operations Description report.

The research team used the identified features, operational needs and performance parameters to develop a high-level design or system architecture for the Bronco Express EDAPTS system (see Figure 3.1). The high-level design describes subsystems (such as vehicle on-board systems, vehicle wireless data communications systems, central site software, advanced transit management system, dynamic roadside displays, roadside communications, and system input data) and their functional relationships.

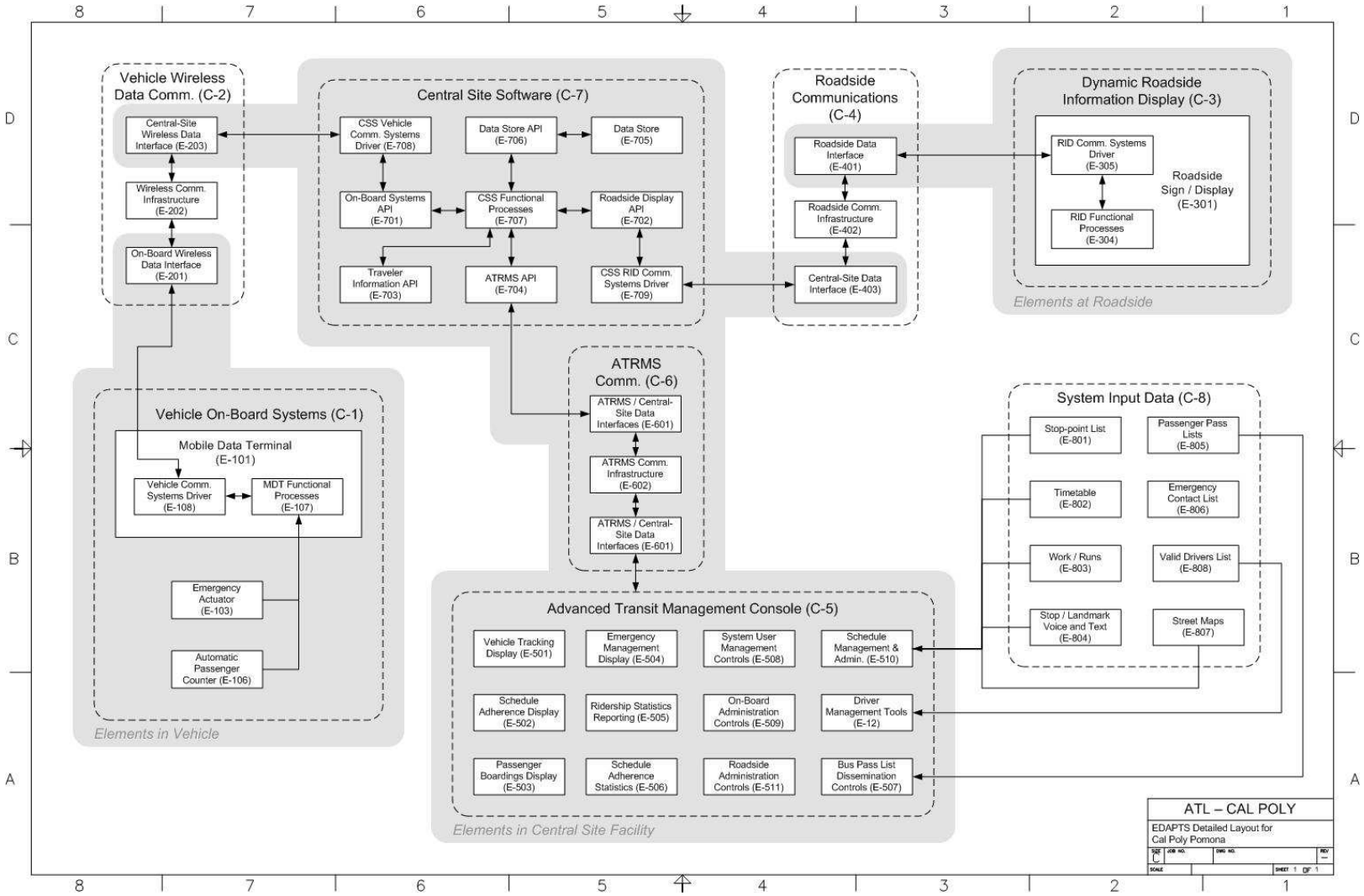

Figure 3.1 High-Level Design of the Bronco Express EDAPTS System specified by stakeholders

3.2.4 Cal Poly Pomona EDAPTS Test Deployment EDAPTS System Requirements and Performance Specification

The research team then used the high-level design for the Bronco Express EDAPTS system as inputs to the EDAPTS Spec Generator software and generated system requirements and performance specifications for the Bronco Express EDAPTS RFP. This report documents the results of this first application of the tool to an actual APTS deployment.

The system and performance requirements generated by the EDAPTS Spec Generator software consist of system-wide requirements and requirements specific to components and elements within each subsystem of the Bronco Express EDAPTS system. Interested readers may refer to this report for specification details that are related to vehicle on-board systems, vehicle wireless data communications systems, central site software, advanced transit management system, dynamic roadside displays, and roadside communications.

The research team found the EDAPTS Spec Generator software easy to use and the results that came out of the software were directly applicable to the specific APTS solution for the Bronco Express EDAPTS system. The research team also found that the system and performance requirements generated for this demonstration were useful in guiding the Bronco Express team and the winning contractor during procurement and installation of the EDAPTS system. The system and performance requirements were utilized for verification of the Bronco Express EDAPTS system.

3.2.5 EDAPTS Request for Proposal No. 07-014, Cal Poly Pomona, 2007

The research team, working with the University's Parking and Transportation Services (PTS) and the Procurement & Support Services (PSS), prepared and wrote the EDAPTS Request for Proposal (RFP) document. The collaborative development effort ensured that the document not only reflected the most desirable user features, operational requirements and performance specifications for the Bronco Express EDAPTS system, but it also complied with the University's policies and procedures.

