

Florida Statewide ITS Strategic Plan

ITS Cost Analysis Issue Paper

The following is an excerpt from the approved Consultant scope of work:

The Consultant shall perform an analysis of the cost of recent ITS deployment in Florida and shall determine an acceptable cost range that can be used for planning purposes. The product of this subtask will be an ITS Cost Issue Paper and a corresponding section on ITS cost in the Strategic Plan. In the subtask, the Consultant shall incorporate the essential components of current studies being performed by the FHWA Peer to Peer Review Group and by the FDOT ITS Working Group. The FDOT will furnish all available information, data and copies of studies and ongoing coordination work to the Consultant. This paper shall address factors that may affect and cause a variance in ITS costs such as:

- Extended warranties for equipment and systems;
- Software support and maintenance for COTS and Vendor supplied software;
- Payment or staging requirement (i.e., basis of payment, retainage, etc.)
- Type and quantity of communications infrastructure;
- Initial versus future system coverage;
- System functional requirement and resulting hardware requirements; and
- Level of functional integration (i.e., single “third party” control platform versus multiple vendor supplied software systems)

1. PURPOSE

The purpose of this ITS Cost Issue Paper is to:

- Establish a cost range for planning future deployment costs
- Review and discuss various project factors that affect cost
- Provide general guidelines to illustrate ways to control ITS project cost

The intended audience of this paper is state, federal and local staff assigned to plan and estimate the deployment costs of future ITS projects. The paper will also assist deployment project managers and agency administrators responsible for policy associated with project development and administration. It is suggested that this information be included in the Florida ITS Strategic Plan as a chapter on cost factors and recommended guidance on way to control ITS deployment and operations costs.

2. BACKGROUND

The Florida Department of Transportation has become aware of apparent discrepancies between costs of ITS projects of a similar nature in different regions of the state. This concern has led to a review by the District Traffic Operations offices involved, with a presentation of the

factors contributing to the individual projects' costs. These contributing factors and the plans and specifications themselves were reviewed by other State's DOTs through the Peer-to-Peer program, sponsored by FHWA. While there were numerous factors cited, the Department has requested further analysis of the cost issues. The analysis of the specific projects is contained in a separate paper. The general factors relating to cost of future ITS projects are addressed in this issue paper.

3. SUMMARY OF RECENT ITS DEPLOYMENT COST EXPERIENCE

3.1. FREEWAY MANAGEMENT SYSTEMS IN FLORIDA

Introduction

Freeway management systems are a cornerstone of the urban intelligent transportation infrastructure. They represent a significant cost element of the ITS infrastructure and thus are the focus of the cost analysis presented in this paper.

The typical freeway management system affects a large number of trips in an urban region. It provides a communications backbone and a transportation operations center, which can serve multiple ITS purposes beyond basic freeway surveillance and control. Examples of these additional purposes are traveler information, and emergency management.

Freeway management systems and their associated costs can generally be broken down into components. For planning purposes, the number of components is kept at a basic level. Freeway management systems typically include the following major components:

- Transportation Operations Center (TOC)
- Communications Subsystem
- Detection Stations
- Changeable Message Signs (CMS)
- Highway Advisory Radio (HAR)
- Closed Circuit Television (CCTV)
- Ramp Metering

Rather than planning the cost of freeway systems on a per mile basis, this component level approach is more detailed due to its 'bottom up' nature. Planning costs on a component basis also normalizes the effect of different spacing of the components along the freeway centerline.

A summary of the component costs of recent freeway surveillance and control projects in Florida is presented in the separate paper intended to analyze the project cost differences discussed earlier. One result of this analysis is that there is substantial variety in the project approaches and the detailed nature of the component designs themselves. For example, in three projects, the changeable message signs (CMS) range from a standard CMS on a cantilever structure, a standard CMS on an overhead truss, to a CMS with a prescribed protocol on custom trusses across the freeway.

The cost experience of ITS deployment in Florida therefore cannot be quantified to a single set of costs which will be reliable for future planning purposes at this time. The variation should be studied further with the benefit of more cost experience, either resulting in a range of high, medium and low costs, or an effort to make ITS costs more consistent statewide, which will stabilize future deployment costs.

3.2. NATIONAL EXPERIENCE

ITS cost data is not as readily available as other transportation infrastructure costs, such as for road and bridge construction. Sources are emerging, however, as more experience is gained by ITS infrastructure deployers. *Great caution must be used in interpreting ITS costs from other deployments however, due to the many local variations in existing conditions, standards, and deployment methods, to name a few of the variables which ultimately affect ITS deployment cost.*

The descriptions and Table 1 below summarize ITS deployment initial capital costs, which are available in the literature for freeway management systems on a component basis.

