Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-97/1389-1F		

4. Title and Subtitle
DEVELOPMENT OF A MULTI-VENDOR ENVIRONMENT FOR TRAFFIC CONTROLLERS

5. Report Date
November 1996

6. Performing Organization Code

7. Author(s)
Edward J. Seymour

8. Performing Organization Report No.
Research Report 1389-1F

9. Performing Organization Name and Address
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
Study No. 0-1389

12. Sponsoring Agency Name and Address
Texas Department of Transportation
Research and Technology Transfer Office
P. O. Box 5080
Austin, Texas 78763-5080

13. Type of Report and Period Covered
Final
September 1993 - August 1996

14. Sponsoring Agency Code

15. Supplementary Notes
Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.
Research Study Title: Development of a Multi-Vendor Environment for Traffic Controllers

16. Abstract

The overall goal of the study was to determine to what extent different vendors' traffic controllers can be effectively used in closed-loop signal systems in a manner acceptable to TxDOT engineers and maintenance personnel. Specific objectives to meet the goal included:

- Objective 1: Identify current practices and needs of TxDOT engineers and maintenance personnel.
- Objective 2: Define alternatives for providing closed-loop type traffic signal systems.
- Objective 3: Evaluate the feasibility and cost of implementing alternative system architectures for closed-loop traffic controller type systems.

The findings of the work included a recommendation for TxDOT to proactively be involved in the National Transportation for ITS Protocol (NTCIP) and begin deployment of NTCIP compatible systems as soon as practical. The communications study also included a recommendation that TxDOT should actively be involved in the development of Advanced Transportation Controller standards, including controllers, cabinets, and software.

17. Key Words
National Transportation Communications for ITS Protocol, NTCIP, ITS, ATMS, ITS National Architecture, Traffic Management Data Dictionary

18. Distribution Statement
No restrictions. This document is available to the public through NTIS:
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	116	

DEVELOPMENT OF A MULTI-VENDOR ENVIRONMENT

FOR TRAFFIC CONTROLLERS

by

Edward J. Seymour
Research Engineer
Texas Transportation Institute

Research Report 1389-1F
Research Study Number: 0-1389
Research Study Title: Development of a Multi-Vendor Environment
for Traffic Controllers

Sponsored by the
Texas Department of Transportation
In Cooperation with
U. S. Department of Transportation
Federal Highway Administration

November 1996

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

IMPLEMENTATION STATEMENT

This project investigated existing ITS capabilities in the Dallas area and advanced ITS technology and developed a comprehensive ITS plan for the Dallas Urban Area. Specific projects are delineated, and a phased implementation is provided.

DISCLAIMER

The contents of this report reflect the views of the author who is responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation, nor is it meant for construction, bidding, or permit purposes.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. STUDY PROBLEM STATEMENT

1.1 Background

Many signal systems with different programming details and system control features have been developed by various controller manufacturers. Most of these micro-computer-based closed-loop systems can only communicate with controllers from the same manufacturer. This creates problems in maintaining statewide equipment standards, cost-competitive procurement processes and system operational practices. In addition, some hardware interconnection techniques cannot fully take advantage of many built-in advanced control features provided in some of the advanced traffic signal controllers. Basic sets of standard communications protocols and system control features should be established for different signal controllers provided to TxDOT such that controllers from different vendors can be integrated into a seamless traffic management system.

Texas has historically purchased NEMA traffic signal controllers. These controllers are compatible to the extent that they can be interchanged between manufacturers within individual field cabinets although there is no consistency with regard to user interface or diagnostics. This compatibility allows the purchase of equipment from multiple vendors. However, when traffic signals are interconnected through a closed-loop communication system, controllers can not be mixed among manufacturers because of differences in communications and differences.

TxDOT has been purchasing NEMA TS-1 traffic signal controllers. NEMA TS-1 does not specify standards for coordination, communication, or systems functions. In addition, controllers today are NEMA "plus" controllers which have features in excess of the NEMA standards, further complicating compatibility.

The new NEMA TS-2 standard provides additional enhancements to the NEMA TS-1. The new NEMA TS-2 standard provides greatly enhanced cabinet design and functionality. However, the new NEMA TS-2 standard does not address systems data, user interface, or the communications architecture issues between cabinets.

An alternative pursued by some agencies to reduce the costs associated with multiple equipment types is to develop a hardware specification. The alternative pursued by several states including California and New York and several cities including Dallas, San Antonio, and Austin is the Type 170/179 controller. The Type 170/179 controller is a hardware based specification that requires the purchase of third party software. The 170/179 controller while non-proprietary, is 15 year old technology.

With the deployment of Traffic Management Systems around the state, significant new interest in operations, and the need to modernize many traffic signal systems, a fresh look at alternatives for traffic signal controllers and systems is warranted. Clearly, closed-loop signal systems are extremely attractive alternatives for many applications within the state. Nevertheless, the need for compatibility continues to be an important and difficult issue.

It should also be noted that increasing interest and developments in the area of Intelligent Transportation Systems (ITS) will result in additional demands on Traffic Management Systems. Any examination of closed-loop signal systems without consideration of future developments would be short sighted. California, New York, and others are working on an Advanced Transportation Controller (ATC) for applications including weigh-in-motion (WIM), coordinated ramp metering, incident detection, video surveillance, and other evolving applications. The goal of the Advanced Transportation Controller is to provide a fully open system for utilizing "off-the-shelf" electronics.

1.2 Objectives of Study

The overall goal of the study is to determine to what extent different vendors' traffic controllers can be effectively used in closed-loop signal systems in a manner acceptable to TxDOT engineers and maintenance personnel. Specific objectives to meet the goal include:

Objective 1: Identify current practices and needs of TxDOT engineers and maintenance personnel.

Objective 2: Define alternatives for providing closed-loop type traffic signal systems.

Objective 3: Evaluate the feasibility and cost of implementing alternative system architectures for closed-loop traffic controller type systems.

Objective 4: Document the findings and recommendations in a Final Report.

1.3 Work Plan

A brief summary of the work plan is presented in the following paragraphs.

- Task A: Review Current Practice

  This task includes a survey of the existing local controller marketplace to determine current manufacturers and products. The task includes an assessment of current practices within the state including TxDOT districts and selected cities.

- Task B: Establish Advisory Committee

  In order for the study to be successful, a consensus must be developed among various users, vendors, and system integrators. An Advisory Committee is established composed of representatives from TxDOT (Technical Panel), other users, vendors, and system integrators.

- Task C: Analyze Problems Of Multi-Vendor Environment

  Based upon the review of current practice in Task A, an identification and analysis of issues associated with the existing and evolving multi-vendor environment is developed.

- Task D: Develop Communications Standards

  Task D focuses on the definition of communications messaging standards as a prominent option in the identification of alternative system configurations. This task defines a potential communications protocol and messaging standard(s) which incorporates the features of existing local controllers from various manufacturers and permits the addition of evolving features which may be added to local controllers as operational strategies evolve.

- Task E: Determine Integration Requirements

  There are a variety of approaches to meet the requirements of a multi-vendor environment for traffic controllers. This task develops the criteria against which alternative system configurations can be evaluated.

- Task F: Identify Alternative System Configurations

  Given the large number of installed controllers and the extensive development effort in current closed-loop systems, alternative configurations should be developed to take advantage of previous work. This task identifies numerous deployment alternatives.

- Task G: Evaluate Alternatives

  The evaluation of alternative configurations is based on the criteria developed in Task E and subsequently applied to the alternatives developed in Tasks D and F.

- Task H: Develop Recommendations

  This task produces specific recommendations based on the evaluation conducted in Task G and provides the necessary information for TxDOT to pursue a course of action which could result in a multi-vendor environment for traffic signal controllers.

- Task I: Final Report

  The results of the study are included in the final report.

- Task J: Refinement of NTCIP and Impacts on ATC Devices

  The effectiveness of the FHWA sponsored NTCIP (National Transportation Communications for ITS Protocol) and evolving advanced transportation controller (ATC) are investigated to determine their effectiveness in providing a multi-vendor environment.

2. TASK A: REVIEW CURRENT PRACTICE

2.1 Introduction

The objective of Task A is to summarize current practices of TxDOT engineers and maintenance personnel. The data for Task A was gathered through a 1994 survey of TxDOT districts and selected Texas cities. In addition, closed-loop product descriptions were solicited from vendors as well as deployment summaries for vendor systems.

2.2 Summary of Task A Deployment Findings

There are an estimated 3,698 transportation control devices for which TxDOT Districts are responsible. Seventy-one percent (71%) of the control devices are located in urban areas, and 29% are located in rural areas. Most (97%) of the devices are NEMA controller specification based.

Half (57%) of the devices (excluding diamond interchange signals) are operating in synchronized systems. Of the 3,698 control devices, only 289 (8%) are operating in closed-loop system environments. Three vendors (Naztec, Multisonics, and Econolite) have supplied three-quarters (75%) of these closed-loop systems.

District comments regarding system features reflect a desire for standardization. Their suggestions include the following "desired features" for traffic system control: standardization, common user interface for users, and a universal software for system control.

The cities surveyed had 75% of their signals in systems (excluding diamond interchange signals). The majority of these computer controlled systems were provided by Safetran, Sonex, and Multisonics (53%). Nine other suppliers provided the remaining systems.

2.3 Survey Overview

A survey questionnaire was to mailed to TxDOT districts and twelve selected Texas cities. Table 2.4 (page 2-9) and Table 2.9 (page 2-15) identify specific districts and cities which were asked to complete questionnaires.

The survey consisted of two questionnaires — one written by Texas Transportation Institute soliciting responses regarding field deployment of control equipment and another written by the TxDOT Traffic Signal Team focusing on system deployment and features. Sample copies of the surveys are included in Section 2.4. Responses from both surveys are used in this study, *Multi-Vendor Environment for Traffic Controllers*.

The TTI questionnaire was structured in a manner that paralleled the survey conducted by TxDOT in the fall of 1993. That is, it contained the same categories of controller deployment: isolated, closed-loop, hardwire/time-based, non-coordinated, diamond and ramp meter. The TTI survey solicited further information regarding urban/rural mix and type of controller.

The TxDOT Traffic signal Team questionnaire solicited information regarding system feature preferences and configuration of deployed systems.

A request for information regarding deployment of closed-loop systems was distributed to vendors.

Section 2.8 contains observations pertaining to product descriptions of the vendor organizations that responded to the survey.

2.4 Survey Instrument

This section contains a copy of the survey forms distributed to TxDOT districts and to selected cities. The cover page soliciting the response and explaining the study has not been included.

TRAFFIC SIGNAL TEAM QUESTIONNAIRE

	SYSTEM 1	SYSTEM 2	SYSTEM 3	SYSTEM 4	SYSTEM 5
City					
Vendor					
Date of Installation (MM/YY)					
# of Intersections					
# of Diamond Interchanges					
# of split Diamond Interchanges					
Are all controllers the same brand? Y/N					
# of subsystems					
Subsystem coordination needed? Y/N					
# of submasters (if applicable)					
# of system detectors					
Max # of system detectors per local					
# of patterns utilized					
Traffic Responsive operation used? Y/N					
Time-of-Day Operation used? Y/N					
Is central control software on a network (LAN)? Y/N					
Are real-time displays reliable? Y/N					
Is security sufficient? Y/N					
Performance expectations met? Y/N					

DEFINITIONS FOR USE IN THE QUESTIONNAIRE:

<u>Subsystem</u> - group of intersections within the system operating under common control
<u>Split Diamond</u> - Intersection of two one-way pairs (e.g., frontage roads at a 3 level interchange)
<u>Sub-Master</u> - On street unit required to operate subsystems
<u>Subsystem Coordination</u> - Coordination between two subsystems (e.g., crossing arterials)
<u>Pattern</u> - Cycle length, split, phase sequence, and offset combinations

1. Name and telephone number of the person completing this questionnaire:

   NAME: ____________________ PHONE NUMBER: ____________________

2. List the five most important features you desire in a traffic signal system.

   ____

   ____

   ____

   ____

3. Provide a list of features that you would change or add to your present traffic signal systems.

   ____

   ____

   ____

   ____

4. Importance of a common user interface for all traffic signal systems:

   Not Important   Very Important

   1   2   3   4   5

5. Do you need the capability on your traffic signal system to monitor and control a Texas Diamond controller? Yes or No.

6. Do you need the capability on your traffic signal system to monitor and control a split level diamond?
   Yes or No.

7. Should a traffic signal system include control of:

	Not Important				Very Important
Dynamic Lane Assignment Signs?	1	2	3	4	5
Sign Lights?	1	2	3	4	5
School Zone Flashers?	1	2	3	4	5
Illumination systems?	1	2	3	4	5
Sprinkler Systems?	1	2	3	4	5
Changeable Message Signs?	1	2	3	4	5
Other: ____________________	1	2	3	4	5
Other: ____________________	1	2	3	4	5

8. What types of Local Area Networks does your agency support?

____

____

9. Please attach copies or descriptions of reports you find most useful.

Comments: ____

____

____

____

____

If you have any questions concerning this questionnaire, please contact Ms. Janie P. Light at (512) 416-3258.

Table 2.1. Urban/Rural & Actual/Pretimed

Category	Number		Urban		Rural		Total
	Control Devices	Systems	Actuated	Pretimed	Actuated	Pretimed	
Intersection signals (not including diamond interchange signals or signals within systems)							
Intersection signals within closed-loop & computer controlled systems							
Number of closed-loop & computer controlled systems							
Intersection signals within hardwire interconnected and time based coordinated systems							
Number of hardwire & time based coordinated systems							
Diamond interchange signals							
Ramp meter signals							
Total							

Table 2.2. Type of Controller

Category	Number		Type of Controller				
	Control Devices	Systems	NEMA TS 1 & TS 2	Type 170 & 179	Non-NEMA Solid-State	Electro-mechanical	Total
Intersection signals (not including diamond interchange signals or signals within systems)							
Intersection signals within closed-loop & computer controlled systems							
Number of closed-loop & computer controlled systems							
Intersection signals within hardwire interconnected and time based coordinated systems							
Number of hardwire & time based coordinated systems							
Diamond interchange signals							
Ramp meter signals							
Total							

2.5 Sampling Details

Most survey responses included complete answers to all applicable questions. However, a few agencies submitted incomplete data on some portions of the survey. In addition, six TxDOT districts did not respond to the survey. For the purpose of summarizing the data, the analysis took the following actions with regard to missing data.

1. Where traffic controller deployment by "equipment type" in Table 1 and Table 2 of the survey was not provided by an agency (e.g., number of NEMA controllers, number of actuated controllers), the proportion of traffic controllers of each type for that category for the district was estimated equal to the proportion for those that completely responded to the questionnaire.

2. For example, if a district indicated they had C intersection signals of a specific category (e.g., the category "within closed-loop & computer controlled systems") and they did not indicate how many were of the type: urban actuated (UA), then the estimated number of signals that are urban actuated was estimated to be:

   $$UA = C * P \quad (2.1)$$

   where:

UA =	number of urban actuated signals
C =	number of intersection signals of the category "within closed-loop & computer controlled systems" for a district
P =	the proportion of urban actuated signals that are "within closed-loop & computer controlled systems" for those districts that completely responded to the survey

3. Where the total number of intersection signals for a category in Table 1 and Table 2 of the survey was not provided by a district, the quantity for the district was estimated equal to the values previously submitted to TxDOT in the fall of 1993.

4. Five TxDOT districts did not respond to the survey: Austin, Bryan, El Paso, Pharr, and San Antonio. Missing data for these districts were estimated based on values submitted for the 1993 TxDOT survey and the proportions of equipment types for districts that submitted completed surveys in 1994.

2.6 TxDOT Survey Results

The following two Sections 2.6.1 and 2.6.2 summarize the results of the survey with respect to TxDOT control device and system deployment. Responses pertinent to desired traffic control system features are discussed in Chapter 4.

2.6.1 Traffic Controller Deployment

Data regarding deployment for Table 1 and Table 2 of the survey for TxDOT districts are summarized in Table 2.3. The 1993 TxDOT survey did not gather information relating to urban/rural implementation or type of control equipment. However, data from the 1993 survey were used for estimating district quantities where no response to the 1994 survey was received.

As a check on the accuracy of the 1994 survey, a comparison was made to the results obtained on the 1993 survey. The primary changes relate to (a) an increase in the number of control devices within closed-loop and computer controlled systems and (b) a decrease in the number of intersections within hardwire and time based systems. There is also an increase in the number of ramp meters due primarily to an increase in the number of ramp meters reported by the Houston District.

Table 2.3. The 1993 TxDOT Survey and the 1994 TTI Survey

	Number of Control Devices			
Category	**Task A Summer 1994 Survey**	**1994 Survey + Fall 1993 Values for 5 Missing Districts**	**Fall 1993 TxDOT Survey**	**Percent Change from Fall 1993 Survey**
Intersection signals (not including diamond interchange signals or signals within systems)	1,284	1,847	1,830	101%
Intersection signals within closed-loop & computer controlled systems	293	336	255	132%
Intersection signals within hardwire interconnected and time based coordinated systems	762	984	1,056	93%
Diamond interchange signals	275	450	449	100%
Ramp meter signals	80	81	54	150%
Totals	2,694	3,698	3,644	101%

Table 2.4 identifies TxDOT districts that received questionnaires and designates those districts which returned completed surveys. Nineteen of the districts (79%) completed and returned the questionnaires.

Table 2.4. TxDOT Districts: Status of Questionnaire Responses

Name	Returned Survey
Abilene	Yes
Amarillo	Yes
Atlanta	Yes
Austin	No
Beaumont	Yes
Brownwood	Yes
Bryan	No
Childress	Yes
Corpus Christi	Yes
Dallas	Yes
El Paso	No

Names	Returned Surveys
Houston	Yes
Lubbock	Yes
Lufkin	Yes
Odessa	Yes
Paris	Yes
Pharr	No
San Angelo	Yes
San Antonio	No
Tyler	Yes
Waco	Yes
Wichita Falls	Yes

Table 2.5 identifies the urban/rural deployment status of existing systems within TxDOT districts. The data in Table 2.5 were adjusted according to the procedures defined in Section 2.5 and represent estimates of current deployment.

Table 2.5. TxDOT Districts: Urban/Rural Deployment Status

			Urban		Rural	
Category	**Number Control Devices**	**Number Systems**	Actuated	Pretimed	Actuated	Pretimed
Intersection signals (not including diamond interchange signals or signals within systems)	1,847		907	168	684	88
Intersection signals within closed-loop & computer controlled systems	336		241	1	94	-
Number of closed-loop & computer controlled systems		33				
Intersection signals within hardwire interconnected and time based coordinated systems	984		394	386	107	97
Number of hardwire & time based coordinated systems		192				
Diamond interchange signals	450		354	79	-	-
Ramp meter signals	813		80	1	-	-
Total	3,698		1,976	636	902	185

Figure 2.1 illustrates this urban/rural deployment.