The RFP document reflected the benefits of the active involvement of PTS and PSS staff in the stakeholder workshops. With a good understanding of the system and performance requirements specific to the Bronco Express EDAPTS system, staff played the major role in deciding which subsystems would be purchased and how the system would be operated and managed. The RFP document incorporated these procurement decisions into its scope of work.

The RFP document provided detailed insight into the intended usage of the system, allowing potential contractors to better focus their responses. The creativity and innovation that individual contractors chose to build into their proposals were used in judging the proposals.

The RFP document specified the work schedule, milestones, deliverables, and due dates for the basic system. It also required the contractors to provide an optional maintenance service agreement. The purpose of the optional maintenance service agreements was to ensure long-term operation of the system after it is delivered to the University and clear visibility into the longer term cost of keeping the system available.

The research team used the University's standard review and comment process in developing the RFP document. After the preliminary document was framed, it was reviewed and commented on by the EDAPTS Advisory Panel. The research team then modified and revised the document based on the comments and recommendations received from the reviewers.

The RFP document also included a set of criteria for proposal evaluation. This allowed vendors advance knowledge of the scoring process and helped ensure a fair and equitable decision was made during the vendor selection process.

The RFP document was viewed by some proposers of this project as the most comprehensive RFP document they had received for deploying an APTS solution at a transit agency. The research team recommends that the RFP document be used as a template for deployment of APTS solutions at transit properties.

3.2.6 Cal Poly Pomona EDAPTS Test Deployment Installation and Technical Review Report v5.0

This report documents the installation, system verification and validation processes for the Bronco Express EDAPTS system. It describes a number of critical system deployment activities after the RFP system supplier selection phase was completed. These critical activities include (1) establishment of new web services, (2) installation and integration of vehicle on-board COTS subsystems, (3) design, delivery, installation and integration of the new solar-powered roadside information display signs, (4) system testing, and (5) system verification and validation.

3.2.6.1 Installation

This report provides small transit properties who are considering an APTS deployment with a detailed look at the installation, test, and operation of the installed Bronco Express EDAPTS system. It presents a set of insightful information on how an APTS solution is installed and tested, as well as how the system functions in real life. This can be of help to them as they try to grasp the complexity of an APTS solution and identify the necessary steps associated with their installation and test.

The research team closely observed the Bronco Express EDAPTS system installation process and compared the functional blocks (hardware and software components) of the installed system against those required in the Bronco Express RFP and the supplier's proposal. This report

documents the comparisons and Table 3-1 shows the results of those comparisons.

Table 3-1 System Components in the EDAPTS RFP, System Supplier's Proposal, and Installed System

EDAPTS Components		Requested in RFP	Pledged in System supplier's Proposal	Implemented
1	8 sets on onboard equipment, including AVL, MDT, emergency button, automatic passenger counter, wireless communications	Yes	**Yes**	**Yes**[2]
2	Vehicle-to-central site wireless communications system	Yes	**Yes**	**Yes**
3	Central Site Server Software	Yes	**Yes**	**Yes**
4	Transit Management Dispatch Client Software	Yes	**Yes**	**Yes**
5	Provide 4 dynamic messaging signs with wireless communications at bus stops	Yes	**Yes**	**Yes**
6	Dynamic messaging sign wireless communications system	Yes	**Yes**	**Yes**

3.2.6.2 System Verification

The report also provides the system verification plan and its associated test procedures for the installed EDAPTS system. It walks the reader through the process of creating good verification tests from the system performance requirements and providing a methodology that can be replicated by a transit property or consultant.

The research team, in working with the system supplier and Bronco Express, developed the system verification plan and its associated test procedures. Using the test plan and procedures, the research team then verified the installed subsystems and functionality against (1) those required in the RFP, (2) those provided in the system supplier's proposal, and (3) those

[2] Yes refers to the fact that the subject EDAPTS component exists in the installed EDAPTS system. It does not imply that all the elements within the components meet the system and performance requirements set forth for the Bronco Express EDAPTS system.

described in the Bronco Express EDAPTS Operations Guidelines. The system verification resulted in the following primary findings:

1) The data recorded on the system verification worksheets were analyzed, detailing where project needs were met and where deficiencies occurred. Overall, many of the requirements laid out in the EDAPTS Performance Specification were met by the system supplier.

2) Documentation standards such as readability, style, and formatting were well met. User manuals were supplied by the system supplier; however, a higher-level system manual including theory of operation and maintenance instructions was not provided. The research team found that, while the troubleshooting sections included in some of the user manuals were thorough and complete, not all manuals included a troubleshooting section. This indicates that additional attention needs to be given that area if an agency intends to do maintenance of this type of system on its own.

3) Parts manufactured for both the roadside and vehicle onboard systems largely met all requirements, including part edge trueness, corrosion resistance, mounting-hole tolerance, and part commonality. No significant deviations were noted by the research team.

4) Vehicle onboard components functioned reliably, providing consistent and accurate location updates to the system and users. However, very few parts bore a manufacturer's nameplate and some installed cables lacked the necessary label markers. The locations of installed components were well laid out and did not impede driver view of the road or regular operations.

5) The MDT offered only minimal functionality, providing only driver emergency button and text messaging capabilities. Most of the RFP required driver feedback functionality was not implemented and while the lack of MDT functionality was described in the supplier's proposal, it did represent a significant trade-off of performance for cost by Bronco Express during the evaluation process. The hope is that Bronco Express can afford to enhance performance of the MDT features sometime in the near future and provide additional funding in a subsequent upgrade contract.