- The Texas Transportation Institute (TTI) has compiled cost estimates for the core infrastructure for ITS. The data for the 1995 study was derived from systems in Texas, Virginia, Massachusetts, Washington, Georgia, Minnesota, Maryland, Delaware, and California along with discussions with ATMS experts. The costs are described by TTI as worst case scenario and reflect areas that are assumed to have no existing infrastructure. The costs reflect state of the practice technologies as if they were procured and deployed in 1995.
- The National Architecture for ITS provides an estimate of life cycle costs for an evaluatory ITS design. The costs are based on the detailed equipment categorization provided by the defined equipment packages in the architecture. The unit prices for these are based on available information for recently deployed ITS projects. The costs are in 1995 dollars.
- Caltrans provided planning costs used currently for freeway management systems in the peer-to-peer review, and a follow-up interview. These costs reflect Caltrans' actual cost experience and their use of standards. They further consider local variation from their benchmark costs and include contingencies in total project costs.
- PB Farradyne (PBF) maintains ITS deployment cost data based on its actual project deployment experience nationally. The data are current and updated as more experience is gained and price trends are realized. The data reflect current assembly costs and are supported by make and model of many of the actual devices. The communications cost includes one SONET hub every four miles.
- The ITS Planning Handbook, prepared by JHK provides unit costs for ITS deployment. This handbook is under review and unpublished at this time.
- The Seattle ITS Case Study, prepared by Mitretek provides costs of this deployment. The Seattle ATMS is a mature ITS, currently operating as a Model Deployment Initiative.
- A national survey of selected ITS operating agencies was conducted as part of this project. The range of results from 13 respondents are shown. The communications cost includes one SONET hub every four miles.

Reference	Traffic Operations Center	Communications Subsys (mi)	Detection Station	Changeable Message Signs	Highway Advisory Radio	CCTV Cameras	Ramp Meters (/Intrch)
TTI	4,900	240	40 (VID)	200	20	20	40
Nat. Arch.	982 (w/o bldg)	Assumes leasing	5 (loops)	180	16	60	30
Caltrans	varies	250-300	50 (VID)	200	20	30	65
PBFI	964 (w/o bldg)	166	24 (radar)	150	28	35	15 (per ramp)
ITS Planning Handbook	3,744	N/A	8 (loops)	200	N/A	43	N/A
Seattle ATMS	N/A	400	25 (loops)	125	20	25	30
National Survey		29 - 134	5-45 (loops) 3-30 (radar) 25-40 (VID)	100 - 250	3 - 250	7 - 100	20 - 250

Table 1 ITS Component Initial Capital Costs (thousands of 1995 Dollars)

These costs provide a starting point and possible baseline for future ITS costs for deployment of freeway management systems. The reader is again cautioned about using the costs directly without examining the assumptions, local conditions, and other factors associated with the particular project. Other factors under consideration by the Florida Department of Transportation such as standards, and procurement method will influence costs of future deployments.

4. PROJECT DEVELOPMENT AND IMPACTS ON TOTAL SYSTEM COST

The planning and programming of costs for a Florida DOT freeway management system must include consideration of each phase of the work. These phases include the feasibility, design, construction and operation stages of a project. The conduct of each of these phases influences the overall project cost, but the degree of this influence cannot be determined in a hypothetical context. However, each project phase activity affects all of the ITS components deployed.

4.1. FEASIBILITY STUDY PHASE

The purpose of the system feasibility study is to perform an analysis of the problems, and determine the recommended solution. The study then develops various alternative

concepts, which result in a preliminary conceptual design. During this stage it is essential to perform an implementation plan.

FHWA requires that implementation plans be prepared for both new traffic control systems, as well as expansions of existing systems, which use Federal funds. The requirements for implementation plans are contained in the Federal Aid Policy Guidelines, transmittal 12 - NS 23 CFR 655.409D. The requirements as outlined below show each area to be addressed.