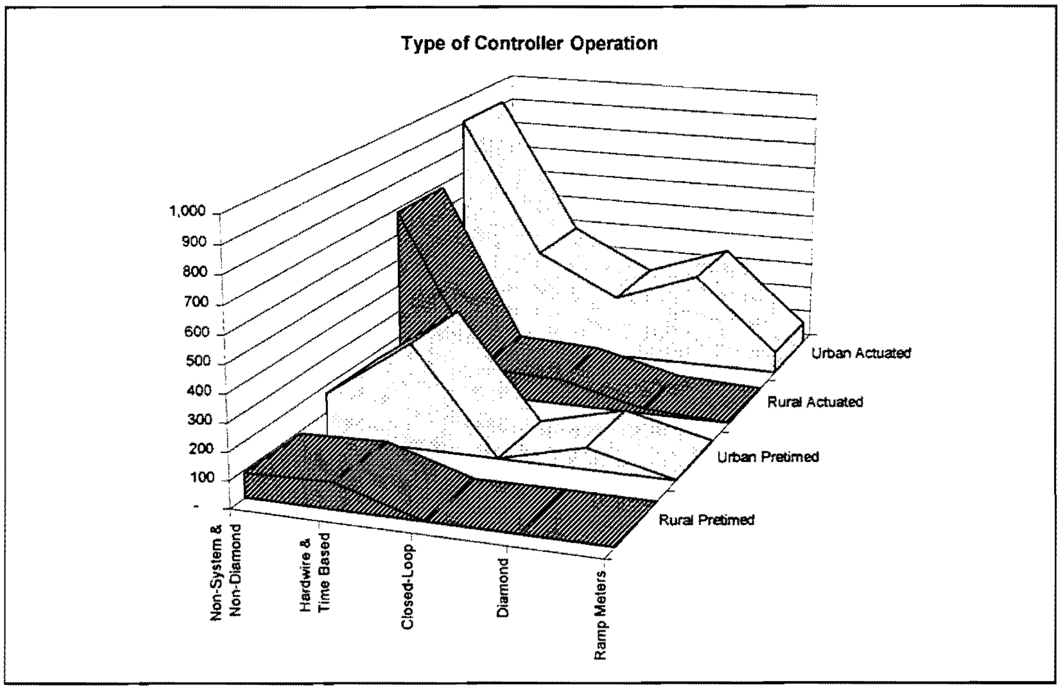

Figure 2.1. TxDOT: Urban/Rural Controller Deployment

Table 2.6 identifies the controller types for existing systems within TxDOT districts. Figure 2.2 illustrates this deployment.

Table 2.6. TxDOT: Type of Controller Deployment Status

Category	Number		Type of Controller			
	Control Devices	Systems	NEMA TS 1 & TS 2	Type 170 & 179	Non-NEMA Solid-State	Electro-mechanical
Intersection signals (not including diamond interchange signals or signals within systems)	1,847		1,836	-	7	4
Intersection signals within closed-loop & computer controlled systems	336		336	-	-	-
Number of closed-loop & computer controlled systems		33				
Intersection signals within hardwire interconnected and time based coordinated systems	984		984	-	-	-
Number of hardwire & time based coordinated systems		192				
Diamond interchange signals	450		413	-	37	-
Ramp meter signals	81		2		79	-
Total	3,698		3,571	-	124	4

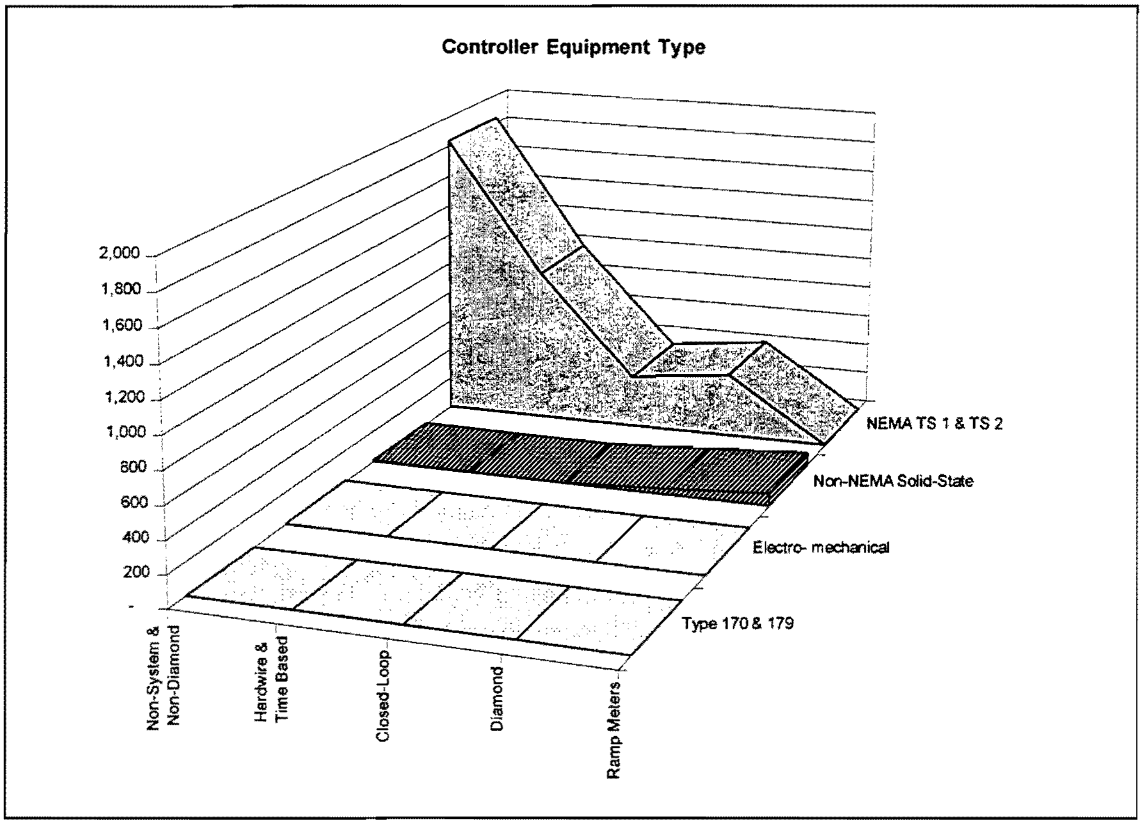

Figure 2.2. TxDOT: Controller Type Deployment

2.6.2 Traffic Control System Deployment

The distribution of systems by vendor is shown in Table 2.7. Some districts did not identify the vendor who supplied their systems; therefore they were categorized as "unidentified" in the table.

Table 2.7. TxDOT: Distribution of Systems by Vendor

Vendor	Number of Signals	Percent of Signals
Naztec	93	32%
Multisonics	64	22%
Econolite	59	20%
TxDOT	16	6%
Unidentified	57	20%
Total	289	100%

Table 2.8 summarizes the deployment of traffic signal systems within TxDOT districts that responded to the survey.

Table 2.8. TxDOT: Traffic Signal System Deployment Summary

District	Number of Intersections in Systems	System		
		Vendor	Date	Number of Intersections
Brownwood	13	Naztec	Apr - 94	2
		Naztec	Sep - 93	5
		Naztec	Aug - 91	3
		Naztec	Jun - 87	3
Childress	7		Feb - 87	2
			Nov - 86	5
Corpus Christi	69	Econolite		12
		Multisonics		16
		Econolite		6
		Econolite		17
		Econolite		8
		Econolite		5
		Econolite		5
Dallas	48	Multisonics	Jul - 94	4
		Multisonics	Jun - 93	12
		Multisonics	May - 92	7
		Multisonics	Aug - 90	12
		Multisonics	Mar - 90	13
Houston	16	TxDOT	Oct - 93	8
		TxDOT	Jul - 93	8
Lufkin	57	Econolite	Jun - 93	6
		Naztec	Mar - 93	16
		Naztec	Mar - 93	26
		Naztec	Oct - 92	3
		Naztec	Mar - 91	6
Paris	13	Naztec	Jul - 95	1
		Naztec	Jun - 95	2
		Naztec	Jun - 95	1
		Naztec	Jul - 94	5
		Naztec	Jun - 94	4
San Angelo	23		Apr - 94	7
			Apr - 94	3
			Jan - 93	3
			Sep - 91	3
			Oct - 90	7
Tyler	16	Naztec		12
		Naztec		4
Wichita Falls	27		Mar - 94	2
			Mar - 94	2
			Oct - 93	7
			Oct - 93	9
			Apr - 93	7

2.7 Selected Texas City Results

Table 2.9 identifies Texas cities that received questionnaires and designates those cities which returned completed surveys.

Table 2.9. Texas Cities: Status of Questionnaire Responses

Name	Returned Survey
Amarillo	Yes
Austin	No
Bryan	Yes
Corpus Christi	No
Dallas	Yes
El Paso	No
Fort Worth	Yes
Lubbock	No
Richardson	Yes
San Angelo	Yes
San Antonio	No
Waco	No

2.7.1 Traffic Controller Deployment

Table 2.10 identifies the urban/rural deployment status of existing systems within surveyed cities. The data in Table 2.10 were adjusted according to the procedures defined in Section 2.5 and represent estimates of current deployment.

Table 2.10. Cities: Urban/Rural Deployment Status

Category	Number Control Devices	Number Systems	Urban Actuated	Urban Pretimed	Rural Actuated	Rural Pretimed
Intersection signals (not including diamond interchange signals or signals within systems)	764		708	32	10	14
Intersection signals within closed-loop & computer controlled systems	1,411		891	410	110	-
Number of closed-loop & computer controlled systems		53				
Intersection signals within hardwire interconnected and time based coordinated systems	874		747	127	-	-
Number of hardwire & time based coordinated systems		116				
Diamond interchange signals	268		249	18	-	1
Ramp meter signals	-		-	-	-	-
Total	3,317		2,595	586	120	15

Figure 2.3 illustrates this urban/rural deployment.

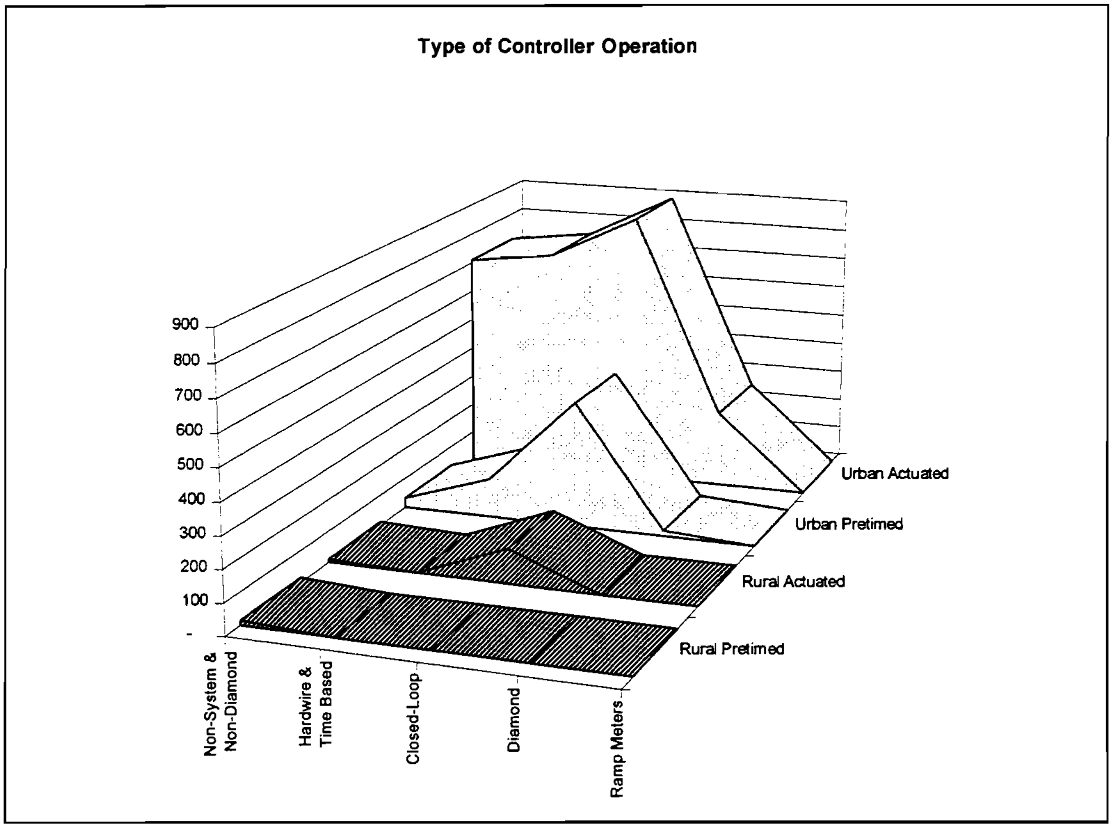

Figure 2.3. Cities: Urban/Rural Controller Deployment

Table 2.11 identifies the controller types of existing systems within the cities surveyed. Figure 2.4 illustrates this deployment.

Table 2.11. Cities: Type of Controller Deployment Status

	Number		Type of Controller			
Category	Control Devices	Systems	NEMA TS 1 & TS 2	Type 170 & 179	Non-NEMA Solid-State	Electro-mechanical
Intersection signals (not including diamond interchange signals or signals within systems)	764		544	147	40	33
Intersection signals within closed-loop & computer controlled systems	1,411		673	618	120	-
Number of closed-loop & computer controlled systems		53				
Intersection signals within hardwire interconnected and time based coordinated systems	874		537	199	138	-
Number of hardwire & time based coordinated systems		116				
Diamond interchange signals	268		227	30	11	-
Ramp meter signals	-		-	-	-	-
Total	3,317		1,981	994	309	33

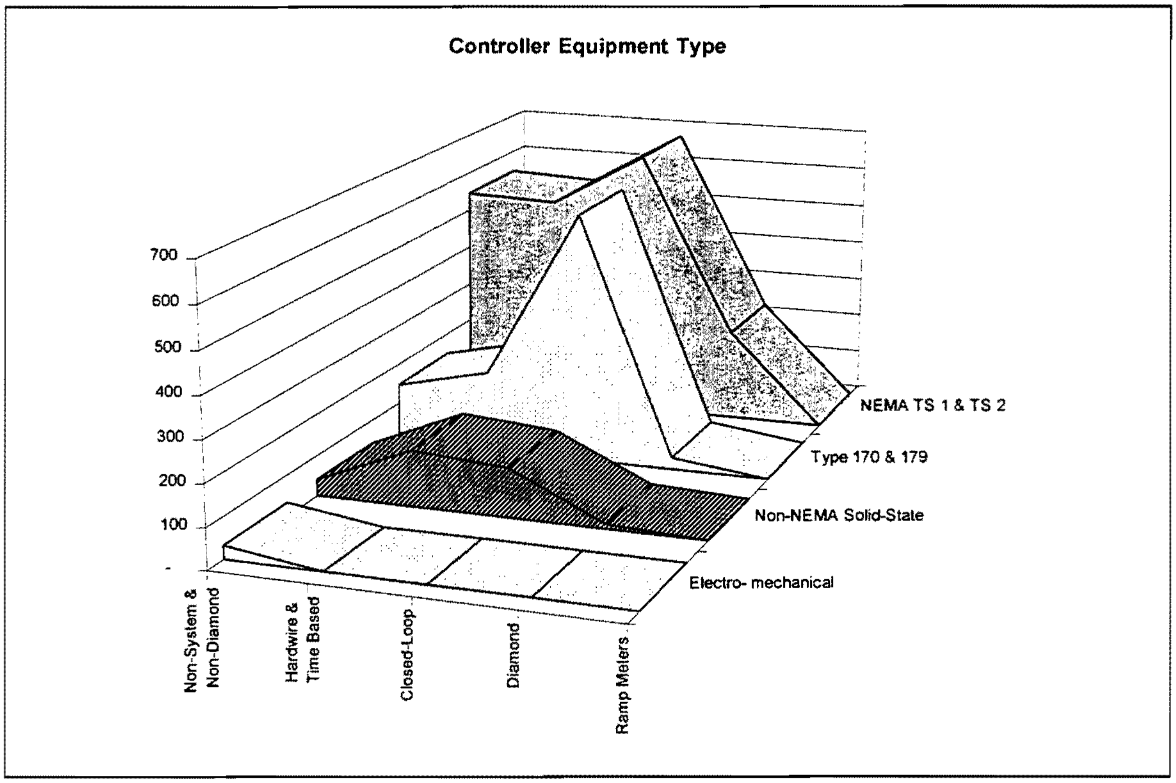

Figure 2.4. Cities: Controller Type Deployment

2.7.2 Traffic Control System Deployment

The distribution of systems by vendor is shown in Table 2.12.

Table 2.12. Cities: Distribution of Systems by Vendor

Vendor	Number of Signals	Percent of Signals
Safetran	402	28%
Sonex	174	12%
Multisonics	185	13%
Computran	121	8%
BiTrans	105	7%
Sperry	103	7%
IIM	92	6%
Concurrent	70	5%
Naztec	64	4%
Eagle	56	4%
Kentronics	29	2%
Econolite	25	2%
Total	1,426	100%

Table 2.13 summarizes the deployment of traffic signal systems within cities that responded to the survey.

Table 2.13. Cities: Traffic Signal System Development Summary

District	Number of Intersections in Systems	Vendor	System Date	Number of Intersections
Amarillo	151	Concurrent	Mar - 92	70
		Eagle	Jun - 90	56
		Econolite	Jun - 86	25
Austin	402	Safetran	Aug - 87	402
Bryan	29	Kentronics	Apr - 92	5
		Kentronics	Sep - 91	2
		Kentronics	May - 89	9
		Kentronics	May - 89	13
Dallas	382	BiTrans	Jun - 94	105
		Sonex	Jun - 93	174
		Sperry	Jun - 82	103
Ft. Worth	185	Multisonics	Jun - 87	140
		Multisonics		32
		Multisonics		6
		Multisonics		7
Lubbock	123	Naztec	Mar - 94	2
		Computran	Dec - 82	121
Richardson	92	IIM		92
San Angelo	62	Naztec	Aug - 91	25
		Naztec	Aug - 91	24
		Naztec	Jul - 93	13

2.8 Vendor Survey

In addition to providing customer lists pertaining to deployment of products, the vendors supplied various cut-sheet descriptions and functional specifications relevant to their products. Common features of closed-loop systems included:

- Uploading and downloading of data,
- Clock setting and synchronization,
- Daylight savings adjustments,
- Special function commands,
- Traffic responsive selection parameters,
- MOE sampling and estimation,
- Other traffic signal local controller functionality typically equivalent to NEMA TS I (e.g., min. green, red clearance, max. 1 and 2, min. gap, max. gap, phasing sequence definitions),
- Displays of intersection operation,
- Operator interface based on a graphical user interface,

- Error checking,
- Reporting, and
- Security.

Because there are NEMA standards for local controllers and because there are generally accepted implementations of Type 170 controllers, the functional capabilities of the vendor systems is less different than their user interfaces. In fact, there is almost no commonality among vendors regarding:

- Database structures and data entry,
- "Look and feel" of the graphical user interfaces (GUIs), and
- Specific displays relevant to intersection graphics, reports, and alarms.

Further, the products vary considerably with regard to use of operating systems and incorporation of "standard" PC based software (like spreadsheets). Discussions with some vendors indicate there is also a variety of software represented in the source code. The predominate languages are Basic and C.

With the exception of Type 170 systems, most of the closed-loop systems work with a limited number of types of local controllers. This is because the database mapping within the local controllers is typically considered proprietary information by suppliers, and they are generally not willing to release the information to competitors.

Many of the systems that interface with local controllers offer limited functionality with regard to other transportation functionality (such as camera control, variable message sign communications, and automatic vehicle identification).

3. TASK B: ADVISORY COMMITTEE

3.1 Introduction

The objective of Task B is to provide a forum for developing a consensus among users, vendors, and system integrators with regard to a multi-vendor environment for traffic controllers.

The communications and functionality consensus process that has evolved throughout this project is one that involves NEMA (National Electrical Manufacturers Association) representatives, the FHWA, and user input.

3.2 Background

Historically, the national communications and functionality consensus process began in 1992. NEMA traffic control equipment manufacturers began to formulate a National Transportation Communications for ITS Protocol (NTCIP) shortly after finalizing the TS 2 traffic control hardware standard. Among other considerations, TS 2 Standards addressed communications between equipment components within the cabinet (1). However, these standards did not pertain to communications protocols between traffic signal local controllers and other devices external to the cabinet.