6) Roadside components also functioned reliably, providing minutes-until-arrival information to riders utilizing both visual and audible methods. The displays and their posts and foundations were solidly constructed, and met the requirements for weather and vandal resistance. ADA requirements for message display and clarity were also met. While the signs function admirably, they do not meet the required level of fourteen days of solar autonomy[3], nor do they recharge from a fifty percent battery capacity level within the specified time of five days. The installed signs are only capable of

[3] Solar Autonomy is a measurement that indicates how long the solar powered battery can sustain to its fifty percent capacity.

approximately six days of autonomy, and take about eight days to fully recover from a fifty percent battery discharge level. Notwithstanding these discrepancies, the sign represents a significant accomplishment for the project as a whole and is the commercialization of a major component coming out of the EDAPTS research effort that originally started with the prototype design at SLO Transit.

7) The predicted arrival information was found largely accurate, though questionable at times. Extensive testing and documentation of this core function was done during both the verification and validation phases of the evaluation to better understand the reasons for this inaccuracy and to assist the system supplier in resolving the issue. The inaccuracy was shown to be related to the supplier's algorithm used for predicting bus arrival time and the lack of traffic information on the bus routes. The supplier has indicated that they are working on the algorithm to resolve the issue.

8) The Bronco Express EDAPTS solution provided most of the features necessary to manage the fleet, including both map-based and tabular vehicle tracking displays. It also provided useful reports to the user, detailing both stop arrival times and passenger loading information. It provided the desired schedule adherence functions, a key RFP function required for operations. However the functions were not implemented to help the Bronco Express operate on fixed schedules. The installed system also did not provide management or diagnostic functionality for either the onboard or roadside hardware; and while this functionality is less critical in a service-based system, it was still required as part of the original specification. The ability to broadcast public-service or banner-type messages on the roadside display signs was missing from the client.

9) The central software and associated data store also provided most of the required functionality and supports most of the specified features. This includes: (a) data store management and backup, (b) requirements related to capacity, security, and uptime, and (c) response times for both data traversal through the software and to user queries. The vendor did not provide open access to the data store nor the necessary documentation necessary for doing so. Instead it provided XML feeds to disseminate operational data (such as bus location, speed, engine status, etc) to a Web link.

10) The system met all applicable state and Federal standards, including Department of Transportation (DOT) requirements for vehicle onboard components and Federal Communications Commission (FCC) licensing requirements for wireless data communications devices.

The system verification process demonstrated that the Bronco Express EDAPTS system met the capacity and support requirements set out in the Bronco Express RFP, supporting far larger quantities of vehicles, drivers, stops, and routes than those set forth in the RFP. However, the installed system failed to comply with some performance requirements originally specified in the RFP. It is noted here that these areas of non-performance were clearly noted as exceptions

by the selected system supplier within their proposal and accepted by the reviewing committee prior to entering into the contract arrangement for Bronco Express.

One of the important findings of this research is that all responding vendors took exception to the Bronco Express RFP. In large part, the general areas where those exceptions occurred were similar in nature, though typically different in specific details. Because of this, one of the resulting recommendations of the research team was that they revisit the performance specification area and look at simplifying the performance specification generator approach. This recommendation was addressed in other research efforts outside of this demonstration contract.

3.2.6.3 System Validation

Finally, the report documents the system validation plan, validation test procedures and test results on the installed Bronco Express EDAPTS system.

The Bronco Express system validation was a process of testing and scoring the compliance of the installed system to the features described in each operational scenario listed in the Cal Poly Pomona Test Deployment EDAPTS Operations Description report. There are three possible outcomes for validation results: (1) Pass, (2) Fail, or (3) Not Validated. Pass for a scenario indicates that the installed met all of the objectives in the specific scenario. Fail indicates that the installed system did not meet the objectives in the specific scenario. This includes the situation where some of the requirements were met, just not all of them. Not Validated indicates that the objectives described in the scenario did not apply to the installed system and were therefore not validated at all.

The results of this effort provided the EDAPTS project with a set of validation findings that were beneficial to Bronco Express and potentially to other small transit agencies desiring to deploy their own EDAPTS solution.

Table 3-2 shows the validation results.

1) The installed system met the user needs and operational requirements described in sixteen of twenty-seven operational scenarios.

2) The installed system failed ten operational scenarios. The majority of the failures were in scenarios related to the functionality of the MDT devices.

3) One of the twenty-seven scenarios was not tested due to the fact that the Bronco Express EDAPTS system provided a service that substituted the service described in the testing scenario.

In summary, this report covers the process of system validation, demonstrating in practical

detail how to convert operational scenarios into validation tests for the Bronco Express EDAPTS solution. It walks the reader through the process of creating good validation tests by indentifying crucial features in operational scenarios and providing a validation methodology that can be replicated by a transit property or consultant. A detailed summary of all completed validation test procedures and test results is included in the report.

Table 3-2 Validation Results

Operational Scenario	Validation Result
3.1.1[4] CPP professor walks up to a bus stop to catch a bus	Pass / Fail / Not Validated
3.1.2 CPP Student in the library needing to catch a bus	Pass / Fail / Not Validated
3.1.3 CPP Student with a cell phone needing to catch a bus (Possible future feature)	Pass / Fail / Not Validated
3.1.3A CPP Student with a cell phone needing to catch a bus	Pass / Fail / Not Validated
3.1.4 CPP Student with a web-enabled cell phone needing to catch a bus[5] (Possible future feature)	Pass / Fail / Not Validated
3.2.1 Cal Poly or Laidlaw driver starting the day's work	**Pass / Fail / Not Validated**
3.2.2 Cal Poly or Laidlaw driver changing shift	**Pass / Fail / Not Validated**
3.2.3 Cal Poly or Laidlaw driver logout	**Pass / Fail / Not Validated**
3.2.4 Cal Poly or Laidlaw driver on route and picking up passengers	**Pass / Fail / Not Validated**
3.2.5 Cal Poly or Laidlaw driver on route and picking up passengers with automatic passenger counter (APC) (POSSIBLE FUTURE FEATURE)	**Pass / Fail / Not Validated**
3.2.6 Dangerous situation on bus	**Pass / Fail / Not Validated**
3.2.7 Going on break	**Pass / Fail / Not Validated**
3.2.8 Fueling	**Pass / Fail / Not Validated**

[4] 3.1.1 refers to the Section 3.1.1 scenario in the Bronco Express EDAPTS System Validation Plan.