- Legislation
- System Design
 - System Designer
 - System Design Life
 - System Coverage
 - System Design and Operations/Maintenance Philosophies
 - System Architecture
 - Integration with Other Functions
 - System Components and Functions
 - Communication Subsystem Design Approach
 - Traffic Operations Center Design Features
 - Project Phasing/Scheduling
 - Design Review
- Procurement methods
 - Sole-Source
 - Engineer/Contractor (turn-key)
 - Two-Step Engineer/Contractor
 - Systems Manager
 - Design/Build
- Construction management procedures
 - Division of responsibilities
 - Scheduling and establishing mileposts
 - Conflict mitigation
 - Coordination with other projects
- System Start-up Plan
 - Software acceptance tests
 - System acceptance tests
 - Partial acceptance
 - Documentation
 - Transition from old to new control
 - Operational support and warranty period
 - Training
 - Coordination with the media
- Operations and maintenance plan
 - Evaluation
 - Maintenance Plans
- Institutional arrangements
 - Contact persons
 - Delineation of organizational responsibilities

Periodic management updates
Utility arrangements
Written cooperative agreements
Consideration of an advisory committee
Personnel and budget resources
Staffing plan
Personnel shifts
Contract operations
Provisions for new staff training
Sources of budgetary resources
Estimates of annual expenses
Signatures of each operating agency, state and FHWA

Cost Implications

The feasibility study is the most important part of the project development cycle in determining the nature of the project that is developed. This makes the implementation plan decisions a critical determinant in the projects' ultimate life cycle cost. The feasibility study should provide a detailed estimate of life-cycle costs of alternatives before a final concept is determined. Life-cycle costing is emphasized in the TEA 21 legislation in addition to the implementation guidelines.

Two tools are available to support Life-Cycle cost analyses. The *National ITS Architecture Cost Document* provides a set of linked spreadsheets. This is a useful tool in determining the project alternative capital costs and the concomitant recurring costs of each alternative. Another tool for use in the feasibility study is a communications tradeoff analysis. A step by step procedure for preliminary communications system design is contained in Chapter 11 of the *Communications Handbook for Traffic Control Systems*, by FHWA.

4.2 DESIGN PHASE

The purpose of the design and specification for ITS projects is simply to communicate to the installation contractor what he needs to know to properly bid and install the field devices. At this stage, final decisions are made on equipment location, installation requirements and specification. When the contractor has responsibility beyond his core area of skill, such as providing software, timing plans, or integration, the designer must be very careful to clearly delineate all responsibilities and requirements.

Current Department requirements utilize the *FDOT Standard Specifications for Road and Bridge Construction* to the fullest extent possible. *FDOT Roadway and Traffic Design Standards for Design, construction, Maintenance and Utility Operations on the State Highway System* and the *FDOT Minimum Specifications for Traffic Control Signals and Devices* are also typically referred to. The most difficult part of ITS design becomes the areas outside of these standards, and knowing when the standards do not apply. The most common example of this is the use of conduit for communications. The FDOT standards apply more to electrical service

and interconnect wire and not fiber optic or twisted pair communications cable. Therefore, the designer must design all 'non-standard' project requirements.

The design phase is also where final decisions are made on critical ITS technology and standards. The design must judge where to draw the line between state of the practice and advanced technology, which may not be proven or readily available.

Guidance on ITS design and implementation is provided in Chapter 11 of the *Traffic Control System Handbook*. In this reference, a system selection process is defined which includes sections on: defining system requirements, identifying alternative systems, evaluating alternatives and selecting the desired approach.

Cost Implications

The cost implications of the design phase are a function of how well the plans and specification define the work required of the contractor. The more clear and consistent they are the less risk the contractor will perceive, resulting in a lower bid on the project. Overly difficult or restrictive practices will also result in higher costs. Examples of these are exhaustive equipment testing and limited work hours in the field.

Where flexibility can be permitted, such as with conduit installation, or the choice of functionally equivalent equipment, the contractor can be allowed flexibility to determine the best market price. However, if a certain piece of equipment is required for compatibility with the system approach, this should be specified without any flexibility to avoid implementation problems.

The time allotted to construct the project, and the related penalties also has a direct bearing on cost. Compressed schedules require premium labor, increase accidents, and risk liquidated damages. Too much contract time results in increased overhead costs and unnecessary disruption of travel for the public.

4.3. CONSTRUCTION PHASE

The construction phase of the ITS project includes:

- Installation of ITS infrastructure
- Development and integration of hardware/software
- Component and system testing
- Training and documentation
- Warrantee
- Construction observation (CEI)

There is variation as to how this work is accomplished, essentially based on who is responsible for the various project parts. The Department has used several of the various procurement methods, including: Sole source, Engineer/Contractor, Two-step Engineer/Contractor, and Systems Manager. Each method has its strengths and weaknesses, which may differ in a given region. These are addressed further in a separate issue paper.

