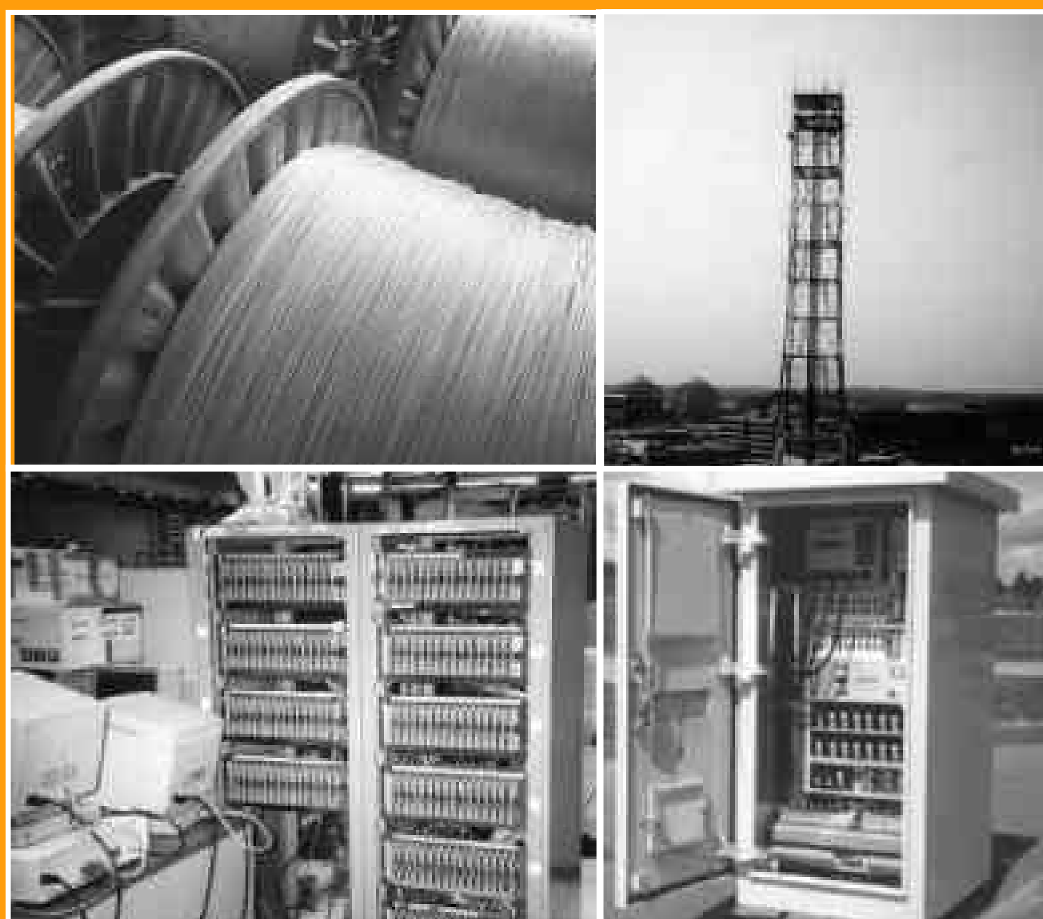
Communications for Intelligent Transportation Systems

Successful Practices

A Cross-Cutting Study



Reaching Cost-Effective Solutions through Better Decision-Making Techniques

November 2000

Foreword

Dear Reader,

We have scanned the country and brought together the collective wisdom and expertise of transportation professionals implementing Intelligent Transportation Systems (ITS) projects across the United States. This information will prove helpful as you set out to plan, design, and deploy ITS in your communities.

This document is one in a series of products designed to help you provide ITS solutions that meet your local and regional transportation needs. The series contains a variety of formats to communicate with people at various levels within your organization and among your community stakeholders:

- **Benefits Brochures** let experienced community leaders explain in their own words how specific ITS technologies have benefited their areas;

- **Cross-Cutting Studies** examine various ITS approaches that can be taken to meet your community's goals;

- **Case Studies** provide in-depth coverage of specific approaches taken in real-life communities across the United States; and

- **Implementation Guides** serve as "how to" manuals to assist your project staff in the technical details of implementing ITS.

ITS has matured to the point that you are not alone as you move toward deployment. We have gained experience and are committed to providing our state and local partners with the knowledge they need to lead their communities into the next century.

The inside back cover contains details on the documents in this series, as well as sources to obtain additional information. We hope you find these documents useful tools for making important transportation infrastructure decisions.

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Executive Summary

Telecommunication resources impact almost every activity of the public's daily lives. This pervasive influence is likely to increase as dependence on information technology continues to grow. ITS, where technology is applied to improve the effectiveness of transportation, are particularly impacted in many ways by telecommunications issues.

Telecommunications infrastructure is an important factor in enabling an ITS to function. It ties together and moves data between the major elements of an ITS, including roadside equipment, vehicles, the vehicle operator, and central operations facilities such as transportation management centers (TMC). Telecommunications is equally critical to creating optimal value, by integrating the individual elements over telecommunications lines (and through the use of standards) to command the resources and provide the information needed to improve overall transportation efficiency. Telecommunications infrastructure can also be the single most expensive part of ITS, both in implementation and in operations/maintenance. Thus, arriving at the telecommunications solution that best suits the agency in support of the ITS program, whether local, regional, or statewide, is a very high priority.

Arriving at the telecommunications solution best suited to the agency's needs is, in many cases, one of the most intimidating undertakings performed by a transportation agency. The skills required to understand the options, and how those options compare to one another, are not found in the educational background of most transportation agency personnel. This is further complicated by the rapid pace of change in telecommunications, driven by technology, by deregulation, and by new business paradigms such as the exchange of access to right-of-way for telecommunications resources. Relationships with telecommunications consultants, vendors, and service providers are relatively new to these agencies, if they exist at all. The significant need for informed assistance is addressed by this document in two ways: what processes work best, and what factors should be considered in making telecommunications decisions.

The first critical process in addressing any system-related need is to understand the requirements. In telecommunications, the requirements are often extensive. This document discusses methods and experience in analyzing telecommunications requirements in order to determine an optimal solution. Three processes—a thorough and structured requirements analysis, use of a regional ITS architecture, and development of a telecommunications architecture—are discussed.

This document discusses processes and decisions which can be applied in making important telecommunications choices for the specific needs of ITS. Although the processes and decisions are applicable far outside the field of transportation, their application will only be discussed within the context of transportation and from a transportation perspective.

The latter portion of the document discusses five critical decision areas facing agencies in need of telecommunications services:

- Should the systems and the network services be distributed or centralized?
- Should network support be staffed internal to the agency or outsourced?
- How can the agency meaningfully compare leased vs. owned network options?
- How can primary network technical alternatives be compared?
- What factors should be addressed when considering acquiring telecommunications services from a competitive access provider?

Where possible, example situations from agency ITS programs have been described. We would like to express our appreciation to the Departments of Transportation (DOT) of the states of California, Georgia, Maryland, Michigan, Minnesota, Missouri, New York, Texas, Virginia, and Wisconsin, for providing examples of successful practices in ITS telecommunications for this document.

Our analysis of the telecommunications experiences of the states reviewed for this study, as well as issues and concerns that have arisen in supporting ITS deployment in other states has brought several points into focus:

- There are many complex choices to be made in selecting the telecommunications solution to support ITS implementation. The telecommunications solution is critically important, both because of the essential technical function it provides to the system, and because of its significant financial impact on total system implementation and operations/maintenance cost and resources.
- The typical public agency will benefit greatly from access to qualified professional telecommunications consulting assistance in performing technical and business analyses and developing system design.
- There are ITS telecommunications examples we can learn from, such as the experiences of the states studied for this report. It should be recognized that the factors involved in the decisions made by these agencies continue to change, and that their decisions might be different if they were making the decisions under current conditions.
- Effective techniques to use in addressing the telecommunications design issues include development of a regional ITS architecture and an ITS telecommunications architecture.
- A careful systematic requirements analysis is essential in obtaining the telecommunications solution best suited to an agency's needs.

Introduction

Purpose

In many ITS implementations, the telecommunications solution was arrived at without the kind of rigorous examination that would have accompanied similarly significant and complex technical/business choices. The purpose of this document is to present several of the best techniques which can be used to explore telecommunications alternatives, and to determine which one or ones are acceptable, and possibly optimal, for a specific agency and program.

Audience

The intended audience for this document includes both the public and private sectors. The primary objectives are to raise the awareness of and provide a tool for public agencies responsible for transportation programs including or supporting ITS. This includes agencies involved in several phases of the ITS program life cycle, but is focused on those agencies performing program planning and design. The document is also expected to be of value to the traditional traffic and transportation consulting community which may be assisting such agencies.

Organization of the Document

The document begins by focusing on performing an effective needs assessment before selecting a telecommunications solution. Three elements in the needs assessment phase are addressed:

- Requirements analysis
- The use of a state or regional ITS architecture in defining telecommunications needs
- Development of a telecommunications architecture

For each item, the document provides a definition and justification, and then describes how the process may be performed. Where possible, examples from actual cases are included.

The second section of the document addresses several of the key technical issues which arise in selecting telecommunications solutions. These include:

- Distributed vs. centralized
- Outsourcing vs. staffing
- Lease vs. own
- Technical alternatives
- Competitive Access Providers

The approach to each issue is similar; defining the choice, demonstrating possible approaches, discussing relevant issues, and providing real examples where possible.

Needs Assessment

Understanding the need to be met is the most fundamental step before undertaking design, procurement, and implementation. Typically this involves gathering information from a variety of sources, such as the stakeholders in all life cycle phases of the eventual system. The process may involve looking ahead for a significant period, in order to understand how the chosen solution can meet present needs, and can evolve to meet future ones. It always includes defining what issues are critical: is the decision to be driven by cost, capability, reliability, or other factors?

This document will address three possible activities within the overall needs assessment: requirements analysis, the use of a state or regional ITS architecture in determining needs, and the development of a telecommunications architecture. While the first of these three is relatively common, the other two are, respectively, rare and almost unknown.

Requirements Analysis

How have states traditionally chosen telecommunications solutions?

Many factors must be considered in deciding upon the right telecommunications solution for an ITS program. Requirements analysis, a process commonly encountered in engineering programs, is well suited to telecommunications. Requirements analysis includes formal definition of requirements, as well as development of alternative solutions and comparative analysis of the alternatives.

A requirements analysis is a hierarchical, iterative process for deriving and describing the full set of needs to be satisfied by a product, system, or service provider.

Requirements analysis is a common practice in the civil engineering field when building highway or mass transit infrastructure, and is often standard operating procedure in state DOTs. Often, a civil engineering project is years in planning before it ever reaches design. The method used in such projects is quite similar to the one used by the Maryland State Highway Administration (Maryland SHA) to choose their telecommunications solution: requirements and costs are carefully analyzed for several alternatives before a final decision is made on a particular option.

DOT's have done relatively few comparable telecommunications requirements analyses, however, because historically there were few options from which to choose. In the history of traffic signal systems, for example, prior to deregulation typically the only alternatives available to an agency were the use of purchased services through dialup or leased lines, or the implementation of an agency-owned and –operated cable plant of twisted pair or coaxial cable. Often the decision of which route to take was based on:

- Budget considerations
- The approach taken by neighboring jurisdictions
- A direction set by higher levels within the agency
- Pre-existing agreements with telecommunications service providers.

Needs Assessment

Many such decisions were developed from a relatively narrow perspective. Often they were based upon an internal perspective only (no broad stakeholder assessment), or upon the needs of only one project at a time. Thus the elements contributing to an ability to grow and evolve, and to achieve significant integration were not recognized.

Requirements analysis is a common activity of transportation agencies. It involves the definition of needs: what things the eventual solution must do or provide/produce. It is equally important for product– or system–related projects as it is for service-related ones. Our objective is to address how accepted requirements analysis techniques should be applied to effectively address the specifics of the complex and critical telecommunications solution choice.

What is a Requirements Analysis?