[5] This scenario, different from Section 3.1.3 scenario, can access to the public website (http://www.broncoshuttle.com) of the Bronco Express EDAPTS System.

Table 3-2 Validation Results (cont'd)

Operational Scenario	Validation Result
3.3.1 Dispatchers at work	Pass / Fail / Not Validated
3.3.2 Dispatchers know where vehicles are	Pass / Fail / Not Validated
3.3.3 Dispatch bus with serious mechanical failure	Pass / Fail / Not Validated
3.4.1 Using passenger loading reports to optimize vehicle size	Pass / Fail / Not Validated
3.4.2 Using schedule adherence reports to adjust schedule (Potential future feature)	Pass / Fail / Not Validated
3.5.1 Providing the monthly report to Cal Poly	Pass / Fail / Not Validated
3.6.1 Schedule and route updates	Pass / Fail / Not Validated
3.6.2 Addition of new stops on a route	Pass / Fail / Not Validated
3.6.3 On-board Hardware Maintenance	Pass / Fail / Not Validated
3.6.4 Dispatch Console Maintenance	Pass / Fail / Not Validated
3.6.5 Vehicle to central dispatch communication link fails	Pass / Fail / Not Validated
3.6.6 On-board equipment fails	Pass / Fail / Not Validated
3.6.7 Transit sign fails	Pass / Fail / Not Validated
3.6.8 Computer console or server fails	Pass / Fail / Not Validated

4. DISCUSSION AND CONCLUSIONS

The EDAPTS test deployment for the Cal Poly Pomona Bronco Express system provides a real life test of the EDAPTS approach for efficient deployment of APTS solutions at small and medium transit properties. This deployment not only resulted in an operational APTS and a set of technical reports, but also provided opportunities to assess the effectiveness of using the EDAPTS approach for the procurement, installation, and operation of the Bronco Express EDAPTS system. The below discussion summarizes the results of the assessment:

4.1 Systems Engineering in Action

Although the systems engineering process is required for ITS (including APTS) deployments using Federal Highway Trust Funds (FHWA, 2007), effective use of it can prove daunting. The systems engineering process, as implemented by the V-model, provides the opportunity to implement a system solution which meets user needs and requirements to the maximum extent possible. Couple these facts with the likelihood that a small transit property may be using the systems engineering processes for the first and possibly only time, it may find itself overwhelmed by the prospect of developing a full Concept of Operations (CONOPS) and performing the required system verification and validation to ensure that the functionality delivered is coherent with the functionality desired and specified.

The Bronco Express EDAPTS Demonstration research team undertook the systems engineering process with two key objectives:

1) Deploying a best-fit APTS solution at Cal Poly Pomona.

2) Documenting the use of the simplified system engineering process so that small transit properties might benefit from the team's experiences with the model and reduce the overhead associated with these efforts.

4.1.1 Systems Engineering a Best-Fit APTS for Bronco Express

The research team successfully utilized the modified V-model, with good, but slightly imperfect results. The "good" aspect of these results was that the deployed system largely met the needs of the University, with system stakeholders being fully vested in the system. The "imperfect" aspect of these results was that the deployed system fell short of the desired functionality in a few places, as described below in Section 4.5, System Functional Issues

. However, the functionality shortcomings were largely related to performance-for-cost tradeoffs made by the vendor selection committee during proposal evaluation and less to do with problems in the use of the modified V-model.

Regardless of the imperfections, the APTS system deployed at Cal Poly Pomona appears to be a

good fit for the University, providing a useful service both to the system operator and Bronco Express riders. The system engineering process helped this happen as it allowed Cal Poly Pomona stakeholders to be part of the solution from the beginning. Stakeholders participated in early concept exploration workshops, developing and reviewing operational scenarios and system requirements. They then were actively involved in writing the procurement documents and selecting a system supplier. One of the most important results of vesting stakeholders in the system from the earliest stages was that they became true system advocates. They actively pushed for procurement and deployment of the system and supported it through to project completion. These same stakeholders now feel that the system truly belongs to them and see the Bronco Express APTS solution as a valuable improvement in their system. As a consequence, the benefits they receive from the use of the installed system are now embedded in their planning efforts and vision for the future of Bronco Express transit service as a whole.

4.1.2 Enhancing the Stakeholder System Vision and Increasing Advocacy

Although Cal Poly Pomona stakeholders participated in the systems engineering process with enthusiasm and vigor from the onset, their vision of what the system would do was limited. This was because APTS solutions were completely new to them and they had no first-hand experience with this type of technology. Upon receipt and review of system supplier responses to the published RFP, stakeholders made a field trip to the University of California Riverside campus to see a similar APTS in operation. Seeing an APTS in action energized the Bronco Express stakeholders and gave them a level of comfort in making the system supplier selection and finalizing the purchase.

4.1.3 Modifying the V-Model to Fit Project Needs

Bypassing the three steps at the lower levels of the V-Model (detailed design, software and hardware development, and unit testing) made use of this comprehensive system engineering tool tenable in the small transit environment, allowing system suppliers to offer packaged COTS solutions to small agencies. This allowed the Bronco Express system procurers and the research team to take advantage of a “CONOPS type” of development to gain detailed knowledge of how well the deployed system actually met the pre-defined user needs.