As NEMA's discussions proceeded, the FHWA sponsored a Signal Manufacturers Symposium in Washington, D.C. in May 1993. The participants included NEMA members, the FHWA, states, cities, and other industry representatives. Dr. Seymour from TTI attended the meeting serving as one of three FHWA selected facilitators. The conclusion of the Symposium was to identify five priority issues for action (2). They were as follows.

1. Development of a communications standard.
2. Designation of the local controller as a "field processor" for various control applications.
3. Simplified operations and maintenance of traffic signal control equipment.
4. Improved procurement practices.
5. Deployment options with identified funding.

These issues were consistent with published objectives for ITS and also consistent with prior FHWA reports on the following related topics.

- Report on *Operation and Maintenance of Traffic Control Systems* (3).

- Expert panel report on *Traffic Control Systems Operations and Maintenance* (4).

- Report on *Traffic Control Systems Operations and Maintenance - A Plan of Action* (5).

Significant progress for developing a publicly available NTCIP occurred during 1994 and the first half of 1995. For almost two years, the Technical Committee of the NEMA Traffic Control Systems Section worked closely with representatives of the May 1993 Signal Manufacturers Symposium Steering Committee to facilitate definition of the protocol. In May 1994 at the recommendation of the Symposium Steering Committee, FHWA asked Oak Ridge National Laboratory (ORNL) to evaluate the work-in-progress draft protocol definition. As a result, ORNL retained a consultant, Opus One, to review the draft and to search for software sources to support the NTCIP. Opus One's conclusion was that no suitable software was available and that it would be cost effective to develop the required software.

From June 1994 through December 1994, the NEMA Technical Committee refined the NTCIP protocol definition so that it was roughly 90% complete. Concurrently, Oak Ridge National Laboratory initiated a contract with Opus One for development of NTCIP software, and the NEMA Technical Committee distributed the draft NTCIP for widespread informal review and comment.

Then in February 1995, FHWA sponsored a national NTCIP Workshop in Reston, Virginia to review the progress of the NTCIP. Thirty-nine individuals who had a stake in the protocol were invited to work on issues in three NTCIP related areas: Signal Operations, Freeway Management, and Systems Integration.

The groups were asked to consider the following issues with respect to each of the NTCIP areas (6):

Definitions
- Messages Types
- Data Types

Address Registration
- Requirements
- Scope
- Authority

Message Registration
- Requirements

Scope

Authority

Addressing Schemes

Protocol Implementation Conformance Statement

Compliance Testing and Certification

The conclusion of the Reston meeting was as follows:

- Interoperability should be a goal of the NTCIP, not just a communications framework.
- Marketing needs to be done to ensure user buy-in.
- The Internet Communications Protocol (IP) should be considered in place of X.25.
- A Steering Group should be formed to develop an NTCIP implementation plan and guide its deployment.

3.3 NTCIP Steering Group

Subsequently, an NTCIP Steering Group was formed. Dr. Seymour with TTI was appointed as its chair. Participation by Dr. Seymour in this Steering Committee has provided a forum for the development of a consensus among users, vendors, and system integrators with regard to a multi-vendor environment for traffic controllers as described in Task B.

Sections 3.3.1 -3.3.3 describe the goals and objectives of the Steering Group and identify the Steering Group members (7).

3.3.1 Goal of NTCIP Steering Group

Through the Steering Group's expertise and its interaction with other agencies, expedite the first implementation of the NTCIP; facilitate extension of the NTCIP Specification to other ITS areas; and establish a mechanism for long term ownership and maintenance of the standard beyond the first implementation.

3.3.2 NTCIP Steering Group Objectives

1. Identify issues requiring Steering Group input relevant to the first implementation of the NTCIP.
2. Initiate a consensus process for adoption of NTCIP as a national standard for ITS applications.
3. Establish a mechanism for long term ownership and maintenance of the standard beyond the first implementation. Identify an agency willing and capable to assume this role.

4. Develop a roadmap of action items to support the goal of the NTCIP Steering Group.

5. Identify priority ITS areas for extension of the NTCIP, and develop an action plan to accomplish this objective.

6. Develop an outreach program to key stakeholders to promote acceptance and implementation of the NTCIP.

3.3.3 Steering Group Members

- *Paul Bell*, TRANSYT Corporation (representing NEMA)
- *Rick Denney*, Barton-Aschman Associates (systems integrator)
- *Bruce Eisenhart*, Loral Federal Systems representing the National ITS Architecture process
- *Michael Forbis*, Washington State DOT
- *Robert Gottschalk*, Florida State DOT
- *Anson Nordby*, City of Los Angeles DOT
- *Tim Pagano*, State of Virginia DOT
- *Raman Patel*, I-95 Corridor Coalition
- *Chuck Perry*, State of California DOT
- *Al Santiago*, Federal Highway Administration
- *Ed Seymour*, Texas Transportation Institute representing TxDOT
- *Ken Vaughn*, Farradyne Systems (systems integrator)

3.4 References

1 *NEMA Standards Publications No. TS 2-1992, Traffic Controller Assemblies*, National Electrical Manufacturers Association, Washington, D.C., 1992.

2 *Proceedings of the Signal Manufacturers Symposium*, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., May 12-13, 1993.

3 Federal Highway Administration Office of Program Review, *Operation and Maintenance of Traffic Control Systems*, U.S. Department of Transportation, Washington, D.C., Sept. 1990.

4 Federal Highway Administration, *Traffic Control Systems Operations and Maintenance, Expert Panel Review*, U.S. Department of Transportation, Washington, D.C., Mar. 10, 1992.

5 Federal Highway Administration, *Traffic Control Systems Operations and Maintenance, A Plan of Action*, U.S. Department of Transportation, Washington, D.C., Nov., 1992.

6 ANSTEC, Inc., "National Traffic Control ITS Communications Protocol (NTCIP) Workshop Results" (Reston, Virginia meeting minutes), Fairfax, Virginia, Feb., 1995.

7 Ed Seymour, "NTCIP Protocol Steering Group, May 1, 1995 Meeting Minutes", U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., May, 1995.

4. TASK C: PROBLEMS OF A MULTI-VENDOR ENVIRONMENT

4.1 Introduction

The objective of Task C is to identify, analyze, and classify issues associated with the existing and evolving multi-vendor environment.

4.2 Background

Typical closed-loop deployment scenarios are shown in Figure 4.1. However, with advances in technologies, especially with regard to communications, and with increased emphasis on ITS service delivery, implementations of closed-loop control are becoming more complex.

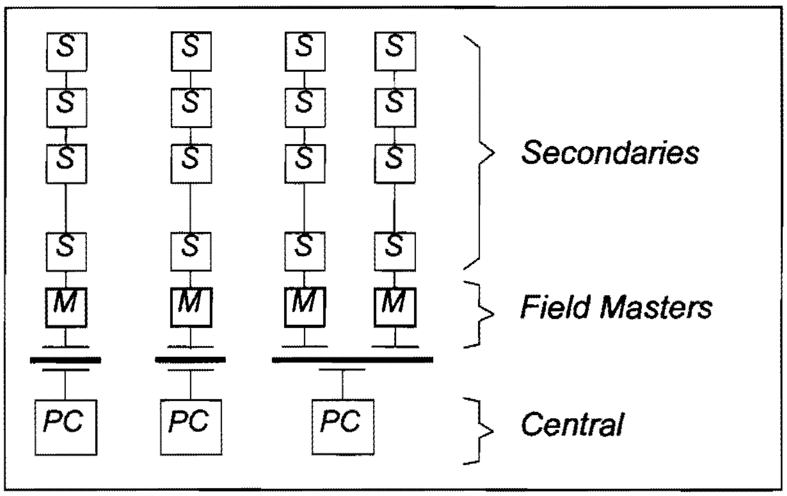

Figure 4.1. Typical Closed Loop Scenario

Figure 4.2 illustrates a deployment scenario utilizing various communications paths and incorporating functionality with devices other than traffic signals. This scenario is patterned after an example in the *National Traffic Control / ITS Communications Protocol, Working Draft for Committee Reference* (1). The NEMA sponsored Protocol Committee developing this "National Traffic Control" communications protocol considers Figure 4.2 an example of network configurations likely to be implemented in the future. That is, multiple devices with multiple functionality will be linked by a variety of communications media.

In Figure 4.2, a coaxial network interconnects three "central" computers which control and monitor various transportation subsystems. The subsystem on the left in this figure is connected to traffic signal controllers and variable message signs. The middle subsystem is connected to a field master which in turn is connected to other controllers and a variable message sign. The subsystem on the right is connected to a field processor which communicates with traffic signal controllers, cameras, and variable message signs.

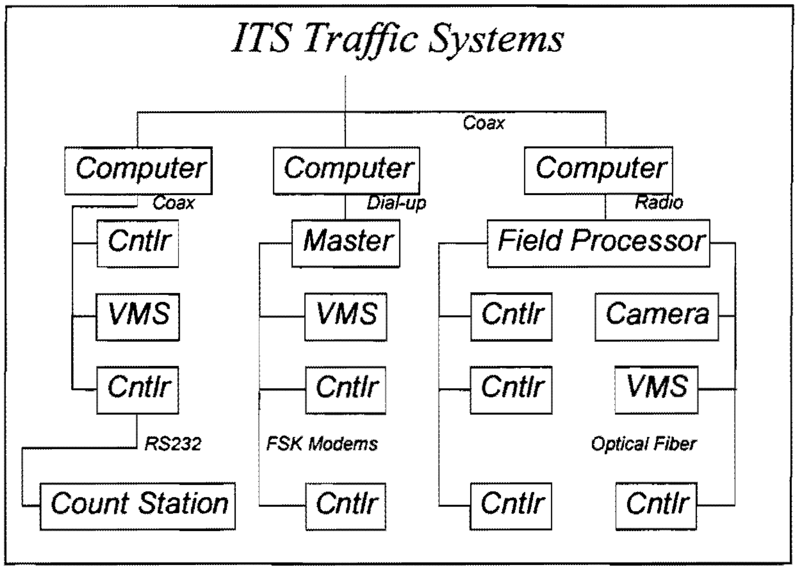

Figure 4.2. Evolving ITS Closed-Loop Scenario

4.3 Survey Results

In 1994, a deployment survey questionnaire was mailed to TxDOT districts and to selected Texas cities. Results pertaining to deployment are contained in Chapter 2.

In addition to deployment data, the questionnaire solicited information regarding traffic system features. The data in Table 4.1 and Table 4.2 lists the traffic system features "most important" to TxDOT Districts and to selected Texas cities. The data in Table 4.3 and Table 4.4 list the traffic system features "most needing change" as suggested by these TxDOT districts and Texas cities.

The items mentioned in these tables are consistent with published objectives for ITS and also consistent with prior FHWA reports on the following related topics.

- Report on operation and maintenance of traffic control systems (2).
- Expert panel report on traffic control systems operations and maintenance (3).
- Report on an action plan for traffic control systems operations and maintenance (4).

Table 4.1. TxDOT Districts' Traffic System Feature Preferences

District	# System Inter.	Most Important Features Desired In A Traffic Signal System				
Amarillo	0	Dependability	Menu driver operation in controllers	Common user interface	Common Modem protocols for all controllers	User friendly software
Atlanta	0	User Friendly				
Brownwood	13	Reliability	Versatility	Ease of use	Standardization	
Childress	7	Synchronization	Traffic response	Monitoring from remote locations	Detection	Flexibility or user friendly
Corpus Christi	69	Real-time Displays	Real-time system displays	Upload Download Timer & System Data	True Network compatibility	Arterial performance feedback: i.e., split usage & green band display
Dallas	48	Timer meeting specifications	Signal cabinet meeting specifications	Working detector loops	Presence of interconnect cable	Dial-up telephone access to Master
Houston	16	Responsive & time-of day operation	Network compatibility	Real time intersection & system displays	User friendly interface	Off the shelf parts
Lubbock	0	Reliable coordination & synchronization	Remote timing changes by operator	Side street actuation not interfering with coordination		
Lufkin	57	High speed communications for primary & secondary links	Common interface for the user	Capability to interchange controller brands within systems	High resolution graphics with user defined displays	Network compatibility & multi-tasking
Odessa	0	Compatibility with other systems	Computer / Modem access to all controllers in system	Full range of diagnostics		
Paris	13	User Friendly	Common User Interface	Intersection display - Real Time	Arterial displays - Real Time	Traffic Responsive on street Control
San Angelo	23	Progression	Minimum Delays	Easy to program and make changes	Minimum Accidents	
Tyler	16	Ability to upload & download data remotely	Ability to monitor malfunctions	Easy to program and set up	Little or no maintenance on software and hardware	Reliable Communications
Wichita Falls	27	NEMA configuration	Remote computer program operation			
Yoakum	0	User friendly	Software / program backup system	Real-time capability	Troubleshooting capability from central office	Report generation

Table 4.2. Texas Cities' Traffic System Feature Preferences

City	# System Inter.	Most Important Features Desired In A Traffic Signal System				
Amarillo	151	User Friendly	Product reliability / integrity	Manufacturer / distributor support	Downward compatible (older equipment work with newer software)	Able to update controllers and software at minimal cost
Austin	402	Open architecture	Multitasking	Third party software	Remote accessibility	Varying levels of security access
Bryan	29	Ability to utilize multiple timing plans	Ability to change mode of operations	Auto-coordination	Master controller with the ability to be a master or secondary by turning a bit on or off	Real time display
Dallas	382	Monitoring of intersection status & communications	Alarms	Database control of controller timings	Report generation of intersection history	Remote access to system
Ft. Worth	185	All controllers must be able to control ANY type of intersection	The ability to transmit local and coord. timing changes to controller from central	The ability to monitor each controller for equipment malf. & correct coord.	The ability to upload from the local controller reports of failures, count data, etc.	The ability to adopt the controller or central for new features
Lubbock	123	User Friendly	Flexibility	Compatibility		
Richardson	92	Adequate Staff	Accurate time-base (clocks set to WWV time standard)	Lead / Lag left-turn phasing	Minimum of 16 plans with 3 offsets and splits per plan	Minimum of 20 day plan capable of overriding a standard (or "normal") day plan based on an annual calendar
San Angelo	62	Effective, proper signal display	Good phasing and timing plans	Flexible, state of the art controllers	Reliable system communications	Reliable physical hardware

Table 4.3. TxDOT Districts' Traffic System Feature Change Preferences

District	# System Inter.	List Of Features That You Would Change Or Add To Your Present Traffic Control System				
Childress	7	Monitoring capabilities	Hardware interconnect	Loop detection	Software upgrade	Pedestrian movement of left-hand turns
Corpus Christi	69	Multi level security for users	Quality reports that are flexible and user friendly	More information on Real-time display	Smaller upload - download blocks	Record locking instead of file locking on shared files
Dallas	48	Add telephone line to each Master	More information at the central			
Houston	16	Network capable	Other ways to calculate splits	Pedestrian override & coordination	Transition time set by phase	Ability to change recall functions
Lufkin	57	Econolite - rework menu & depart from older style system	Econolite - expand user capabilities in area of real-time displays	Naztec - provide option on connection (direct or modem)	Naztec - import signal timing files w/o exiting to utilities	
Odessa	0	Closed loop system in several locations				
San Angelo	23	Actuation	Closed loop system	Subsystem coordination	Emergency vehicle preemption	Build main lanes
Tyler	16	More reliable way to communicate than modems and leased phone lines, but not the expense of fiber optics	A universal software such as Sonex for system control			
Wichita Falls	27	MIN 2 - on TOD Command	GAP 2 - on TOD Command			

Table 4.4. Texas Cities' Traffic System Feature Change Preferences

City	# System Inter.	List Of Features That You Would Change Or Add To Your Present Traffic Control System				
Amarillo	151	Dual Coordination (Eagle has it - Econolite doesn't)	Quicker/smoother transition (Econolite has - Eagle doesn't)	Allow individual intersection grouping (be able to flash or run free individual controllers when calling for a particular pattern)		
Austin	402	No response				
Bryan	29	Add the ability of software to utilize system detection data to create graphs to show traffic changes	Add the ability to make changes in the coordinated data in the controller and the controller software be able to refigure data			
Dallas	382	Maintenance log via lap top computer to central				
Ft. Worth	185	No response				
Lubbock	123	Video surveillance	Radio station	Backup capability		
Richardson	92	The reliability of our clock is inadequate	Having 4 lead / lag combinations instead of 16 limits our plans	Plan transition should not skip phases or hang in phases	Our current system software should monitor more then flash & preempts.	Our communication throughout should be increased from 9600 band to 19.2 K band on CATV
San Angelo	62	On 5 section left turn heads, I would like to drive the ball indications with overlaps, to increase display options	I would improve the physical accessibility of many controller cabinets			

4.4 Problems of Multi-Vendor Environment

Sections 4.4.1-4.4.6 describe issues relevant to the multi-vendor environment. They are based on the reports cited in references (2), (3), and (4) and incorporate the survey results defined in Section 4.3. The issues are structured by category in these sections. Following each category are issue statements with a few comments/questions that exemplify the concerns pertinent to each issue.

4.4.1 Acquisition Category

Acquisition issues relate to the specification and procurement of traffic systems and their components. Factors involved in acquisition of closed-loop systems include the following issues.

- Specification Complexity

  This issue includes hardware, software, and their relationship to the infrastructure. Can agency staff write the specifications or will consultants be hired? What kind of investment in dollars, time, and staff resources are required to develop specifications?

- Procurement Procedures

  Are there appropriate procurement procedures available for purchase of the products (e.g., low bid, catalog purchases, competitive proposals)? Can compliance to the specifications be assured?

- Litigation

  Given the specification and procurement processes, high likely is the organization to be legally challenged on the outcome of the procurement? What are the impacts of the challenge (whether successful or unsuccessful)?

- Acquisition Time Period

  Is the entire specification and procurement process likely to be completed in a reasonable time frame? What are the expected costs associated with delays?

4.4.2 Deployment Category

Deployment issues relate to cost and timeliness of installation/activation and to the existing investment in deployed traffic systems in TxDOT districts. These issues also impact city deployment where there is a need to interface district and city operations.

- Compatibility with Existing Infrastructure

  Is the system compatible with existing infrastructure? Does it have equal or better performance/maintenance characteristics than existing deployed infrastructure?

- Installation and Activation

  Are the installation and activation processes straightforward? Can they be effectively managed? How likely are they to experience delays and complications? Are change orders likely?

4.4.3 Operations Category

Operational considerations include:

- Functionality

  Does the equipment provide the appropriate functionality? For instance, are the appropriate NEMA features supported?

- Safety

  Are there any issues which relate negatively to safety of operation? Is there an appropriate fail-safe strategy?

- Security

  Is there adequate security to restrict unauthorized access to the system? Are appropriate audit trails maintained to track changes to the system?

- Programming Of Features

  Is it difficult to invoke desired functionality (both in the field and in control facilities)? Are the user interfaces consistent? Are the user interfaces intuitive?

- Staffing

  What kind of investment must be made to train staff? Can continuing education be effectively delivered? Can the organization pay an appropriate (market based) salary to employ individuals capable of operating and maintaining the systems? What career paths are available to encourage long term employment of trained staff?

- Standardization

  Is the equipment and software standard? Are similar products available in the marketplace?

- Maintainability

  Can the equipment be expeditiously maintained? Are spares readily available? Are there multiple vendors for the products? Are logs adequate to assist in repair operations?

- Reliability

  Is the equipment and software reliable? Will it be running correctly without failure most of the time?