A requirements analysis is a hierarchical, iterative process for deriving and describing the full set of needs to be satisfied by a product, system, or service provider. It typically begins by defining, or using pre-defined, program level goals and objectives. These goals and objectives are the bases for the derivation of high-level or generalized requirements, which can then be decomposed further into lower-level technical requirements. Thus, each requirement is traceable to its parent, and thereby to the higher level need it fulfills.

Without identifying detailed telecommunications requirements by consensus on functional objectives, there is no basis for a technical solution other than its technological appeal.

At the lowest level, requirements must be objectively measurable, along all relevant parameters. Only in this manner can they be of use in determining if the specified technical approach is appropriate. Thus, if delivery of a specified amount of power is the requirement, it must be measurable both in terms of units of energy and in terms of time.

Requirements at the lowest level should not overlap because there is the risk of duplication and resultant inefficiency.

The requirements analysis should also ensure that all requirements are captured, understood, and agreed upon. As will be discussed later, reaching full consensus among stakeholders about the requirements is an essential element in determining the optimal solution.

Why do a Requirements Analysis?

The Maryland SHA Chesapeake Highway Advisories Routing Traffic (CHART) program reported the logic behind its rigorous requirements definition process. Maryland SHA saw telecommunications requirements analysis as similar to the situation where design, engineering, and construction of new roadways and bridges cannot begin until careful planning identifies why they are needed, who they will serve, and where they will be. Only then can the road be adequately designed based on the nature of the traffic and the volume of vehicles expected to travel over it. Likewise, an efficient telecommunications network for CHART could not be implemented without knowledge of why it was needed, who would be served, and how it would be used by the CHART program. Only then could the technical characteristics of the data, video, and voice traffic be identified with any certainty.

Without identifying detailed telecommunications requirements by consensus on functional objectives, there is no basis for a technical solution other than its technological appeal. Therefore the risk is high that the solution employed will not meet the functional program requirements, and may have to be revised at significant cost. This is similar to a case where a road or bridge is under-designed and must be rebuilt because volumes or vehicle types were poorly understood prior to design. Maryland SHA wanted to avoid this.

How to do a Requirements Analysis

Step 1: Identify ITS Program Goals, Objectives, and Requirements
Since the telecommunications network is intended to support an intelligent transportation system, requirements analysis for ITS telecommunications cannot begin without the formulation of ITS goals and objectives by the ITS stakeholders.

As will be described in a later section on the use of a regional ITS architecture, such an architecture can serve as an important source of information about telecommunications requirements. The telecommunications requirements and the ITS systems and services they support must also be consistent with the regional ITS architecture if one has been developed. Information is available on how architecture consistency is defined and can be demonstrated via the USDOT ITS Joint Program Office's web site, at http://www.its.dot.gov.

There may be a variety of existing resources to help understand requirements, among them:

- ITS Early Deployment Plans
- High Level Statewide, Regional, or Project ITS Architectures
- Statewide ITS Strategic Plan
- Regional and Statewide Transportation Strategy and Plan
- Feasibility Studies
- Preliminary Engineering Studies
- Conceptual Design Analyses
- Transportation Improvement Program
- Statewide Transportation Improvement Plan.

How to do a Requirements Analysis

Step 1– Identify ITS Program Goals, Objectives, and Requirements

Step 2– Derive Technical Requirements

Step 3– Document Requirements

Step 4– Validate Requirements

Step 5– Manage Requirements

Types of Requirements:

- **Functional**
- **Operational**
- **Performance**

Step 2. Derive Technical Requirements
For convenience, the telecommunications requirements are categorized by requirement types. Requirement types to be considered include functional, operational, and performance requirements.

Functional requirements identify what is to be done. A sample functional requirement might be that the network must carry incident information from the traffic management system to the traveler information system.

Operational requirements identify who or what performs the function, where the function is performed, how many perform the function, and when it is performed. A sample operational requirement might be that the system should provide notice of freeway incidents to up to five local law enforcement and emergency service providers within 30 seconds of incident confirmation.

Performance requirements quantify measures such as how much, how often, or how fast. A sample performance requirement might be that the network must be able to provide up to five full-motion, full-color video images at 30 frames per second at all times, within 15 seconds of a request.

Requirements must be analyzed and translated into terms that telecommunications engineers can use to derive technical architectures. Video; data; voice; local area network (LAN); reliability, maintainability, and availability (RMA); and security are recommended architectural components that should be derived from the program-level requirements.

With regard to video, the initial definition of requirements should identify the number and locations of the closed circuit television (CCTV) devices, video quality and motion requirements, and the locations of some, but not necessarily all, of the consumers of video. From an analysis of each class of situation in which the system will be applied (using case analysis), the following telecommunications requirements can be derived: the location of all consumers of video; the number of images to be viewed simultaneously at each location; all locations that will select and control the video; the maximum number of images to be transmitted between any two facilities; and the directionality of video. The video data rate (kilobits per second or megabits per second [Kbps or Mbps] per image) can be derived from the program-level video quality and motion requirements.

With regard to data, program-level requirements should identify those device types that will be polled for status and/or data, those that will automatically transmit data at pre-specified intervals, and those that will transmit data on an exception basis only. Through analysis, these requirements can be decomposed into derived telecommunications performance requirements: identifying polling frequency; fixed data transmission frequency (where applicable); average and maximum exception-based frequencies (where applicable); format and size of the status and data messages for each device type; and the maximum allowable time to transmit each message. The message size and timing requirements can be further decomposed into transmission rates (Kbps, Mbps) per message. Requirements should also identify who (which location) will control the traveler information devices.

In Maryland, Maryland SHA desired to ensure that there was no bias for or against any solution, equipment, or acquisition method, so requirements were described by the nature of the traffic that the network would have to support. This included serial data from the ITS devices and field controllers, LAN data, voice, and video traffic.

Important requirements were derived for each type. Examples of the detailed requirements are device message sizes and formats, frequency of transmission, polling interval for low-speed devices, image and motion quality, transmission delay, number of simultaneously viewable images, and camera selection and control constraints for CCTV. Overall reliability, maintainability, and availability requirements for the network backbone were also derived during this step from information obtained about ITS device failure rates and the ability to respond to outages on the road systems during peak travel times.

Step 3. Document Requirements

Each program-level and derived telecommunications requirement should be assigned to the appropriate requirement type (e.g., functional, operational, etc.). For each type of requirement, each high-level requirement should be assigned a unique identifier. A simple numbering scheme will generally be sufficient. Each requirement statement should be as concise as possible, and unambiguous. By convention, requirement statements are drafted using the verb "shall." A given requirement statement can be subdivided into two or more clearly identified parts. Also, a requirement statement can reference a table or tables that contain detailed information. This is normally done to reduce the size and complexity of the requirement statement. Any requirement that was derived from a high-level requirement should retain the identifier of the parent as part if its identifier.

Step 4. Validate Requirements

After the requirements have been assembled, it is necessary first to analyze and compare them to ensure that neither conflicts nor gaps exist. Each requirement is also reviewed for measurability.

The requirements should be presented to the stakeholders, initially in writing, and then preferably in a group forum type of working session. Leading up to the presentation, it may be useful to perform some requirements "outreach" in order for key participants and their organizations to fully understand and have considered the requirements before arriving at the discussion forum. In this process, these participants should be afforded the opportunity to ask questions "off the record" which they may not feel comfortable asking in front of the group as a whole. In this way, these issues can later be brought before the assembled group in a non-confrontational manner.

It is necessary for someone at an appropriate level of responsibility at each stakeholder organization to indicate approval and to "take ownership" of the requirements.

In the presentation, the requirements are described and explained, relating the requirement to the purpose (goal or objective) it supports, but not linking it to any specific stakeholder. Implications of each requirement should be presented as well, in order to gain a full understanding of the requirement, and to stimulate consideration of whether each should be modified to alter its impact on cost, risk, reliability, or any other important decision-making criterion.

It is necessary for someone at an appropriate level of responsibility at each stakeholder organization to indicate approval and to "take ownership" of the requirements. This process may require additional meetings or discussions if all key individuals are not able to attend a single meeting. It is also important to recognize that there may be multiple separate elements within each stakeholder organization whose opinions are not uniform. It is preferable that these elements meet beforehand to resolve internal differences of opinion. Reaching consensus will be facilitated if each stakeholder organization "deputizes" an individual to speak for its interests and with the authority of the organization (or that their common supervisor be available to do so).

Step 5. Manage Requirements

The resultant requirements document is a "living" document and should be managed in a controlled manner. Although the information may be made available online, the document or database itself should be carefully secured as would be any other contractual or design document.

The requirements database should be managed under the same configuration management program as is used for other critical information. Thus, each change made to the database would be logged, described, the requestor noted, and the reason for the request described. Changes would only be made after formal review and approval of the configuration control board, representing the official views of each of the stakeholder organizations. If there is a constant flow of changes, the board may be required to meet on a regularly scheduled basis. Typically, some form of change control notice is issued in advance of a board meeting, along with the information necessary to hold a meaningful discussion. Following the reaching of consensus, a signature sheet is passed, on which each organization's assent is noted. Notice of the change is then distributed, likely to a broader audience than just the change board.

It is extremely important that DOTs arm themselves with appropriate telecommunications expertise and experience to adequately play in this arena.

Hiring A Consultant Team With Industry-Specific Network Design Experience

ITS telecommunications is one of the most expensive components of ITS programs and may rival medium to large civil engineering projects in cost. It, therefore, makes sense to perform the same kind of up-front planning and analysis that is performed for civil engineering projects. Like transportation, the telecommunications industry is huge and complex with an entirely different set of technical disciplines that DOTs may not be familiar with. This should be recognized up front and planned for either by retaining appropriate in-house staff or contracting with a firm experienced with a range of technical disciplines in this industry. It is extremely important that DOTs arm themselves with appropriate telecommunications expertise and experience to adequately play in this arena. Not to do so heightens the risk of making unwise cost and design decisions.

Maryland SHA recognized that it did not have the resident expertise in building and maintaining a large telecommunications infrastructure to make a decision of the desired level of quality. Thus, it turned to a systems integration firm to perform the study. The systems engineering division of a major aerospace/defense firm was retained under subcontract to an engineering firm with which the state already had a flexible contract mechanism. The aerospace/defense firm had specific expertise and experience in analyzing and building large complex networks. The analysis developed technical options based on functional and performance requirements. It compared the costs of those options (including owning versus leasing) over a ten-year life cycle; the appropriate length of the life cycle for use in the analysis is itself an early and important decision.   The telecommunications analysis lasted nine months and consisted of three phases:

1) functional and performance requirements analysis and validation

2) development of various network options

3) the costing of those options.

The appropriate length of the life cycle for use in the analysis is itself an early and important decision.

The Virginia DOT has found itself, several times, faced with developing plans for network implementation or evaluating alternative approaches recommended by firms already under contract. In these cases, the state has made use of systems firms with significant aerospace/defense backgrounds already under contract to perform the analyses. In one instance, a major contractor, having recently won the contract to perform a significant expansion of the regional advanced traffic management system (ATMS) and the telecommunications network supporting it, came forward with a variety of alternatives to the recently bid plans and specifications. Virginia DOT relied upon the systems consultant hired to perform inspection and independent validation and verification to investigate available alternatives in detail, and analyze the implications.

In a later situation, Virginia DOT recognized the need to create a regional network, unifying existing network elements and providing expansion capability to support significant growth. Virginia DOT used the same firm previously retained to assemble the primary requirements and to develop the network concept. Virginia DOT then had an additional systems firm with significant aerospace/defense background which was also under an existing flexible contract to perform detailed analyses of the technical alternatives.

Needs Assessment

Often both technical expertise and telecommunications contracting expertise is needed.

The technique used to hire a telecommunications consultant is similar to that used by most agencies to hire consultants for other purposes, with a few important exceptions. Because relatively few telecommunications consultants have highway experience and if qualification-based selection is used, then experience outside of the transportation trade should be carefully considered. This may include work for other types of government agencies (and even foreign governments), and for the private sector. In cases of the latter, not all information may be subject to disclosure regarding an assignment, potentially including the name of the client. In many industries this information is extremely proprietary, and consultants are prohibited in their contracts from divulging the client's name. Thus, for example, if an agency were to use the Architect-Engineer and Related Services Questionnaire (SF254) and Architect-Engineer and Related Services Questionnaire for Specific Projects (SF255) forms as the primary method for collecting information from bidders, these forms may prove to be inadequate. These forms do not contain staffing or project categories necessary for a complete description of telecommunications experience and capability.