The modified V-model worked well in that many of the benefits of the systems engineering process were realized while bypassing inappropriate, low-level detail steps. These benefits included increased stakeholder commitment and empowerment, a detailed understanding of what the planned system would do, and a thorough knowledge of the actual performance of the system once it was installed and operational.

4.2 Use of the EDAPTS Performance Specification

The deployment of an APTS solution at Cal Poly Pomona was illuminating with respect to the

use of the EDAPTS Spec Generator which provided exhaustive details regarding system performance across many areas. It appeared to researchers that all vendors submitting proposals in response to the Bronco Express RFP did not specifically respond to the performance specification within the RFP, but rather to the general system functional objectives presented within the RFP.

The research team determined that the EDAPTS Spec Generator likely provided too much detail; effectively overstating the Bronco Express specification of the system to the point that it was largely ignored by potential system suppliers. As a result, they simply bid their own COTS system elements that they had already developed or were planning to develop as part of their existing product lines. In our final analysis, the team believes that the breadth and depth of the EDAPTS performance specification used in the Bronco Express RFP was far too detailed and effectively hindered its usefulness. This is not to say that there is not a place or a use for a highly detailed performance specification. A detailed performance specification, such as that used in this procurement, is well suited for two purposes: (1) specifying a system for which the supplier is going to develop a system from the ground up in response to a set of high-level requirements, (2) serving as a measurement standard for qualifying systems to be EDAPTS compatible in a standardized procurement model.

Lastly, it would be useful if the EDAPTS Performance Specification Generator Tool provided outputs that could be used for checking the responsiveness of proposals submitted in response to the RFP and in performing system verification. These new features were identified because these were tedious and time consuming tasks in the demonstration, both from a planning and an implementation standpoint.

4.3 EDAPTS Test Procurement Strengths and Limitations

It is obvious to the research team that the EDAPTS test procurement at Cal Poly Pomona had both strengths and limitations. While it worked sufficiently well to procure an APTS system that met user needs for Cal Poly Pomona Bronco Express, it did not necessarily result in a deployed system which was inherently different or superior to any other existing commercially available product

The general procurement approach utilized, which included performing a needs analysis, writing an operations concept document, writing requirements, and then writing an RFP worked well from the perspective of procuring a system. Bids by system suppliers were generally responsive to the published RFP. There were a few exceptions in the selected system's ability to meet prescribed users needs and these are typically related to specific system functional requirements where the vendor took exception. It is interesting to note that although all bids were evaluated based on a variety of pre-established criteria, all but one of the responses were greater than the project budget. Because of this, price became the driving factor in selection of the system supplier.

If there had been significant additional time and budget available to re-bid the system or to do

intensive one-on-one negotiations with all bidders, it might have been possible to restructure the procurement in such a way that some of the other responders could have better participated. However, this bid does represent the realities of life, both time and money are typically in short supply and the potential benefits that might be achieved by accepting open-ended delays and over-budget procurements are simply not a luxury most agencies have available.

The Bronco Express procurement also resulted in by-products useful to others procuring a similar system, which include a sample operations description (or a simplified concept of operations) and sample verification and validation documents. The value of these by-products to the procurement process should not be understated, as they provide the opportunity for a great starting point and framework for any smaller transit agency desiring to procure an APTS solution, regardless of the specifics of a system.

This test procurement focused on procuring the Bronco Express EDAPTS system an off-the-shelf APTS solution. The APTS deployed in this test procurement fit the prescribed functional requirements of Cal Poly Pomona. The COTS procurement approach is a step towards the general EDAPTS ambition of finding system suppliers that will meet the original EDAPTS precepts of selling an open architecture and TCIP framework APTS for transit use. However, the EDAPTS dream still has a long way to go to become the industry norm.

4.4 Use of a Service-Based Business Model for APTS

The APTS installed at Cal Poly Pomona is based on a service-based model, where the system supplier provides all aspects of system installation, maintenance, and operation in exchange for single monthly usage fee. Because of this, Cal Poly staff has been unburdened from tasks such as payment of communications usage charges, system administration, and system maintenance. They effectively don't have to do any technical or recurring support tasks except pay the monthly bill to the system supplier, and they find this to be a very workable and likable arrangement.

The service-based approach to APTS deployment and operation can be advantageous to a small transit property because it places little additional load on operations staff; transit personnel simply utilize the system and gain its operational benefits in exchange for a monthly rental. The potential down side of this service based approach is that the system supplier has control of the monthly cost for operating the system, which may ultimately place the transit property in a difficult position when renewing the service agreement. Another potential downside of the service-based approach is that the customer is dependent on the system supplier and their ability to operate the system to the satisfaction of the customer. However, as long as the provider is competent it may well be an enticing arrangement for small agencies and should be considered an opportunity worthy of evaluation during any procurement.

It is apparent to the research team that any transit property selecting a service-based system must carefully weigh the pros and cons of this arrangement over an agency-owned system,

where the operator owns the system and takes full responsibility of system operation and maintenance after the system is installed by the system supplier. Selection of a service-based system does provide significant freedom from many of the on-going administrative tasks and responsibilities that come with an agency-owned system, but it comes at the price of lack of independence from the system supplier. Each individual agency must make the decision of an agency-owned versus a service-based solution, taking into account its own needs and limitations.

4.5 System Functional Issues

The delivered system falls short of desired functionality in several areas, which are described in general in the following sections. Specific details regarding these system limitations can be found in the previously published PATH working paper: Cal Poly Pomona EDAPTS Test Deployment Installation and Technical Review Report Version 5.0.