- Multi-Jurisdictional Aspects

  Can the systems be configured to allow multiple jurisdictions to exercise control where there is a need?

4.4.4 Technology Category

Technology issues include:

- Obsolescence

  Is the system likely to be obsolete in the near future?

- Expandability

  How difficult and/or costly is the addition of functionality to the system?

- Communications

  Will the system be compatible with evolving communications efforts like NEMA's National Transportation Communications for ITS Protocol (NTCIP) (5)? What kind of network configurations are supported?

4.4.5 Funding Category

Issues relevant to funding include the following.

- Capital Costs

  Are the capital costs appropriate? Is capital funding available in the near term?

- Operations Costs

  Are operating funds available in the near term? Can all operating costs be funded (including staffing, training, materials, and equipment)? What level of service is likely to be provided given the expected operating funding? Could a less costly implementation be pursued that would deliver an appropriate level of service per dollar invested?

- <u>Private Sector Funding</u>

  Are private sector funds available or likely to be leveraged through these investments?

- <u>ITS Cost Impacts</u>

  As ITS user services become deployed, are these closed-loop systems likely to assist or hinder the ITS deployment process with respect to costs?

4.4.6 Impacts Category

Issues relevant to benefits include the following.

- <u>Clean Air Act</u>

  Will deployment assist with mitigation of pollutants consistent with Clean Air Act Amendment guidelines?

- <u>ITS Architecture and Services</u>

  Is a closed loop system consistent with the National ITS Architecture? As ITS user services become deployed, are these closed-loop systems likely to assist or hinder the ITS deployment process with respect to user services?

- <u>Control Strategies</u>

  Will closed-loop systems promote or impede deployment of new control strategies [such as OPAC (Optimization Polices for Adaptive Control) (<u>6</u>) and SCATS (Sydney Co-Ordinated Adaptive Traffic System) (<u>7</u>)]?

4.5 Summary

The following list summarizes the issues identified in Section 4.4.

- Acquisition
  - Specification Complexity
  - Procurement Procedures
  - Litigation
  - Acquisition Time Period
- Deployment
  - Compatibility with Existing Infrastructure
  - Installation and Activation
- Operations

- Functionality
  - Safety
  - Security
  - Programming Of Features
  - Staffing
  - Standardization
  - Maintainability
  - Reliability
  - Multi-jurisdictional Aspects
- Technology
  - Obsolescence
  - Expandability
  - Communications
- Funding
  - Capital Costs
  - Operations Costs
  - Private Sector Funding
  - ITS Cost Impacts
- Impacts
  - Clean Air Act
  - ITS Architecture and Services
  - Control Strategies

4.6 References

1 Federal Highway Administration, *Traffic Control Systems Operations and Maintenance, A Plan of Action*, U.S. Department of Transportation, Washington, DC, Nov., 1992

2 Federal Highway Administration Office of Program Review, *Operation and Maintenance of Traffic Control Systems*, U.S. Department of Transportation, Washington, DC, Sept., 1990.

3 Federal Highway Administration, *Traffic Control Systems Operations and Maintenance, Expert Panel Review*, U.S. Department of Transportation, Washington, DC, Mar. 10, 1992.

4 Federal Highway Administration, *Traffic Control Systems Operations and Maintenance, A Plan of Action*, U.S. Department of Transportation, Washington, DC, Nov., 1992.

5 National Electrical Manufacturers Association Traffic Control Systems Section, *National Traffic Control / ITS Communications Protocol, Working Draft for Committee Reference*, National Electrical Manufacturers Association, Washington, DC, May, 1994.

6 Nathan Gartner, "OPAC: A Demand-Responsive Strategy for Traffic Signal Control". In *Transportation Research Record 906, Urban Traffic Systems*. Transportation Research Board, Washington, DC, 1983.

7 *Volume 5, The AWA SCATS System*. AWA Traffic Systems America, Inc., Okemos, Michigan, 1992.

5. TASK D: DEVELOP COMMUNICATIONS STANDARDS

5.1 Introduction

The objective of Task D is to define a messaging standard which incorporates the features of existing local controllers from various manufacturers and permits the addition of evolving features which may be added to local controllers as operational strategies evolve.

The evolution of operational strategy and technology is meant to include: the Advanced Transportation Controller (ATC), further deployment of NEMA TS 2 standards, delivery of ITS services, ITS National Architecture efforts, NEMA communications initiatives, and adaptive controller system strategies (for example: OPAC [Optimized Policies for Adaptive Control]).

The most appropriate communications choice for TxDOT should accommodate developing trends and mitigate issues associated with the existing multi-vendor environment.

During this project, the work effort has been to facilitate the development of a communications standard (NTCIP), including message definitions, that is accepted on a national basis by other infrastructure operators and for which equipment suppliers are building products. Such an approach should help lower capital and operating costs for TxDOT through increased competition by suppliers.

5.2 NTCIP

Specific objectives relevant to communications standards that have been emphasized in the National Transportation Communications for ITS Protocol (NTCIP) Standard development efforts are (1):

- Develop a design that is fully documented and that could serve as an "open standard."
- Keep communications separate from applications.
- Define a protocol that can be implemented.
- Allow multiple vendor's products shared use of the same communications path (connectivity).
- Share common functions between like products (interoperability).
- Enable development of "field processors" that are communications and control nodes in an IVHS network (not just local controllers).

5.2.1 Protocol Standards

The NEMA Traffic Control Systems Section made these comments relevant to the link and network layer models (2):

> . . . models were chosen because the communications requirements for traffic control and traffic management generally fall into two levels. These are referred to as *link level* and *network level* communications. At the link level, a communication protocol must deal with passing data between directly connected devices such as a traffic controller connected to an arterial master. At the network level, a protocol must deal with end-to-end oriented communications where data may have to pass through several intervening devices to reach its destination. For example, a telephone conversation passes through several switching stations before reaching the destination party. In a traffic control application, the scenario might be a central computer downloading a controller database through an arterial master.

The NTCIP design approach is based upon communications network models that have been designed for other non-transportation systems. Therefore, it is a goal for the protocol to conform to existing network methods and standards. The standards chosen for NTCIP include:

- HDLC - High Level Link Data Control (ISO 3309 and ISO 4335) at the link level (3) (4).
- X.25 - (ISO 8208 and ISO 8878) at the network level (5) (6) or IP (Internet Protocol) at the network layer (7).
- SNMP (Simple Network Management Protocol) at the application layer (8).

These standards are based on the seven layer ISO (International Organization for Standardization) network model (9). The seven layers of the ISO model are: physical, data link, network, transport, session, presentation, and applications.

Data transport	1.	physical
	2.	data link
	3.	network
	4.	transport
Data processing	5.	session
	6.	presentation
	7.	application

Briefly, these layers are defined as follows.

1. Physical: Defines how bits are transmitted are transmitted over a communications channel. Deals with mechanical and electrical interfaces.

2. Data link: Transforms information received over a channel into data "free" of transmission errors.

3. Network: Controls how packets of data are routed from source to destination.

4. Transport: Organizes data so that they can be efficiently passed to and from lower layers.

5. Session: Allows different equipment to establish dialogues.

6. Presentation: Manages the syntax and semantics of information.

7. Application: Concerned with file transfers and device access methods.

NTCIP uses four layers of the OSI model.

5.2.2 NTCIP Features

Key features of the standards supported by the NTCIP are as follows.

- Support for connection-oriented and connectionless services at the network layer.

- Support for connectionless services at the data link layer.

- A mechanism for acknowledged and unacknowledged transfers.

- An error detection algorithm scheme that ensures the probability of accepting a bad frame is exceedingly small.

- A structured approach that supports transmission media and data rate independence.

- An addressing scheme that is extensible to cover existing and future requirements.

- Support for variable message or frame length structures.

5.2.3 NTCIP Application Design

At the application level, the NTCIP has several key design objectives.

Network configurations other than PC master controller (e.g., multiple arterial masters connected simultaneously to a single host, etc.), include:

- Transfer of data between ITS field processors.
- Transfer of setup information to/from secondary devices in the controller cabinet (e.g., to/from detector amps).
- Uploading of collected data from devices connected to the TS 2 Port 1 channel 13 (e.g., a stand alone vehicle classifier).
- Uploading of application specific event data from the TS 2 Malfunction Management Unit (MMU).
- True peer-to-peer message transfers where any device can communicate directly with any other device.

Table 5.1 illustrates that the NEMA NTCIP application layer accommodates typical functionality associated with traffic signal local controllers in the Dallas area. The table lists the functionality of NEMA TS 1, NEMA TS 2, Caltrans 170, and TxDOT local controllers. The last column defines the associated functionality of the NTCIP.

Table 5.1 Comparison of Features

COMPARISON OF FEATURES: CONTROLLER SPECIFICATIONS AND NTCIP

	FEATURE	TxDOT	NEMA TS 1	NEMA TS 2	Caltrans 170	NEMA NTCIP Protocol
Phase Data	Minimum Green	NEMA TS 1 (2.1; p. 1-24)	Range: 1-30 sec Increment: 1 sec (14.3.2.1; p. 60)	Range 1-255 sec Increment: 1 sec (3.5.3.1; p. 54)	Range: 0-255 sec Increment: 1 sec (Chapt. III; p. 28,33)	Range: 1-255 sec Increment: 1 sec A.4.C PHSE Object phseMinGm
	Passage Time	NEMA TS 1 (2.1; p. 1-24)	Range: 0-9 sec Increment: 0.25 sec (14.3.2.1; p. 60)	Range 0-25.5 sec Increment: 0.1 sec (3.5.3.1; p.54)	Range: 0-25.5 sec Increment: 0.1 sec (Chapt. III; p. 28,33)	Range: 1-25.5 sec Increment: 0.1 sec A.4.C PHSE Object phsePass
	Maximum 1	NEMA TS 1 (2.1; p. 1-24)	Range: 1-99 sec Increment: 1 sec (14.3.2.1; p.60)	Range 1-255 sec Increment: 1 sec (3.5.3.1; p.54)	Range: 0-255 sec Increment: 1 sec (Chapt. III; p. 28,33)	Range: 1-255 sec Increment: 1 sec A.4.C PHSE Object phseMax1
	Maximum 2	NEMA TS 1 (2.1; p. 1-24)	Range: 1-99 sec Increment: 1 sec (14.2.3.1; p. 60)	Range 1-255 sec Increment: 1 sec (3.5.3.1; p.54)	Range: 0-255 sec Increment: 1 sec (Chapt. III; p. 28,33)	Range: 1-255 sec Increment: 1 sec A.4.C PHSE Object phseMax2
	Maximum 3	YES (4.15.2; p. 10-24	Not Specified	Not Specified	Yes (Chapt. III; p. 28,33)	Not Specified
	Yellow Change	NEMA TS 1 (2.1; p. 1-24)	Range: 0-7 sec Increment: 0.25 sec (14.3.2.1; p.60)	Range 3-25.5 sec Increment: 0.1 sec (3.5.3.1; p. 54)	Range: 3.0-6.0 sec Increment: 0.1 sec (Chapt. III; p. 30,33)	Range: 3-25.5 sec Increment: 0.1 sec A.4.C PHSE Object phse YelChg
	Red Clearance	NEMA TS 1 (2.1; p. 1-24)	Range: 0-7 sec Increment: 0.25 sec (14.3.2.1; p. 60)	Range 0-25.5 sec Increment: 0.1 sec (3.5.3.1; p. 54)	Range: 0-25.5 sec Increment: 0.1 sec (Chapt. III; p. 30, 33)	Range: 0-25.5 sec Increment: 0.1 sec A.4.C. PHSE Object phseRedClr
	Walk	NEMA TS 1 (2.1; p. 1-24)	Range: 1-30 sec Increment: 1 sec (14.3.2.1; p. 60)	Range 0-255 sec Increment: 1 sec (3.5.3.1; p. 54)	Range: 0-255 sec Increment: 1 sec (Chapt. III; p. 33)	Range: 0-255 sec Increment: 1 sec A.4.C PHSE Object phseWalk
	Pedestrian Clearance	NEMA TS 1 (2.1; p. 1-24)	Range: 0-30 sec Increment: 1 sec (14.3.2.1; p. 60)	Range 0-255 sec Increment: 1 sec (3.5.3.1; p. 54)	Range: 0-255 sec Increment: 1 sec (Chapt. III; p. 33)	Range: 0-255 sec Increment: 1 sec A.4.C PHSE Object phsePedClr
	Added Initial	NEMA TS 1 (2.1; p. 1-24)	Range: 0-30 sec/act Increment: 0.125 sec (14.3.2.1; p. 60)	0-25.5 sec/act (3.5.3.1; p.54)	Range: 0-25.5 sec/act Increment: 0.1 sec (Chapt. III; p. 33)	Range: 0-255 sec Increment: 1 sec A.4.C PHSE Object phseAddIni

Table 5.1 Comparison of Features (continued)

COMPARISON OF FEATURES: CONTROLLER SPECIFICATIONS AND NTCIP

	FEATURE	TxDOT	NEMA TS 1	NEMA TS 2	Caltrans 170	NEMA NTCIP Protocol
Phase Data	Max. Variable Initial	NEMA TS 1 (2.1; p 1-24)	Fixed at 30 sec or Settable 0-60 sec w/1 sec increments (14.3.2.2b(1)(c); p.60)	Settable: 0-255 sec w/ 1 sec Increments (3.5.3.2.1b(1)(c); p. 54)	Initialized at 30 sec Range: 0-255 sec Increment: 1 sec (Chapt. III; p. 28, 30, 33)	Range: 0-255 sec Increment: 1 sec A.4.C PHSE Object phseMaxIni
	Time to Reduce	NEMA TS 1 (2.1; p. 1-24)	Linear Reduction Range: 1-60 sec Increment: 1 sec (14.3.2.1; p. 60)	Linear Reduction Range: 1-255 sec Increment: 1 sec (3.5.3.1; p.54)	Step function REDUCE GAP (in sec) REDUCE GAP EVERY (sec) (Chapt. III; p. 28,33)	Range: 0-255 sec Increment: 1 sec A.4.C PHSE Object phseTTR
	Time Before Reduction	NEMA TS 1 (2.1; p. 1-24)	Range: 1-60 sec Increment: 1 sec (14.3.2.1; p.60)	Range 1-255 sec Increment: 1 sec (3.5.3.1; p.54)	Function of INITIAL GREEN and REDUCE GAP EVERY (Chapt. III; p. 29)	Range: 0-255 sec Increment: 1 sec A.4.C PHSE Object phseTBR
	Minimum Gap	NEMA TS 1 (2.1; p. 1-24)	Range: 0-7.75 sec Increment: 0.125 sec (14.3.2.1; p. 60)	Range 0-25.5 sec Increment: 0.1 sec (3.5.3.1; p.54)	Range: 0-25.5 sec Increment: 0.1 sec (Chapt. III; p. 28, 32, 33)	Range: 0-25.5 sec Increment: 0.1 sec A.4.C PHSE Object phseMiniGap
	Pedestrian Recall	Yes (per phase) (4.10; p. 9-24)	Front Panel Entry (14.3.2.7; p.64)	Program Entry (3.5.3.7; p.57)	Yes (Chapt. IV; p. 40)	Yes A.4.C PHSE Object phseMask, bit 10
	Conditional Service	Yes (4.15.1; p. 10-24)	Not Specified	Yes (3.5.3.9; p. 57-58)	Yes (Chapt. IV; p. 51-52)	Yes A.4.C PHSE Object phseMask, bit 09
	Simultaneous Gap Out	Yes (4.15; p. 9-24)	Not Specified	Yes (3.5.5.2; p. 60)	Yes (Chapt. IV; p. 49)	Yes A.4.C PHSE Object phseMask, bit 08
	Dual Entry Phase	Yes (4.9; p. 9-24)	Not Specified	Yes (3.5.5.3; p. 60)	Yes (Chapt. IV; p. 41)	Yes A.4.C PHSE Object phseMask, bit 07
	Maximum Recall	Yes (per phase) (4.10; p. 9-24)	Front Panel Entry (14.3.2.5; p.64)	Program Entry (3.5.3.5; p.57)	Yes (Chapt. IV; p. 52)	Yes A.4.C PHSE Object phseMask, bit 06
	Minimum Recall	Yes (per phase) (4.10; p. 9-24)	Front Panel Entry (14.3.2.6; p.64)	Program Entry (3.5.3.6; p.57)	Yes (Chapt. IV; p. 40)	Yes A.4.C PHSE Object phseMask, bit 05
	Initialize in Red Clearance	NEMA TS 1 (2.1; p 1-24)	Yes (14.3.4.1; p. 67)	Yes (3.5.5.1; p. 60)	Not Specified	Yes A.4.C PHSE Object phseMask, bit 03

Table 5.1 Comparison of Features (continued)

COMPARISON OF FEATURES: CONTROLLER SPECIFICATIONS AND NTCIP

FEATURE		TxDOT	NEMA TS 1	NEMA TS 2	Caltrans 170	NEMA NTCIP Protocol
Phase Data	Initialize in Yellow	NEMA TS 1 (2.1; p. 1-24)	Yes (14.3.4.1; p.67)	Yes (3.5.5.1; p.60)	Yes (Chapt. IV; p. 42)	Yes A.4.C PHSE Object phseMask, bit 02
	Initialize in Min Green or Walk	NEMA TS 1 (2.1; p. 1-24)	Yes (14.3.4.1; p.67)	Yes (3.5.5.1; p.60)	Yes (Chapt. IV; p. 42)	Yes A.4.C PHSE Object phseMask, bit 01
	Red Revert	NEMA TS 1 (2.1; p. 1-24)	2-6 sec adjustable (14.3.4.4; p. 69)	2-6 sec adjustable (3.5.5.7; p. 65)	2.0-25.5 sec in 0.1 sec incr. (Chapt. III; p. 30, 33)	1-25.5 sec in 0.1 sec incr. A.4.D UNIT Object unitRedRev
	Number of Overlaps	8 (4.13; p. 9-24)	Min: 3 (14.3.7.1; p. 69)	4 (3.5.8; p. 68)	4 Overlaps and 2 Right-Turn Arrow Overlaps (Chapt. 1; p. 5)	16 A.4.D UNIT Object various olp objects
	Phase Omit	Yes (per phase) (p. 9-24)	Pedestrian Only (14.3.2.2; p. 62)	Pedestrian Only (3.5.3.2; p. 57)	Not Specified	Yes A.3.M Message 13

Table 5.1 Comparison of Features (continued)

COMPARISON OF FEATURES: CONTROLLER SPECIFICATIONS AND NTCIP

	FEATURE	TxDOT	NEMA TS 1	NEMA TS 2	Caltrans 170	NEMA NTCIP Protocol
Preemption	Number of Preempts	Min: 5 (p. 5-24)	Not Specified	6 (3.7; p.67)	2 railroad and 4 emergency vehicle preempts (Chapt. IV; p. 46-47)	Not defined
	Preempt Delay	Range 0-99 Increment: 1 sec (7.3: p. 19-24)	Not Specified	Not Specified	Yes (Chapt. III; p. 35)	Not Specified
	P.E. Minimum Green	Range 0-9 Increment: 1 sec (7.3: p. 19-24)	Not Specified	Not Specified	Not Specified	Not Specified
	P.E. Yellow	Range 3-9.9 Increment: 0.1 sec (7.3: p. 19-24)	Not Specified	Not Specified	Not Specified	Not Specified
	P.E. Red Clearance	Range 0-9.9 Increment: 0.1 sec (7.3: p. 19-24)	Not Specified	Not Specified	Not Specified	Not Specified
	Track Green	Range 0-99 Increment: 0.1 sec (7.3: p. 19-24)	Not Specified	Not Specified	Yes (Chapt. III; p. 35)	Not Specified
	Track Yellow	Range 0-9.9 Increment: 0.1 sec (7.3: p. 19-24)	Not Specified	Not Specified	Not Specified	Not Specified
	Track Red	Range 0-9.9 Increment: 0.1 sec (7.3: p. 19-24)	Not Specified	Not Specified	Not Specified	Not Specified
	Minimum P.E. Duration	Range 0-99 Increment: 1 sec (7.3: p. 19-24)	Not Specified	Not Specified	Not Specified	Not Specified
	Return Yellow	Range 0-9.9 Increment: 0.1 sec (7.3: p. 19-24)	Not Specified	Not Specified	Not Specified	Not Specified
	Return Red Clearance	Range 0-9.9 Increment: 0.1 sec (7.3: p. 19-24)	Not Specified	Not Specified	Not Specified	Not Specified

Table 5.1 Comparison of Features(continued)

COMPARISON OF FEATURES: CONTROLLER SPECIFICATIONS AND NTCIP

FEATURE		TxDOT	NEMA TS 1	NEMA TS 2	Caltrans 170	NEMA NTCIP Protocol
Coordination	Timing Plans	Min: 10 event plans (5.7.1; p. 16-24)	Not Specified	Min: 16 plans (3.6.2.1; p. 66)	9 control plans (Chapt. I; p. 6)	32 A.4.E Coor Object coorEntry
	Cycle Lengths	Min: 4 Rane: 30 to 200 sec Increment: 1 sec (4.17; p. 11-24)	Not Specified	Min: 1 per plan Rane: 30 to 255 sec (3.6.2.1.1; p. 66)	40 to 255 sec in 1 sec incr. (Chapt. V; p. 64)	Range: 0.. A.4.E Coor Object coorCycle
	Spilts	Min: 3 per cycle length (4.17; p. 11-24)	Not Specified	Min: 1 per phase per plan (0-100% or 0-255 secs) (3.6.2.1.2; p. 66)	1 per phase per plan (Chapt. VI; p. 64)	1 per phase per plan Range: 0.. Increment 1 sec coorPhse01 - coorPhse16
	Number of Offsets	1 per cycle/split Range: 0 to 200 seconds Increment: 1 sec (4.17; p. 11-24)	Not Specified	Min: 3 per plan (0-100% or 0-254 secs) (3.6.2.2; p. 66)	3 per timing plan (Chapt. V; p. 64)	8 per plan Range 0.. Increment 1 sec coorOff01 - coorOff08

5.3 Network Profile

The following table represents a profile of the messages typically being transported in existing traffic management systems.