The current FDOT requirements for construction include a biddable PS&E, a construction contract, and administration of the construction contract. The Department's practice has been to use in-house staff, consultants, or a combination of these to observe the construction contractor and document the project. This is done in accordance with the *Construction Project Administration Manual (CPAM)*. On some projects the CEI consultant has been the design firm, and on others it has been a firm independent of the design.

Cost Implications

The cost implications of the construction phase are most obviously a function of the ITS design and construction amount. This cost however, is a function of decisions made in the feasibility and design phases. Other significant costs result from construction contract administration of ITS projects. These costs are based on the manpower and duration required to fully administer the project. When the CEI team is independent of the designer, and the designer has no post design support role, the work of the CEI consultant is increased. He must fully analyze test results and determine project acceptance. In the case of new systems with software this is particularly complex. In the worst case, there is an example of a project in Florida where the cost of CEI on a signal system project exceeded the total construction cost.

The fact that a contractor marks up a profit on all items and subcontracts is a cost implication for ITS deployments. Where the Department has a choice on how to procure the item or service, a cost saving can be realized. Alternatives include in-house work, statewide procurement contracts, and use of a system manager consultant for some equipment components and services.

4.4. OPERATION AND MAINTENANCE PHASE

Operation and maintenance of ITS is extremely important for successful deployment. As with all public works projects, the Department must show a benefit from the investment made in the system. This benefit is derived through effective operation of the freeway management system. Effective operation of ITS provides increased public awareness and support for the benefits of ITS and may lead to support for further investments.

Current trends in ITS are to place more emphasis on O&M. This is confirmed in the TEA 21 legislation. Under *Use of Funds, Section 5210*, "Those applying for ITS funds must submit; an analysis of the life-cycle costs of operations and maintenance, if capital costs exceed \$3 million; and a multi-year financing and operations plan." The implementation plan guidelines discussed earlier provide the initial planning of this project stage.

Cost implications

The cost implications of the O&M phase are considerable. They must be addressed in order

to effectively operate the system and provide the public with the intended benefits. O&M takes into account the following activities, each with associated costs:

- System operation
- Management
- Maintenance
- Equipment/Software upgrade/replacement
- Public Information
- Inter-agency coordination
- Evaluation
- Training

Whether these tasks are performed in-house by the Department, other agencies or contracted, they must be funded adequately to achieve a successful ITS program. There are many examples of successful partnerships and creative funding opportunities in the O&M phase of ITS which FDOT should explore. Examples of these include: housing of the Orlando SMIS in a Florida Highway Patrol building at no direct cost to the Department and more recent activity to co-locate FHP with the upgraded freeway management system, and Florida DOT funding of FHP enforcement of HOV restrictions during peak hours

5. OTHER FACTORS AFFECTING TOTAL PROJECT COST

There are numerous factors, which affect ITS project deployment cost. These factors and their cost impacts are discussed below.

5.1. PROJECT DESIGN LLIFE

Decisions should be made early in the project planning stage on the ITS project design life. This is due to the need to design for the project's life cycle, through the O&M phase. The requirement for determining a project's life cycle and supporting requirements is reflected in Federal Aid Policy Guidelines, transmittal 12 - NS 23 CFR 655.409D., **Implementation Plan Guidance**.

Determining the design life of the ITS design project will avoid the following pitfalls:

- Over-design of field infrastructure, (eg. unused conduits, fibers, hub site capacity,)
- Over-design of central infrastructure, (e.g. unused central hardware/software capacity, unused control center space, peripherals, and communications channels)
- Early obsolescence of components requiring replacement prior to planned upgrade

The typical design life of a roadway project is 20 years, with 50 years assumed for structures. ITS however is built upon communications and information processing technologies, which turn over more rapidly. This is due to the rapid development of new and more advanced technologies, which perform a function faster, cheaper, and easier. A case in point is the computer industry, on which ITS depends. A principle called Moore's law has been accepted

which observes that information processing capability doubles every two years. This leads to a more rapid obsolescence of ITS than traditional transportation improvements.

PCs become obsolete in about five years. At this point, parts and support are no longer available. An example of this is the Intel 486 based PCs. Once the state-of-the-art, this chip is no longer made or supported. PC based software also develops rapidly as has been seen with the rollout of Windows 3.1, Windows 95, Windows NT, Windows 98, and so on. Microsoft no longer supports the earlier versions of operating systems, such as Windows 3.1, causing systems to require periodic upgrading.