As with hiring any other consultant, the agency should be sure to require relevant experience. If the requirements are limited to the wide area network, then only that type of experience is necessary. If the analysis is to include both local and wide area networks, both types of experience should be sought. Typically, experience with switches and multiplexers is also appropriate to specify. Often, both technical expertise and telecommunications contracting expertise is needed. Although experience with local providers and conditions is helpful, it is a far lesser concern than having the appropriate technical expertise.

Of utmost importance is retaining a telecommunications consultant that is independent and objective.

It may be difficult to retain a qualified telecommunications consultant under existing agency overhead and profit ceilings. This is because most telecommunications consultants serve the private sector, where such ceilings do not exist. If this is the case, the agency should seek methods to pay prevailing telecommunications consulting rates.

Of utmost importance is retaining a telecommunications consultant that is independent and objective. This almost always excludes firms that sell or install telecommunications equipment. The agency will need to decide whether this also excludes firms providing the requirements analysis from proposing on the detailed design of the system, or whether there is sufficient benefit from efficiencies in carryover of the needs understanding and client relationship to leave this option open.

What Were The Lessons Learned From An Example Telecommunications Requirements Analysis?

The Maryland SHA performed an extensive formal telecommunications requirements definition and analysis of alternatives in the early stages of its ITS planning. They hired a consulting firm with specialized telecommunications expertise to provide a requirements analysis process, to supply advice in development and analysis of the requirements, and later to identify options that would meet requirements. This experience serves as an excellent case study providing lessons learned in the requirements analysis process.

Designing a network is a complicated undertaking and requires a skill set not readily available in Maryland SHA.
Maryland SHA recognized it did not internally have the appropriate expertise and experience in determining all of the requirements and in identifying and comparing financial and technical alternatives for large-scale networks. The agency also recognized that this expertise was not readily available through its traditional transportation engineering consulting community. Thus, they hired a firm experienced in both telecommunications and systems integration. This firm worked in concert with Maryland SHA's internal transportation engineering staff and transportation engineering consultants to Maryland SHA on the analysis.

Virginia DOT found the same experience in planning and implementing a large telecommunications network to support its traffic signal system in Northern Virginia. From both technical and contractual perspectives, Virginia DOT found its own knowledge and experience less than it desired. To remedy this, it hired two retirees from the local phone company, one with central office (switching and networking) experience, and the other with field installation experience, to supplement its existing in-depth understanding of transportation/traffic engineering and traffic signal systems.

There may be several network designs that meet requirements, but each alternative can have widely varying costs, particularly when using leased services.

How a network is designed is a critical determinant of the total cost.
The goal of the Maryland SHA requirements analysis was to define the most cost-effective and technologically viable option based on defined functional and performance requirements. Its formal definition and documentation of requirements provide a method of assuring that any proposed solution could provide at least the basic telecommunications capability it needed. Without the information developed during the requirements definition, SHA would not have been able to perform the financial and technical analyses that it used to assist in determining its eventual telecommunications solution.

Different network designs may meet the same requirements, but may have widely varying costs, both for implementation and for operations/ maintenance. Maryland SHA analyzed the financial implications of each of the requirements-based design options it considered. Through performing this analysis, Maryland SHA was able to develop a network configuration which dramatically reduced the total cost by:

- Minimizing the number of times that the network had to cross long distance zone boundaries
- Minimizing the bandwidth consumed by typically bandwidth-intensive video transmissions

- Utilizing the intelligence of its field devices to reduce the volume of data transmitted
- Making optimal use of the communications infrastructure it already owned and used.

The timeframe assumed in the analysis can drive the decision.
Based on its prior experience, Maryland's analysis assumed that the accumulation of long-term lease charges would be higher than the capital costs of building a fiber optic network over time. Therefore, it was unexpected that the least expensive leased option was half the cost of the full build option for the ten-year analysis period which they had chosen. In Maryland SHA's opinion, ten years was an appropriate network life cycle since it was long enough to consider factors such as technical obsolescence of current generational fiber optic equipment, but short enough to assume that the value of leased bandwidth remained unchanged for each year. Since many factors—including the rapid evolution of technology, the ability to upgrade the network significantly without replacing it, and the end-of-life "residual value" of the system—are important in choosing a life cycle length for analysis, great care is warranted in selecting this value. Some "sensitivity analysis," comparing results when the life cycle length is varied from the chosen value, is appropriate in order to assure that the assumptions have not predetermined the final network solution.

Risk can be minimized.
By undertaking the analysis, Maryland SHA reduced two important risks: 1) that the agency would build a network that would not meet its needs, and 2) that the agency could not capitalize on technology and competitive changes that may yield lower telecommunications costs during the life of the network. By understanding and documenting its requirements, particularly by identifying who needed access to the information and how much bandwidth was required to provide acceptable access, Maryland SHA could build a network that adequately addressed these requirements. Without understanding its requirements, Maryland SHA ran the risk of building a network that would be costly to change or redesign in order to take advantage of technology improvements or to serve additional agency needs that arose after it was implemented.

Maryland State Highway Administration Summary Lessons Learned

- **Designing a network is a complicated undertaking and requires a skill set not readily available in Maryland SHA.**
- **How a network is designed is a critical determinant of the total cost.**
- **The timeframe assumed in the analysis can drive the decision.**
- **Risks can be minimized.**

Technology trends, the passage of the Telecommunications Act of 1996, and the unfolding of a deregulated environment have generally resulted in overall lower costs of equipment and services. Maryland's telecommunications consultant recommended that Maryland SHA keep a watchful eye on specific technologies (e.g., Digital Subscriber Line technologies) that could reduce ongoing charges. It also recommended that Maryland SHA not pursue long-term leases but rather only three-year leases so that Maryland SHA could capitalize on telecommunications reform. If lower costs did not materialize, the agency could still pursue a build option or renegotiate with providers for better prices.

What is a Regional ITS Architecture? What is it not?

Regional ITS Architecture

A regional ITS architecture can provide significant value in helping to define telecommunications requirements. By identifying types, volumes, sources, and users of transportation information, the regional ITS architecture helps in understanding connectivity and bandwidth requirements, as well as the nature (periodic, continuous, random) of the communication flow.

A regional ITS architecture progresses from defining the highest level of needs to the specifics of data elements and data flows, and the standards which may be applicable to methods used to implement these flows. For the purposes of this document, a regional architecture can be viewed as ranging from a single municipality or rural area to statewide scope. It is not limited to urban environs, and may include both urban and rural components, and the means for their integration for comprehensive regional transportation management.

A key component in every step of regional ITS architecture development is that inputs be gathered from a full range of stakeholders. Equally important is that consensus be achieved between the key stakeholders on the outcome of the architecture.

A key component in every step of regional ITS architecture development is that inputs be gathered from a full range of stakeholders. Equally important is that consensus be achieved between the key stakeholders on the outcome of the architecture. Often this involves both public and private sectors, representation from multiple modes, and participants from many different components of the transportation environment such as law enforcement and towing services. As it progresses into greater detail, the architecture will:

- Inventory the existing transportation resources and systems which will need to be served by the telecommunications network, and which may provide telecommunications capability supporting transportation needs
- Gather needs as viewed by the stakeholders, including their priorities
- Discuss their respective roles and responsibilities in transportation management
- Identify resources operated by them
- Define opportunities for sharing of information between them.

This process should identify many opportunities for partnerships, public-public, public-private, and private-private. Sharing of roles, and taking advantage of resources owned or activities already performed by agencies can result in both increased performance and decreased total cost. Thus,

The Concept of Operations Answers:

- **What are we going to do?**
- **How are we going to do it?**

The logical architecture also provides the relationships between the functional processes, by identifying the information which each process uses, stores, or generates, and the information which moves between the processes.

the regional ITS architecture development process assists in creating both technical and institutional infrastructure supporting future ITS deployment.

The architecture development begins by identifying ITS user services (originally defined in the National ITS Program Plan) which satisfy the user needs outlined in the transportation planning process. In the architecture, high level user services are further subdivided into user service requirements, more clearly identifying the specific services required to address the region's transportation needs.

At this point a preliminary concept of operations is drafted. It adds a "how we are going to do it" to the "what we are going to do" that was described in the user services analysis. Its focus is on roles, responsibilities, and resources. The concept of operations is an excellent point at which to clarify roles and responsibilities of each of the stakeholder participants, and to initiate discussion of how the stakeholders and their systems will interact in the broader transportation management context.

Once the specific user services are defined, a logical architecture can be constructed. The logical architecture performs a structured decomposition of the identified user services into the functional processes necessary to deliver these services. The logical architecture also provides the relationships between the functional processes, by identifying the information which each process uses, stores, or generates, and the information which moves between the processes. Thus, it provides a clearly defined specification for each process, a data flow diagram of the information moving between processes, and a data dictionary of the data elements themselves.

This information is of significant value in telecommunications analysis. Once the locations and means of processing are identified further along the systems engineering process, this information will allow the calculation of data access points and bandwidth needs.

The physical architecture is the next step. It begins by identifying the physical entities where functions may be performed. These entities would include such facilities as a traffic operations center, a freeway management center, or a transit operations center.

The physical architecture proceeds further to identify the subsystems which belong within each physical entity. Typically these divisions are clear, based upon the roles, responsibilities, and jurisdictions which either existed previously or which were defined in the concept of operations. It also identifies interfaces between the subsystems, as well as internal and external physical interfaces.

The physical architecture allocates the processes identified in the logical architecture into the subsystems. The basis for this allocation is that subsystems:

- Group tightly coupled functions
- Group tightly synchronized functions
- Group performance/security/safety critical functions
- Align with cost allocations
- Align with deployment options
- Align with market segments.

The subsystems are aggregated (and later integrated) as needed for actual deployment. A tool which may assist in this process is the use of market packages. Market packages contain multiple, related equipment packages from one or more subsystems. They are defined to make them more easily related to actual ITS infrastructure elements, such as an incident management program or an electronic fare payment system. For example, the transit vehicle tracking market package contains both the transit center tracking and dispatch, and the on-board trip monitoring equipment packages. Market packages, and the relationships between market packages, considerably simplify the preparation of an implementation strategy.

The architecture identifies the interconnections between subsystems, and may identify the standards which are appropriate for these interconnections. Where subsystems exist in different systems or different centers, telecommunications is also required to accomplish the interconnection.

The information flow data derived in the logical architecture step can be related to the interconnections identified in the physical architecture step, providing a relatively complete picture of the telecommunications needed to support the regional ITS implementation.

Subsystems are composed of equipment packages, which in turn contain one or more processes derived in the logical architecture. Thus, the information flow data derived in the logical architecture step can be related to the interconnections identified in the physical architecture step, providing a relatively complete picture of the telecommunications needed to support the regional ITS implementation. The result is a complete picture of the information flows between subsystems, and between systems and the facilities in which they are located and operated.

Another characteristic of the architecture interconnection analysis is that it recognizes the nature of the telecommunications, i.e., whether they are random (voice), steady state (constant polling or sensor data), or bursty (pre-processed and locally stored for later transmission). The physical architecture contains a telecommunications "layer" which can assist in modeling the telecommunications needs for the systems to be deployed.

Needs Assessment

The most important contribution of a regional ITS architecture in defining telecom-munications requirements is that when taken to its most detailed level, it identifies the information to be communicated between external elements and the ITS systems/subsystems, and between the ITS systems/subsystems themselves.

The most useful tool in developing a regional ITS architecture is the National ITS Architecture. The National ITS Architecture (available online and on CD-ROM) provides an exhaustive list of the elements at each step in the process, from which those appropriate to the region's architecture can be selected. This provides the foundation from which the necessary regional customization can be accomplished. Sources for access to the National ITS Architecture are provided later in this document.

An ITS architecture is not a system design or a complete telecommunications architecture, although it provides important information for use in each. It does not define where (physically) the required functions are performed, or how they are implemented. An architecture is technology independent, although it should reflect the needs and capabilities of pre-existing ITS infrastructure.