Table 5.2. Network Profile

Transaction Type	Number of Messages	Message Size	Time Limit	BER	Freq	Loss Detection	Real Time	Seq/ Priority	Local/ Global
Fast control Acknowledge Primary to Secondary (camera)	2 (data, ack)	data<10 bytes, ack<5 bytes	0.1 sec	HDLC	0.1 sec	None	Yes	No/ Low	Global
Fast control Primary to Secondary (camera)	1	<10 bytes	N/A	HDLC	0.1 sec	None	Yes	No/ Low	Global
Medium control Primary to Secondary (sec by sec)	2 (request/ response)	both<10 bytes	40 ms	HDLC	1 sec	None	Yes	No/ High	Local
Slow control Primary to Secondary (timing plan)	2 (request/ response)	both<32 bytes	sec/ min	HDLC	60-600 sec	None	No	No/ High	Global
Fast Status Unsolicited Secondary to Primary	1	<16 bytes	N/A	HDLC	1 sec to 1 hour	None	Yes	No/ Low	Global
Fast Status Solicited Secondary to Primary	2	<5 bytes, <16 bytes	40 ms	HDLC	1 sec	None	Yes	No/ Medium	Global
Error Status Unsolicited Secondary to Primary	2 (request/ ack); maybe 3	100s of bytes	secs	HDLC	60-6000 sec	None	Yes	No/ Low	Global
Slow Status Secondary to Primary	2 (request/ response)	100s of bytes	secs	HDLC	30-6000 sec	None	Yes	No/ Medium	Global
Large Upload/ Download	3 way handshake	maybe very large	slow	HDLC	weekly/ monthly	None	No	Yes/ Low	Global
Small Upload/ Download	3 way handshake	<500 bytes	slow	HDLC	weekly/ monthly	None	No	Yes/ Low	Global

5.4 Monza: Prototype Implementation of NTCIP

As part of the software development process, FHWA is funding a prototype implementation of the protocol known as Monza.

5.4.1 Objectives and Scope of Monza

Monza will be a publicly available protocol implementation which can be used by traffic control system manufacturers to:

1. Provide a reference implementation of the NTCIP protocol which can be adapted (or used directly) as part of a traffic control system.

2. Explore the standard defined by the NTCIP protocol to find defects, problems, inconsistencies, and other protocol definition errors which would prevent smooth adoption and development of NTCIP-compatible traffic control systems.

3. Provide a test bed for networked traffic control systems using open protocols for potential future standardized telecommunications protocols and message formats.

4. Provide a test system which can be used to informally validate any other implementation of the NTCIP protocol by demonstration of interoperability with Monza.

5.4.2 Requirements

- Monza will be portable across a variety of machine architectures.

- Facilities will be included in Monza to assist in debugging and tracing.

- A simple hardware abstraction layer will be defined which is easily portable across operating system architectures.

- A simple operating system abstraction layer will be defined which is easily portable across other operating systems.

- All source code for Monza will be delivered in ANSI standard C.

- No assumptions can be made about a C run-time library for the production Monza.

- Monza will be entirely royalty-free and freely available.

- Monza will emphasize performance over memory utilization.

- Monza code will include standardized, built-in documentation.

5.4.3 Schedule

A demonstration of a functional Monza NTCIP prototype is scheduled for the TRB meeting in January 1996 in Washington, D.C.

5.5 References

1 National Electrical Manufacturers Association Traffic Control Systems Section, *National Traffic Control / IVHS Communications Protocol, Working Draft for Committee Reference*, ibid.

2 National Electrical Manufacturers Association Traffic Control Systems Section, *National Traffic Control / IVHS Communications Protocol, Working Draft for Committee Reference*, ibid. p. 3.

3 International Organization for Standardization, *ISO Standard 3309-1991, Data Communication - High Level Data Link Control Procedures - Frame Structure*, 1991.

4 International Organization for Standardization, *ISO Standard 4335-1991, Data Communication - High Level Data Link Control Procedures - Elements of Procedures*, 1991.

5 International Organization for Standardization, *ISO Standard 8208-1990, Information Technology - Data Communications - X.25 Packet Layer Protocol for Data Terminal Equipment*, 1990.

6 International Organization for Standardization, *ISO Standard 8878-1992 Use of X.25 Information Technology - Telecommunication and Information Exchange System - Use of X.25 to Provide the OSI Connection Mode Network Services,* 1992.

7 Douglas, Comer, *Internetworking with TCP/IP: Principle, Protocols and Architecture*, Prentice Hall, 1988.

8 Sidni Feit, *SNMP: A Guide to Network Management*, McGraw-Hill, 1995.

9 International Organization for Standardization, *ISO Standard 7498 Information Processing Systems - Open Systems Interconnection - Basic Reference Model*, 1984.

6. TASK E: DETERMINE INTEGRATION REQUIREMENTS

6.1 Introduction

The objective of Task E is to develop the criteria against which alternative multi-vendor system configurations can be evaluated.

Figures 6.1 and 6.2 illustrate the relative importance of various issues as solicited through the Task A survey. These figures are the result of classifying the responses according to the issues listed in Section 4.4. Few responses were observed that pertained to procurement and funding; the survey questions were focused on operations and deployed systems. It is noteworthy to observe that most of the responses identified the following three issues:

- functionality;
- user interface; and
- communications

For the purposes of the evaluation of alternatives identified in Task G, the following criteria weights will be used. They represent the relative opinions of those responding to the survey. For instance, functionality was roughly as important as user interface. Hence, ten points are assigned to functionality and ten to interface (five to local controller interfaces and five to central system interfaces).

- Functionality = 10;
- Local Interface = 5;
- Central Interface = 5;
- Communications = 5;
- Maintenance = 3; and
- Expansion = 3.

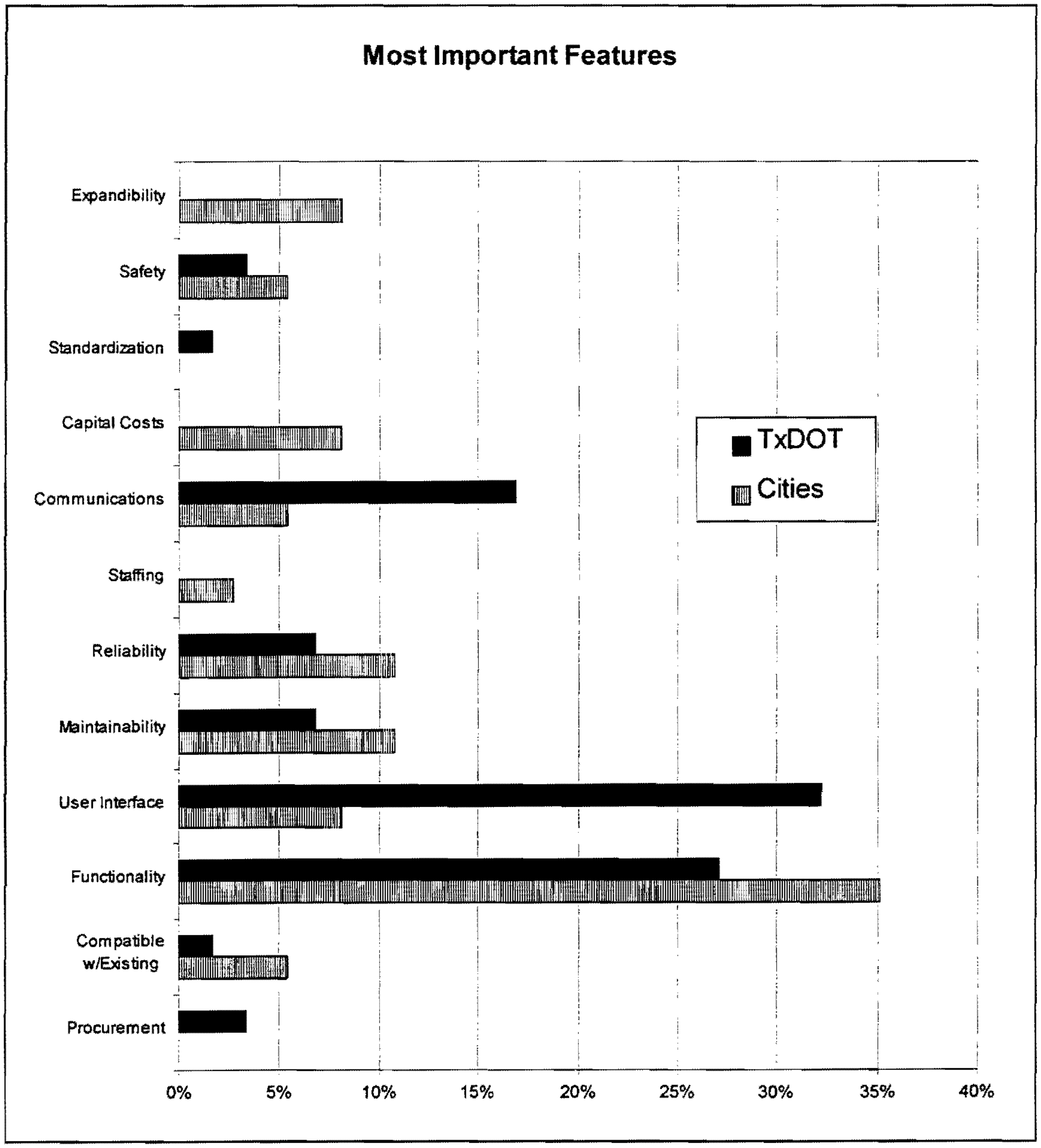

Figure 6.1. Most Important Traffic System Features

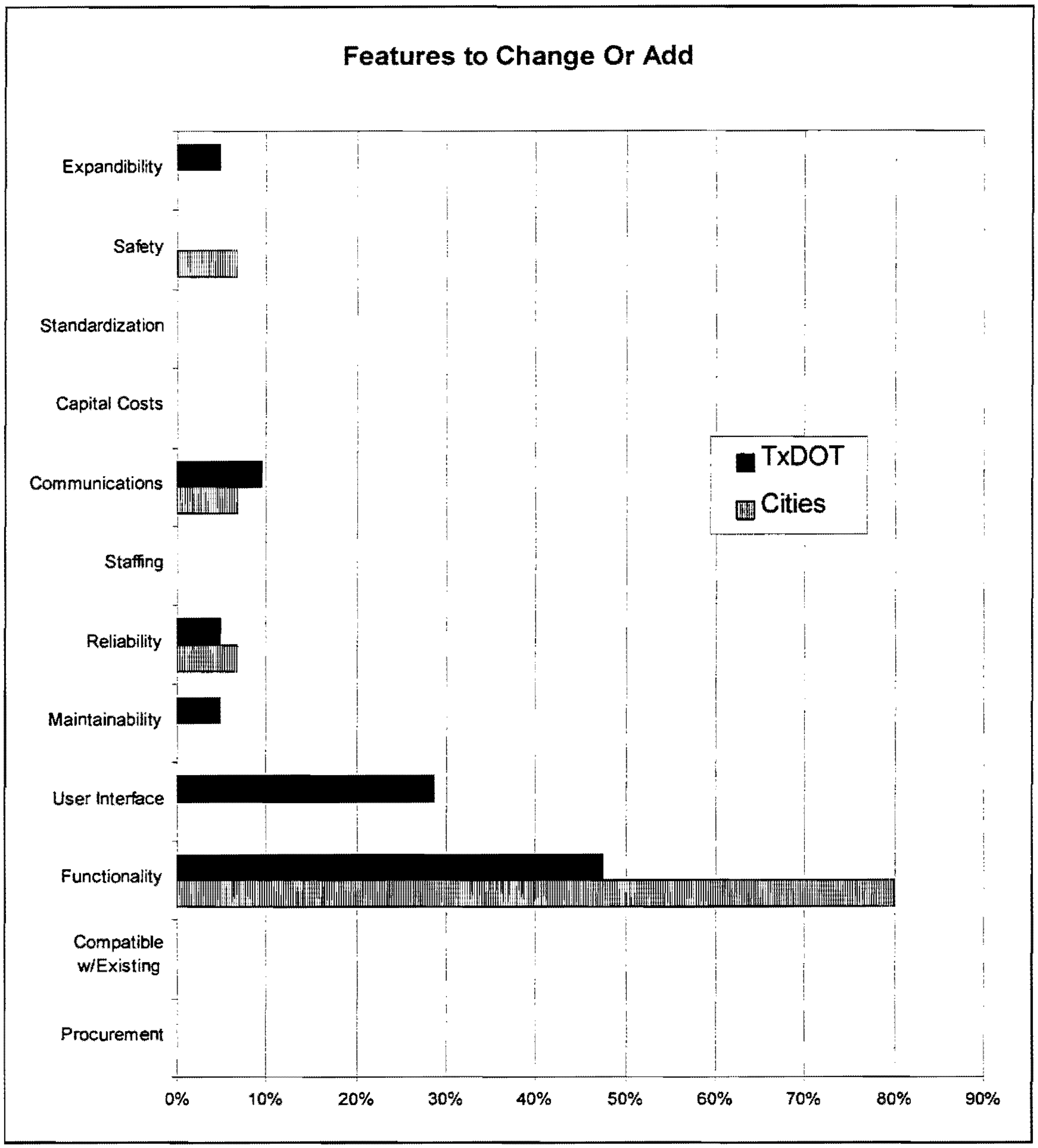

Figure 6.2. Preferred Feature Changes

7. TASK F: IDENTIFY ALTERNATIVE SYSTEM CONFIGURATIONS

7.1 Introduction

The objective of Task F is to identify alternative system configurations appropriate for TxDOT taking into consideration the existing deployment base in Texas.

7.2 System Component Alternatives

Figure 7.1 identifies alternative component choices for closed-loop systems with regard to communications protocol, local controllers, and central systems.

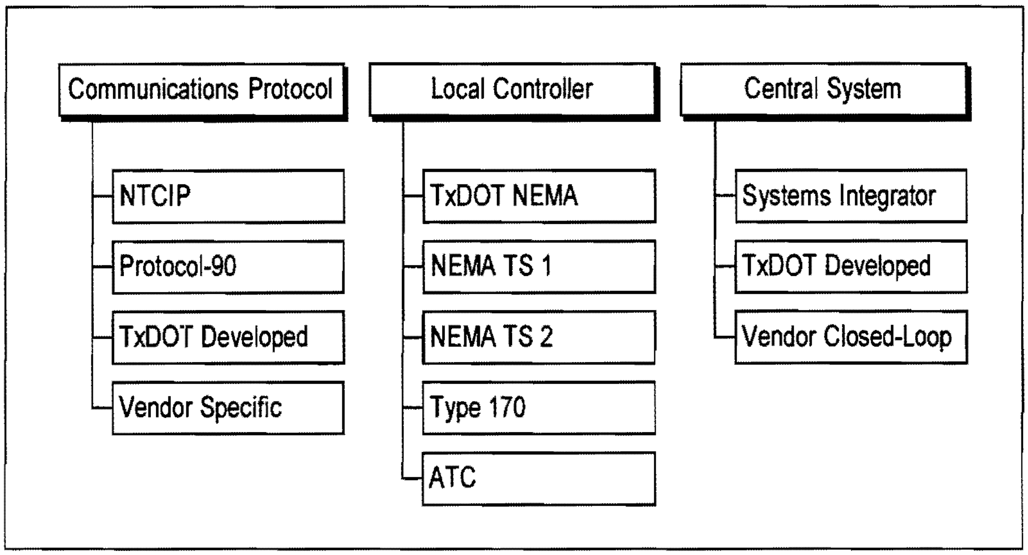

Figure 7.1. System Component Choices

Note: "TxDOT Developed" choices identified in the above illustration are not meant to imply that TxDOT would exclusively fund their development. Opportunities for joint development with other agencies are assumed.

Protocol-90 is a publicly available application layer definition. It is not a full communications protocol in the same sense as NTCIP.

There is only one ATC software set in the public marketplace.

7.3 System Configuration Alternatives

Table 7.1 lists the sixty combinations of system configurations that could be achieved by various arrangements of these system elements.