Based on the Freeway Management Handbook and the ITS National Architecture, Table 2 provides service lives for ITS Components:

Ramp meters	5 years
Loops	5 years
Video cameras	10 years
Camera supports	20 years
Changeable message signs	20 years
Changeable message sign supports	20 years
Highway advisory radio	20 years
Freeway control software	5 years
Freeway control hardware	5 years
TMC peripherals	5 years
Integration	5-20 years
Communications lines	20 years

Table 2 Equipment package service lives

These analyses provide the important variable, time, which must be considered in tradeoff studies during the course of design. The design life assumptions can be tailored to the individual regional ITS.

The project implementation plan should reflect the operation and maintenance capability of the agencies responsible for this activity. That is, the ability to operate the system effectively, and maintain the software and hardware physical plant. Any of these activities can be contracted out by the operating agency, but must nonetheless be considered. The implementation plan balances the ITS deployment and the responsible agencies' commitments to implement, expand, operate and maintain the system over its design life.

The project implementation plan should include periodic upgrades during the design life for those items which have the shorter lives, such as computer hardware and software. This periodic upgrading of the system will provide a longer overall life for this system, maintaining or improving functionality cost effectively.

The design should consider systems scalability to extend the design life. Examples of this could be having enough space in a communications rack for the ultimate number of modems, or having the software sufficiently sized to handle the number of intersections anticipated within

the design life. A longer design life lowers the life-cycle cost. Systems can also be modular to potentially extend the design life and distribute costs by allowing features to be added to the existing system gradually, without significant replacement. These features could be Highway Advisory Radio or Electronic Toll Collection/Traffic Management or Ramp Metering, to name a few, added to the traditional detection (loops), verification (CCTV) and motorist information (CMS) subsystems.

5.2. COMPLETE VS. INCREMENTAL DEPLOYMENT

Complete Deployment

Complete deployment of ITS in a region is probably the ideal approach. Complete deployment has the following advantages:

- Continuity of approach through a single deployment team
- Lower cost through economy of scale
- Earlier benefits derived through shorter deployment time
- Compatibility of equipment through a single deployment
- Ease of integration through singular project controls

The greatest difficulty with complete deployment is the large capital funding requirement for ITS throughout a region. Many ITS deployments in Florida have therefore been incremental. There have been three types of incremental deployment:

- Incremental area covered
- Incremental features deployed over the same area
- Incremental provision of service on a time-of-day, day-of-week basis

Incremental area covered

This approach is typified by the signal system build-out that is done in phases, with groups of intersections in each phase. Another example is the freeway mileage that is added to a freeway management system in phases over time.

Benefits

Potential benefits of incremental deployment by area are:

- Related projects such as the expected widening of a freeway can be accommodated
- Lessons learned can be applied to later phases
- Limited cash flow can be accommodated

Risks

The risks of this approach are:

- Incompatibility of the hardware among the increments
- Difficulty of incremental integration of hardware on an existing central/core system

- Added start-up costs of the separate increments

Each of these risks can be mitigated through project design and implementation management when they are fully understood.

In the case of incremental system deployment by area, the central control software should be sufficiently sized to be able to accommodate the expanded area and its devices, within the range of the software's useful life. This will allow the Department to achieve compatibility among devices deployed during various phases, and to avoid having to replace any software before its expected life.

In the project planning phase, under the framework of FHWA's implementation guidelines the Department should seek the right balance between small project increments, and large or a single project increment. The decision criteria should consider the benefits and risks above, and the maximum benefit to the traveler that can be achieved by the project.

Incremental features deployed

This approach has been used recently in Florida for freeway system deployment. Examples of this are the I-595 and I-95 Changeable message sign systems, and the I-95 Freeway management system in Miami-Dade County.

In the case of the Broward County systems, changeable message sign systems are being constructed. The project features include three detection stations on I-595 and none on I-95. No cameras or other roadway features are included in the current packages. The signs will be supported by a vendor-supplied system, which will not require integration with other subsystems.

In the case of the Miami-Dade System, four mainline and four approach changeable message signs, 27 cameras, 15 video image and loop detection stations are being deployed over an 18 mile length. The system supports ramp metering and variable trailblazer signs, but these are being deployed in later phases of the project.

Benefits

- Incremental ability to operate and maintain can be matched with project
- Incremental public acceptance of new features can be accommodated
- Cash flow can be managed

Risks

- Portions of the system could be obsolete before all of the planned features are deployed
- The individually deployed subsystems may not be compatible for integration
- The benefits to travelers are reduced if all features which often complement one another are not deployed initially

- Added start-up costs of the separate increments

Each of these risks can be initially addressed within the framework of FHWA's Implementation Plan Guidelines.