USDOT has developed a product, entitled "Turbo Architecture", to assist in rapid, efficient, and thorough development of a regional ITS architecture. Information on obtaining the Turbo Architecture tool, training, assistance, and documentation will be available through the USDOT ITS Joint Program Office's web site at http://www.its.dot.gov.

What is the value of a Regional ITS Architecture in defining telecommunications requirements?

The most important contribution of a regional ITS architecture in defining telecommunications requirements is that when taken to its most detailed level, it identifies the information to be communicated between external elements and the ITS systems/subsystems, and between the ITS systems/subsystems themselves. Thus, it provides the foundation for determining the telecommunications capacity and access points required in the eventual network(s). The material contained in the National ITS Architecture goes further, indicating the most common general telecom-munications categories between systems, although this information is subject to revision under the rapid evolution of telecommunications technology and the deregulatory institutional environment.

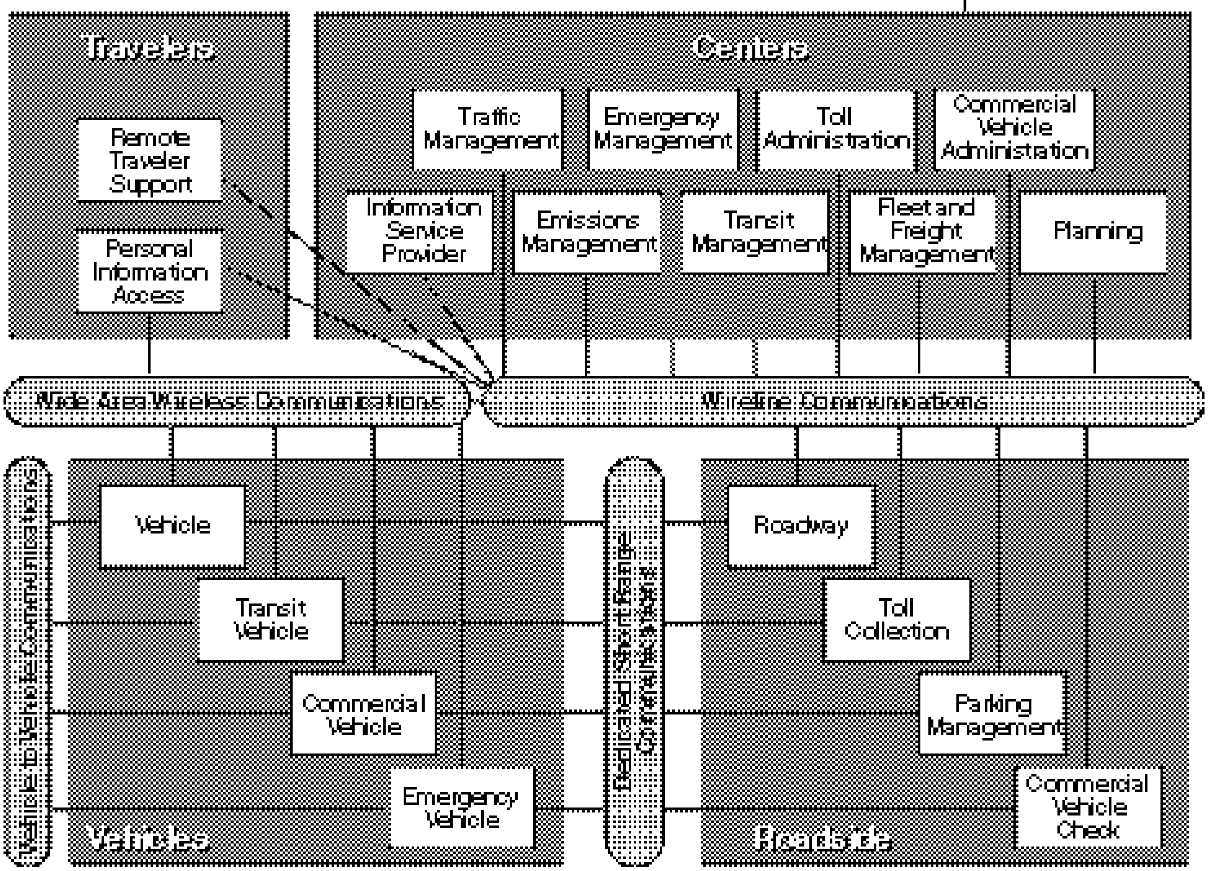
Unfortunately, due to the relative newness of ITS architecture development, we were unable to identify at the time of this study any agency which had applied this approach. Thus, most agency telecommunications decisions have been made without the benefits of the information a regional ITS architecture provides. Lacking this information, there are several likely problems:

- The network may be sized too small to meet the eventual demands
- The network configuration may not match the user's needs
- An approach may be adopted which results in significant additional cost to be expanded to meet the full set of requirements.

Regional ITS Architecture

How is a Regional ITS Architecture developed?

In addition to the highly summarized description above, readers interested in information on the development of an ITS architecture are referred to the USDOT courses and training materials described below. USDOT is also preparing a scope of services which agencies will be able to use to procure the services of a consultant to assist in preparation of a regional ITS architecture.



Communication Relationships within the National ITS Architecture

References on developing an ITS architecture

A series of case studies of the preparation of regional ITS architectures noted below has been developed by the Volpe National Transportation Systems Center, and are available via the USDOT Electronic Document Library (EDL) at http://www.its.dot.gov/welcome.htm—or from Federal Highway Administration Devision Offices and Resource Centers.

- The New York - New Jersey - Connecticut Region
  Building a Framework for Regional ITS Integration
  Publication number FHWA-OP-99-021; EDL number 9643
- The Gary-Chicago-Milwaukee ITS Priority Corridor
  Building a Framework for Tri-State ITS Corridor Integration
  Publication number FHWA-OP-99-022; EDL number 9644
- The Houston ITS Priority Corridor
  Building a Framework for Regional ITS Integration
  Publication number FHWA-OP-99-023; EDL number 964
- The Southern California ITS Priority Corridor
  Building a Framework for Regional ITS Integration
  Publication number FHWA-OP-99-024; EDL number 9646
- Arizona's Rural Statewide ITS Architecture
  Building a Framework for Statewide ITS Integration
  Publication number FHWA-OP-99-025; EDL number 9647
- Developing a Regional ITS Architecture: A Cross-Cutting Study
  Building a Framework for Regional ITS Integration
  Publication number FHWA-OP-99-026; EDL number 9649
- Electronic Credentialing for Commercial Vehicle Operations
  Building a Framework for ITS/CVO Integration
  Publication number FHWA-OP-99-027; EDL number 9650

The reader interested in ITS architecture training is directed to the web site for the National Highway Institute (http://www.nhi.fhwa.dot.gov) and the National Transit Institute (http://policy.rutgers.edu/nti) where the most recently available related course material can be found. Resources available on these web sites include courses on the application of the systems engineering process and the use of the National ITS Systems Architecture in planning, design, implementation, and operations/maintenance of ITS facilities. The course catalog is available at http://pcb.volpe.dot.gov/98catalg.htm.

The National ITS Architecture documents, including the full details of the "sausage" connectivity diagram on page 19, are available online at http://www.odetics.com/itsarch and through ITS America's web site at http://www.itsa.org. It is also available on CD-ROM from USDOT's Federal Highway Administration Resource Centers and from the ITS Joint Program Office.

Telecommunications Architecture

What is a telecommunications ITS architecture? What is it not?

A telecommunications ITS architecture describes the points of need for telecommunications service, and the nature of their need (bandwidth and type of service). On top of this "needs map" the telecommunications ITS architecture overlays the network topology, thus identifying both the network routing, and the points of interconnection (nodes). As with an ITS architecture, it is not a system design; it does not identify the specific devices or the technologies, although it may identify standards that are appropriate.

How is a telecommunications ITS architecture useful in defining telecommunications requirements?

The telecommunications architecture provides a picture of the geographic distribution of the needs, the size and type of the needs, and a view of the layout of the network.

The telecommunications ITS architecture:

- Provides a comprehensive view of the telecommunications needs for the project or regional ITS program
- Assists in understanding both budgeting and project scheduling requirements by illustrating the geographic layout of the system
- Provides information to those wishing to determine suitability of specific equipment to the system's needs
- Assists the implementing agency in understanding where multiple, dispersed needs may be cost effectively combined and projectized
- Provides information to those that may benefit from interconnecting to the ITS telecommunications network, or with whom the ITS program desires to interconnect
- Provides a comprehensive view of the ITS telecommunications network for other agencies who may wish to take advantage of the network's resources in order to accomplish their non-ITS missions
- Provides view of the network to assist in planning for network growth and evolution.

How is a telecommunications ITS architecture developed?

A telecommunications architecture represents the combination of information from several efforts. The map of devices needing telecommunications support is often developed as part of an ITS architecture preparation, or may have been assembled in preparation of an ITS Early Deployment Plan or other similar document. The probable "build-out" plan, representing likely additions to the field equipment, is also likely the outcome of a significant planning effort.

Telecommunications Architecture

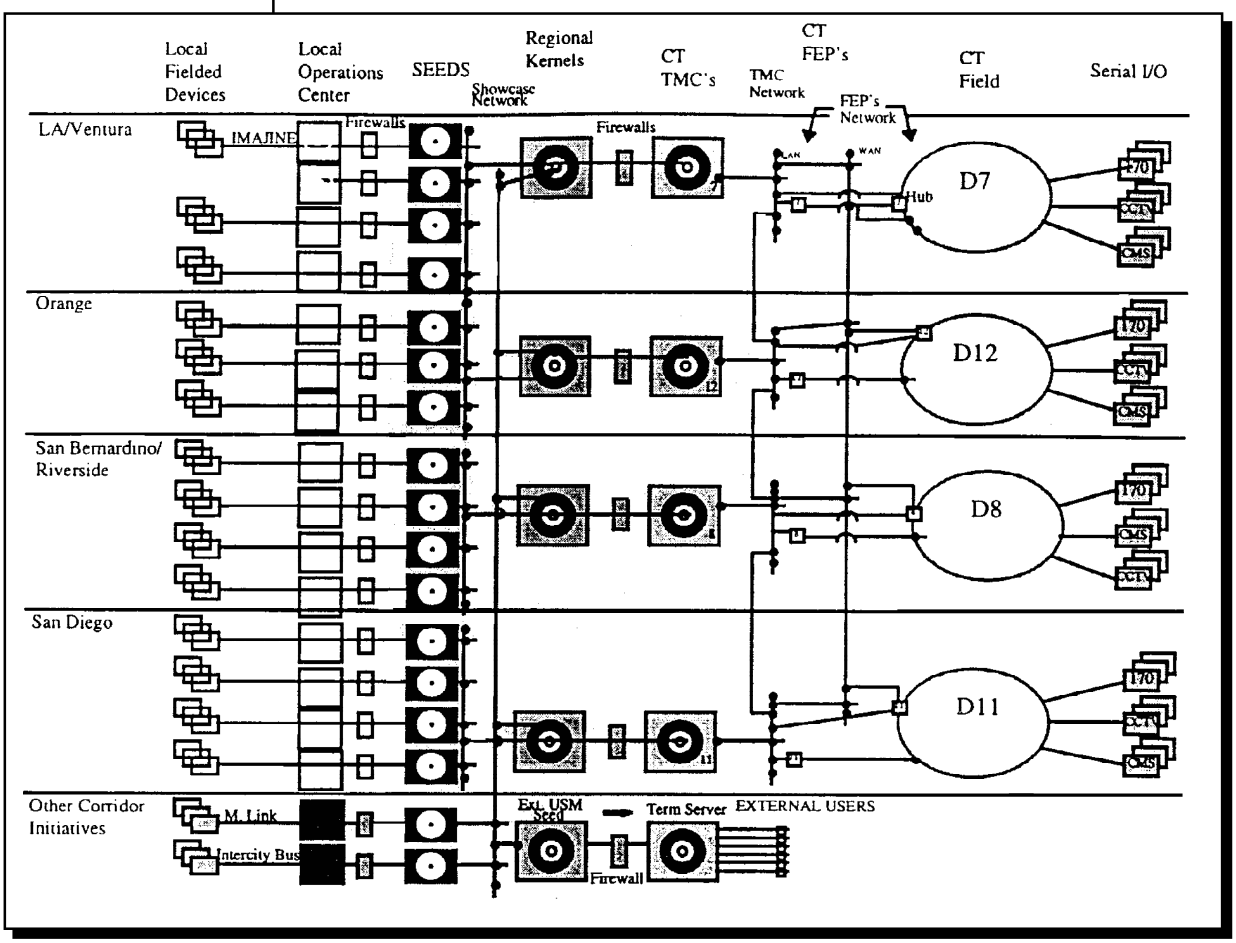
The telecommunications architecture provides a picture of the geographic distribution of the needs, the size and type of the needs, and a view of the layout of the network.