Table 7.1. Potential System Configurations

No.	Communications Protocol	Local Controller	Central
1	NTCIP	TxDOT NEMA	Systems Integrator
2	NTCIP	NEMA TS 1	Systems Integrator
3	NTCIP	NEMA TS 2	Systems Integrator
4	NTCIP	Type 170	Systems Integrator
5	NTCIP	ATC	Systems Integrator
6	NTCIP	TxDOT NEMA	TxDOT Developed
7	NTCIP	NEMA TS 1	TxDOT Developed
8	NTCIP	NEMA TS 2	TxDOT Developed
9	NTCIP	Type 170	TxDOT Developed
10	NTCIP	ATC	TxDOT Developed
11	NTCIP	TxDOT NEMA	Vendor Specific
12	NTCIP	NEMA TS 1	Vendor Specific
13	NTCIP	NEMA TS 2	Vendor Specific
14	NTCIP	Type 170	Vendor Specific
15	NTCIP	ATC	Vendor Specific
16	Protocol-90	TxDOT NEMA	Systems Integrator
17	Protocol-90	NEMA TS 1	Systems Integrator
18	Protocol-90	NEMA TS 2	Systems Integrator
19	Protocol-90	Type 170	Systems Integrator
20	Protocol-90	ATC	Systems Integrator
21	Protocol-90	TxDOT NEMA	TxDOT Developed
22	Protocol-90	NEMA TS 1	TxDOT Developed
23	Protocol-90	NEMA TS 2	TxDOT Developed
24	Protocol-90	Type 170	TxDOT Developed
25	Protocol-90	ATC	TxDOT Developed
26	Protocol-90	TxDOT NEMA	Vendor Specific
27	Protocol-90	NEMA TS 1	Vendor Specific
28	Protocol-90	NEMA TS 2	Vendor Specific
29	Protocol-90	Type 170	Vendor Specific
30	Protocol-90	ATC	Vendor Specific
31	TxDOT Developed	TxDOT NEMA	Systems Integrator
32	TxDOT Developed	NEMA TS 1	Systems Integrator
33	TxDOT Developed	NEMA TS 2	Systems Integrator
34	TxDOT Developed	Type 170	Systems Integrator
35	TxDOT Developed	ATC	Systems Integrator
36	TxDOT Developed	TxDOT NEMA	TxDOT Developed
37	TxDOT Developed	NEMA TS 1	TxDOT Developed
38	TxDOT Developed	NEMA TS 2	TxDOT Developed
39	TxDOT Developed	Type 170	TxDOT Developed
40	TxDOT Developed	ATC	TxDOT Developed
41	TxDOT Developed	TxDOT NEMA	Vendor Specific
42	TxDOT Developed	NEMA TS 1	Vendor Specific
43	TxDOT Developed	NEMA TS 2	Vendor Specific
44	TxDOT Developed	Type 170	Vendor Specific
45	TxDOT Developed	ATC	Vendor Specific
46	Vendor Specific	TxDOT NEMA	Systems Integrator
47	Vendor Specific	NEMA TS 1	Systems Integrator
48	Vendor Specific	NEMA TS 2	Systems Integrator
49	Vendor Specific	Type 170	Systems Integrator
50	Vendor Specific	ATC	Systems Integrator
51	Vendor Specific	TxDOT NEMA	TxDOT Developed
52	Vendor Specific	NEMA TS 1	TxDOT Developed
53	Vendor Specific	NEMA TS 2	TxDOT Developed
54	Vendor Specific	Type 170	TxDOT Developed
55	Vendor Specific	ATC	TxDOT Developed
56	Vendor Specific	TxDOT NEMA	Vendor Specific
57	Vendor Specific	NEMA TS 1	Vendor Specific
58	Vendor Specific	NEMA TS 2	Vendor Specific
59	Vendor Specific	Type 170	Vendor Specific
60	Vendor Specific	ATC	Vendor Specific

In order to facilitate the discussion of alternatives in Chapter 8, it is helpful to organize the 60 system configuration alternatives into Table 7.2. It is organized so that the alternatives are grouped first by communications protocol and central control alternatives, and then, lastly, by local controller choice.

Table 7.2. System Configuration Alternatives

Communications Protocol	Local Controller	Central: Systems Integrator	Central: TxDOT Developed	Central: Vendor Specific Closed-loop
NTCIP	TxDOT NEMA			
	NEMA TS 1			
	NEMA TS 2			
	Type 170			
	ATC			
Protocol-90	TxDOT NEMA			
	NEMA TS 1			
	NEMA TS 2			
	Type 170			
	ATC			
TxDOT Developed	TxDOT NEMA			
	NEMA TS 1			
	NEMA TS 2			
	Type 170			
	ATC			
Vendor Specific	TxDOT NEMA			
	NEMA TS 1			
	NEMA TS 2			
	Type 170			
	ATC			

8. TASK G: EVALUATE ALTERNATIVES

8.1 Introduction

The objective of Task G is to evaluate the alternatives identified in Chapter 7.

8.2 Communications Alternatives

The impacts of the various communications alternatives are as follows.

Using the NTCIP:

- Leverages the NEMA and FHWA development investment.
- Uses a protocol likely to be adopted by other infrastructure agencies.
- Enhances the procurement process since multiple agencies will be using the same protocol Therefore, with a larger market for their products, more vendors will be able to bid in compliance with a requisition.
- Reduces cost when compared to other communications alternatives because of the increased availability and competition at the time of procurement.
- Public domain software for the protocol will be available. TxDOT can use the software and knowledge of the protocol for other non-controller applications.
- Facilitates the deployment of other ITS applications that could use the same communications media as traffic controllers (e.g., camera control, changeable message signs).

Using Protocol-90:

- Facilitates deployment of multiple vendors' local controllers. A number of manufacturer's have delivered products compliant with Protocol-90.
- Does not address sharing communications media with non-controller devices (no Protocol-90 application messages are defined for these devices).
- Public domain software is not available.
- Not formally adopted by the NEMA supplier community and, therefore, not likely to have as great an impact as NTCIP with regard to procurement procedures and cost.

Using TxDOT Developed:

- TxDOT is likely to shoulder the full cost of the development effort without assistance from the FHWA or other states who have been investing in NTCIP.

- Evolving national sentiment is to utilize the NTCIP. It is unlikely to expect that TxDOT could persuade a significant number of other infrastructure operators to adopt a TxDOT protocol so that product procurement and cost issues could be mitigated.

- A full development effort is likely to take two years. This is not a timely deployment when compared to the schedule of the NTCIP.

Using Vendor Specific:

- Does not support multiple vendors' traffic control products sharing the same communications media.

- Does not provide a path for deployment of ITS applications that could use the same communications media as traffic controllers (e.g., camera control, changeable message signs).

- Requires multiple central control computers and software for each vendor. This has a negative impact with regard to training of personnel.

Table 8.1 highlights the impacts associated with various communications protocol alternatives independent of the choice of local controller and central system configuration.

Table 8.1. Communications Impacts

Communications Protocol	Local Controller	Central		
		Systems Integrator	TxDOT Developed	Vendor Specific Closed-loop
NTCIP	Leverages NEMA & FHWA development investments. Likely to be adopted by multiple agencies and therefore assists procurement.			
Protocol-90	Software not in the public domain. Is only application layer definition.			
TxDOT Developed	Requires TxDOT development effort. Other agencies (e.g., Caltrans) supporting NTCIP.			
Vendor Specific	Does not support multiple vendors' products.			

8.3 Central Control Alternatives

Impacts of the various central control alternatives are as follows.

Using a Systems Integrator Approach:

- Central systems can be procured competitively, and they can be procured independent of the type of local controller or communications protocol in use. However, if multiple communications protocols are in use on separate media, then the cost and complexity of the system increases.

- If multiple brands of local controllers are in use, then the manufacturers must provide definition of their protocols to the systems integrator in order to incorporate their products into the system.

- It takes longer to deploy a systems integrator furnished central system than an off-the-shelf vendor supplied closed-loop system.

- TxDOT can specify the functionality and user interface they desire. With a vendor supplied closed-loop system, the vendor usually dictates the functionality and user interface since they are supplying off-the-shelf products with little customization.

- It typically costs more to supply a systems integrator supplied central system than a single closed-loop central system for small scale systems.

- Only a single interface is needed when compared to a closed-loop central system which typically has one central system for each brand of local controller.

- Typically TxDOT would not own the computer software code and, therefore, could not make incremental changes on their own. The ownership issue favors the original systems integrator with regard to enhancements in the system.

Using a TxDOT Developed Approach:

- Requires a TxDOT software development and maintenance effort. Staffing the development effort typically requires a larger investment than the software maintenance effort. After the initial development effort is completed, there is a need to reassign the development staff and yet maintain sufficient expertise to accommodate future enhancements and maintenance.

- Could provide a single operator interface throughout the state. This positively impacts training and staffing.

- TxDOT would own the computer software code and could implement incremental functionality enhancements with their own staff.

- A targeted set of functionality that closely matched the district staff's requirements could be provided. Would not need to settle for off-the-shelf products that provided functionality that did not match the district's needs.

- TxDOT would need to negotiate for protocol knowledge with each of the controller manufacturer's if they chose not to use the NTCIP Protocol.

Using Vendor Specific Closed-Loop Approach:

- The software and operator interface are typically off-the-shelf products offering a fixed set of functionality and an interface that would vary by manufacturer.

- Typically one set of hardware and software is needed for each brand of local controller purchased.

- Would require that vendors use a common protocol (like NTCIP) in order to implement multiple vendors products on a single communications media.

Table 8.2 highlights impacts associated with various central control alternatives independent of the choice of local controller and communications protocol.

Table 8.2. Central Control Impacts

<table>
<tr><th rowspan="2">Communications Protocol</th><th rowspan="2">Local Controller</th><th colspan="3">Central</th></tr>
<tr><th>Systems Integrator</th><th>TxDOT Developed</th><th>Vendor Specific Closed-loop</th></tr>
<tr><td>NTCIP</td><td>TxDOT NEMA
NEMA TS 1
NEMA TS 2
Type 170
ATC</td><td rowspan="4">Competitive procurement. Each procurement could implement latest technology.</td><td rowspan="4">Requires TxDOT development and maintenance effort. Provides uniformity throughout Districts. Positively impacts training and user interface issues.</td><td rowspan="4">Software & interface off-the-shelf. Could negatively impact controller choice depending on protocol decision.</td></tr>
<tr><td>Protocol-90</td><td>TxDOT NEMA
NEMA TS 1
NEMA TS 2
Type 170
ATC</td></tr>
<tr><td>TxDOT Developed</td><td>TxDOT NEMA
NEMA TS 1
NEMA TS 2
Type 170
ATC</td></tr>
<tr><td>Vendor Specific</td><td>TxDOT NEMA
NEMA TS 1
NEMA TS 2
Type 170
ATC</td></tr>
</table>

8.4 Weighted Criteria Scoring of Alternatives

In Chapter 6, weighted criteria were developed based primarily upon the feedback obtained from the Task A survey. Based upon the discussions earlier in this chapter, the various alternatives were ranked on a scale of from Low to High for each criteria. Table 8-3 on the next page summarizes the scores received for each alternative for each evaluation criteria.

Table 8.3. Ranking of Alternatives by Criteria

Communications Protocol	Local Controller	Central: Systems Integrator						Central: TxDOT Developed						Central: Vendor Specific Closed-Loop					
		Functionality	Local Interface	Central Interface	Communications	Maintainability	Expandibility	Functionality	Local Interface	Central Interface	Communications	Maintainability	Expandibility	Functionality	Local Interface	Central Interface	Communications	Maintainability	Expandibility
NTCIP	TxDOT NEMA	H	L	H	H	M	M	H	L	H	H	M	M	H	L	L	H	M	M
	NEMA TS 1	L	L	H	H	M	M	L	L	H	H	M	M	L	L	L	H	M	M
	NEMA TS 2	L	L	H	H	M	M	L	L	H	H	M	M	L	L	L	H	M	M
	Type 170	M	H	H	H	H	M	M	H	H	H	H	M	NA	NA	NA	NA	NA	NA
	ATC	H	H	H	H	H	H	H	H	H	H	H	H	NA	NA	NA	NA	NA	NA
Protocol-90	TxDOT NEMA	M	L	H	M	M	L	M	L	H	M	M	L	NA	NA	NA	NA	NA	NA
	NEMA TS 1	L	L	H	M	M	L	L	L	H	M	M	L	NA	NA	NA	NA	NA	NA
	NEMA TS 2	L	L	H	M	M	L	L	L	H	M	M	L	NA	NA	NA	NA	NA	NA
	Type 170	M	H	H	M	H	L	M	H	H	M	H	L	NA	NA	NA	NA	NA	NA
	ATC	M	H	H	M	H	L	M	H	H	M	H	L	NA	NA	NA	NA	NA	NA
TxDOT Developed	TxDOT NEMA	H	L	H	H	M	M	H	L	H	H	M	M	H	L	L	H	M	M
	NEMA TS 1	L	L	H	H	M	M	L	L	H	H	M	M	L	L	L	H	M	M
	NEMA TS 2	L	L	H	H	M	M	L	L	H	H	M	M	L	L	L	H	M	M
	Type 170	M	H	H	H	H	M	M	H	H	H	H	M	NA	NA	NA	NA	NA	NA
	ATC	H	H	H	H	H	H	H	H	H	H	H	H	NA	NA	NA	NA	NA	NA
Vendor Specific	TxDOT NEMA	H	L	H	L	L	L	H	L	H	L	L	L	H	L	L	L	L	L
	NEMA TS 1	L	L	H	L	L	L	L	L	H	L	L	L	L	L	L	L	L	L
	NEMA TS 2	L	L	H	L	L	L	L	L	H	L	L	L	L	L	L	L	L	L
	Type 170	M	H	H	L	L	L	M	H	H	L	L	L	NA	NA	NA	NA	NA	NA
	ATC	H	H	H	L	L	L	H	H	H	L	L	L	NA	NA	NA	NA	NA	NA

Based on the rankings received, each alternative was computed a "alternative score" equal to the sum of the ranking values (High=3, Medium=2, Low=1, NA=0) each multiplied by the criteria weighting. The criteria weights are:

- Functionality = 10;
- Local Interface = 5;
- Central Interface = 5;
- Communications = 5;
- Maintenance = 3; and
- Expansion = 3.

The results of this analysis are presented in Table 8.4.

Table 8.4. Scoring of Alternatives

Communications Protocol	Local Controller	Central: Systems Integrator	Central: TxDOT Developed	Central: Vendor Specific Closed-loop
NTCIP	TxDOT NEMA	77	77	67
	NEMA TS 1	57	57	47
	NEMA TS 2	57	57	47
	Type 170	80	80	0
	ATC	93	93	0
Protocol-90	TxDOT NEMA	59	59	0
	NEMA TS 1	49	49	0
	NEMA TS 2	49	49	0
	Type 170	72	72	0
	ATC	72	72	0
TxDOT Developed	TxDOT NEMA	77	77	67
	NEMA TS 1	57	57	47
	NEMA TS 2	57	57	47
	Type 170	80	80	0
	ATC	93	93	0
Vendor Specific	TxDOT NEMA	61	61	51
	NEMA TS 1	41	41	31
	NEMA TS 2	41	41	31
	Type 170	61	61	0
	ATC	71	71	0

Figure 8.1 depicts the outcomes from the scoring of alternatives. It indicates that the vendor-specific central closed-loop systems score worse than the systems integrator or TxDOT developed central systems for all local controller types. It further shows that there is no real difference in scoring between the systems integrator and TxDOT supplied central system alternatives. It also shows no significant difference in scores between NTCIP and TxDOT protocol alternatives. Finally, it shows that ATC and 170 type solutions score higher than NEMA alternatives.

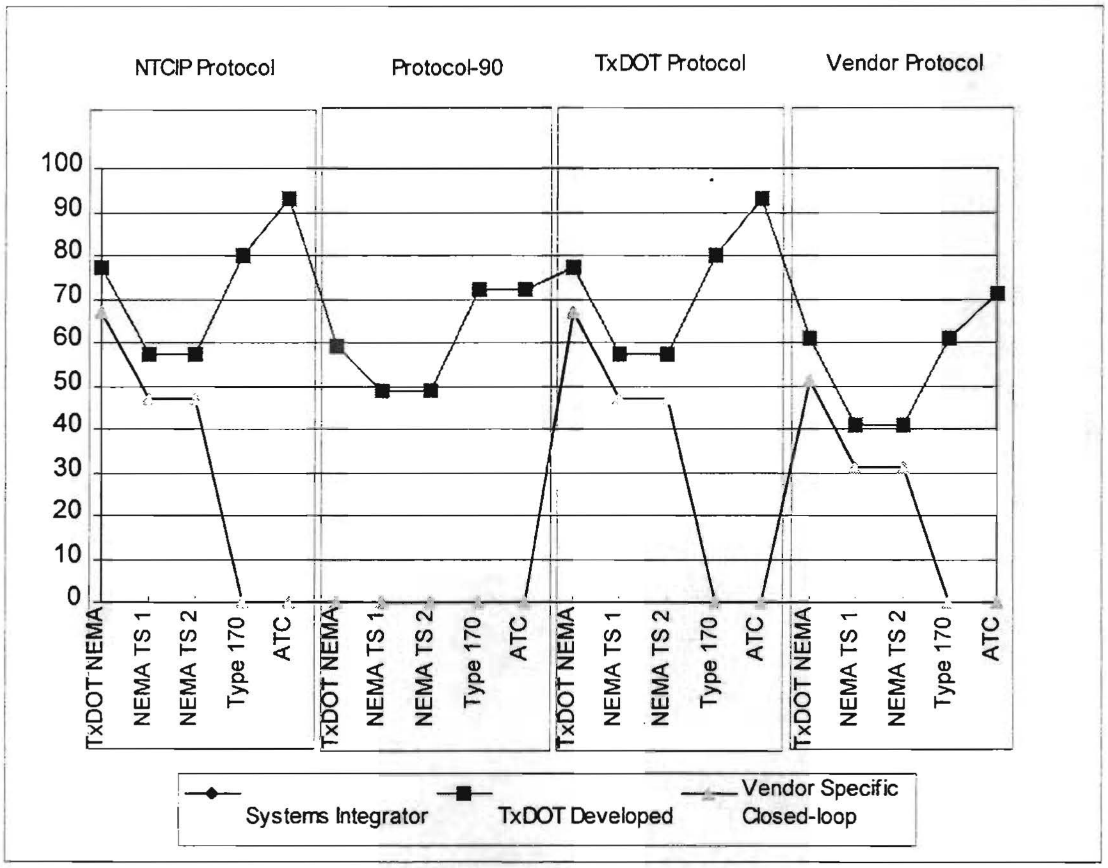

Figure 8.1. Alternative Scores

9. TASK H: RECOMMENDATIONS

9.1 Introduction

The objective of Task H is to propose recommendations for TxDOT implementation.

9.2 Recommendation

The alternative ranking process of Chapter 8 recommended a solution which used either an NTCIP or TxDOT protocol with either a systems integrator or TxDOT supplied central system using the ATC controller. It should be noted that the alternative evaluation process did not explicitly consider cost. Further, in the summer of 1995 there were no ATC products available using NTCIP protocol. However, this set of outcomes might best serve the needs of TxDOT given appropriate pricing and product maturity.

Therefore, the Task H recommendation for this study is as follows.

1. Continue to work with the NTCIP Steering Group and influence NTCIP design so that TxDOT functionality is incorporated into its deployment. It is not recommended that TxDOT initiate an independent protocol development effort at this time given the forthcoming delivery of this public domain communications protocol.

2. Enter into a joint working relationship with Caltrans and the Los Angeles DOT to develop a public domain software package for the ATC. The absence of vendor software support makes the evaluation and pricing of the ATC impractical.

3. Continue to promote the deployment of consistent user interfaces for both local controllers and central control systems. This could be accomplished by:

    a) Defining desired local controller interfaces when working with Caltrans and the Los Angeles DOT.

    b) Working with Caltrans and the Los Angeles DOT if they initiate development of a master software set for the ATC.

    c) Working with NEMA if they initiate development of an open architecture local controller.

It is anticipated that a number of these efforts will be substantially completed by the summer of 1996 (especially the NTCIP and the Caltrans/Los Angeles ATC software).

10. TASK J: REFINEMENT OF NTCIP AND IMPACTS ON ATC DEVICES

10.1 Background

The largest of Tasks A through I in this project was the development of a communications protocol, Task D. The TxDOT Technical Panel decided this effort could most effectively be accomplished by working with NEMA, FHWA, Caltrans, and others to develop a multi-agency-based protocol that also served the needs of TxDOT. This national multi-agency protocol is termed NTCIP (National Transportation Communications for ITS Protocol).