Incremental provision of service

This approach applies to a pure service, such as the use of service patrols for incident management, or a traveler information service. Currently, service patrols are incrementally deployed on a time-of-day, day-of-week basis in Miami-Dade, Broward and Palm Beach Counties.

The benefits and risks of this approach are similar to those for the other types above, depending on the actual type of project involved.

5.3. PROJECT INTEGRATION

The current trend in ITS, supported in the TEA 21 legislation is to require regional integration. Regional integration is the foundation of the National ITS Architecture, and also is the means to leverage the ITS infrastructure by using it for multiple purposes. An example of this is joint use of a TMC by Traffic managers and law enforcement personnel.

Level of functional integration within a project

The level of functional integration within a project affects cost when extra effort is required to integrate the various ITS subsystems. Sometimes this is not extra effort, when available control platforms already accommodate this integration. It is generally understood that on a life cycle basis, a project with integrated subsystems will be cheaper than separate systems due to the common use of computer hardware, software, database, and O&M. The alternative of separate systems, each requiring its own infrastructure, deployment and O&M will likely increase costs..

Stand-alone project

A stand-alone project is more simple than a project which must be integrated with other projects or existing infrastructure. The cost implications of this would vary however, depending on the complexity and risks of the individual project. For example, a stand-alone freeway management system would be less costly than one which would be required to share data with an independent information provider and with emergency management agencies. However, the stand-alone project could be more costly, than one, which mirrors another within the same or neighboring region.

Regionally integrated project

A regionally integrated project is the most complex of ITS deployments. They require a rigid systems engineering approach to accommodate all of the required functions, and integrate the data interfaces. They typically have larger central hardware/software platforms and TMCs

where they reside. However, it can be said again, that *one system*, accommodating all of the ITS objectives and requirements is less costly on a life cycle basis than separate systems achieving the same functional requirements would be. This in fact is the premise behind ITS, where the whole of a regionally integrated ITS is greater than the sum of its parts.

To conclude, the degree of integration does affect cost, but should not be determined based on cost alone. A functionally integrated stand-alone project, or one integrated with other systems within a region can be expected to be less costly on a life cycle basis than separate, functionally equivalent stand-alone systems.

5.4. SPECIFICATION TYPE

There are two fundamental types of specifications; prescriptive and performance that can be applied to ITS projects. Each has different characteristics and cost implications.

Prescriptive Specifications

Prescriptive specifications are the more detailed of the two types, providing explicit requirements for most or all ITS project components. An example of this would be the specification of a specific controller firmware for changeable message signs. This requirement could name the actual item and supplier, essentially making it sole source, or it could fully describe the protocol and possibly say this is available from certain vendors. Many times the “or equal” clause is also used in this context, presumably to create the impression of an open procurement.

The benefits of prescriptive specifications are:

- Provide compatibility with existing components
- Provide compatibility with specific user requirements/preferences
- Provides a basis for enforcement of quality and operability of contractor’s work
- Can reduce the testing and acceptance effort when submittals match the specification

Performance Specifications

Performance specifications focus on the performance requirements of the system and subsystems, but leave a degree of flexibility for the contractor to shop the marketplace and to innovate with a technology solution addressing the functional requirements of the specification.

The benefits of performance specifications are:

- Allows contractors to innovate with cost effective technologies
- Allows contractors to submit best prices for what they feel will meet requirements
- Avoids defensive specification writing which translates to additional contractor risks/cost

5.5. SOFTWARE ELEMENTS

CUSTOM SPECIFICATIONS VS. "OFF-THE-SHELF"

Clearly, off-the-shelf software is less expensive than custom developed software. Off-the-shelf software typically has undergone a development cycle where it has been developed, debugged, documented, enhanced, and used by a number of ITS operating agencies. This is a long and expensive process, which should not be borne by one agency for an application which is common to the ITS industry. Off-the-shelf software is also typically supported by a company dedicated to that business.

Custom developed software is sometimes necessary because of special features or requirements desired. In this case, the owner should expect longer project duration and careful testing and acceptance. This is especially true if the software is coming from a third party such as a construction subcontractor or supplier, not under the owner's direct control. There are many risks with custom software to the Department and local ITS operating agencies. These include:

- Inadequate documentation and training
- Lack of good programming practice allowing future development and repair
- Surprises at the end of the project over license restrictions.