Needs Assessment

The telecommunications architecture represents imposition of an overall network topology upon the map of the network needs and analysis. It then becomes possible to derive the functions which need to be provided, such as multiplexing, switching, and media conversion.

Example of telecommunications ITS architecture

A relatively thorough telecommunications ITS architecture has been developed by the Southern California ITS Showcase. The Showcase includes 17 projects distributed across 4 California Department of Transportation (Caltrans) Districts. Systems from well over a dozen agencies are included in or interconnected with the Showcase. Each system converses with its peers through a “seed” which performs translation. Seeds are connected to a regional “kernel” which provides routing, network management, security (in addition to firewalls), and other shared network services. Kernels, in turn, are interconnected via the Showcase’s primary network connections.



Telecommunications Architecture for the Southern California Priority Corridor ITS Showcase

Each District also contains a TMC co-owned and operated by Caltrans and the California Highway Patrol (CHP). The TMCs are also interconnected via the state's wide area network. Each district's own network, providing connectivity to its sensors, displays, and other traffic management and traveler information field devices, is also unique, representing differences in age, budget, and technical and management philosophies at their respective dates of development.

The ITS implementing agency faces a multitude of complex decisions in the design and implementation of its telecommunications network. Several of these key decisions, each with a long term impact on the agency, its network, and its systems, are discussed below.

Distributed vs. Centralized

For many years, there have been widely divergent opinions on the optimal level of distribution for traffic control systems, varying from centrally controlled uniform traffic control systems (UTCS) to fully detector-actuated systems with totally local control. Consistent with this distribution of processing and control is a significant change in the type and volume of telecommunications workload. In the classic centrally controlled system, the network must support constant telecommunications between many endpoints and the central computer, constantly moving both data and control. In the fully distributed system the reverse is true; control is totally localized, with information and control messages transmitted only when major faults are detected or when special needs exist for changes to the field devices. Typically these changes are made via dialup; telecommunications linkages only exist when needed.

Characterizing distributed and centralized systems

Distributed systems rely more extensively on processing resources near the equipment being operated.

Distributed systems rely more extensively on processing resources near the equipment being operated. The field processor is relatively complex, typically running installed software. It typically has a fair amount of local solid state memory. The local processor is also typically supported by power conditioning or a modest battery backup so that it can tolerate modest power fluctuations and failures. It may contain a display and means for local debugging such as a keyboard connection, but it contains at least a keypad. Telecommunications with the central facility is less frequent. Telecommunications with the central facility may occur:

- Not at all
- Regularly but infrequently
- Only when malfunction is detected
- Only when the central facility desires to check on field system status
- Only when the central facility desires to make a change in the field system operation.

Major Issue Areas

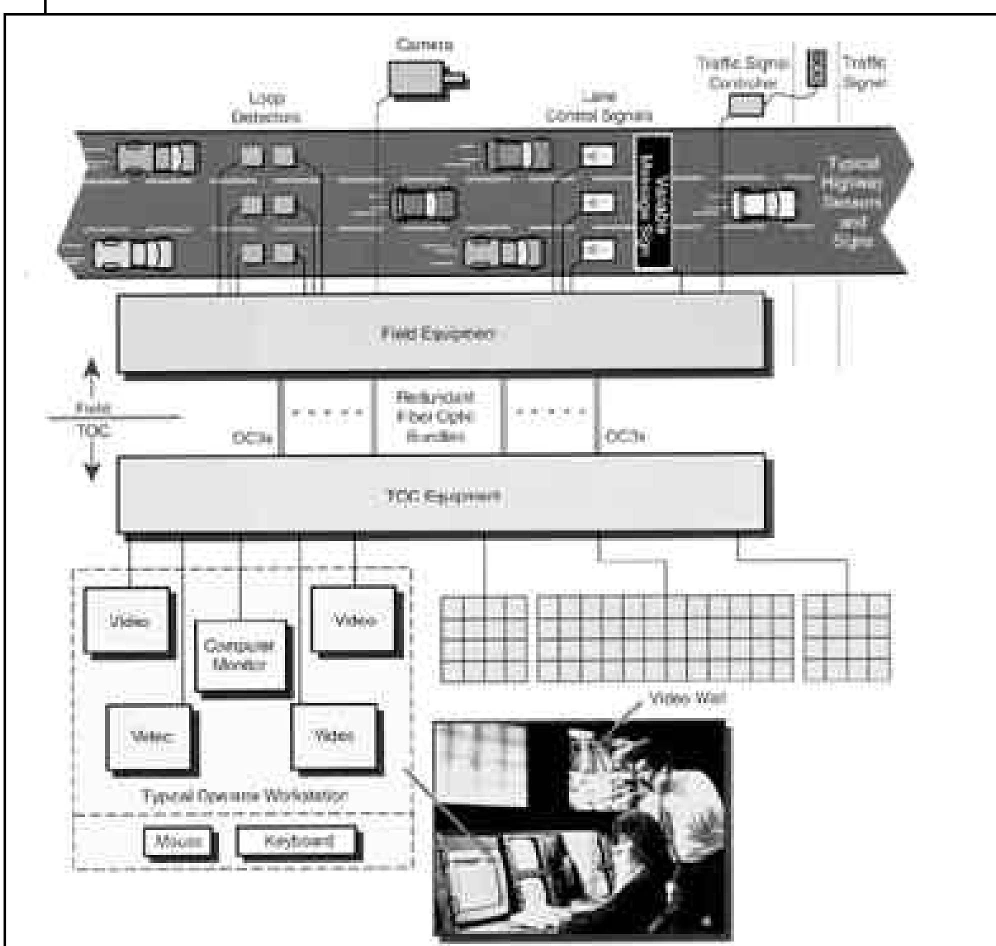
In centralized systems, field devices are in constant telecommunications with the central facility. Local processing power may be minimal, only enough to carry out the commands issued by the central facility.

In centralized systems, field devices are in constant telecommunications with the central facility. Local processing power may be minimal, only enough to carry out the commands issued by the central facility. Typically the local processor has relatively little memory, and may depend totally upon firmware for its local instruction set. The default mode of operation in cases of telecommunications failure or failure of the central facility is relatively basic, such as fixed time. Telecommunications to the central facility is typically intensive, including system status, operational condition, command confirmations, and sensor data which have received little or no processing. Similarly, telecommunications from the central facility typically includes a regular flow of commands and constant polls requesting either sensor data or status checks.

Examples of distributed and centralized systems

Centralized – TransGuide

The TransGuide ATMS monitors and manages freeway traffic in the greater San Antonio, Texas area. Designed in the early 1990s, it utilizes relatively simple field controllers for detector monitoring. Network



TransGuide Architecture

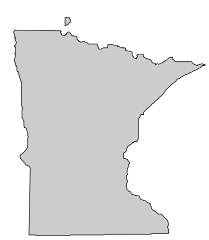
architecture was fully redundant using diverse routing, point-to-point, and all-digital, with over 1 million feet of single mode fiber optic cable run for the first 26 centerline miles of system. Fiber trunks were run from the control center to fiber hubs, which then further divided services to multiple telecommunications cabinets. Data, control commands, and voice were transmitted at modest speeds. These signals were combined into higher speed streams, which were further combined with digitized video signals to make a single signal on each fiber. At the control center end, each of the fiber signals were demultiplexed, with data routed through further demultiplexers and intelligent analyzers, and video routed through a digital switch to monitors and large scale displays.

Primary computing took place on a fault tolerant minicomputer, originally coupled to X-Windows terminals and later to true workstations. Telecommunications was constant, with a steady stream of status polls generated by the central computer and transmitted to each field device, with status responses returned by the field devices. Status polls were generated both regularly and on demand.

Data from detectors were partially pre-processed in the field, both accomplishing data reduction and smoothing irregularities. Smoothed data were returned frequently to the control facility but were captured by intelligent analyzers which passed only further aggregated data and nonstandard condition data to the central computer.

Distributed – Minnesota Virtual Traffic Operations Centers

Minnesota is in the process of implementing a series of "virtual transportation operations centers" for small/medium urban areas with significant surrounding rural regions. Each center will consist of servers and workstations, located at the facilities of the individual agencies whose functions they support, networked together for sharing information. There will be no central facility or central support staff for the center. An example of linked remote centers would be the interconnection of the traffic signal computer(s) at the city DOT and the county department of public works, with pavement and road weather sensor information at the state DOT district office, and video signals from shared CCTV cameras on major routes and at common trouble zones. A logical extension of this concept would be to integrate into this system the output from any local "smart work zone" type of system which may be in operation. The potential exists for the integration of transit information as well. The overall system will be linked to state DOT headquarters for use in integrating traveler information on a regional and a statewide basis.



In this environment, information is shared liberally, and displays are integrated to some extent using a geographic information system representation. Initially, control is not shared, retaining pre-existing jurisdictional boundaries and responsibilities.

Strengths and weaknesses of distributed and centralized telecommunications systems

Distributed systems:

- Reduce the cost of telecommunications and processing by transmitting less information, and by taking advantage of low cost field processing resources
- Are less vulnerable to a single point of failure such as a control center outage
- May be made to be centrally manageable under emergency or other relevant conditions
- Result in reduced dedicated staffing by making system operation one of a number of responsibilities of the "operations staff" at each agency's location.

Centralized systems offer:

- Ease of management through use of centralized management tools
- Ease of access for repair and modification since most processing and switching devices are centrally located
- The opportunity to share the cost of more capable resources such as large scale video displays or switches
- Easier ability to take a corridor or regional approach, since extensive information is available centrally for processing in this manner.

Interfaces between different technologies

A primary difference in centralized and decentralized implementations is in the interfaces between the devices that are interconnected. Using an advance traffic management system as an example, devices such as vehicle detectors, closed circuit television cameras, dynamic message signs, and highway advisory radio transmitters are considered "field devices." These devices interact with "central equipment", such as a traffic management computer system, which may be located in a TMC. The interaction is via a telecommunication network. If the computing intelligence is highly centralized, then large volumes of raw, unprocessed data would typically be transmitted over the network from the field devices (especially detectors) to the center where they would be processed by the computer. Similarly, with minimal intelligence in the display devices such as the dynamic message sign, the central computer would issue simple commands to the sign as well as commands to verify that the commands were executed successfully, and would "poll" the sign frequently to assess its operational status. This environment places heavy demands upon the telecommunications network to carry volumes of data and commands, and network failures typically make the system essentially non-functional.

Distributed vs. Centralized

In a distributed environment, the detectors would filter and analyze their raw data, providing only summary or exception data over the network to the center. Similarly, the dynamic message sign would have significant self-diagnostic capability, would require only minimal direction, and would automatically report only deviations from normal operation. This environment requires much less capacity in the telecommunications network, and may be able to operate with some effectiveness even if the field devices are disconnected from the control center. An example of this type of operation can be found in the fog warning system operating in the Northern California approaches to the Rocky Mountains. In this system, visibility sensors trigger standard messages to be displayed on dynamic message signs, and cancel the messages when visibility returns to acceptable levels, without intervention from the regional transportation management center. The primary differences in interfaces include:

A primary difference in centralized and decentralized implementations is in the interfaces between the systems and technologies that are interconnected.