The Cal Poly Pomona RFP articulated the required system functionality in two separate areas within the documentation package: 1) within the functional requirements area of Exhibit A (Cal Poly Pomona EDAPTS Test Deployment EDAPTS System Requirements and Performance Specification) and 2) within the operational scenarios section of Exhibit C (Cal Poly Pomona EDAPTS Test Deployment Operations Descriptions). These two descriptions, although written in different styles, were very compatible in their description of what the requested EDAPTS system should do. Again, it should be noted that the lack of desired functionality in the installed system does not automatically indicate that the delivered system is non-compliant to the contractual agreement between Bronco Express and the selected system supplier. It may simply indicate that a performance-for-cost tradeoff was made at some point in the procurement process and the failure is the logical outcome of that tradeoff.

4.5.1 <u>On-Board Systems/Vehicle Wireless Data Communications System Functions Not Fully Delivered</u>

On-board functions which were specified in the RFP, yet not fully delivered in the procured system include:

1) Driver login capability; including the inability to enter the vehicle odometer value at the start of the shift, the inability of MDT to indicate the next stop to the driver, and the inability to record deadhead miles to the beginning of the assigned route.

2) Driver logout capability; including the inability to record odometer data at the end of work period and the inability to record deadhead miles from the end of the route to the bus parking area.

3) Real-time status capability; including the inability to display next stop, current stop, time

to departure from current stop, and current schedule adherence information for a given stop. In actual operation, the current MDT fails to display any information of value to the driver that will assist them in maintaining desired schedule adherence on their route.

4) Time-of-day status capability; the MDT does not display the current time to the driver in a large digit format clock when the coach is in motion.

5) Current passenger status capability; including the inability to display passenger boarding counts and total passengers on the bus to the driver. The APC information is sent to the dispatch center and public web site, but it is not displayed to the driver.

6) Discrete driver's emergency button capability; the emergency button is not located in a discrete, out of the way position where it can be pressed by the driver without observation. It is located on the face of the MDT where it can be easily pushed, potentially causing false emergency alarms if accidently pressed.

7) Driver break notification capability; the MDT does not display a notification to the driver when they should be on a scheduled break.

8) Vehicle fuel logging capability; the MDT does not allow the driver to enter odometer data and gallons of fuel loaded onto the vehicle at fueling stops.

These functional limitations reduce the ability for Bronco Express management to maximize the efficiency of their operations, including standardized scheduling of driver breaks and helping the drivers maintain proper headway and spacing between vehicles operating on the same route.

4.5.2 Standardized Communications Interfaces not Utilized

The deployed Bronco Express EDAPTS system does not follow any standardized open communications protocols such as TCIP as requested in the RFP. The architecture of this installed system, while providing simplicity of deployment and operation, effectively hides all communications details from Cal Poly Pomona, or any system developer or integrator who may need to work on the installed system in the future.

The proprietary architecture effectively makes the deployed APTS a closed system, rather than a system that subscribes to an open architecture and communications framework. It is only malleable to support unforeseen future features if they also seem important to the system supplier.

4.5.3 Central Site Software

No audible or visual alarms are created at dispatch when an emergency is declared by a driver.

4.6 System Operational Issues

4.6.1 Bronco Express Fixed Schedule Not Implemented

Bronco Express has not yet taken full advantage of the installed EDAPTS system to implement a fixed schedule operation; therefore the buses continue to operate on a random, unscheduled headway basis. The research team and the University community have observed that the Bronco Express buses sometimes still arrive closely spaced, indicating that they are undesirably bunched together and hence not meeting the operational requirements described in the Bronco Express EDAPTS Operational Guidelines.

The reasons for this operational discrepancy may be related to:

1) Unclear documentation on how to use the installed EDAPTS system to implement a fixed schedule for Bronco Express. The system supplier has indicated in their online documents of the EDAPTS system that a fixed timetable can be implemented. However, Bronco Express has not yet requested training on how to implement fixed bus schedules.

2) A lack of priority in developing fixed bus schedule. The Parking and Transportation Services (PTS), which manages the Bronco Express bus operations, has not made the development of a fixed timetable for the system a priority item.

3) It may be that there are restrictions in the current service contract with the system operator that are inhibiting the initiation of fixed schedule services. The operator currently contracted to operate the Bronco Express shuttle bus services has a service contract that states it will provide general support for installing and operating the Bronco Express EDAPTS system on shuttle bus services. However, the contract does not specifically state they will provide fixed schedule services. Contractual discussions, to determine if this is a real issue, remain to be initiated by PTS.

Whatever the case, Parking and Transportation Services has plans to get PTS staff trained on developing fixed bus schedules and to add fixed schedule service operational requirements in its next service contract with the system operator.

4.6.2 Bronco Express Bus Drivers Without Real-time Information

The installed EDAPTS system provides real-time bus locations and bus arrival time information to dispatch and users in the University community. However, Bronco Express bus drivers do not get these same types of “intelligent benefits”. The bus operators complain that they cannot know via an MDT whether or not they are ahead or behind schedule (and by how much). The Bronco Express EDAPTS system doesn’t currently help them maintain schedules or prevent “bunching”. They feel that they drive their buses almost “in the dark,” having only limited verbal communications with dispatch via radios. This issue demonstrates that the installed MDT is not meeting the operational requirements described in the EDAPTS RFP. It is clear that, while the

research team and Bronco Express management initially expected the procured MDT devices could assist bus drivers by informing them of the location of other buses, the tradeoffs made during supplier selection adversely impacted this feature set.

4.7 System Deployment Contractual Issues and Challenges

4.7.1 Roadside Information Display Deployment Delays and Expense Overruns

The Bronco Express EDAPTS Demonstration was significantly delayed and its original projected cost was overrun due to the need for the system supplier to design, build, test, and deliver the solar-powered roadside information display (RID) sign. Since solar-powered RID signs meeting the Bronco Express EDAPTS system requirements and specifications were not commercially available at the time of contract award, the system supplier could not provide or install the signs at the same time as the Automatic Vehicle Location (AVL), Automatic Passenger Counter (APC), and Mobile Data Terminal (MDT) subsystems were installed. While the design, build and installation of this item were approved by Bronco Express, it nonetheless led to additional cost and delay in the effort when compared with the initial estimates. Since the sign was a high-priority need for the University, this cost overrun was covered by additional PTS funds that were set aside for this purpose.