The cost implications are simply that custom software is more expensive than off-the-shelf software. It should be understood however, that detailed databases need to be developed for either case in order for the application software to function.

From the contracting standpoint, off-the-shelf software is sometimes suitable for a contractor to provide in his bid, with him passing through the costs with mark-up, and having complete responsibility for the system operation. For custom software, contractors should not be required to provide this in a project bid, because of their lack of control over it, and the lack of involvement by the software providers in the software requirements specified.

Proprietary vs. Public Domain

Traffic control system software is nearly always proprietary. No company who bears the costs of developing software can allow it to be given away freely where others could legally sell it. One can only read the license restrictions on all commercial PC software to see the widespread use of restrictions on the use of proprietary software.

While these restrictions may cause concern, many ITS software suppliers simply provide a site license for the operator to use the software perpetually for his purposes. Some more ominous restrictions have been used in the ITS industry, which put more of a burden on the operating agency such as reporting or software security requirements.

There have been two attempts to create public domain software for ITS. The first was the UTCS program which began in the 1970s. This program resulted in two versions being created and tested, and made available to the public on request. These versions were never thoroughly developed and user friendly to the point where an operating agency could actually make the software run without additional development support. The program was ultimately cancelled.

Thus, all UTCS deployments were performed by systems developers and licensed. A more recent example is the software developed for the Atlanta region prior to the 1996 Olympics. This software was developed with the requirement that it be in the public domain. Discussions are ongoing as to how the software will be provided to other agency/operators.

Commercial-off-the-Shelf Software (COTS)

COTS offers an advantage to ITS deployers and agencies alike in ever increasing ways. Commercial software serves a broad market, involving millions of users, (far more than the number of ITS users). This mass market affords commercial development companies the ability to invest greatly in development, testing, documentation and support. It is most cost effective for ITS system developers to take advantage of this whenever possible. Areas where this is possible are:

- Operating systems
- Database
- Graphics
- Maintenance management
- Communications management
- Device drivers
- Tools

COTS are usually the least expensive types of software, and can be required of a contractor or a system developer with minimal risk/cost.

5.6. PAYMENT METHOD

Traditional Methods

The traditional method of contractor payment is found in the Standard Specification for Road and Bridge Construction. These provisions allow:

- Partial Payment of up to 75% of bid amount for stockpiled materials
- Retainage of 10% of value of work completed exceeding 75% of Contract amount
- Full payment, less retainage upon conditional acceptance

The Department also applies liquidated damages to contractors who fall significantly behind their planned progress or fail to complete the work within the allotted contract time.

Special Retainage Many ITS projects invoke more restrictive retainage and/or withholding practices. This is typically done to motivate the contractor to maintain job progress and make the system work at the end of the project. For example, the retainage scheme is used in the I-95 ICS project shown below:

	Payment
Equipment On Hand/Factory Acceptance complete	40%
Stand-Alone/Field Test Approved	55%

Subsystem Test Approved	75%
Conditional Acceptance	90%
Final Acceptance	100%

These types of provisions, restricting payment beyond the Department’s standard practice, cause contractors to factor in the time value of money in their bid. The costs they have tied up in material equipment and labor costs which they are not being paid for on a monthly basis become an added cost to the owner.

The ITS construction contract should place the risks where they are best mitigated. In the case of the installation contractor, risks like maintaining a production rate for installing ducts, and procuring and installing field electronics should be addressed with some withholding to assure all requirements are met.

The construction contract should not impose aggressive withholding on contractor events outside the contractors responsibility or in areas where he is dependant on others, such as for third party software and/or integration.

Extended System Warrantees

Extended warrantees are being used by the Department on ITS projects recently. An example is the Broward County CMS project. In this example, a performance bond in an amount of 20% of the contract amount is specified. The warrantee is typically used to ensure the reliability of the ITS component equipment.

Equipment warrantees are secured from the suppliers, with the costs passed through to the owner with mark-up. Therefore equipment warrantees add a burden on the contractors in areas where he has little if any responsibility. This burden results in higher overall ITS project costs. Alternatives could be to contract for maintenance separately rather than in the context of the original construction contract or to increase the warrantee of manufacturers in the standard specification.

6. SUMMARY AND RECOMMENDED GUIDELINES

The cost factors and recommended guidelines below are a starting point as the Department develops more experience with ITS deployment. This experience, coupled with potential new policies, standards, and industry developments will cause ITS cost considerations to evolve toward more cost effective ITS deployments in Florida.