- The interface may move a little or a lot of information, depending upon the ability of the field devices to pre-process the information, and upon the level of field system intelligence and the degree of decision-making authority allocated to the field system.
- The interface may or may not allow control capability to be moved from one center to another. Although sharing of information between centers is increasingly common, the ability to share control or to transfer control from one facility to another can be significantly more complicated, both institutionally and technically.
- The interfaces between systems must exist at many levels. Physical medium, network protocol, and application programs must be compatible in order for the systems to successfully exchange information or interoperate. The objective of many of the early ITS standards being developed is to support multiple alternatives for some basic telecommunications decisions, such as the physical transmission medium in order to accommodate existing infrastructure, and in order to maintain a vigorously competitive marketplace.
- The interfaces may create either peer-to-peer (the devices work cooperatively) or master/slave (one device controls the other) relationships between the systems that are interconnected.
- Interfaces are the logical locations for the use of standards. When no standards exist, the interfaces are often accomplished with proprietary or closed systems, severely limiting the system owner's ability to expand or access the system without the assistance of the system vendor.
- The interface may have impact on one or more of the systems that are interconnected. This is particularly true when connecting multiple legacy systems or legacy systems with newer ones. The interface may have to serve as a "translator" into the native language of the legacy system, requiring storage and processing power for the translation. Further, the legacy system may have limits on the rate at which it can accept, process, and acknowledge data and commands, thus forcing the interface and the partner systems to wait on it.

Major Issue Areas

Outsourcing vs. Staffing

An important consideration in making lease versus own and technology decisions is how the agency will operate and maintain the telecommunications infrastructure. This applies to both local and wide area networks, and to the devices which connect the two. In this section, several of the primary determinants in making the decision as to whether to use agency staff or contractor personnel to perform network operation and maintenance, or whether to contract for telecommunications services rather than to own the network, are discussed.

Skills Required

Most agencies find it challenging to hire and retain personnel with the skills required to operate and maintain a wide area network.

Most agencies find it challenging to hire and retain personnel with the skills required to operate and maintain a wide area network. These skills often have to cover more than one technology. In multi-technology implementations such as Detroit, where microwave, fiber optics, and both coaxial cable and twisted pair copper are used, the skill set needed is quite broad, and includes skills often found in both engineer and technician job categories.

Certain skills are likely to be vendor-specific, particularly when dealing with the particular switches and multiplexers deployed in the system. This also applies to the particular tools which the agency has procured for monitoring and managing its system, and for its maintenance. As an example, a good working knowledge of the operation of one model of fiber optic cable fusion splicer does not guarantee competency or successful results with another brand.

This vendor-specificity also applies to dealing with the telecommunications partners to whose systems the agency's network may be interfaced. An understanding of the signal system and controllers which a network supports is critical to properly designing and maintaining the system. This becomes even more complex if the system is poorly documented, if vendor support is no longer available, or if the system (such as the routing occurring at a central office) is indeterminate (changes with time).

Skills relevant to ITS telecommunications are in extremely high demand in the private sector.

Skills relevant to ITS telecommunications are in extremely high demand in the private sector. The agency desiring to hire personnel with these skills is likely to find that agency salary and benefit limits and career paths make it very difficult to successfully compete with the private sector for these personnel, or to retain such personnel if the agency is able to hire them. The primary competitors for such personnel include the Regional Bell Operating Companies, equipment vendors, major corporations, and engineering and consulting firms.

Procurement

In the procurement of telecommunications support services, the scope of services must be both specific and complete. The RFP should specify all of the services desired, under what conditions they must be performed (i.e. 24 hours per day, 365 days per year), and what resources will be provided or are required. Typically this will include both operations and maintenance, and the maintenance will include both preventive and emergency maintenance. The agency will need to determine if additional services, such as network planning, design, and installation are required for network modifications or expansions.

The specific qualifications required need to be clearly identified. In most cases, this will include the particular equipment and tools which the agency is planning to procure or has procured. Special considerations may be required based on the installation itself (overhead, in tunnels, underwater). As in other service procurements, the agency will be looking for successful service experience that most closely resembles its own needs. This may be challenging, as many providers may not have experience working in a roadside or traffic environment, and thus may need the assistance of a traffic control subcontractor or the agency's maintenance department traffic control capability.

The agency should specify a structure for the bidder's pricing or rates. It is likely that the contractor will uncover unsuspected conditions or such conditions will emerge from network modification or expansion. Thus, factors influencing the cost to the contractor of delivering acceptable service may be outside the contractor's control. The maintenance contractor for the INFORM ITS system on Long Island was allowed a specified number of weeks to identify such circumstances which could be considered exceptions to its financial responsibility for repair.

Perhaps the most important step in the selection process is determining the criteria for selection. The agency may need to carefully consider upon what basis or bases the selection decision should be made. Often price is the default; however this can lead to significant difficulties in achieving acceptable service levels. Appropriate consideration of qualification, experience, key personnel, and price is more likely to result in a satisfactory result.

The most important step in the selection process is the criteria for selection.

Major Issue Areas

Contracting

Length of contract is a significant determinant in price and level of satisfaction. Contractors will price more aggressively for longer contract periods, unless economic times are highly unpredictable. The contractor is also likely to be more productive over a longer period, as it will have longer to overcome any learning curve. The agency will need, however, to leave itself the ability to terminate the contract at appropriate times for poor service. A commonly used contract structure is to have a "base" period with multiple option years that can be exercised successively.

The type of contract itself determines the degree of sharing of risk

The type of contract itself determines the degree of sharing of risk, as in all services contracts. The agency may desire to limit its financial risk, and may opt for a fixed price contract. This is only recommended if the network to be maintained is in good shape and is well documented, or contractors will levy a significant risk penalty in their prices. The agency will experience the maximum flexibility from a cost-plus type of contract, where it is able to specify the types and levels of service on a reasonably real-time basis. As is widely recognized, however, the agency's financial liability is open-ended, which may be inconsistent with its budgetary policy.

The agency will want to consider how easy it is to amend the contract. As the network is likely to grow over the duration of the contract, and may change in nature with the replacement of various network devices, contract terms may need to be adjusted to reflect realistic work requirements. Complex and lengthy amendment processes, or processes that artificially limit the number of amendments, may make it difficult for the agency to procure the services it requires as the needs change.

As in many service contracting situations, the location of the contractor's staff can greatly influence their ability to deliver services and interact with the agency effectively. Milwaukee's MONITOR system has recently begun contracting for full-time service positions, to be delivered on site at the MONITOR offices. Thus, the contractor's personnel are immediately available to respond to short-term MONITOR needs.

Pay and benefits

Due to the extreme demand in both commercial and public sectors for telecommunications professionals, compensation for quality personnel is commonly higher than for similarly trained and experienced staff in civil engineering. Market rates vary widely, based on local supply and demand. Rates also reflect both the extent of education within and beyond the degree program, and the extent and relevance of experience. Agencies considering hiring telecommunications staff should consult market surveys available to their personnel departments, and possibly trade journals which regularly carry regionally based salary comparisons.

Lease vs. Own

In making a lease vs. own decision, the agency must consider both financial and technical implications of its choice. The agency should understand both the quantifiable considerations and the risks which are assumed with each option, many of which will be impossible to quantify, but which will impact the long term operation and growth of the region's ITS program.

How to conduct the financial analysis comparing leasing versus owning

The essence of the lease versus own financial analysis is to identify all forms of cost to be experienced during the analysis period, and the time at which each cost will be incurred. This includes all elements of the system life cycle, including planning, design, installation, testing, operations, and maintenance. In order to perform this analysis, the agency will need to fully understand its networking needs, and to have designed multiple networking scenarios. Maryland found that its preliminary leased network was not financially optimized, and thus revised the design in order to optimize it while still meeting performance goals. Similarly, it compared a totally new owned network to one using some of its existing resources.

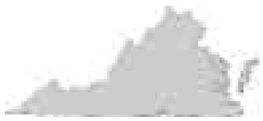
The essence of the lease versus own financial analysis is to identify all forms of cost to be experienced during the analysis period, and the time at which each cost will be incurred.

Some costs are "fixed," and should not be considered in the analysis. They include costs which are present in either scenario, such as the cost of certain agency personnel and perhaps the costs of equipment to interface the wide area network to the local area network.

Some more difficult decisions must be made in order to equitably compare options. Typically the most challenging decision is determining the required quality of video signal transmitted through the system. As video often represents the greatest bandwidth demand on an ITS network, all network options should represent essentially equivalent qualities of video service. A similar decision will need to be made regarding the need for each classification of device to be online full-time, or whether dialup service is acceptable. This is particularly true for relatively static devices, such as changeable message signs, ramp meters, and signal systems which operate primarily under local rather than central control. Without full time connectivity, however, the transportation management center responsible for these devices may be unaware for an extended period of the failure of a device, or of traffic problems which are created by suboptimal operation of the device, such as queueing onto an arterial caused by a mistimed ramp meter.

Some factors will be difficult to value in the analysis, such as the ease and speed of expansion of the network. Unless such factors can be quantified in the price quotations of competing vendors, they will receive only qualitative consideration.

Major Issue Areas



The period used in calculating the present value is important. In determining the time period of calculation, analysts need to recognize not only how many years the network is expected to be in operation, but also when it may be "built out" or expanded to cover a larger area or provide greater capacity. Since up-front expenditures are most heavily weighted in a present value calculation, and are also the greatest portion of the investment in an owned network, the timing and length of payments for leased services can greatly influence the outcome in comparing leasing and owning. This timing difference is somewhat reduced in importance if the lease payments are made in advance in recognition for lower overall rates, such as was done by Virginia DOT in Northern Virginia.

Some assumptions may need to be made for changes in the cost of telecommunications services. Most long-term telecommunications contracts are subject to renegotiation as options for expansion or other changes are exercised. Since telecommunications services are generally decreasing in cost, the agency may encounter conditions under which the cost of leased services may decline. The opposite may be experienced if an agency uses a service which its local carrier decides to deemphasize. An example of this is when carriers decided to stop making relatively inexpensive "unloaded" (not in use) analog lines available, driving users of this service to considerably more expensive telecommunication alternatives. A carrier may also "economically motivate" users away from a less profitable service by dramatically increasing its service price, perhaps forcing users into more expensive alternative services.

A factor complicating the choice of present value calculation period is the difference in lifetime and residual value of the different elements of the system. Although some elements, such as proprietary electronics that cannot be upgraded, may have a limited lifetime and little residual value, the conduit itself may last for many years and in some cases has been known to appreciate in value.

As a result of their own analysis, Maryland SHA decided not to build a fully owned private fiber optic network, but rather a hybrid network infrastructure relying predominantly on leased services while also pursuing resource sharing initiatives. By opting not to build its own fiber optic network, Maryland SHA expects to save $72 million. This decision was based primarily on cost in the ten-year lifetime but also on identified technical solutions that could fulfill defined business objectives and mitigate the agency's risk from rapid technology and telecommunications industry change. While the lease versus build issue was an important theme of the analysis, other critical system factors came to light that affected decisions for ITS telecommunications and diminished the lease versus build issue. The lease versus build question simply became two options of the many that Maryland SHA considered which could fulfill Maryland SHA's ITS requirements.

Lease vs. Own

In the development of this document, no comparable analysis was identified which led to an agency deciding to build and operate its own network. Numerous factors exist which could, however, lead to such a decision. For example, many agencies have relatively generous capital budgets that can be applied to fund construction of an agency-owned system, but find it very difficult to obtain the operations funds that would be used to pay for network leases. Under such circumstances, a decision by the agency to build and operate a network rather than to lease services may be quite logical.

A comparable decision to own rather than to lease may occur if the agency is able to trade an asset, such as access to right of way, to a contractor who would then provide a network which would be owned and possibly operated by the agency. This alternative, if executed correctly, can be extremely attractive both financially and in terms of the capacity and connectivity received. Ideally, the agency may be able to avoid paying both implementation and operations/maintenance costs. In an agreement by the Missouri DOT, the state was able to arrange for connectivity statewide in a single contract, avoiding an estimated $40 million implementation cost. Even in situations where service is acquired for less than total geographic coverage, use of such an arrangement to link sub-networks across local access transport area (LATA) or long distance boundaries can result in major long-term savings. Individuals interested in more information about shared resource programs should investigate the Federal Highway Administration (FHWA) and American Association of State Highway Transportation Officials (AASHTO) reports on this topic cited in the References section of this document and the December 1999 opinion of the Federal Communications Commission regarding Minnesota's shared resource program.