The demonstration was also impacted due to the need to fully comply with ADA requirements as directed by Cal Poly Pomona policy. It required additional funds be added to the project and delayed the schedule in order to fully comply. However, in the end the procurement and installation of the ADA compliant solar-powered signs in this project demonstrated the value to transit agencies of making good, strategic choices when procuring APTS solutions.

4.7.2 Test Deployment Contractual Challenges

The Bronco Express Test Demonstration research project was funded by Caltrans and the Federal Transit Administration (FTA). Because of this, the procurement process for the installed system considered not only the procurement requirements of the University, but also the contractual terms and requirements of Caltrans and FTA.

The research team, facing these contractual challenges, established the EDAPTS Advisory Board, consisted of representatives from FTA, Caltrans, and Cal Poly Pomona Stakeholders. The Advisory Board members greatly helped the Procurement & Support Service (PSS) clarify all contractual requirements before the Bronco Express EDAPTS system was procured installed, and put into operation. The EDAPTS Advisory Board approach is useful to any small or medium transit agency trying to procure an APTS solution.

4.7.3 "ITS Champion" Needed

Deploying the Bronco Express EDAPTS system was a joint effort between many different institutional organizations. The research team along with the EDAPTS Advisory Board played an important role in advancing EDAPTS concepts towards full public use. However, his demonstration also showed that it is equally clear that ***one individual*** must step forward, lead, and take responsibility for the success or failure of the project. This "ITS Champion" may be required to expend additional efforts far beyond the originally anticipated bounds foreseen in the early planning stages. Much will be required of that individual and if the extra effort is not forthcoming the project may stutter, falter, or even fail. This is perhaps one of the more important findings of this research demonstration. Any agency desiring to deploy an APTS solution needs to first find its own "ITS Champion."

5. NEXT STEPS AND RECOMMENDATIONS

The Bronco Express EDAPTS system demonstrated to the transit community that using the EDAPTS approach for APTS procurement and deployment is good business practice. However, this EDAPTS approach still needs technical improvements and more exposure to professionals in the transit industry. Below are some key recommendations for EDAPTS enhancement:

5.1 Utilize COTS When Possible

Use COTS products as much as possible. The COTS approach can help ensure the deployed APTS is low cost and the system parts are interoperable.

5.2 Procure With Performance Specifications

Procure the EDAPTS system using performance-based specifications. The performance-based specifications reflect the desirable characteristics of APTS solutions for transit agencies. They can also incorporate performance specifications for cutting-edge technologies that can be applied in APTS.

5.3 Improve the EDAPTS Performance Specification Generator Tool

The Bronco Express EDAPTS Demonstration showed that the EDAPTS Spec Generator Tool is simple to use and effective in generating EDAPTS performance specifications that are tailored to the Bronco Express environment. However, this tool needs improvement in the following areas:

1) It would be useful for the EDAPTS Spec Generator software to automatically generate a procurement checklist. The checklist can help a procuring agency verify the performance proposed in a vendor's proposal against the performance specifications required in an EDAPTS RFP. The checklist could allow a procuring agency to easily assess the level of compliance of the vendor's proposed EDAPTS system to the specifications required in the RFP.

2) The EDAPTS Spec Generator should be adapted to generate compact and concise output of EDAPTS performance specifications for different stakeholders. Compact, concise outputs could help smaller procuring agencies understand quickly what the key functional and performance requirements are for the EDAPTS system to be procured and installed. Detailed, complex output would be useful to more advanced systems and larger agencies with more complex needs.

3) The EDAPTS Spec Generator software should be enhanced to include an option to filter outputs of performance specifications, permitting a report to be generated that details requirements only for specifically desired metric categories.

4) It would be useful to expand the EDAPTS Spec Generator with functions to automatically generate a simplified Operations Guideline document from operational scenarios and verification and validation plans from the down selected performance specifications.

5) The EDAPTS Spec Generator should be enhanced to be compatible to the TCIP Implementation Requirements and Capabilities Editor (TIRCE). Such compatibility helps procuring agency procure an EDAPTS solution that is TCIP compatible.

5.4 Use TCIP Compliant Interfaces

It is possible that selection of the non-TCIP compliant system architecture for this deployment might have been driven by the fact that there simply was not sufficient time for the supplier to provide a TCIP compliant system. However, the theme of low cost ITS promoted in the EDAPTS deployment approach also makes development of new, fully-compliant systems economically challenging when compared to using an already developed proprietary approach. It is likely that achieving the widespread use of TCIP compliant systems in transit APTS solutions will require focused pressure on suppliers to do so. The research team believes that this pressure will be most effective if it comes from the sources providing the base funding for these solutions, from supporting industry organizations such as American Public Transportation Association (APTA), and from the procuring agencies themselves. These organizations need to continue, and even increase, their drive to make TCIP compliant systems the standard for transit ITS solutions.

5.5 Integrate With Other ITS Systems

Many low-cost, off-the-shelf advanced public transportation systems (APTS) are expected to be deployed through use of the EDAPTS approach at small transit agencies. Ideally, these APTS ITS solutions might be expected to be integrated with other ITS solutions at the city and regional levels to allow better coordinate and manage traffic in different modes.