6.1 COST FACTORS

A summary of the factors that have impacts on project cost are provided below.

Subsystem Design

The individual subsystems' design is a major cost factor. Designs can range from the most simple to highly complex custom designed systems. Costs range proportionate to the complexity and risk perceived by the deployers.

Implementation Plan

The overall system concept is a major cost factor. This includes the design itself, and also the implementation strategy for the overall concept from which a life-cycle cost is determined.

Degree of Project Integration

The degree of integration both within an individual project, and among other projects or phases affects costs relative to the degree of difficulty of the integration. A stand-alone project is likely to be the least costly initially, from this standpoint but may cost more in the end if it does not provide expected benefits.

Specification Type

The type of specification; prescriptive or performance affects project cost. A highly prescriptive specification leaves the contractor competitively bidding labor only. A performance specification allows the contractors to develop the best approach from a performance and cost standpoint.

Procurement Method

The procurement method affects cost in several ways. Costs are reflected in the dollar value of contracts, but also in the time required to complete a project.

The ITS project procurement method chosen should reflect the overall system concept and implementation plan to minimize total life-cycle costs.

Software

Software can be a significant cost item relative to the degree of customization involved. Software also represents a significant amount of internal development for a company. For a previously undeveloped software application, the costs can be extremely high in the context of one project.

Payment Method

The payment method, including retainage, withholding and warrantees, affects project cost proportionally to the interest costs the contractor must pay to cover his true costs prior to payment by the owner. Warrantees are considered by contractors as a pass-through item on which they mark up a profit.

Table 3 summarizes the relative impact each of the cost factors and their affects on the project phases' cost.

Cost Factor	Feasibility	Design	Construction	Operation
Subsystem Design	\$	\$\$		\$

Implementation Plan	\$\$	\$	\$\$	\$\$
Degree of Integration	\$\$	\$\$\$	\$\$\$	\$\$\$
Specification Type		\$\$	\$\$\$	
Procurement Method	\$	\$	\$\$	\$
Software	\$	\$\$	\$\$\$	\$\$
Payment Method			\$\$\$	

Table 3 Summary of cost factors (\$ symbols indicate low (\$), medium(\$\$), high(\$\$\$) impacts

6.2 RECOMMENDED GUIDELINES

General guidelines are provided below, illustrating ways to control total project life-cycle cost while maximizing effectiveness.

Prepare a Regional ITS Architecture

Each urban region should develop a framework for short and long term comprehensive ITS deployment. This framework will create a concept, which will allow for multiple uses of the infrastructure, thus lowering costs by avoiding replication of subsystems for individual purposes.

The regional architecture approach also takes advantage of the ITS National architecture as a starting point and template for the appropriate user services and market and equipment packages for the region. This systems engineering approach also saves costs by avoiding early obsolescence or failure of ITS projects/subsystems. There are tools available, which accommodate top level ITS cost planning.

Prepare an Implementation Plan

Each regional ITS deployment and individual project should prepare a detailed implementation plan in conjunction with the MPO in accordance with FHWA guidelines. All parts of the guidelines should be addressed for a well thought out project concept and deployment plan. One approach to ITS deployment does not fit all projects. Each regional and project implementation plan should have adequate resources applied to thoroughly address all implementation plan aspects with project specific analyses to maximize benefits relative to cost and provide decision inputs to the design, construction and operations project stages.

Perform Preliminary Design Studies

ITS project design should include preliminary design studies and tradeoff analyses to determine the most cost effective design from a life-cycle cost standpoint. This is especially important with the major subsystems such as communications, control centers, changeable message sign, detector stations and closed circuit television subsystems.

Recurring costs of the Department and operators resulting from the design over the project's life cycle must be considered also.

Develop Statewide ITS Specifications, Standards and Guidelines

The Department would benefit from statewide ITS specifications, and standards for project elements, which are now becoming common to projects around the state. They need not be singular for each component, but serve as a baseline for system designers, contractors and suppliers. This will serve to level the costs of ITS elements around the state and reduce the overall costs as bidders begin to recognize the lower risk of known and understood requirements.

ITS design guidelines should be developed for ITS projects in the areas of component details and placement, and their density along the roadway. These guidelines will be helpful for streamlining the planning and design process for new deployments. The guidelines will also serve as a starting point for consistent regional deployments.

Guidelines should also be developed for the contract administration of ITS projects, addressing procurement methods, and warrantee and payment provisions.

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