Agencies should consider the level of risk they experience in justifying an ongoing operations cost when compared to the cost of a capital acquisition when comparing leasing and ownership.

As with any long-term contracting situation, the specifics of the shared resource agreement are critical to the success of the arrangement. Since communications has a significant impact on both implementation and operation cost, and on operational procedures, a careful and well-planned approach to the negotiation of such arrangements, utilizing specialized expertise where appropriate, is necessary.

When comparing leasing and ownership, agencies should consider the level of risk they experience in justifying an ongoing operations cost when compared to the cost of a capital acquisition. In some agencies, lease fees are paid from relatively scarce operations funding, which must be justified anew each year. Thus, the agency faces the risk of either having to reduce system operation if operations funding is cut, or of having to sacrifice other operations activity in order to continue funding the lease. Capital funds, on the other hand, are dedicated once allocated, although agencies must also consider that even an owned network will require a lesser amount of operations and maintenance funding.

Major Issue Areas

Certain commonly leased telecommunication architectures are inherently vulnerable to failure.

Technical impacts of leasing

The technical impacts of leasing are brought about primarily because the network user does not know or have control of the following factors, which also may change without the user's knowledge:

- Network switching
- Network routing over long distances, including repeated amplification of the signal
- Multiplexing and demultiplexing of signals
- Termination devices at network endpoints.

The first three of these actions can result in signal degradation, either through loss of signal strength or through introduction of noise or other signals into the primary signal stream. The last impact reflects the fact that the signal may be delivered in a manner specified by the carrier from its central office and through points of presence (POPs), rather than in a manner most compatible with the end-use device.

The diversity of impacts, as well as the complexity of the analysis of these impacts, further supports the importance of retaining appropriate consulting experts while making the lease/build decision. An effective consultant will assist the agency in understanding the issues and can analyze their impact on meeting the agency's objectives and supporting its systems.

The use of dialup services (a subset of leased services) on an ITS system can be significant as well. Typically in dialup systems, only periodic communication is established with the field devices, perhaps only on an as-needed basis. The agency faces the risk that either the field device or the communication circuit will malfunction between calls, and will be found to be nonfunctional only when it is needed.

The agency should also consider the complications of integrating a leased network with an owned network. The devices at the interface will often be a point of contention with the carrier when discussing system problems.

It may be difficult to use diagnostic tools successfully past the point of demarcation between the owned and leased systems. This extends further to a general difficulty in diagnosing leased networks using digital services, because the network may be periodically reconfigured by the service carrier, and the signals likely undergo extensive multiplexing and demulitplexing between end nodes.

Certain commonly leased telecommunication architectures are inherently vulnerable to failure. A prime example is the "multidrop" network architecture, where many slower devices are fed from a single higher speed line. The transition point between a slower device and a higher speed line is called a "drop." In such an architecture, a single cut in the "backbone" will take all "upstream" drops offline. Similarly, a malfunction in one drop which causes it to transmit constantly can effectively block the ability to sustain communications with any other drops on the line.

The impacts of leasing on network maintenance have been discussed earlier.

Procurement and contracting of leased and owned systems

Procurement

Procurement of either owned or leased telecommunications services can be complex for the transportation agency. In the case of an owned system, the capital required to implement the telecommunications system may exceed half of the total ITS system implementation cost, thus making it the largest and potentially the most important single system within the ITS deployment. If services are procured instead of acquiring a system, the service cost may be quite significant in comparison to the total operation and support cost of the remainder of the ITS infrastructure. In either case, the design must be sufficiently flexible to address technical evolution as well as significant system expansion and alteration over an extended number of years. As telecommunications is the single element which enables most of the infrastructure to operate in an optimally effective manner, and which allows centrally controlled equipment to receive necessary commands, it is likely the most critical element to proper system operation. Thus, the investment made and the relationships established in the telecommunications procurement phase of the ITS deployment represent some of the most important decisions in the region's ITS program.

...the service cost may be quite significant in comparison to the total operation and support cost of the remainder of the ITS infrastructure.

In the case of an owned system:

- The agency will often find itself procuring items with which it has little experience, and therefore has few pre-existing standards and specifications. This is another area where the use of a proven telecommunications consultant can be of significant value to the agency.
- Existing specifications and standard plan details (such as grounding, cable burial depth, conduit schedule and sealing, manholes/pull boxes, cabinet size and placement, power supply, and overload suppression) may be inappropriate, having been developed often for illumination, or for use in dialup or leased line situations, rather than for current telecommunications cable and equipment.
- Standard documentation, training, testing, spares, and system support procurement clauses may also be inappropriate for the telecommunications system.
- The telecommunications system represents a broad variety of perhaps separately procured or pre-existing devices which must interact successfully at many levels. A failure at any interface may totally prevent functioning, and may impact many additional devices further "down

Major Issue Areas

As telecommunications devices vary widely in capability and quality, and may be offered with a multitude of features and options, a "best value" approach may lead to more satisfactory results.

the line." Thus, full and absolute proven compatibility is essential to assure success.

- Common practices of dividing major projects into multiple procurements may also create significant challenges in properly assigning responsibility for difficulties in bringing the system online. In Atlanta, in preparation for the 1996 Olympic Games, 10 contracts were bid to install cable, and separate contracts were then let for equipment installation and systems integration. Some contractors had finished their work months (or years) ahead of the system acceptance which would eventually prove that their portion of the system worked correctly.
- Methods of measuring completion of work and of assigning value for payment may also be inappropriate where trenching represents the greatest cost, but where a few switching devices represent the most critical functionality.
- A basic assumption in most public procurements, that price should be the single determining factor, may need to be challenged. As telecommunications devices vary widely in capability and quality, and may be offered with a multitude of features and options, a "best value" approach may lead to more satisfactory results.

In the case of a leased system:

- The agency should define requirements in such a way that it may be possible to solicit both from the local phone company and from competitive access providers. Requirements should be defined exhaustively, including acceptable levels of service and responsiveness to outages. Responsibility and interaction in response to network problems or failures should be clearly identified. Penalties for outages should also be quantified.
- The contract length and ease of modification should be considered in order to receive the best pricing possible, and to simplify contract administration as the network grows and needs change.
- The selection criteria should be defined in such a way that the local phone company is not excluded from the competition, but that all relevant service factors are considered in making the selection.
- The agency should consider how the network is specified, i.e., between which points. The procurement should also consider whether a hybrid configuration, which takes advantage of existing agency telecommunications infrastructure or of existing agency bulk leased telecommunications services, offers a more economical solution.
- The agency should investigate other existing state contracts to determine whether superior terms are already available under an existing contract. The DOT should consider, however, how it will effectively interact with the contract-holding agency, which may have little understanding of the transportation agency's unique telecommunications needs.

- The Request for Proposal (RFP) should specify how the contract will or will not respond to changes in telecommunications tariffs and to market prices for comparable services during its lifetime.

Contracting

- When contracting for telecommunications service, the agency should consider how it will exercise the necessary leverage over the provider in order to ensure the level of responsiveness that is desired or needed. Any single procurement will likely represent only a small portion of the business the agency or state does with its primary carrier, and that will be only a small portion of the carrier's total business. Thus, the agency project manager may find that he or she has little leverage to get the carrier to perform as desired. This can include situations where the quality of service does not meet specified standards, where the system is in need of diagnosis and repair, or where the agency would like the system expanded or reconfigured.

- The agency may find that diagnosing telecommunications problems is challenging when moving through the public network. Ordinary diagnostic tools may find inconsistent or unusable results due to the variety of switching and cable installations between endpoints, and the practice that the route may be different each time the call is routed, or the circuit brought up or down.

- The agency may find that the carrier's installation specifications are quite different from its own, particularly regarding cable burial depth, trench fill, conduit composition and schedule (or lack of conduit), inspection of the installation, etc. An agency imposing specifications different from the carrier's may encounter resistance or elevated cost.

- Often ITS field equipment is placed at intersections or along the roadside. Most commercial carriers use street addresses to identify network installation points. The lack of formal street addresses in some geographic areas may complicate the carrier's network planning and installation, at additional cost to the agency.

- If the agency procures services at tariffs normally associated with standard business, government, or consumer service, the network user's repair response time and reliability requirements may not be met by what the carrier delivers. In ordinary consumer service and for many economically attractive tarriffs, the carrier does not guarantee either response time to a problem call or the period within which a repair will be made. Typically carriers provide a guaranteed response time only at a higher fee level.

- The carrier contract needs to be carefully crafted to support expansion of the network and extension of the contract. Expansion may include a longer network, more access points, alternative services such as frame relay or asynchronous transfer mode (ATM), and additional total bandwidth.

When contracting for telecommunications service, the agency should consider how it will exercise the necessary leverage over the provider in order to ensure the level of responsive-ness that is desired or needed.

- The agency must be aware of the potential for escalation in the leasing rates between contracts. Most agencies find it difficult to transition from leased service to owned service even when lease costs increase unexpectedly. Typically the agency is not in a position to terminate operation of some or all of its system while arrangements are made for an alternate carrier or while an owned system is installed if the current carrier decides to greatly increase prices.
- Agencies face similar challenges when expanding a network across local access transport area lines, thus moving from "local" to "long distance" or distance-based fee structure. In such cases, the cost for a relatively short extension of the network can be much greater than had been experienced for much of the network thus far.

Technical Alternatives

Choosing the technology or technologies to be implemented in an ITS telecommunications system is a complex and far-reaching decision. It may have a large impact on both initial and long-term costs, and will affect the performance and cost of the system throughout its lifetime. Many choices abound, often mixed within a single solution. An intelligent transportation system contains devices varying from having little telecommunications need to having a very great need, from near to remotely distant, and from easily accessible to very difficult to reach. Thus, the telecommunications technology decisions are of critical importance and deserve to be considered carefully before setting them as part of the program's course.

The technology or technologies to be implemented in an ITS telecommunications system may have a large impact on both initial and long-term costs, and will affect the performance and cost of the system throughout its lifetime.

What are the technology choices?

Telecommunications technology alternatives abound, each with its own set of distinct features. Media technologies are typically divided into two categories: wireline and wireless. In an ITS context, wireline typically includes:

- Twisted pair copper
- Coaxial cable
- Fiber optic (multimode and single mode).

Commonly considered wireless alternatives include, but are not limited to:

- Microwave
- Cellular (digital and analog)
- Cellular digital packet data (CDPD)
- Spread spectrum
- Digital and trunked radio systems.

In concert and consistent with the media choice are decisions on approaches to the other telecommunications "layers." Alternatives such as ATM, frame relay, digital subscriber line, and switched multimegabit data service (SMDS) also greatly influence the capability and flexibility of the telecommunications solution, as well as the cost and time to implement and operate it.

How are the choices made?

There are a great many factors to consider when choosing the right telecommunications technology. The choice should reflect a long term perspective, as the cost and effort necessary to replace a system are significant, and system shortcomings may significantly reduce the effectiveness of a much larger investment in control center systems and field equipment. Some of the factors considered in decisions examined for this study include:

- How easy will it be to interface with the existing ITS telecommunications infrastructure?
- How reliable is it in operation?
- How easy is it to maintain, and will it require additional maintenance skills (or will existing personnel be able to maintain it)?
- Does it offer the capacity to meet our current needs?
- Is it capable of expanding to meet our growth needs, both in total capacity and in terms of geographic distribution of the telecommunications need?
- What are the implementation costs, total life cycle costs, and available budget?
- How long will it take to implement, and is this consistent with our other project plans/needs/priorities?
- Will we be able to operate and maintain the eventual network, considering both staffing and skills constraints?

The recommended technique begins with understanding all aspects of the requirements.

The recommended technique begins as this document does, with understanding all aspects of the requirements. This includes a complete assessment of the existing telecommunications infrastructure, and a decision whether the implementation is to be added to the existing network, or whether it will presently or eventually replace the network. As an example of the latter choice, the Virginia DOT concluded that it would leave systems inside the I-495 Washington, D.C. Beltway on an aging coaxial cable system while implementing a fiber optic-based system on I-95 and I-66 outside the Beltway, in order to remain within the limits of the Virginia DOT district's capital budget.