There is an increasing demand for advanced public transportation systems (including EDAPTS systems) to “talk” to all other ITS solutions. For example, a city with two independent intelligent transportation systems (e.g. an advanced traffic management system (ATMS) at Traffic Management Center (TMC) and an APTS at a Transit Management Center) would like to see the integration of the ATMS and APTS. Perhaps, this integration will help the city monitor bus operations and traffic at intersections coordinately to provide better overall coordination of traffic and mitigate the impacts of congestion. Buses might be used as “pilot” vehicles, experiencing real-time traffic conditions in traffic flow. Bus dispatchers, with knowledge of intersection traffic conditions that are received from these “pilot” vehicles and ATMS, will better manage their bus operations and improve schedule adherence. Buses equipped with GPS-based signal priority transponders could also change signal timing at intersections and trigger updates to the ATMS.

The national trends on corridor management and congestion reduction greatly enforce the integration of APTS with other ITS solutions. For example, the Los Angeles Metropolitan Transportation Authority (MTA) established a regional ITS integration network (called the RIITS Network) (see http://www.riits.net). This RIITS Network integrates freeway operations (Caltrans District 7, 8, and 12), LADOT's traffic signal controls, Metro's transit systems (Bus ATMS[6], Rapid Bus TPS[7], and Rail SCADA[8] Operating System for Red and Green Lines), Long Beach Transit's Transit Management System (TMS), Foothill Transit Automatic Vehicle Location (AVL) system, and California Highway Patrol (CHP) incident reporting systems. It presents real time multi-modal transportation information through the RIITS Agency Website (http://www.riits.net) and Metro's Website (http://www.metro.net) under Real Time Traffic. The RIITS Agency Website is a private and privileged internet site established for public agencies access only. The purpose of the website is to share and exchange real time traffic congestion and incident information among transportation agencies, transit operators and emergency services to coordinate the operation and management of the regional transportation network in Los Angeles County. The Metro Real Time Traffic Webpage allows the general public to access the latest traffic congestion information. The RIITS Network has been operational since November 2004.

EDAPTS research should expand its technical strength, facilitating the trend to make APTS solutions ready for system integration at city and regional level. One immediate upgrade of the Bronco Express EDAPTS system to support this integration effort might be to develop interfaces between the EDAPTS system and the mini Advanced Traffic Management System[9] at Cal Poly Pomona. These interfaces could move APTS research to next higher level and establish a new test environment for the integration of APTS solutions with other ITS solutions.

5.6 Training and Outreach

EDAPTS research activities have helped researchers from both Cal Poly Pomona and Cal Poly SLO accumulate a great deal of technical and institutional experience in deploying APTS solutions at small and medium size transit properties. In addition, the research tasks themselves have continued to build a good business case for use of EDAPTS concepts during the procurement of small agency APTS solutions. All in all, this research has demonstrated that using the EDAPTS approach is "smart business practice" and has developed a ready-made pool of small transit ITS deployment expertise.

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[6] ATMS - Advanced Transportation Management System installed on the entire Metro bus fleet. It consists of Transit Radio System (TRS), Computer Assisted Dispatch (CAD), Automatic Vehicle Location (AVL), Automatic Passenger Counting (APC), Automatic Voice Annunciation (AVA), and Video Surveillance system.

[7] TPS – Transit Priority System installed for Rapid Buses in Metro

[8] SCADA –Supervisory Control and Data Acquisition System for light rail trains in Metro.

[9] Advance Traffic Management System (ATMS) at Cal Poly Pomona is a system which consists of a set of traffic controllers, video detection systems, and traffic control software. The system is currently for instructional use for Civil Engineering undergraduate and graduate students.

But, for all of this to be effective, transit agencies need to become more familiar with the EDAPTS approach as they plan to deploy APTS solutions for their transit service improvements. To do this, we need to make EDAPTS training a core task in our transfer of EDAPTS research results and experiences to the transit community. Through specialized EDAPTS training, open access to technical reports on EDAPTS procurement methodologies, system verification and validation processes, and exposure to the EDAPTS Spec Generator small agencies can become more effective and more efficient in their procurement and deployment of APTS solutions. All of this information needs to be made available to them through workshops and seminars that are focused on helping small transit agencies deploy advanced public transportation systems and the EDAPTS research team stands ready to help.

5.7 Additional Research Into "Best Use" Of APTS in Small and Medium Transit Properties

The research team found that there are few (if any) low-cost, off-the-shelf, open source APTS solutions available for small or medium size transit properties. This was certainly true during the timeframe when the Bronco Express EDAPTS system was procured and installed. Many current APTS solutions are aimed at larger transit agencies and their installation costs, operation and maintenance costs were far higher than what we could afford to pay for in this demonstration.

However, the team believes that there will be an increasing availability of low-cost, off-the-shelf APTS solutions for transit during the next decade or so. More and more, bus manufacturers are making AVL, MDT, and APC systems standard built-in items in their bus configurations. Assuming this trend continues, it will significantly reduce the cost of deploying an APTS solution for small transit agencies and increase their use in that environment. This projected increase in availability of APTS solutions for small and medium transit agencies encourages further research on how to best accommodate and use these standardized vehicle on-board systems in a small agency's unique operational environment in order to get the most benefit from them.

5.8 Fixed-Schedule Timetable Implementation at Bronco Express

Implementing a fixed-schedule timetable will be a good future task for improving Bronco Express' on-time performance. It will help them maintain evenly spaced bus arrivals and avoid bunching at stops.

For Bronco Express, fixed-schedule timetables will allow passengers to better time their arrival at a stop to more closely match the arrival of a specific bus, thus increasing reliability and helping reduce their wait time. Passengers can also make better informed decisions on whether to wait for the bus or walk to their destination.

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7. APPENDICES

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2) Cal Poly Pomona EDAPTS Test Deployment User Features, Operational Needs and Performance Parameters (or Appendix A of Cal Poly Pomona EDAPTS Test Deployment Procurement Documentation Package Version 7.0)
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