During the 1995-1996 fiscal year, the research work investigated the emerging FHWA sponsored NTCIP protocol and evolving advanced transportation controllers (ATCs), including those with NEMA interfaces, to examine their effectiveness in development of a TxDOT multi-vendor environment as defined in Tasks E, F, and G. Specific areas of interest expressed by the Technical Panel included assessment of the national NTCIP protocol and ATCs. TTI attended meetings associated with these activities to gather data relevant to the research work and to assure that the needs of TxDOT were represented nationally with respect to a multi-vendor environment.

10.2 NTCIP

10.2.1 Background

In May 1995, the NTCIP Steering Group was formed. It consisted of the members listed in the following table. Ed Seymour from TTI and Al Santiago from FHWA were named as Co-Chairs.

Table 10.1. NTCIP Steering Group Members

Name	Organization
Al Santiago	FHWA
Jim Clark	FHWA
Paul Bell	TRANSYT Corporation
Rick Denney	Barton-Aschman Associates
Bruce Eisenhart	Loral Federal Systems
Michael Forbis	Washington State DOT
Robert Gottschalk	Florida State DOT
Anson Nordby	City of Los Angeles DOT
Tim Pagano	State of Virginia DOT
Raman Patel	I-95 Corridor Coalition
Chuck Perry	State of California DOT
Ed Seymour	Texas Transportation Institute
Ken Vaughn	Farradyne Systems

At a May 1995 meeting, the Steering Group established a goal statement for the Group's work effort and identified a number of objectives in support of that goal statement. The goal and objectives were defined as follows.

Goal of NTCIP Steering Group

Through the Steering Group's expertise and its interaction with other agencies, expedite the first implementation of the NTCIP, facilitate extension of the NTCIP Specification to other ITS areas, and establish a mechanism for long term ownership and maintenance of the standard beyond the first implementation.

Objectives

1. Identify issues requiring Steering Group input relevant to the first implementation of the NTCIP.

2. Initiate a consensus process for adoption of NTCIP as a national standard for ITS applications.

3. Establish a mechanism for long term ownership and maintenance of the standard beyond the first implementation. Identify an agency willing and capable to assume this role.

4. Develop a roadmap of action items to support the goal of the NTCIP Steering Group.

5. Identify priority ITS areas for extension of the NTCIP, and develop an action plan to accomplish this objective.

6. Develop an outreach program to key stakeholders to promote acceptance and implementation of the NTCIP.

Further, the FHWA states the purpose of NTCIP as follows.

> The National Transportation Communications for ITS Protocol (NTCIP) is being developed to support interoperability and interconnectivity of traffic control and ITS devices and support capabilities such as variable message sign control, camera control, vehicle classification, and general purpose data collection and device control. (1)

The NTCIP Steering Group has posted on their World Wide Web home page the following objective of NTCIP.

> The primary objective of the National Transportation Communications for ITS Protocol (NTCIP) is to provide a communications standard that ensures the

interoperability and interchangeability of traffic control and Intelligent Transportation Systems (ITS) devices. The NTCIP is the first protocol for the transportation industry that provides a communications interface between disparate hardware and software products. The NTCIP effort not only maximizes the existing infrastructure, but it also allows for flexible expansion in the future, without reliance on specific equipment vendors or customized software. (2)

10.2.2 Major Technical Issue: X.25 Versus IP at the Network Layer

One of the first issues facing the Steering Group was the choice of either X.25 or IP at the network layer. In order to aid in making the decision, FHWA hired a consultant, Opus One, to assist with defining the technical implications associated with the two alternatives. Opus One identified a number of parameters that could be used to describe the types of messages that would typically be encountered in ITS applications. Together with Opus One, the Steering Group then built the description of these messages summarized in Table 10.2.

Table 10.2. Description of Typical ITS Messages

Transaction Type	Number of Messages	Message Size	Time Limit	BER	Freq	Loss Detection	Real Time	Seq/ Priority	Local/ Global
Fast control Acknowledge Primary to Secondary (camera)	2 (data, ack)	data<10 bytes, ack<5 bytes	0.1 sec	HDLC	0.1 sec	None	Yes	No/Low	Global
Fast control Primary to Secondary (camera)	1	<10 bytes	N/A	HDLC	0.1 sec	None	Yes	No/Low	Global
Medium control Primary to Secondary (sec by sec)	2 (request/ response)	both<10 bytes	40 ms	HDLC	1 sec	None	Yes	No/High	Local
Slow control Primary to Secondary (timing plan)	2 (request/ response)	both<32 bytes	sec/mi n	HDLC	60-600 sec	None	No	No/High	Global
Fast Status Unsolicited Secondary to Primary	1	<16 bytes	N/A	HDLC	1 sec to 1 hour	None	Yes	No/Low	Global
Fast Status Solicited Secondary to Primary	2	<5 bytes, <16 bytes	40 ms	HDLC	1 sec	None	Yes	No/ Medium	Global
Error Status Unsolicited Secondary to Primary	2 (request/ ack); maybe 3	100s of bytes	secs	HDLC	60-6000 sec	None	Yes	No/Low	Global
Slow Status Secondary to Primary	2 (request/ response)	100s of bytes	secs	HDLC	30-6000 sec	None	Yes	No/ Medium	Global
Large Upload/ Download	3 way handshake	maybe very large	slow	HDLC	weekly/ monthly	None	No	Yes/Low	Global
Small Upload/ Download	3 way handshake	<500 bytes	slow	HDLC	weekly/ monthly	None	No	Yes/Low	Global

A general Steering Group discussion ensued regarding the impact of selecting either X.25 or IP. Representative comments were as follows.

- Device control and configuration is the intent of the October 1994 NTCIP draft.
- We lose the benefits of a protocol if we make our own and don't provide all the services.

- SNMP allows for the coexistence of multiple protocol stacks.
- There is a need for "hopping capability" but not a lot.
- Error rate threshold is 1^{-10}.
- The definition of real-time should be: predictable and bounded delay.
- Real-time without acknowledgment is exemplified by a message that moves a camera in discrete increments.
- Medium control is about 0.5 seconds in centralized control environments.
- Slow control is about once per minute and exemplified by a command to transition to a timing plan.
- The size of the packet is the distinguishing characteristic for fast/slow status.
- SNMP does not do bulk transfers well. FTP or Telenet may be better for bulk transfers.
- X.25 could require a lot of software code development.
- Limited programmer resources are available for X.25.
- X.25 collapses at high speeds.
- There is a growing resource pool of trained programmers for IP.
- IP software is generally more available than X.25.
- We could accomplish much of the network layer at the data link layer with some changes to semantics.
- Many users are being indoctrinated about IP through the proliferation of the Internet. Few have heard of X.25.

A formal vote on the following two questions was solicited from those present.

1. *Should the Steering Committee request changes to Class B semantics but not syntax for the purpose of having a minimal addressing/routing function on Class B?*

   Goal: Eliminate some use of Class A communications in legacy equipment.

   Results: Yes: 20 votes; No: 2 votes

2. *Should the Steering Committee request changes to Class A to use IP?*

   Goal: Meet requirements of NTCIP using Internet Protocol.

   Results: Yes: 17 votes; No: 5 votes

10.2.3 The NTCIP Standard

The standard has been structured into multiple documents that will be acted on individually. The first three submitted for ballot pertain to: Overview, Class B Profile, and STMF.

TS 3.1 - National Transportation Communications for ITS Protocols - Overview

> This document provides an overview of the Class Profile documents and where the NTCIP development efforts are headed.

TS 3.2 - National Transportation Communications for ITS Protocols - STMF

> This document provides a specification of the Simple Transportation Management Framework (STMF). The STMF provides the rules for encoding information at the Application Layer and defines the mechanism to define data elements for NTCIP. This Framework is based on the concepts of the Simple Network Management Protocol (SNMP) but provides a more bandwidth efficient approach.

TS 3.3 - National Transportation Communications for ITS Protocols - Class B Profile

> This document provides a draft specification of the Class B Profile for the NTCIP. The Class B Profile fulfills the need for a communications stack that minimizes overhead in order to maximize the use of low bandwidth media. It is based on PMPP and does not include a Network or Transport Layer.

TS 3.4 - National Transportation Communications for ITS Protocols - Global Object Definitions

This document provides a draft version of the global objects. The Global Objects are those data elements which are found in multiple types of devices. For example, many devices will support storage of the current time; this standard will define how this data element is stored in all of the devices.

TS 3.5 - National Transportation Communications for ITS Protocols - ASC Object Definitions

This document provides a draft version of the objects for actuated signal controllers. All of the data elements required for traditional signal controller operation are defined in this document. Data elements for adaptive type signal control are not defined in this document and will be the subject of a future standard.

TS 3.6 - National Transportation Communications for ITS Protocols - VMS Object Definitions

This document provides a draft version of the objects for variable message signs. All of the data elements required for VMS operation are defined in this document. This document includes mechanisms to support such features as graphics, but such advanced features are not required.

TS 3.7 - Detector Object Definitions

TS 3.8 - Priority Object Definitions

TS 3.9 - Ramp Meter Object Definitions

TS 3.10 - CCTV Object Definitions

TS 3.11 - Road/Weather Object Definitions

TS 3.12 - Highway Advisory Radio Object Definitions

10.2.4 Profiles

The following table illustrates how the NTCIP Standard specifies a family of protocols, designated as profiles, that can be used for various media and for various kinds of system deployments. For instance, Class B communications can be used when there is a need to minimize overhead in order to maximize the use of low bandwidth media. The Class A Profile fulfills the need for a communications stack that supports routing.

Table 10.3. NTCIP Profiles

		PROFILES			
		Class B	Class A	Class C	Class E
PROTOCOLS	Application	STMF	STMF	Telnet FTP SNMP	Telnet FTP SNMP
	Presentation	Null	Null	Null	Null
	Session	Null	Null	Null	Null
	Transport	Null	UDP	TCP	TCP
	Network	Null	IP	IP	IP
	Data Link	PMPP	PMPP	PMPP	PPP
	Physical	EIA 232E FSK	EIA 232E FSK	EIA 232E FSK	EIA 232E

10.2.5 NTCIP Exerciser

In order to test systems for NTCIP compliance and in order to maintain deployed NTCIP systems, it would be useful to have an NTCIP Protocol Exerciser. In the Spring of 1996, the NTCIP Steering Group developed the following functional description of an NTCIP Exerciser. FHWA has agreed to fund the development of the product so that it could be used by infrastructure agencies, product suppliers, and system integrators.

Objectives of the NTCIP Exerciser

- Allow NTCIP software developers to debug their code
- Allow end user to perform basic acceptance testing
- Allow end user to do communications testing and debugging on installed systems
- Enhance the ability of the NTCIP Steering Group to demonstrate NTCIP

Features of an NTCIP Exerciser

- Support static objects and manual control
- Provide basic automation and allow for transmission of dynamic objects
- Provide a macro capability
- Emulate a secondary station

- Support Class A messages

10.2.6 Outreach Activities

10.2.6.1 Review of NTCIP Standard

In the summer of 1995, the NTCIP Steering Group distributed a draft version of the NTCIP Standard for public comment. Approximately 300 mailings were completed, including relevant organizations like ITE, ITS America, and TRB.

10.2.6.2 NTCIP Guide

As an aid to understanding NTCIP and to assist in deployment of NTCIP, the Steering Group decided to author an "NTCIP Guide" that contained topical chapters as described below in this section. The anticipated date of completion for the Guide is the summer of 1996.

NTCIP Interpreter. This chapter will be a user's guide to NTCIP communications. It will be geared toward engineers without communications protocol experience. The chapter will contain examples in simple terms that describe the key concepts (e.g., objects, framing, tree structure) of NTCIP communications.

How to Use NTCIP. The target audience for this chapter is traffic engineers who do not wish to be concerned with communications but want to know how NTCIP impacts systems (including procurement and operations).

Systems Developers Guide. This chapter will reference where code can be secured, who has successfully developed various applications, and lessons learned. The target audience for this chapter is systems integrators and engineering consultants.

NTCIP Standards Development, Maintenance, & Modification Process Guide. This chapter will be written by NEMA and will reflect the procedures applicable to updating NTCIP profiles and objects.

10.2.7 Roadside Devices Message Sets

10.2.7.1 Actuated Traffic Signal Controller (ASC)

The NEMA Technical Committee developed a draft set of actuated traffic signal controller (ASC) objects. After review of the proposed NTCIP ASC object set, the

Steering Group expressed the following concerns to NEMA regarding the ASC object set.

1. The mandatory objects essentially define TS-2 functionality (like Port 1 Device Present). Other controller implementations may not be compliant. The Steering Group suggested it might be possible to separate ASC hardware dependent objects into options groups for various controller types (TS-2, 170, etc.).

2. In many cases, the ranges for objects will have an impact on the usefulness of NTCIP. The Steering Group felt the NTCIP should not be held hostage to other standards making organizations with respect to object values.

3. If a user wants to see controller returns, the objects require implementation of once per second polling, and that dictates an architecture. An alternative is to issue a trap, store a value, and ask for reporting when the value changes. The changed data is stored and sent back the next time you ask for something.

4. Another concern was how the system will provide "plug-n-play" operation. The Steering Group believed that NTCIP compatible systems should minimize the amount of integration/configuration effort required for interoperability and interchangeability. Thus, the Steering Group recommends that every device support an object table which specifies the MIBs defining the full functionality of the device.

NEMA's schedule is to vote on May 10, 1996, to send the ASC definitions out for ballot. The VMS objects are scheduled to go to ballot in June 1966.

10.2.7.2 Advanced Detection Systems

JPL has awarded seven detection contracts. Five of these contracts involve video technologies, one involves radar, and one involves lasers. The contracts have been through a development phase and are starting a testing and field evaluation phase in 1996. JPL made a presentation to the NTCIP Steering Group.

JPL Comments pertaining to NTCIP:

- Link travel times and origination/destination data are the key new measures that are being developed.

- Distributed architecture needed for efficient link travel time, O/D data and real-time adaptive control (peer-to-peer) protocol.

- Snapshot or compressed video should be supported to fully utilize video based sensors.

- TCP/IP is preferred for fully distributed network capability.

Comment from the Steering Group:

About 64KB would be required for TCP/IP in order to maintain all the traffic control functionality that would be needed from a traditional traffic control perspective. If you're using twisted pair copper, then you're probably only going to get something like 9600 baud, and therefore you need more powerful processing on the street (something like the 2070 ATC).

JPL Link Layer Issues

1. Polling may not permit the timely delivery of data to the TMC.

   Steering Group answer: Polling is a system design issue. Money tends to drive how infrastructure is built. NTCIP purposely avoids nailing down polling issues which are a performance issue related to infrastructure.

2. Have data compression techniques been considered as a means of easing the contention for bandwidth?

   Steering Group answer: Compression is done to improve effective bandwidth. Again, this is a system design issue.

3. Can or should communications data modes (rates) be standardized to help resolve the issue of bandwidth utilization?

   Steering Group answer: We purposely avoided this because NTCIP is focused on not dictating a design.

4. Has consideration been given to the establishment of a video transmission mode?

   Steering Group answer: Video rules. If you decide to support video, then data transmission becomes an ancillary issue. Video snapshots could be supported. Could develop a class of objects that have a required performance from the system.

JPL Sensor - Related Concerns

1. Guidance is needed on the development and definition of physical/logical lane assignments.

   Steering Group answer: This is probably something the ATMS Data Dictionary effort could address.

2. Standardization of data objects is needed for camera control and orientation.

   Steering Group answer: Objects for these are in development.

3. Lane descriptions (width/direction) and detection zone definitions (type/direction) need to be resolved.

   Steering Group answer: This is probably something the ATMS Data Dictionary effort could address.

4. A consistent, unambiguous approach for the identification of sensor locations needs to be developed (lat./long., other).

   Steering Group answer: There is an effort at Oakridge led by Steve Gordon that is tackling this issue.

5. Is there a need to report data in metric as well as U.S. measurement systems?

   Steering Group answer: It is probably advantageous to use metrics to expedite the use of NTCIP.

10.2.7.3 Roadway / Weather Information System (RWIS)

The Minnesota Department of Transportation is working on a state-wide Roadway/Weather Information System (RWIS) to integrate pavement and weather monitoring stations for response to icing and other weather conditions. Minnesota hosted a workshop to discuss systems architecture and protocols which might support RWIS. The workshop was sponsored by ENTERPRISE and attracted participants from nearby states such as Iowa, Wisconsin, North and South Dakota, and Colorado, as well as AASHTO. AASHTO has formed a subcommittee to develop a protocol to support RWIS.

The AASHTO Subcommittee on Maintenance Work Group was charged with development of a communications protocol and "data format" that could be used with multiple vendors' products. This work was authorized in late 1992. In 1995 at an AASHTO meeting in Branson, Missouri, the decision was made to vote on the resultant "AASHTO RWIS Data Exchange Protocol." The protocol document contains a provision to develop a joint AASHTO - FHWA Standards Committee to "regulate and administer the implementation and any future modifications and additions" to the protocol.

10.2.8 SDO NTCIP Steering Committee

Beginning in August 1996, the NTCIP Steering Group was replaced with a Joint AASHTO/ITE/NEMA Committee on the NTCIP. This consortium of standards development organizations (SDOs) is actively pursuing the development and maintenance of NTCIP standards for roadside devices and center to center communications. These devices include: actuated traffic signal controllers, variable messages signs, ramp meters, video camera control, highway advisory radio, environmental sensors, weigh-in-motion devices, video detection devices, road/weather information systems, and vehicle classification devices. Like the NTCIP Steering Group, these message standards are being developed with the participation of users, manufacturers, and the SDOs. However, the Consortium has secured funding from FHWA to expedite the more informal process previously led by the Steering Group. The applicable time horizon for development of the device message sets is a period ending in 1999.

10.3 Data Dictionary Efforts

ITE is sponsoring an ATMS Data Dictionary effort. The first meeting of its Steering Group was held in Washington, D.C. on March 21 and 22, 1996. The Chairperson of the Data Dictionary group is Jim Wright. They are looking at the Traffic Management Subsystem and its linkages to other subsystems.

On May 16 and 17, 1996, the TMDD Steering Group established a process for developing a proof of concept data dictionary prototype as shown in Figure 10.1. This process uses the National ITS Architecture (Box 1 in Figure 10.1) as the conceptual framework from which data flows and candidate data elements (Box 2 in Figure 10.1) are selected. Selection of the candidate elements are based on technical assistance provided to the Steering Group by consultants and "friends" of the Committee (Box 5 in Figure 10.1).

A prototype data dictionary set of elements will then be developed by considering relevant emerging "deployed" data dictionaries (Box 3 in Figure 10.1), existing operational inputs (Box 4 in Figure 10.1), and technical assistance provided to the Steering Group by consultants and "friends" of the Committee (Box 5 in Figure 10.1). Finally, the proof of a concept prototype data dictionary will be evaluated to determine the quality of the resultant product.

The objective of this prototype process is to identify and refine procedures that can be used by the TMDD Steering Group to complete the data dictionary work.

Since the results of data dictionary groups, like this one focused on Traffic Management Centers, will relate directly to the definition and use of protocol messages, it is important for TxDOT and other infrastructure organizations to provide an active involvement.