Major Issue Areas

The evaluation factors need to be determined and accepted by key stakeholders.

Once requirements have been defined, each technology must be evaluated. The evaluation factors, such as those above, need to be determined and accepted by key stakeholders. Similarly, the way each factor will be evaluated and its level of criticality must be decided. Some factors may become go/no-go items, such as whether the technology offers adequate capacity for the current need. Other factors may be evaluated on a continuous scale, such as the cost to implement and the total life cycle cost. Other factors may be evaluated on limited relative scales, such as high/medium/low or a scale of 1-5, based on probability assessments, such as whether the DOT can retain personnel qualified to operate and maintain the system.

Examples of several technology alternatives

Virginia DOT Hampton Roads – twisted pair to fiber

Virginia DOT has had an operational ATMS in Northern Virginia for over 20 years. Virginia DOT's second venture into ATMS came in the early 1990s with the implementation of the first phase of the ATMS for the Suffolk District, in the Hampton Roads area centered around Virginia Beach. Due to the inexperience of the DOT and its consultant with telecommunications technology, as well as a relatively modest budget for the project, the initial design included telecommunications over copper twisted pair, using repeaters to boost signals over longer portions of the network.

Due to the competitive bidding process, it was not possible for bidders to propose alternate approaches during the bid period. The successful bidder, an electrical contractor, immediately approached Virginia DOT following its selection. It proposed conversion of a significant portion of the network to fiber optic cable, using a mix of multimode and single mode cabling, which would be coupled to the copper and coaxial cable connections of the field devices at telecommunications hubs. They presented Virginia DOT with a number of justifications including:

- The implementation could be done for essentially the same budget.
- The fiber optic system could be expanded more easily in capacity, length, and number of connections than would be possible with the copper network.
- Signal quality on the fiber optic network would likely be, and remain, superior to the specified copper network, as it was not dependent upon repeaters.
- Management tools were available which would make the fiber optic network as easily manageable as the copper network.
- There was less likelihood of degradation of signal and network performance over time due to cable corrosion.

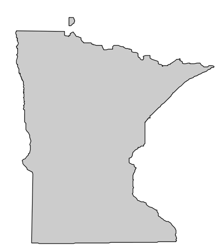
Virginia DOT accepted the contractor's proposal and has continued to expand the system, whose fourth construction program was underway in 1999.

Detroit – fiber/microwave

In the 1990s, Michigan DOT faced a complex situation in deciding upon the telecommunications network to support expansion of the ATMS for the greater Detroit area. The existing system, implemented on M10—the Lodge Freeway—depended upon a coaxial telecommunications cable network whose age was creating significant problems for Michigan DOT's maintenance unit. Michigan DOT faced an ongoing challenge in retaining an adequate staff to repair the system, and had little success in recruiting personnel with appropriate qualifications. Additionally, few spare parts were available for the system, so Michigan DOT found itself often fabricating its own spares, at significant expense.

Michigan DOT had decided to greatly expand the ATMS, from its existing 30 plus centerline miles to 180 centerline miles. This expansion was to take place at the same time that a great deal of road reconstruction was to be undertaken, including I-94 linking Detroit to its airport. Due to this reconstruction, cable-based telecommunications was unattractive, since any cable installed prior to the road work was likely to be damaged by the road work. Furthermore, the possibility of bringing field equipment online early, to aid in traffic management during construction, also was attractive. Michigan DOT's budget for the 150 centerline mile expansion was limited, and considerably less than would have been necessary for installation of most cable-based options. Michigan DOT chose a "light infrastructure" type of approach, with vehicle detectors only every two miles, rather than at more common 0.3 or 0.5 mile spacing.

The result of these factors was a decision to implement a hybrid network. The base of the network is a high-capacity, fully redundant self-healing fiber optic ring. From this ring extend terrestrial microwave spokes to hub locations from which telecommunications to field devices is carried over copper cables.



Minnesota – twisted pair to hybrid fiber/twisted pair

In the Twin Cities area, Minnesota DOT has had an operational ATMS for nearly 30 years. In 1991, Minnesota DOT recognized that its semi-distributed system using coaxial cable for video and twisted pair for data and command would be challenged to expand to the size and complexity foreseen for the region's ITS program. Minnesota DOT commissioned a systems integrator-led team to analyze the current situation and alternatives, and to make a recommendation. The system needed to support:

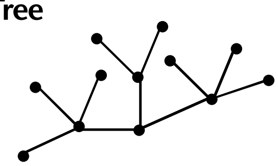
- Ramp metering
- Vehicle detectors
- Changeable message signs
- Lane control signals
- Gate control
- Highway advisory radio.

Major Issue Areas

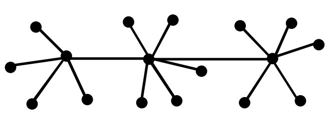
Network Topology Examples

Point-to-Point

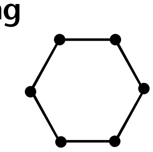
Tree



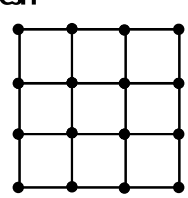
Nodal



Ring



Mesh



The study considered an alternative delivery mechanism as well as leased services, and the following technical alternatives:

- Broadband coaxial cable
- Fiber optic cable
- Copper twisted pair
- Terrestrial microwave
- Digital radio
- Cellular telephone and trunked radio.

A further phase of the study investigated alternate telecommunications topologies (see sidebar for illustrations), including:

- Point-to-point
- Tree
- Nodal
- Ring
- Mesh.

A matrix was created, analyzing each technology in each topology for the intended needs. The consultant's recommendation was based on consideration of the following, which are not in order of priority:

- Total life cycle cost
- Cost of installation
- Quality of service
- Adherence to industry standards
- Ability to deliver at least 100% excess capacity
- Ability to pre-install surplus media which would later be available for system expansion or provision of other services
- Ability to be joined or integrated with the existing system, and particularly the coaxial video cable
- Ability to service field equipment at increased distances from the control center
- Overall level of reliability.

Each of these decisions occurred several years ago. Additional alternatives, such as digital subscriber line now exist, in a considerably less regulated telecommunications environment, which might lead each agency to a different conclusion if the decision were now being undertaken.

Competitive Access Providers

In the deregulated telecommunications environment, agencies have a much wider and more varied choice for telecommunications services. Whereas previously there would have been a single long distance service provider, there are now many, offering different services, prices, and business arrangements. Concurrent with the deregulation, however, have appeared additional fees for services previously delivered as part of the overall service package. In this section the process for selecting a competitive access provider (CAP) and some of the considerations of receiving services from a CAP are discussed.

Competitive Access Providers

Process for making the choice to use a CAP

As was noted in the previous section on making a choice of technology, the first step in considering whether to contract with a CAP is to fully understand and document the requirements. This forms the basis for issuance of an RFP or invitation for bid (IFB), depending upon the chosen contracting mechanism.

Also as found in the process for choosing a technology, the agency needs to decide upon what basis its decision will be made. Several of the factors to consider are:

- The first and most obvious reason to choose a CAP is because it offers a lower price. Pricing may be structured quite differently than the local phone company, with varying levels of discount or premium based on either incremental or total utilization, type of service, time of day, and LATA or long distance boundaries.
- The agency needs to be assured that it will receive an acceptable quality of service. This may be measured in terms of bit error rate, reliability, or other relevant factor.
- The agency should consider the ability it will have to modify the contract for growth. Almost all areas are in only the initial stages of ITS deployment, and few have begun to explore their options for interconnection and integration with systems from neighboring jurisdictions. The ability to achieve these is necessary in the contractual agreement.
- The ability of the CAP to successfully and effectively diagnose and remedy problems, preferably without significant technical involvement by the agency, is important. One measure often employed is the CAP's guaranteed response time to remedy problems.
- Since cross-provider interconnects represent situations where cost is incurred and where responsibility becomes disputed when addressing service problems, the number of access interconnects to get from the TMC to its field equipment should be considered.

The agency needs to decide upon what basis its decision will be made.

- It is necessary to consider exactly what the CAP has offered, since there may be significant differences in the capabilities of various CAPs. Some may be able to offer dark fiber or unloaded twisted pairs, while others may be restricted to specific types of service, such as Integrated Services Digital Network (ISDN), fractional T1, ATM, frame relay, or other specific services.
- As is discussed in the following section, not all CAPs are well founded, solidly backed businesses. The agency should consider the business stability of the various CAPs from whom it has received bids, in order to guage the risk it faces of unsatisfactory operations by the selected CAP.

The implications of choosing a CAP

When contracting with a CAP, a number of implications need to be considered. Access fees charged by the local phone company will be a part of the financial equation, even if they are "invisible" to the network end user. The structure and size of access fees continue to evolve, changing the cost experienced by the CAP.

It is highly likely that there will be a need to interconnect with the local phone company's network. This is particularly true where the agency desires to integrate voice, data, and video. With advances in computer integrated telephony (CIT) and voice over Internet protocol (VOIP), this becomes considerably more likely. The form of the interconnect, and how responsibility is delineated for tracing problems that span the interconnect, should be considered in making the CAP decision.

In the deregulated environment, the assets necessary to become a CAP can be relatively small, and thus the barrier to market entry is low. The result is that smaller firms, relatively poorly staffed and poorly capitalized, can enter the market essentially as resellers of services purchased in bulk. The long-term business stability in the region of such firms is questionable, as they may be unable to create a significant price advantage, and may have trouble making the marketing investment necessary to build a significant business base. Thus, the agency may find itself with a long-term contract with a firm no longer in business in the region, instead receiving service from a firm that has assumed the operation.

In the same vein, the agency may want to investigate the extent of the local manpower resources of the CAP. Although the cost of a service outage to the CAP may be relatively minor, the public relations problems such an outage may cause to the agency may be much greater. Being assured that the CAP has adequate skilled local manpower to diagnose and remedy any outage can be an important component of making the sourcing decision.

Competitive Access Providers

Examples of CAP provided systems

In the early days of the ITS program in Houston, the Texas DOT identified a need to provide telecommunications at minimal cost between its area telecommunications hubs and the interim (pre-TranStar) TMC. Texas DOT identified a local carrier which had fiber optic cable run, primarily overhead, along various routes in the metro area. Upon investigation, Texas DOT found that the carrier had additional capacity available on the fiber and was interested in realizing some revenue in exchange for this unused capacity. Texas DOT was able to arrange to carry some of its signals over the available fiber, in those areas where the fiber had been run, at significantly less cost than would have been experienced either for equivalent leased services, or for the installation of an agency-owned network along the affected routes.

Conclusion

Our analysis of the telecommunications experiences of the states reviewed for this study, as well as issues and concerns that have arisen in supporting ITS deployment in other states has brought several points into focus:

- There are many complex choices to be made in selecting the telecommunications solution to support ITS implementation. The telecommunications solution is critically important, both because of the essential technical function it provides to the system, and because of its significant financial impact on total system implementation and operations/maintenance cost and resources.
- The typical public agency will benefit greatly from access to qualified professional telecommunications consulting assistance in performing technical and business analyses and developing system design.
- There are ITS telecommunications examples we can learn from, such as the experiences of the states studied for this report. It should be recognized that the factors involved in the decisions made by these agencies continue to change, and that their decisions might be different if they were making the decisions under current conditions.
- Effective techniques to use in addressing the telecommunications design issues include development of a regional ITS architecture and an ITS telecommunications architecture.
- A careful systematic requirements analysis is essential in obtaining the best ITS telecommunications solution best suited to an agency's needs.

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- Weather Information for Travelers and Maintenance

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"Telecommunications analysis is undertaken prior to implementing a large communications infrastructure not only because of the cost, but also to avoid building a network that will not meet operational needs.... In each case, the agency made or changed previous decisions based on the information and recommendations presented in the analyses."

—Maryland Department of Transportation

INTELLIGENT TRANSPORTATION SYSTEMS

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FHWA-JPO-99-023 EDL # 11488 FTA -TRI-11-00-02