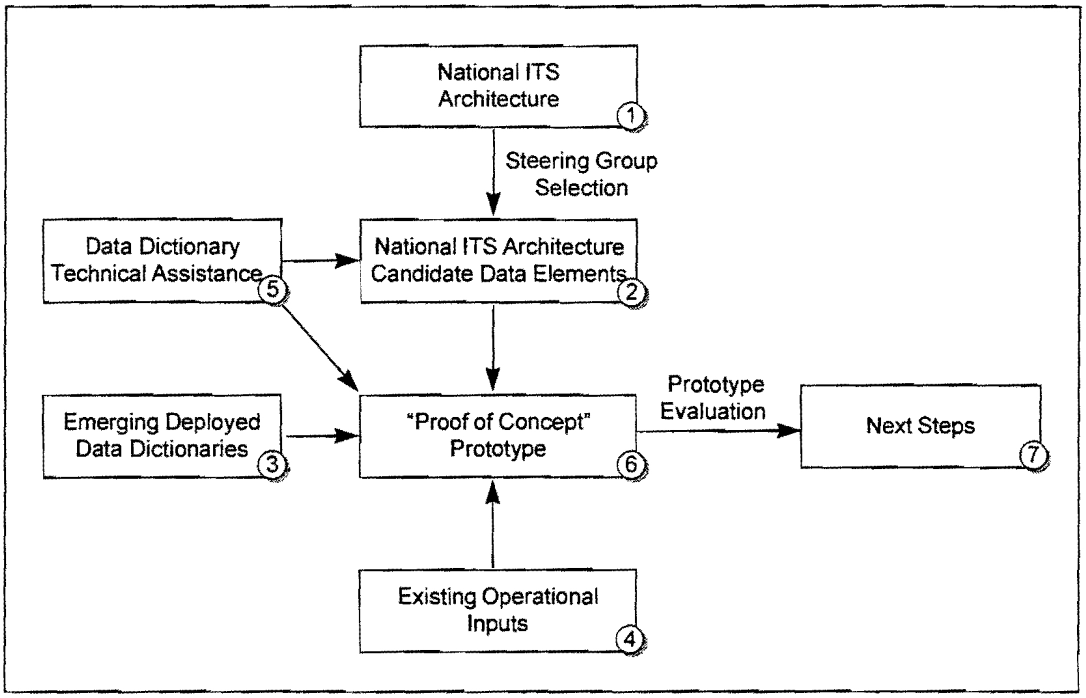

Figure 10.1. Prototype Development Process

10.4 Advanced Transportation Controller (ATC)

Development of "advanced traffic control" (ATC) equipment and software has been an industry goal for many years. In part, this emphasis has been motivated by the public sector's desire to achieve interoperability of traffic signal control hardware and software. The primary objective here was conservation of funding and simplification of operations and maintenance. However, the desire to deploy multiple ITS roadside devices while sharing common resources has also motivated this development. Similar to communications systems, many agencies view an open architecture, advanced traffic control device as an enabling ITS roadside platform that facilitates deployment by providing a fundamental infrastructure resource.

For example, there is an expectation that a 2070 platform could perform the National Architecture ATMS "surface street control" market package function of traffic signal control while simultaneously performing another market package function like the reversible lane management function of the "freeway control" market package.

A coalition of users, suppliers, and affiliated standards development organizations (2070 Steering Group) has met to develop a plan of action to promote 2070 ATC activities and standards. The 2070 Steering Group has identified a mission statement, goals, and actions for their efforts as follows.

Mission Statement

The mission of the 2070 ATC Steering Group is to lead and coordinate development and deployment of open architecture controller devices for ITS applications.

Goals

- Promote a national partnership of users, industry, and developers.

- Encourage public/private partnerships in the development of applications, enhancements, and operations support.

- Establish hardware, software, and user interface standards for the 2070 ATC.

- Facilitate testing, implementation, continuing development, and maintenance.

Actions

- Establish subcommittees to work with interested parties through open meetings and forums to provide input regarding specifications and products.

- Provide outreach opportunities for the ITS community to comment on the Steering Group's activities.

- Facilitate the establishment of hardware, software, and user interface standards by working with Standards Development Organizations.

The Steering Group is pursuing standards for 2070 ATC software regarding application program interfaces, functionality, modularity, interoperability, testing, and documentation. In addition, the Steering Group will work to facilitate the development of standards for an ITS cabinet and for the controller equipment. Figure 10.2 depicts the relationships between these activities, the Steering Group, and subcommittees that will be formed to address specific tasks.

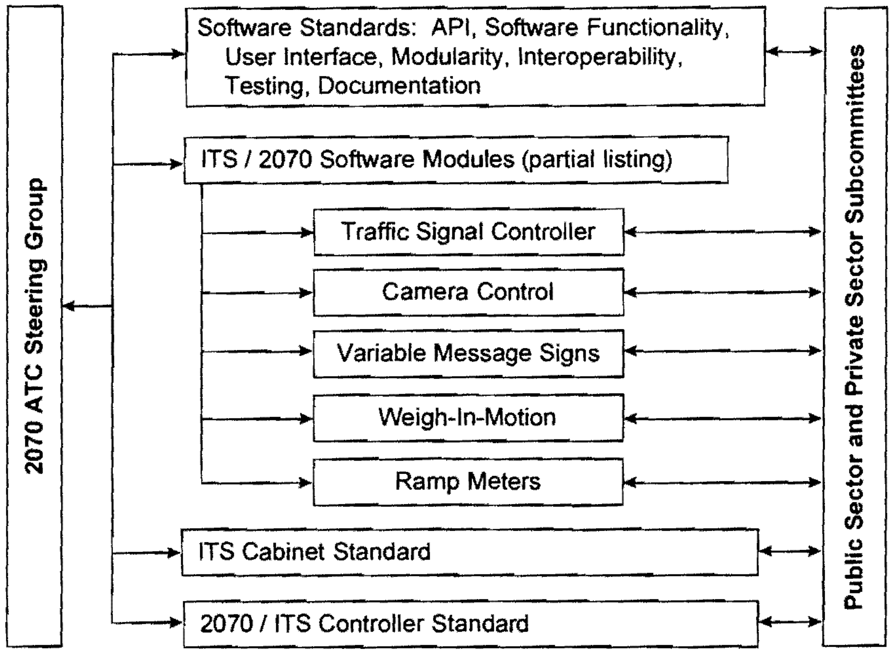

Figure 10.2. Activities and Committees

A few public sector agencies are pursuing the development of software for the 2070 ATC. The next three sections describe the software efforts led by the City of Los Angeles.

LA/Caltrans Participants

- Partners include the City of Los Angeles, Caltrans, City of Irvine, TxDOT
- Meeting occur on a monthly basis
- Software is being written in C
- Pre-production 2070 hardware delivered by mid-June 1996 will allow further development of the software

Features

- Partner agencies are developing a common list of ASC (Actuated Signal Controller) features
- Partners are checking these features against the NTCIP ASC object definitions.

Software Release

- An alpha version of the software could be released to the private sector in the fall for the purpose of testing and debugging hardware.

- A general public release of the software is scheduled for this winter, perhaps through Caltrans as the sponsoring agency.

The Steering Group desires to achieve consensus and standardization with respect to the structure of the software. The next two paragraphs describe this task.

Software Objectives

- Share resources within the 2070 ATC control device
- Operate multiple applications within the 2070 ATC control device
- Standardize interface modules
    - Public domain data modules
    - Public domain hardware modules
- Fully document a library of function calls
- Support NTCIP communications

Software Interface Model

Figure 10.3 is a conceptual representation of the kind of software model that could be used to structure the relationships between software modules.

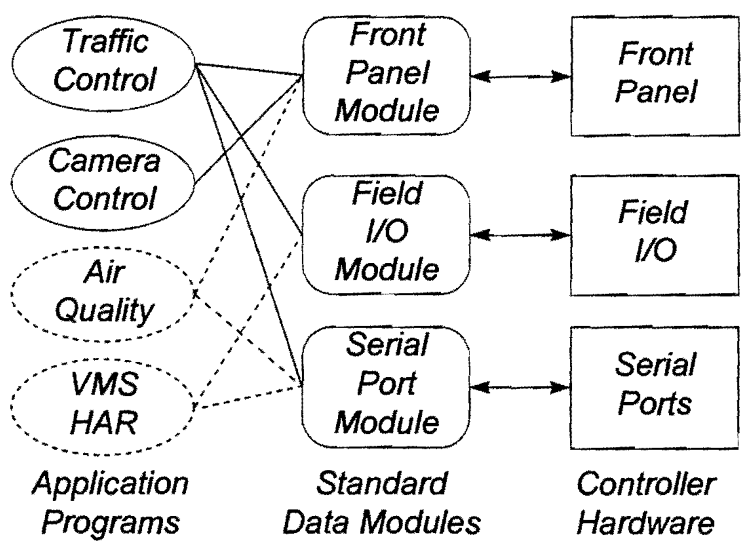

Figure 10.3. Conceptual Software Model

10.5 Implementation Recommendations

The following recommended practices are pertinent to achieving a multi-vendor environment in Texas. Consequently, they are relevant to NTCIP and to achieving the benefits of interoperability and interchangeability.

Recommendation #1: Infrastructure agencies like TxDOT should procure NTCIP compliant roadside devices where there are applicable, approved standards for those devices.

Discussion: A consortium of standards development organizations (SDOs), AASHTO/ITE/NEMA, is actively pursuing the development and maintenance of NTCIP standards for roadside devices. These devices include: actuated traffic signal controllers, variable messages signs, ramp meters, video camera control, highway advisory radio, environmental sensors, weigh-in-motion devices, video detection devices road/weather information systems, and vehicle classification devices. These message standards are being developed with the participation of users, manufacturers, and the SDOs. The applicable time horizon for development of the device message sets is a period ending in 1999.

As TxDOT procures equipment for which there are devices with approved message sets (termed object definitions) during this time period, they should specify that the protocol be NTCIP compliant. Acknowledging that it is not possible to place an NTCIP protocol device in a proprietary communications system, changes to other devices on the communications media may be required. Depending on funding and the life cycle of the system, it may not be feasible to replace major pieces of the system concurrent with the procurement. In this case, the agency should procure the device in such a way that it can operate in either the NTCIP or proprietary manner as configured by the agency. For example, this could mean the device might be delivered with two sets of circuit boards, one for NTCIP and the other for the proprietary protocol. The agency could use the proprietary circuits until the relevant portion of their communications network is converted to NTCIP.

Recommendation #2: Infrastructure agencies like TxDOT should require conversion to NTCIP communications as part of their procurement specification for roadside devices that have been identified in the AASHTO/ITE/NEMA work plan for NTCIP but that have not yet been standardized.

Discussion: The AASHTO/ITE/NEMA work plan will be completed over a period of approximately three years. This recommendation applies to devices that are on the SDO Consortium's work plan but not yet adopted as a standard. As an agency procures these devices during this time period, they should secure a quotation for subsequently converting the device from a proprietary communications protocol to NTCIP. There is enough currently known about the structure of NTCIP to allow a vendor to determine the requirements placed on their device for the purposes of pricing. In order to guard against the possibility of the SDO Consortium not developing a standard for the particular device, the procuring agency might want to structure this additional work as a separate deliverable that could be exercised as an option or price agreement.

Recommendation #3: Infrastructure agencies like TxDOT with large TMCs should actively work with the AASHTO/ITE/NEMA SDO Consortium to standardize center-to-center communications as a part of NTCIP. These infrastructure agencies should allocate some of their work efforts to developing the standard to be consistent with the National ITS Architecture and in agreement with evolving data dictionaries.

Discussion: Center-to-center communications is an important aspect of the National ITS Architecture. As a general guide to describe the various categories of applicable standards, the ITS Architecture contractor teams have written eleven standards documents. These documents provide a general framework for standards development and cover the following topics:

1. Dedicated Short Range Communications (DSRC, formerly known as "VRC")
2. Digital Map Data Exchange and Location Referencing
3. Information Service Provider Wireless Interfaces
4. Inter-Center Data Exchange for Commercial Vehicle Operations
5. Personal, Transit, and HAZMAT Maydays
6. Traffic Management Subsystem to Other Centers (except EMS)
7. Traffic Management Subsystem to Roadside Devices and Emissions Monitoring
8. Signal Priority for Transit and Emergency Vehicles
9. Emergency Management to Other Centers
10. Information Service Provider Subsystem to Other Centers (except EMS and TMS)
11. Transit Management to Transit Vehicle and Remote Traveler Services Interfaces

Of these packages, numbers 6, 7, 8 and 9 have the most impact on the Traffic Management Systems Centers. As depicted by the subjects of these documents, development of standards that might impact center-to-center communications is a complex issue involving many different ITS services. The AASHTO/ITE/NEMA SDO Consortium has significant technical strength to tackle many of the roadside device messages and protocol techniques. But they will need to augment their efforts to achieve success in the center-to-center arena. Therefore, infrastructure agencies with large TMCs should actively work with the AASHTO/ITE/NEMA SDO Consortium to standardize center to center communications as a part of NTCIP. This effort includes allocating some of their work efforts to developing a standard consistent with the National ITS Architecture and in agreement with evolving data dictionaries.

Recommendation #4: The FHWA, states and MPOs should work together to establish funding to augment conversion to NTCIP in large scale Traffic Management Centers.

Discussion: In many cases, the deployment of integrated, large scale traffic management systems will be undertaken before the adoption of standards like NTCIP. Clearly, this has been the case in Houston and San Antonio. Incentives for conversion of these deployed systems to NTCIP should be a priority for the FHWA. In addition to tying the availability of future funding to adherence to these standards, the FHWA might consider targeting the conversion of certain devices to NTCIP through financial incentives. The selection of these devices might be based on the device's ability to further enhance ITS deployment. An example is an ITS node processor that can serve multiple field devices using NTCIP (at least from the node to the field). It could be an Advanced ITS Transportation Controller (ATIC) serving multiple functions like traffic signal control, camera control, etc.

Recommendation #5: The FHWA, states and MPOs should work together to establish dedicated funding to augment the replacement of limited sized, closed-loop traffic signal systems in medium to smaller sized agencies. Legislative mandates that require NTCIP deployment should not be used to force compliance.

Discussion:
Deployment of traffic signal control systems in medium to smaller sized agencies is frequently configured as a series of dedicated "closed Loop" systems. These closed loop systems typically use proprietary communications protocols to transmit data between local control units and master sites using products developed by a single manufacturer. Because of the proprietary communications and limited resources for staffing and funding, these agencies tend to replace existing equipment with like-kind devices. That is, when they buy control equipment spares for a deployed system, they frequently buy a sole source replacement from the original manufacturer that is compatible with the existing system. Rarely do they replace an entire closed loop system when it is time to replenish spares. Not only are the capital costs too high to replace an entire system of components, without access to adequate training, the personnel implications are unmanageable. New equipment means learning new operations and maintenance procedures.

Considering these agencies' limited budgets and technical staff resources, it is necessary to assist them in overcoming the threshold investment required to transition to NTCIP. Therefore, the FHWA, states and MPOs should work together to establish dedicated funding to augment the replacement of limited sized, closed-loop traffic signal systems in medium to smaller sized agencies.

In the State of California, Assembly Bill AB3418 became law on October 4, 1994. It required "that any traffic signal controller that is newly installed or upgraded by the department or a local authority be of a standard traffic signal communication protocol capable of two-way communication." (3) According to the unfunded mandates provisions applicable in California, the legislation also established a State Mandate Claim Fund of $1,000,000 for claims associated with compliance to the law. During the summer of 1996, Caltrans was working to define compliance so that implementation of NTCIP constituted conformance to the mandate.

Legislative mandates of this type should not be used to force deployment of NTCIP. Although AB3418 might have been a necessary tool in 1994, it is not needed in 1996 when standard communications protocols are being adopted by Standards Development Organizations (SDOs).

Recommendation #6: The FHWA should take the lead in developing and conducting training courses pertinent to NTCIP. TxDOT and professional organizations should encourage training in NTCIP through seminars and professional development activities.

Discussion: In 1992 the FHWA established a Traffic Control Systems Operations and Maintenance Expert Panel that recommended for the FHWA to expand its course offerings in the areas of operations and maintenance. (4) What is specifically needed with regard to communications are courses focused on NTCIP. These courses should be developed by the National Highway Institute (NHI) and could include topics like:

- Courses directed to engineers and contract managers who will work with consultants to design systems using NTCIP.

- Courses directed to technicians and engineers who will be using NTCIP in a maintenance mode. This is likely to be a series of courses oriented towards specific devices and tools. An example of a tool is the NTCIP Protocol Exerciser being developed as a part of the NTCIP work program.

Recommendation #7: The FHWA should continue to augment funding for the development of NTCIP objects (messages and their meanings) for new devices and of NTCIP profiles for additional media (procedures for transmission of objects). TxDOT should continue their proactive participation in this process.

Discussion: The Joint AASHTO/ITE/NEMA Consortium for NTCIP provides a significant impetus to facilitate deployment of ITS, especially as it relates to TMCs. At the same time, data dictionary efforts and other standards activities in the transit and CVO areas will yield results which could readily be incorporated into NTCIP. The results will require the development of new NTCIP objects, and they could require the definition of new profiles as new communications media and technologies are deployed. None of these activities for transit and CVO are included in the Consortium's current work plan. The FHWA should continue to fund these activities as relevant data dictionary and other precursor standards activities are concluded. TxDOT should continue to participate in the process through the Joint AASHTO/ITE/NEMA Committee.

Recommendation #8: The FHWA should continue to augment funding for the maintenance of the NTCIP standard until the majority of roadside and center communications have been defined and approved as standards. TxDOT should participate in the work through participation in the Joint AASHTO/ITE/NEMA Committee.

Discussion: The NTCIP process for objects (messages) will involve defining a series of object definitions for each device (actuated traffic signal controllers, variable messages signs, ramp meters, video camera control, etc.). The first set will contain basic functionality that is common among the available products. The next set is likely to contain additional functionality based on consensus meetings resulting from field deployments. Additional sets will be required as other ITS services and market packages are deployed. The FHWA should continue to augment funding for these activities until the deployment of ITI is reasonably mature.

Recommendation #9: TxDOT should actively be involved in the development of Advanced Transportation Controller standards, including controllers, cabinets and software.

Discussion: Development of "advanced traffic control" equipment and software has been a goal of the public sector for many years. In part, this emphasis has been motivated by the public sector's desire to achieve interoperability of both hardware and software associated with traffic signal control. The objective here was conservation of funding and simplification of operations and maintenance. However, this development also has been substantially motivated by the desire to deploy multiple ITS roadside devices while sharing common resources. Similar to communications systems, many public sector agencies view an open architecture, advanced traffic control device as an enabling ITS roadside platform that facilitates deployment by providing a fundamental infrastructure resource.

There is an expectation that a 2070 platform could perform the National Architecture ATMS "surface street control" market package function of traffic signal control, while simultaneously performing another market package function like the reversible lane management function of the "freeway control" market package. In order to accomplish this wealth of functionality, the 2070 platform must be able to accommodate National Architecture flows among ITS Center Subsystems and ITS Roadway Subsystems.

TxDOT should join with ITE, NEMA and other organizations who are actively working on the development of these standards and products.

Recommendation #10: TxDOT should be involved in data dictionary efforts where they relate to National Architecture field devices and center systems.

Discussion: Since the results of data dictionary groups, like this one focused on Traffic Management Centers, will relate directly to the definition and use of protocol messages, it is important for TxDOT and other infrastructure organizations to provide active involvement.

10.6 References

1 Mitretek Systems, U.S. DOT, FHWA, Building the ITI: Putting the National Architecture Into Action, April 1996, Washington, D.C., Publication No. FHWA-JPO-96-011. Page 7

2 http://fhwatml.com/ntcip/, circa July 1996.

3 http://www.dot.ca.gov/hq/traffops/elecsys/ab3418/abtext.htm, circa July 1996.

4 Traffic Control Systems Operations and Maintenance Expert Panel Report to the U.S. Department of Transportation, Federal Highway Administration, 1992.